BIRD STRIKE COMMITTEE EUROPE

BSCE23/WP 30
London, 13 - 17 may 1996

BIRDS AND GRASSLAND ON AIRPORTS

Arie Dekker
Royal Netherlands Air Force
Flight and Ground Safety Division
Natural Environment Section
P.O. Box 2073
2500 ES The Hague

Friso F. van der Zee
National Reference Centre for Nature Management
Wageningen Agricultural University,
Dept. of Terrestrial Ecology & Nature Conservation
Bornsesteeg 69
6708 PD Wageningen

ABSTRACT

The long grass regime has been a wide spread and successful tool in the prevention of on-airfield bird strikes. The RNLAF has carried out experiments with an alternative grassland management. This so-called poor grass regime is aimed at reduction of biomass production. Food will not only be inaccessible (as in the long grass approach) but also less available. Experiments showed that poor grass is at least as unattractive to birds as long grass. Benefits of poor grass over long grass all relate to the better development of the vegetation and include a better resistance to drought and erosion. The lower vole density in poor grassland implies a lower density of its associated predators. Poor grass leads to a more diverse vegetation including rarer species. Flight safety and the development of natural values both profit from a poor grass regime.

Key Words: Habitat Modification, Long-grass

1. INTRODUCTION

The bare fact that birds and aircraft share the same air means that conflicts are to be expected. Aviation therefore has been confronted with bird strikes from its early beginnings. In take-off and landing both civil and military aircraft have to pass through the sometimes very dense blanket of birds covering the landscape. As a consequence, on and near airfield bird strikes form a substantial flight safety hazard. Recognized problem-species include gulls, pigeons, birds of prey and waders like the Lapwing.

Bird control units are introduced on most airfields to clear the runway environment from birds. By reducing bird numbers on the airfield they have been successful in the reduction of the on-airfield bird strike hazard. In the battle against bird strikes corrective actions by bird control units are not the only means. Preventive measures include the management of the runway environment in a way that is most adverse to birds. In time there has been a shift from agricultural co-use of airfields to a long grass regime that is specially geared to reduce bird numbers. This paper focuses on the use of poor grass as an alternative for long grass as ground cover for the runway environment. Poor grass is defined as a herb-rich grassland vegetation of poorer soils. It is not attractive to birds and due to the more varied and species richer vegetation increases the natural value of the terrain.

2. TRADITIONAL MANAGEMENT OF THE RUNWAY ENVIRONMENT

2.1. Agriculture

Agricultural exploitation generally means that production levels are increased and thereby the overall available biomass. Not only the standing crop of the vegetation increases, also the availability of invertebrates. It is not just coincidence that flocks of birds follow the tractor of the farmer. Whatever the specific job done, the tractor nearly always changes the situation of soil and/or vegetation and thereby provides access to the bountiful soil living organisms.

It is therefore not surprising that for more then 25 years ago it was already stated by Stortenbeker that 'birds will always be attracted to fertile soil whatever agricultural use one makes of it' (Stortenbeker 1969). Already in 1969 full agricultural exploitation of German airfields was forbidden (Hild 1969). Also in the RNLAF the relation between bird numbers and agricultural production was recognized long ago (Klooster 1977; Baanstra, Buurma and Heijink 1977; Heijink & Buurma 1978). However, the great agricultural ambitions of a small country like The Netherlands prohibited the complete ban of agriculture on RNLAF airbases. Imposing general restrictions on the types of crop and the timing of agricultural activities nevertheless helped to reduce the bird strike risk. But restrictions that are a compromise are not satisfying to either the farmers (who aim at maximizing yields) or the RNLAF flight safety officers)who are interested in a runway environment that is not attractive to birds at all).

To solve this problem the RNLAF in the mid-eighties introduced a zonation that worked out positive for both agriculture and flight safety. This zonation meant that at distances of over 200 meter from the runway optimal agricultural exploitation was allowed while the 100 meter zone directly adjacent to the runway was taken out of exploitation. In the mid zone in between intermediate restrictions were imposed. These restrictions regulated the type of crops, amount of fertilization and timing of cultivation and harvest. Despite the fact that some crops in itself are not at all attractive to birds, the complete agricultural cycle of the exploitation at some stage still attracts birds. Sugarbeet and maize in itself for instance appeared not to attract birds. Nevertheless, the bare soil that is associated with these crops in winter and the activities that go with this exploitation (ploughing, (slurry) fertilizing and harvest) do attract birds to the same extent as grass that is permanently mown short. This is perfectly in line with Hortons statement that birds are not so much attracted to the standing crops as to the stubble and ground preparations. In his study all species were recorded in highest numbers on the agricultural land (Horton 1984).

2.2 Long grass

In the past several studies have been done as to what kind of ground cover on airfields would reduce the number of birds (Austin-Smith 1969, Hild 1971, Maron 1977, Hild 1978). The general idea was that a grass cover that was kept at minimum height of 15-20 cm would keep bird numbers low. This so called long grass method consists of cutting the grass during the season to 14-15 cm while leaving the clippings. Great care is taken that the grass is at the right length throughout the autumn and winter. By the end of March the grass is mown short at 5 cm and the clippings are removed, including the dead organic matter left from previous years clippings. Fertilizer is applied after this spring cutting. The technique is based on the fact that long grass impedes the birds access to invertebrates in the soil and is an obstruction to the line of sight of birds on the ground. Therefore long grass offers little food to the birds and also is an unsafe environment to be in. Brough and Bridgman (1980) evaluated this so called 'long grass' concept and concluded that 'Although the growing of long grass cannot alone remove birds completely from airfields, it is a long-term technique which should greatly alleviate a difficult problem'. Since then the use of long grass as ground cover on airfields has become wide-spread.

Although successful, it should be noted that already in 1978 Heijink & Buurma (1978) mentioned some shortcomings to the long grass method. The fertilizing and subsequent topping of the grass means that during the growing season a layer of dead organic material accumulates at ground level. Mineralisation of these organic remains effectively means that the fertility of the soil is increasing, offering ideal conditions for high numbers of soil living invertebrates. Although this food resource is not very accessible during the season, it is potentially available. The spring cutting and removal of clippings reveals this rich food resource and then many birds are attracted. The accumulated layer of dead organic material does attract rodents which in turn do attract birds of prey and other birds that feed on rodents (see 3.3). Other complications of long grass are related to the open structure and that it eventually will grow into. These complications include a decrease in carrying capacity an resistance to drought and erosion (see 3.4).

3. POOR GRASS, ANOTHER APPROACH

3.1. Poor grass, an alternative ground cover for airfields

The ideal ground cover would have the well proven advantage of the long grass regime but not the drawbacks that show up after prolonged practice. These drawbacks all relate to the fact that the long grass regime increases soil fertility. So the obvious next step is to choose for a poor grass strategy whereby the total fertility decreases. This can be accomplished by ceasing fertilization and removal of the cuttings after mowing. As a consequence total production and available biomass will decrease. In such a system soil invertebrates are not only inaccessible (as in the traditional long grass regime) but also much less available. At the same time this strategy would not show the open vegetation structure with all its accompanying problems and leads to a vegetation with a well developed root system that is resistant to erosion and drought.

Modification by man has transformed the European landscape into an environment in which food for opportunistic bird species is plentiful. Bird species like Gulls, Lapwings, Starlings and Corvids have been very successful in exploiting this horn of plenty and numbers increased considerably in the last decades. Their best foraging strategy is to fly around. During these opportunistic flights they will nearly always hit a food source, even when flying randomly. In poor habitats on the other hand, birds tend to be less numerous while bird species often are smaller. They survive in these difficult circumstances thanks to their ability to utilize even the smallest or least accessible resources. It is expected therefore that poor grass will attract fewer birds in a species composition that holds species of a lower weight.

The traditional cultivation of grass can be considered as a form of agricultural exploitation. Baring this in mind and using the principle of zonation described earlier, the RNLAF started to regulate the extent of exploitation of grassland instead of focusing primarily on the length of the grass. For the zone adjacent to the runway the objective was to come to the lowest possible biomass production of a grass-type vegetation. To carry this approach into effect the National Reference Centre for Nature Management (IKC) was consulted. Under the inspiring guidance of Prof. dr. P. Zonderwijk this institute acquired considerable knowledge of and experience with poor grass strategies for road and rail verges (Zonderwijk 1979). The general advice was to adopt a grass mowing management in which, depending on the soil fertility, the grass was cut and immediately removed once or twice yearly. If mowing is carefully timed such a regime leads to a vegetation that apart from grass holds an increasing proportion of herbs, is poor in production, firmly rooted and not attractive to birds.

3.2. Birds of poor grass, two case studies on RNLAF airbases.

Twenthe airbase

Until 1986 on Twenthe airbase agricultural exploitation was common practice. The runway environment consisted of a mix of production grassland and arable fields used for the cultivation of sugarbeet, potatoes and maize. From 1986 onwards a strip of 100 meter adjacent to the runway was managed more or less as long grass. Other parts, further from the runway, were still in use as arable fields. By 1991 infrastructural and drainage works had to be executed. At the same time, due to the changing situation on the world market for agricultural products it was possible to abandon agriculture completely. This coincidence of circumstances provided the opportunity to start a poor grass regime on the entire base. Deep ploughing (80 cm) tilted the lower, unfertile, sandy soil to the top and thus creating an ideal starting condition (Anonymous 1991).

The effects of this combination of changes in management are very difficult to disentangle. The overall effect is a decrease in the biomass production. How bird populations reacted to these changes is reflected in figure 1, in which the changes in numbers of the eight most numerous potential hazardous bird species is presented.

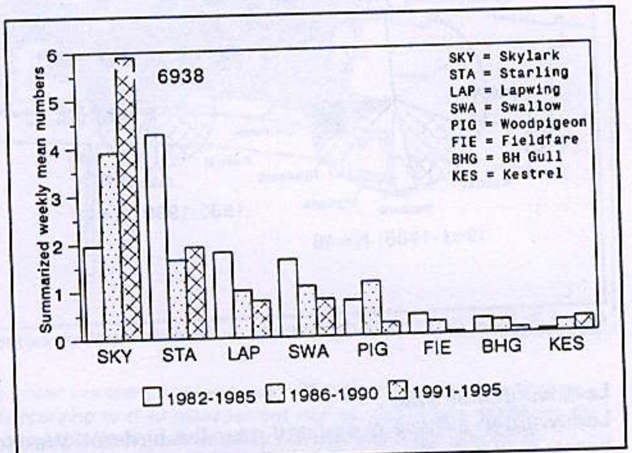

Figure 1: Avifauna of Twenthe Airbase for three periods, expressed as summarized weekly mean numbers.

It is clear that parallel with the changes in management the numbers of most of these bird species decreased, often very significant. Numbers of notorious problem species like Starling, Lapwing, Woodpigeon and Black-headed Gull dropped to levels that are not only much lower than during the first period (full agricultural exploitation) but also lower than in the second period (long grass and restricted agriculture).

The only exceptions to the general decrease in bird numbers are Skylark and Kestrel. The population of Skylark tripled to more than 150 birds for the greater part of the year. Weighing only 38.6 grams on average (Brough 1983) and living spaced out over the entire airfield these small birds, although relatively high in total numbers, do not pose a significant threat to flight safety. Kestrel numbers started to increase during the first transition from full agricultural exploitation (1982-1985) to a combination of long grass and agriculture (1986-1990) and rose slightly more after the second transition to poor grass on the entire airfield. There are indications that the increase in Kestrel numbers is temporarily. After prolonged continuation of the poor grass regime they will decrease again as happened on Leeuwarden airbase (see 3.3.).

The other way to look at the change in bird population is not to focus on bird counts but only regard the ultimate result: local bird strikes. For Twenthe airbase these are presented in figure 2 in which a distinction is made between the bird strikes of the three periods. The decrease in the total number of registered bird strikes is remarkable and not related to significant changes in flight movements on the airbase. Furthermore, the range of species changed to birds with lower weights, thus reducing the risk of a bird strike to cause damage to the aircraft. Problem species like Lapwing, Woodpigeon and Buzzard all have disappeared while apart from the relatively small Kestrel only light weighted Swallows, Swifts and Songbirds remain.

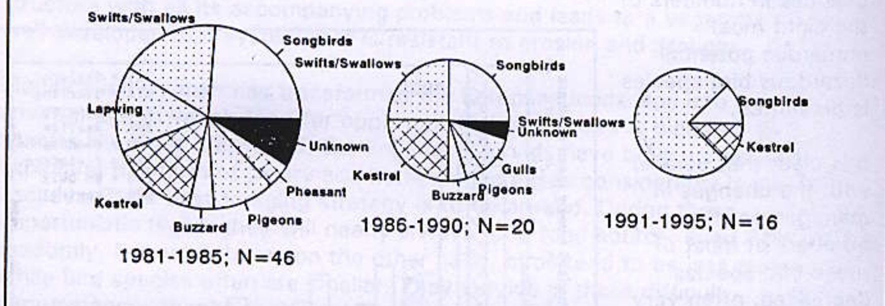

Figure 2: Local bird strikes on Twenthe Airbase during three periods

Leeuwarden airbase
Leeuwarden airbase is situated near the bird-rich Waddensea and has a fertile heavy clay soil. Since gulls (mainly Common Gulls, but also Black-headed Gull and Herring Gull) are the main problem species at this airbase, the effect of management measures are demonstrated using gull densities. As expected, long grass that was implemented on a strip of 100 meter adjacent to the runway has proven to act as a deterrent to gulls. In 1991 the management of this strip of grassland has changed to a poor grass regime. This was as effective as long grass, gull density was even slightly lower than it used to be on long grass. Traditional production grass, that is grown to be cut at least three times during the season scored gull densities of up to hundred times as high as in the poor grass area. This is illustrated in figure 3. The low gull densities on the poor grass adjacent to the runway did not result in a proportional reduction in bird strikes with gulls. It is very likely that this is the result from the on-going gull flight movements across the runway to and from the area of production grassland on which highest gull densities were recorded. The results so far have

proven that it is possible to reduce the gull numbers considerably using a poor grass regime. Therefore steps are taken to turn all the grassland into poor grass and even include grassland outside the boundaries of the airbase in such a management.

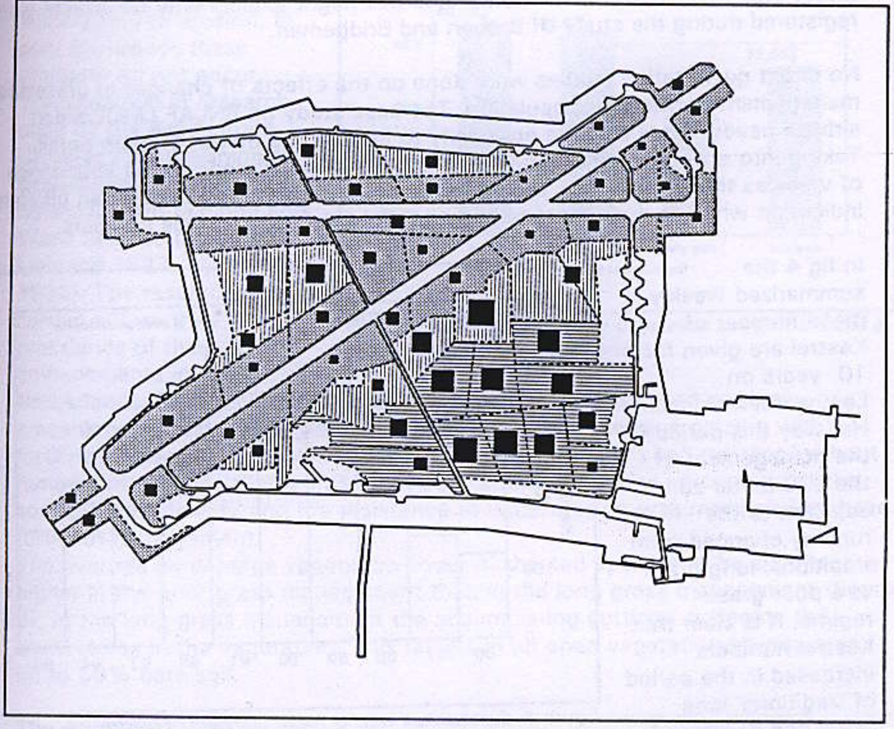

Figure 3: Gull density per plot (mean number per count, per 100 Ha) on Leeuwarden Airbase 1991-1995. Plots are shaded according to their management regime. Poor grass nearest to the runway (speckled) and increasing exploitation further away (vertical and horizontal bars). Numbers vary from 1 (smallest square) to 231 (largest square).

3.3. Poor grass and vole predators

Brough and Bridgman (1980) mention the potential problem of increasing rodent numbers in long grass which in turn might attract predators. Despite occasional inspections of their experimental plots they did not register this phenomenon in their study. The strong point from their study is the fact that the experiments were done on a great number of air bases. And although some of the experimental plots were studied again four years later, none of the experiments lasted longer than about two years on end. Maron (1977) and Heijink & Buurma (1978) also mention an expected increase in vole numbers as a possible complication of the long grass method. Prolonged long grass management on

RNLAF airbases indeed was accompanied by an increase in vole density. The accumulated layer of dead organic material offers shelter to small rodents This is in line with the situation in road verges where highest fieldvole density was observed in areas managed as long grass (van der Reest 1989). If this effect only reveals itself after some time this might explain why no effects were registered during the study of Brough and Bridgeman.

No direct quantitative studies were done on the effects of changes in grassland management on the vole population. The case study on RNLAF Leeuwarden airbase nevertheless offers a possibility to look at this matter in more detail. Taking into account that numbers of Kestrels are dependent on the abundance of voles as their staple diet, the presence of Kestrels can be used as an ultimate indication which is even more relevant to flight safety than vole numbers.

In fig 4 the summarized weekly mean number of Kestrel are given for 10 years on Leeuwarden airbase. Halfway this period the management of the 100 meter zone adjacent to the runway changed from traditional long grass to a poor grass regime. It is clear that Kestrel numbers increased in the period of traditional long grass and decreased again when the poor grass regime was introduced. In his study of poor grass on river embankments van der Zee (1992) also observed that vole density in long grass was always higher than in poor grass.

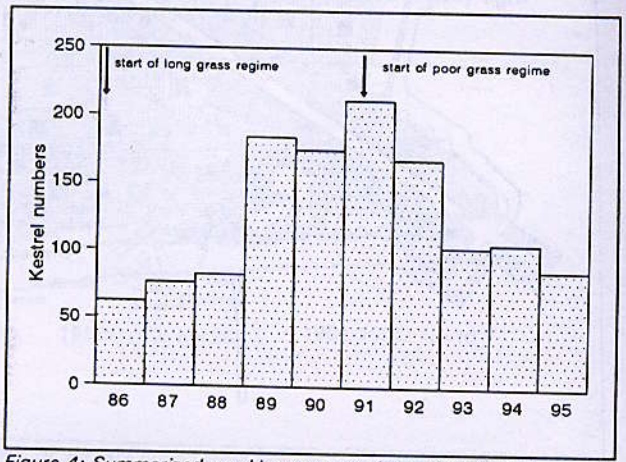

Figure 4: Summarized weekly mean numbers of Kestrel on Leeuwarden Airbase.

3.4 The resistance to drought, erosion and carrying capacity of grasslands

A problem of vegetations with long grass management is the vulnerability to erosion. In poor grasslands these problems do not occur. This is shown in research done by the Agricultural University in Wageningen, Department of Vegetation Science, Plant Ecology and Weed Science (Sykora & Liebrand 1987, van der Zee 1992). The research was carried out on the grasslands of river embankments in the Netherlands. Four groups of management can be distinguished on river embankments: extensive grazing without fertilizing, intensive grazing with fertilizing, mowing with removal of cuttings ('poor grass') and mowing without removal of cuttings ('long grass'). In early spring the cover percentage of the sod, the root density and the resistance to watererosion was measured in these forms of management.

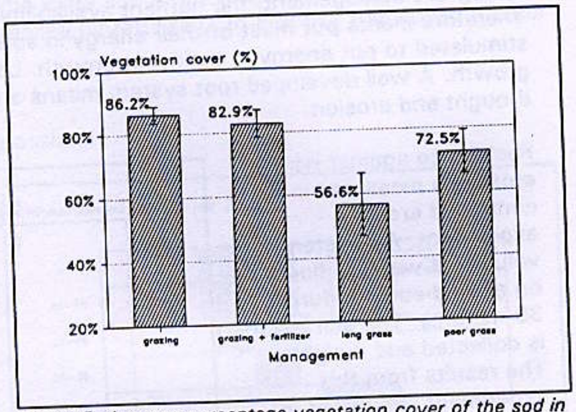

Figure 5: Average percentage vegetation cover of the sod in 4 types of grassland management

The average percentage vegetation cover of the sod appears to be significantly higher in the poor grass management than in the long grass management (figure 5). In the long grass management the accumulating cuttings suffocate the understores in the vegetation. This results in an open vegetation structure and up to 50% bare soil.

The root density is expressed as the length of roots per dm^3. This is measured in different soil layers of 10 cm. Comparing the root density of the different management regimes (figure 6), it is clear that the highest total root lengths are found in the managements 'poor grass' and grazing without fertilizing. This occurs in all different soil layers between 0 and 50 cm. These differences are caused by the soil fertility,

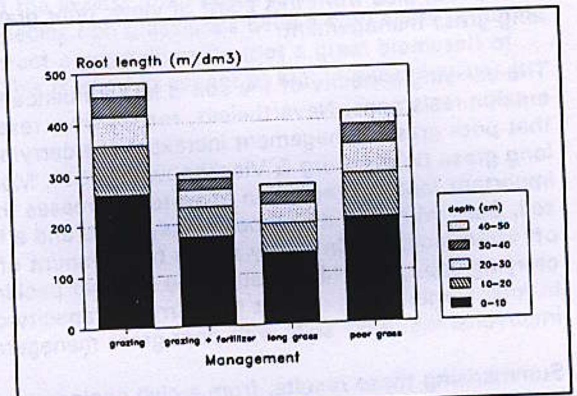

Figure 6: Root density in 4 types of grassland management. Presented is the total root length per soil volume in the soil layer 0-50 cm

extreme nutrient poor situations (pure sand without organic matter), the growth of the vegetation may need some extra support. In that case the erosion prevention capacity will be increased by fertilizing. In practice this doesn't occur on airfields in the Netherlands.

3.5 Natural values of poor grassland

Due to the intensive agricultural practices and acid pollution the low and medium nutrient rich habitats have become scarce in The Netherlands. In these fertilized soils only common and very common species are found. Less common and rare species are found in intermediate and poor conditions. Changing the management from agriculture or long grass into poor grass helps to stop the further deterioration of natural values. After 2-3 years of poor grass management, the biomass production is reduced to a limit where higher species numbers may be expected. In practice this limit fluctuates around 6 tons of dry matter per hectare per year. Above this level high species numbers are seldom observed. On river embankments, grasslands which produce around 5 ton biomass per hectare per year, show the highest number of species and the lowest grasses/herbs ratio (figure 8, van der Zee 1992). This means that species rich grasslands have a high share of herbs. The flowers of these herbs attract a great diversity (not a great biomass!) of butterflies and other insects. This is another aspect of higher natural values in poor grasslands.

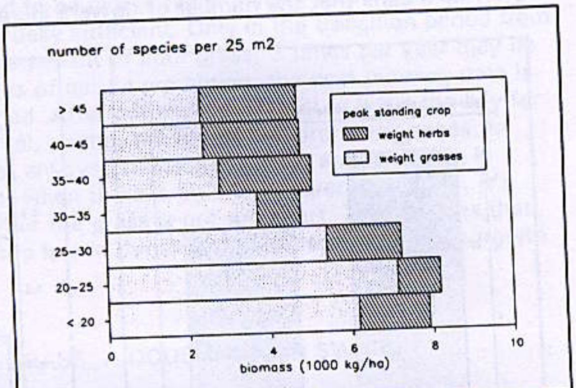

Figure 8: Relation between biomass production and species richness in grasslands on river embankments

The higher natural value of poor grass versus long grass is demonstrated on data from Leeuwarden and Twenthe airbase. On Leeuwarden airbase, situated on heavy clay, the long grass management changed into poor grass management in 1991. Since 1992 vegetation data have been collected. Figure 9 shows the gradual decrease in biomass production after the cessation of long grass management (van der Zee 1995). Parallel with this decrease in biomass production, the herbs/grasses ratio increased between 1992 and 1995 (figure 8). This means that the number of flowers increased at the cost of the grasses.

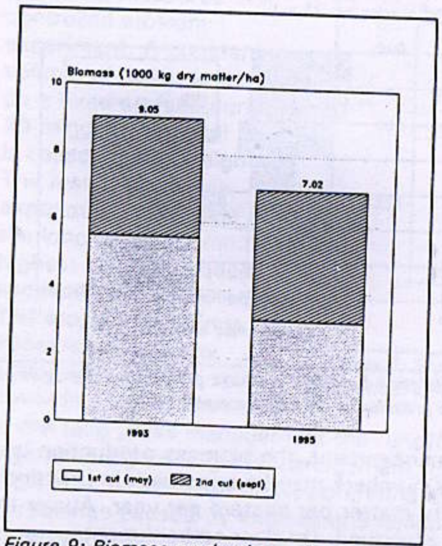

Figure 9: Biomass production on Leeuwarden airfield in 1993 and 1995

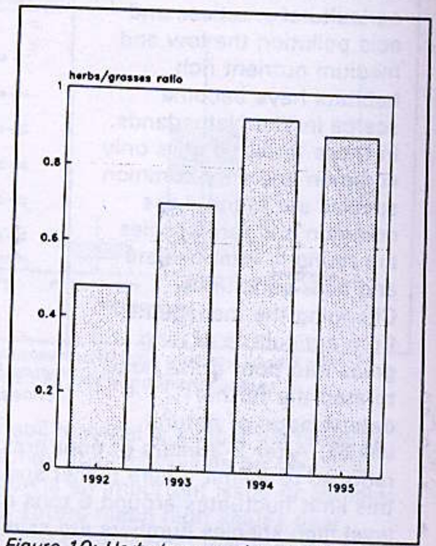

Figure 10: Herbs/grass ratio on Leeuwarden airfield between 1992-1995

On Twenthe airbase the changes in management brought a dramatic change of the landscape. Due to the advantageous starting-point of a loamy sandy soil, the developments went fast. In 1995 a complete vegetation survey of the airfield was carried out. More then 230 different vascular plant species were recorded, 27 of which are rare and less common species in the Netherlands (Vos, in press). Besides the vegetation, butterfly monitoring routes are surveyed every year. Between 1992 and 1995 33 different butterfly species were discovered. Among these were 6 rare and threatened species: Purple Emperor, Sooty Copper, Chequered Skipper, Swallowtail, Bath White & White Admiral (Linckens, 1996). The high species diversity makes Twenthe airfield one of the most species rich butterfly areas in the Netherlands (van Swaay, 1995).

A low biomass production is a prerequisite to increase the species diversity. In our modern fragmented and intensively used landscape however, difficulties in dispersal often prevent spontaneous establishment of new species. If the desired species are not available in the seedbank of the soil or in the nearby environment, re-introduction of species may be necessary. On Leeuwarden airbase an experiment with re-introducing grassland species was carried out

recently. In 1992, two years after changing the management from long grass into poor grass, 10 characteristic herbs were sown in the existing grass sod on relatively small plots. Most of the species established successfully. The idea is that the plots will serve as source-areas, from where the spreading of new species over the rest of the airbase will take place. Yearly monitoring of the vegetation shows that this dispersion progresses gradually.
Poor grass management implies mowing and removal of cuttings, 1-3 times a year. Clay and loam soils need to be mown twice a year, on sandy soils or loamy sands once a year is usually sufficient. Only in the transition period from long grass or agricultural management to poor grass, 3 times per year may be necessary. Considered in terms of nature promotion, the best mowing date is when the seeds are just ripened. After cutting it's optimal to leave the hay for about one week before removal, so that the plants can drop their seeds. In practice on airfields this is not always attainable. Cutting and removing is usually done in one weekend, when there is little or no aircraft activity. It's important that during the winter the grass is not too short. This requires that the last mowing date is not too late in the season, so that still some regrowth will take place.

4. CONCLUSION: POOR GRASS, A DOUBLE EDGED SWARD

Based on theoretical grounds and backed up by five years of experience, the use of a poor grass regime for the maintenance of the runway environment on airfields is a good alternative for the commonly used long grass regime. Long term experiments on two RNLAF airbases show that bird numbers on poor grass are as low or lower than on long grass. Furthermore the species composition of the remaining birds changes to smaller, less heavy species, thus decreasing the risk of a bird strike causing damage.

Poor grass offers a number of advantages over long grass. Vole numbers, and thus predators like Kestrel and Grey Heron, are much lower on poor grass than on long grass. Furthermore, experiences with poor grass on rail and road verges and on river embankments show that the vegetation structure of poor grass is better balanced. Therefore poor grass has a much denser root system and a better coverage than long grass. This means that poor grass is more resistant to erosion and drought than long grass while the carrying capacity is as good.

In a time in which the natural environment is under an increasing pressure the poor grass regime also contributes to the conservation of semi-natural grassland systems. Not only the species richness of the vegetation and the number of rarer species will increases. More varied and well developed grassland will also attract a greater diversity of butterflies and other insects. If the management of the zone between the fields and the more wooded areas in the periphery is carefully planned and aimed at a gradual transition, natural values will develop even better without effecting flight safety or extra costs.

The overall conclusion is that flight safety as well as nature development profit from a poor grass regime in the runway environment.

5. ACKNOWLEDGEMENTS

The experiments with poor grass on RNLAF airbases are the result of a close cooperation between RNLAF as operational user, the DGW&T as the terrain manager and the National Reference Centre for Nature Management as contracted advisor.
Apart from these organisations there are many persons without whom the experiments could not have been carried out successful. As bird controllers on Leeuwarden and Twenthe airbase Harry de Groot, Arend Leijstra, Harrie Linckens and Jan Bergman carried out numerous bird counts and were actively involved in the introduction of poor grass on 'their' airbase. The enthusiastic attitude of the local DGW&T terrain managers Wim Vreman and Rob Apeldoorn has been of vital importance to the success of the experiments.
Luit Buurma, Hans van Gasteren and Wietske van Dijk all read earlier drafts of this paper and made valuable comments. Peter Moonen has been of great help in producing figure 3.

7. REFERENCES

Anonymous (1991). Aanleg- en onderhoudsadvies schrale graslandvegetaties vliegbasis Twenthe. Ministerie van Defensie (DGW&T & RNLAF) and Ministerie van Landbouw, Natuurbeheer en Visserij (Adviesgroep Vegetatiebeheer).

Austin-Smith, P.J. & H.F. Lewis (1969). Alternative vegetative ground cover. Proc. World Conference on bird hazards to aircraft. Kingston, Ontario, Canada, 2-5 september 1969; p.p. 153-160.

Baanstra, Y; L.S. Buurma and J. Heijink (1977). Memorandum over de grasmatbehandeling van de Vliegbasis Leeuwarden. Internal Report RNLAF.

Beuving, J. (1990). Normen voor draagkracht en oorzaken van draagkrachtverschillen in wegbermen. Staring Centrum Wageningen, rapport no. 101.

Brough, T. (1983). Average weights of birds. Report of the Aviation Bird Unit of the Ministry of Agriculture, Fisheries and Food, Worlplesdon, 131 p.

Brough, T. and C.J. Bridgeman (1980). An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology, 17, 243-253.

Heijink, J. & L.S. Buurma (1978). Practical and economical aspects of grassland management at some dutch airbases. Proc. of 13th Meeting Bird Strike Committe Europe, Bern, 29th may - 2nd june 1978, working paper 33.

Hild, J. (1969). Agricultural provisions aginst birds on airfields. Proc. World Conference on bird hazards to aircraft. Kingston, Ontario, Canada, 2-5 september 1969; p. 195-202.

Hild, J. (1971). Seedcorn selection for airport grassland areas. Proc. of 6th Meeting Bird Strike Committee Europe, Copenhagen, 15-16 june 1971, working paper 4.

Hild, J. (1978). About effects of agricultural and grassland use on airfields reducing bird populations. Proc. of 13th Meeting Bird Strike Committe Europe, Bern, 2&29th may - 2nd june 1978, working paper 14.

Horton, N. (1984). Agriculture on aerodromes and its effects on birds. Report of the Aviation Bird Unit of the Ministry of Agriculture, Fisheries and Food, Worlplesdon, 6 p.

Klooster, J. (1977). Graslandbeheer en vogelstand op de vliegbasis Ypenburg. Internal report RNLAF.

Linckens, H.G.V. (1996). Vlindermonitoring vleigbasis Twenthe 1995. Internal Report RNLAF Natural Environment Section.

Maron, J. (1977). Aiport Munich II. Aspects on the economical utilization of the airport area under consideration of the bird strike problem. Proc. Third World Congress on bird hazards to aircraft, Paris, october 1977; p. 140-145.

Reest, P.J. van der (1989). Kleine zoogdieren in wegbermen. Vereniging voor Zoogdierkunde en Zoogdierbescherming, Arnhem, VZZ-mededeling 1.

Stortenbeker, C.W. (1969). Ground cover at Schiphol airport. Proc. World Conference on bird hazards to aircraft. Kingston, Ontario, Canada, 2-5 september 1969; p.p. 161-166.

Soels, T.A. (1984). Winderosie in Nederland. Landbouwhogeschool Wageningen, vakgroep Cultuurtechniek.

Sykora, K.V. & C.I.J.M. Liebrand (1987). Natuurtechnische en civieltechnische aspecten van rivierdijkvegetaties. Landbouwuniversiteit, Vakgroep Vegetatiekunde, Plantenoecologie en Onkruidkunde, Wageningen 194 p.

Swaay, C.A.M. van (1995). Het dagvlindermonitoringproject. Verslag van de eerste vijf jaren 1990-1994. De Vlinderstichting, Wageningen rapportnr. VS 95.28 & CBS, Voorburg.

Vos, E. (in press). De vegetatie van de vliegbasis Twenthe in relatie tot bodem, beheer en het voorkomen van dagvlinders. Landbouwuniversiteit Wageningen, Vakgroep Terrestrische Oecologie en Natuurbeheer.

Wallenburg, C. van & J.J. Vleeshouwer (1987). Resultaten van een landelijke inventarisatie van de stevigheid van de bovengrond in grasland. Stichting voor bodemkartering Wageningen, rapport nr. 1915.

Zee, F.F. van der (1992). Botanische samenstelling, oecologie en erosiebestendigheid van rivierdijkvegetaties. Landbouwuniversiteit, Vakgroep Vegetatiekunde, Plantenoecologie en Onkruidkunde, Wageningen, 271 p.

Zee, F.F. van der (1995). Grasland Vliegbasis Leeuwarden. Vegetatieontwikkeling 1992-1995. Rapport IKC Natuurbeheer Wageningen (Adviesgroep Vegetatiebeheer), Ministerie van Landbouw, Natuurbeheer en Visserij.

Zonderwijk, P. (1979). De bonte berm - De rijke flora en fauna langs onze wegen. Zomer en Keuning, Ede.