Raptors on three RNLAF airbases,
Numbers, strikes, trapping and relocation.

INTRODUCTION.

Since gulls, pigeons, starlings, waders and corvids are the dominant bird species on NW European airfields it is not surprising that habitat management systems are aimed at reducing the numbers of these species from the runway environment. In the RNLAF this is realized by a “poor grass” regime. This is based on the idea that by bottoming out the soil the available biomass will decrease and hence the number of birds foraging on this biomass. In practice this means that the grass is mown and the clippings are removed without applying any fertilization. Neither length nor species composition of the vegetation are focussing points, it is the decrease in soil productivity that counts. Fine tuning the regime is done by choosing the best time of mowing, early enough to prevent seed setting of those herbs that potentially attract birds and late enough to be able to confine to the minimum number of mowings. This regime is gradually introduced in the RNLAF; in the years 1985 to 1995 it was introduced on parts of the airbases while from 1995 onwards the full runway environment on all airbases was managed in this way. After a transition period of only a few years on most airbases it is possible to mow only once a year (Dekker &van de Zee 1996, Dekker 2000).
Opposition against the “poor grass” approach is often centred on the assumption that it would favour rodents and thus be contra productive against rodent dependent raptors. This paper uses 22 years of systematic bird counts on three F-16 airbases to assess the validity of this assumption.
Although raptors only constitute a minor part of the avifauna of an airfield they are well present in bird strike statistics. In the European Military bird strike database raptors take the 4th position (Dekker et al 2003). RNLAF statistics are used to demonstrate the nature of these raptor strikes and the relation with the presence of raptors on airfields. Trapping and relocation of raptors on one airbase is discussed and finally some implications from this study for bird strike prevention are given.

MATERIAL AND METHODS

Airbases
Raptors only occur in significant numbers on three of the RNLAF airbases: Leeuwarden (LWD) in the Northwest, Twenthe (TW) in the East (closed down December 2007) and Volkel (VKL) in the Southeast. The latter two are situated in the “high” part of the country (above sea level) with a secluded small scale landscape and loamy/sandy soil. Leeuwarden on the contrary is situated in the open large scale landscape of low Netherlands (below sea level) on clay soil. All three airbases from which data is used in this paper were used for F-16 operations. Data is used from 1987 up to 2008 for LWD and VKL and up to 2006 for TW.

Figure 1. Location of RNLAF airbases. The three bases used in this paper are indicated. Blue areas are below sea level.
Abbreviations used: LWD = Leeuwarden airbase
TW = Twenthe airbase
VKL = Volkel airbase

Systematic bird counts
Depending of the bird and aircraft activity, bird control units perform a number of runway inspections per day. During these inspections they register the total number of birds per species present in the runway environment using presence classes. In addition to this, more detailed, systematic counts are performed first thing in the morning, before operations start. These systematic counts are executed at least two times a week. The work in this paper is based on these detailed bird counts. In total 3869 counts on LWD, 2813 on TW and 2351 on VKL were used. Details on the frequency of bird counts per year and per week are given in appendix 1.

Bird strikes
The analysis of bird strikes uses Buzzard (*Buteo buteo*) and Kestrel (*Falco tinnunculus*) strikes from three different sources for the period 1987 - 2008. The on-airbase strikes from the RNLAF bird strike database were complemented with strikes with non-RNLAF aircraft and with carcasses found without connection to a specific aircraft. Details are given in table 1. From this table it is clear that the Kestrel is involved in bird strikes much more than the Buzzard. Furthermore it is clear that 70 out of the total of 143 strikes were not reported but based on a carcass found on the runway, these were mostly Kestrels.

Airbase	Bird species	RNLAF strikes	Non-RNLAF strikes	Carcasses found	Total
LWD	Buzzard	9	2	5	16
LWD	Kestrel	18	2	22	42
TW	Buzzard	1	0	1	2
TW	Kestrel	9	10	25	44
VKL	Buzzard	5	0	4	9
VKL	Kestrel	14	3	13	30
Total	Buzzard	15	2	10	27
	Kestrel	41	15	60	116
Grand total					143

Table 1. Raptor strikes per species, per airbase and per source (1987-2008)

Trapping and relocation
Trapping raptors has not been common practice within the RNLAF. Only on TW airbase, for the years 1988 – 2003 raptors were trapped on a regular basis. During this whole period a Larsen trap (figure 2) was situated in the edge of a small wood. Not ideally situated for trapping crows but catching various raptors during the most part of the years. In addition to the Larsen trap from 1993 to 2000 ball chatrii traps (figure 2) and from 2001 onwards cage traps (figure 2) were used during the months July - September, when numbers of Kestrels on the airbase were increasing. The transition from ball chatrii traps to cage traps in 2001 was instigated to reduce the labour intensive trapping with a ball chatrii trap.

All trapped birds were daily transported to Overdinkel ringing station at 10 Km East southeast from the airbase, where they were ringed and released.

Figure 2. left: Larsen trap; middle: Ball-chatrii trap
right: Cage trap

RESULTS – PRESENCE

Raptor species observed

The Total numbers of raptors counted are presented in table 2.

	Leeuwarden (22 y) 3,869 counts		Twenthe (20 y) 2,813 counts		Volkel (22 y) 2,351 counts	
	yrs	**Total N**	**yrs**	**Total N**	**yrs**	**Total N**
Marsh harrier, *Circus aeruginosus*	21	560	0	0	11	31
Hen harrier, *Circus cyaneus*	21	392	2	2	20	141
Montagu's harrier, *Circus pygargus*	1	1	1	1	2	5
Goshawk, *Accipiter gentilis*	16	194	0	0	19	144
Sparrow hawk, *Accipiter nisus*	21	100	0	0	21	156
Buzzard, *Buteo buteo*	22	15,903	20	9,110	22	7,840
Rough legged buzzard, *Buteo lagopus*	9	30	1	42	2	3
Kestrel, *Falco tinnunculus*	22	10,348	20	14,506	22	10,394
Red footed Kestrel, *Falco vespertinus*	1	9	0	0	1	1
Hobby, *Falco subbuteo*	11	21	0	0	11	25
Peregrine falcon, *Falco peregrinus*	7	9	0	0	1	1
Merlin, *Falco columbarius*	5	10	0	0	5	5

Table 2: Years and total numbers of observed raptors on three RNLAF airbases.

As is clear from table 2, on all three airbases the only species of raptors that are counted in relevant numbers were Buzzard and Kestrel. On Leeuwarden the Buzzard was most dominant (57.7% of all raptors) while on Twenthe and Volkel the Kestrel was present in largest numbers (61.3 and 55.4% of all raptors respectively).

All birds versus raptors

For each of the airbases the average total number of birds per count per year was calculated, distinction was made between raptors and non-raptors. The results are given in figure 3.

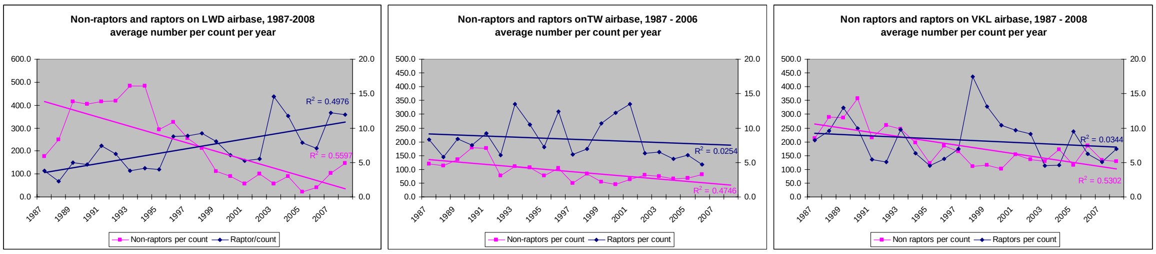


Figure 3: Yearly mean number of birds per count for non-raptors and raptors on Leeuwarden, Twenthe and Volkel airbase.

The general trend for non raptor birds is very clear, on all three airbases there is a significant decrease in the average number per count. This decrease is most marked at LWD airbase from ca. 400 birds in the late eighties/early nineties to ca. 100 birds per count at present. For TW airbase (from ca. 150 to ca. 50) and VKL airbase (from ca. 250 to ca. 150) the decrease is less marked but still very significant. For raptors the picture is not so clear. On LWD airbase there is a significant increase from ca. 5 to ca.10 raptors on average per count; on TW and VKL airbase the average number of raptors per count over the years was erratic but there was no significant trend.

Buzzard and Kestrel

Since Buzzard and Kestrel numbers on all three airbases comprise over 95% of all raptors these species are treated separately. The trend through the years for each airbase is presented in Figure 4.

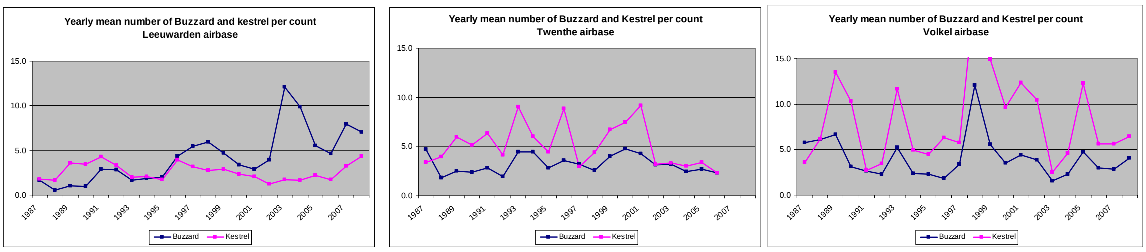


Figure 4: Yearly mean number of Buzzard and kestrel per count on Leeuwarden, Twenthe and Volkel airbase.

Most striking feature in figure 4 are the very significant ($p<0.01$) parallel yearly mean numbers per count of Buzzard and Kestrel on Twenthe and Volkel airbase. The most probable underlying factor is the variation in vole density which does fluctuate considerable in the Netherlands (3 to 5 year cycle (Bijlsma 1993)). For Leeuwarden the situation is different; the numbers of Buzzard and Kestrel do not show a parallel trend. The fluctuation in Kestrel numbers does hardly show a cyclic pattern and remain low through all of the years. Buzzard numbers on LWD do show an erratic pattern but generally have increased dramatically since 2003.
Although the yearly mean number of Kestrels fluctuates in a cyclic way on all three airbases there is not a real upward or downward trend.

In order to get a better insight in the presence of Buzzard and Kestrel, the seasonal patterns are given in figure 5. Parallel to the situation for the yearly totals the seasonal patterns for Twenthe and Volkel are much alike with hardly fluctuating low numbers of Buzzard and a late summer increase for Kestrels starting in the second half of July up to the end of September. During this peak period, the mean number of Kestrels per count on Twenthe is 3,5 times as much as during the rest of the year while on Volkel this is 2,75 times as much.
On Leeuwarden there is only a slight increase in Kestrel numbers in the autumn while Buzzard numbers show a clear increase from mid August onwards, dropping again to very low numbers in the summer months from mid May.

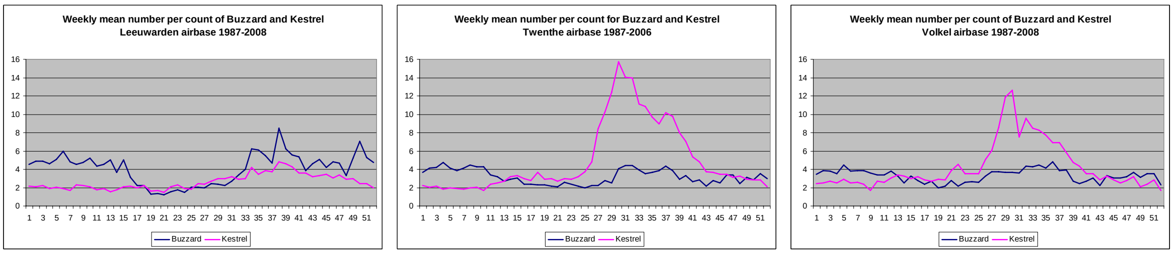


Figure 5: Seasonal patterns of Buzzard and Kestrel on Leewarden, Twenthe and Volkel airbase.

RESULTS - STRIKES

All 143 strikes with Buzzard (27) and Kestrel (116) for the period 1987-2008 are used, regardless of the origin of the report (RNLAF report, non-RNLAF report and the not reported strikes that left a carcass in the immediate vicinity of the runway). The total number of strikes for all three airbases combined is presented in figure 6.

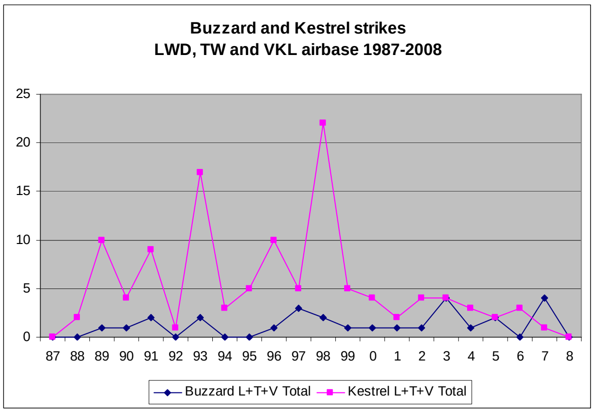


Figure 6: Buzzard and Kestrel strikes per year on Leeuwarden, Twenthe and Volkel airbase combined, 1987-2008.

As is clear from figure 6 the relative low total number of 27 Buzzard strikes does not show any trend through the years. The mean number of strikes is only 1.2 (SD 1,2) per year, ranging from 0 to 4 strikes per year. The much larger number of 116 Kestrel strikes does show an erratic pattern with a mean of 5.3 (SD 5.4) per year, varying between 0 and 22. For the Kestrel however, there is a clear distinction between the period 1987-1999 and the period from 2000 -2008. The mean number of strikes in both periods reduces significant from 7.2 (SD 6.4) to 2.6 (SD 1.4).

The seasonal pattern for Buzzard and Kestrel on each airbase is depicted in figure 7.

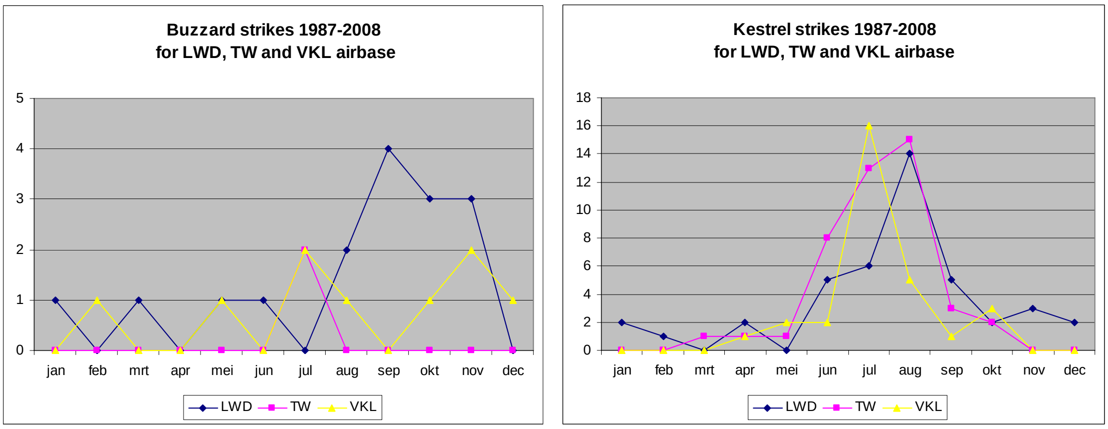


Figure 7: Seasonal pattern for Buzzard and Kestrel strikes on Leeuwarden, Twenthe and Volkel airbase 1987-2008.

Buzzard strikes occasionally occur all through the year with a slight increase in the autumn months. As is also clear from table 1, most Buzzard strikes occurred on Leeuwarden airbase. Kestrel strikes occur on all three airbases and are limited to one or two per month with a distinct summer peak (June to September) culminating to 14 to 16 strikes at the top of the peak in July or August.

RESULTS – TRAPPING

Species and trapping devices

The trapping on Twenthe airbase involved a total of 1398 birds. These were caught, relocated, ringed and released. Table 3 shows an overview of the numbers per species and per trapping device.

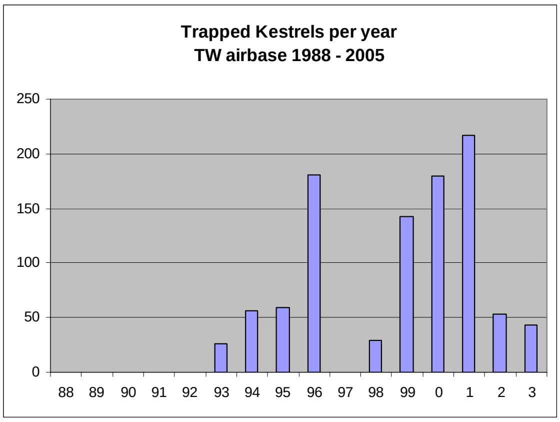
Species		Ball chatrii	Cage trap	Larsen trap	Total
Montagu´s Harrier	*Circus pygargus*	1			1
Sparrowhawk	*Accipiter nisus*			53	53
Goshawk	*Accipiter gentilis*		3	52	55
Buzzard	*Buteo buteo*	27	11	91	129
Kestrel	*Falco tinnunculus*	486	482	23	991
Pheasant	*Phasianus colchicus*			1	1
Woodpigeon	*Columba palumbus*			1	1
Barnowl	*Tyto alba*			5	5
Long eared owl	*sio otus*	1	2	91	94
Tawny owl	*Strix aluco*			13	13
Shrike	*Lanius excubitor*		1		1
Jay	*Garrulus glandarius*		5	36	41
Carrion Crow	*Corvus corone*		2	11	13
Total		515	506	377	1398

Table 3: Number of birds trapped per species and per trapping device.

It is clear from table 3 that a variety of raptors was trapped but only Kestrel, and to a lesser extent Buzzards were trapped in significant numbers. The Larsen trap was mainly successful in trapping woodland species like Sparrow hawk, Goshawk and owls but also Buzzard was trapped in good numbers with this device. Kestrels were equally successful trapped using a ball chatrii trap (up to 2000) and a cage trap (from 2001 onwards). Further analysis of trapping data is limited to Kestrels.

Yearly and seasonal distribution of trapped Kestrels

Trapping of Kestrels was mostly limited to years in which increased numbers were observed. Hence the erratic pattern in trapped Kestrels per year shown in figure 8. Since peak numbers were limited to the late summer months the seasonal distribution of trapped Kestrels is limited to the months July to September (fig. 8).



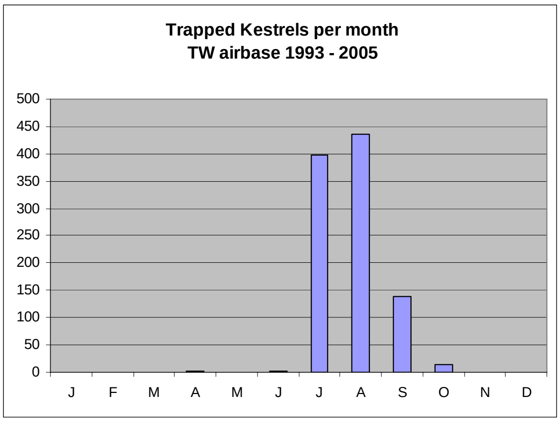


Figure 8: Trapped Kestrel on Twenthe per year (left) and per month (right).

Age and gender of trapped Kestrel

Of 970 out of the 991 trapped Kestrels age could be determined. From these, 71.2% were immature birds. From 906 birds the sex could be determined. The overall distribution over the sexes was 51.5% male against 48.5% female. For immature birds this was 56.4% against 43.6% and for mature birds 39.1% against 60.9%.

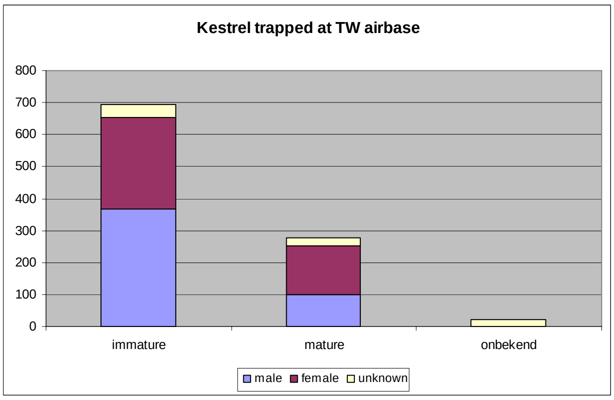


Figure 9: Age and gender distribution of 991 Kestrels trapped on Twenthe airbase 1993-2003.

Location of origin and destination

From the 991 trapped Kestrels 8 escaped before a ring was put on, 53 were already ringed elsewhere. From these, 40 were previously ringed in the Netherlands, 8 in Belgium, 4 in Germany and 1 in Sweden. From birds trapped and ringed on TW, 31 were reported back from elsewhere. Of these, 13 were reported from within the Netherlands, 8 from Germany, 3 from France and 1 from Morocco.

Relocation and retraps.
A total of 47 trapped Kestrels were own re-traps and ringed on the airbase before. This suggests that only 4.8% of the birds returned after been relocated over only 10 kilometre. Whenever possible during the frequent runway inspections and detailed bird counts, Kestrels in the field were always visually checked for rings. Hardly ever this was noticed. It therefore seems safe to conclude that only a very small proportion of the relocated Kestrels returned to the airbase.

DISCUSSION

Number of raptors in relation to the total number of birds.
The introduction of a rigorous shift in habitat management in the early 1990´s (Dekker & van der Zee 1996; Dekker 2000) did induce a very significant decrease in the total number of non-raptors present at the airbases (figure 3). The effect of this shift in habitat management on raptors however is not so clear. In the first place numbers of raptors fluctuated considerably through the years and no significant trend is recognised over the whole period. In the perception of airbase staff in the runway environment (ATC, BCU, pilots) the considerable decrease in numbers of non-raptor birds is accepted very quickly while at the same time emphasis is shifted towards the number of raptors that became relatively dominant once the numbers of other species decreased. Although absolute numbers of raptors did not show a trend, their relative presence became dominant. However, the intuitive conclusion that raptor numbers increased is not supported by the absolute numbers. The only exception being the increase in Buzzard numbers on LWD airbase.
The significant parallel pattern of both Kestrel and Buzzard on TW and VKL airbase (figure 4) suggests a common underlying factor. Although no census data are available it is most likely that fluctuating vole (*Microtus arvalis*) densities are responsible for the varying numbers through the years. Voles are the staple diet for Kestrels and are an important food source for Buzzards.

Number of Kestrels
The more or less stable numbers of Kestrels counted through the years on LWD as well as the erratic pattern on TW and VKL do not reveal a clear trend in Kestrel numbers on the airbases (figure 4). This is in line with the erratic pattern of non-breeding Kestrel in the Netherlands as showed in figure 10.

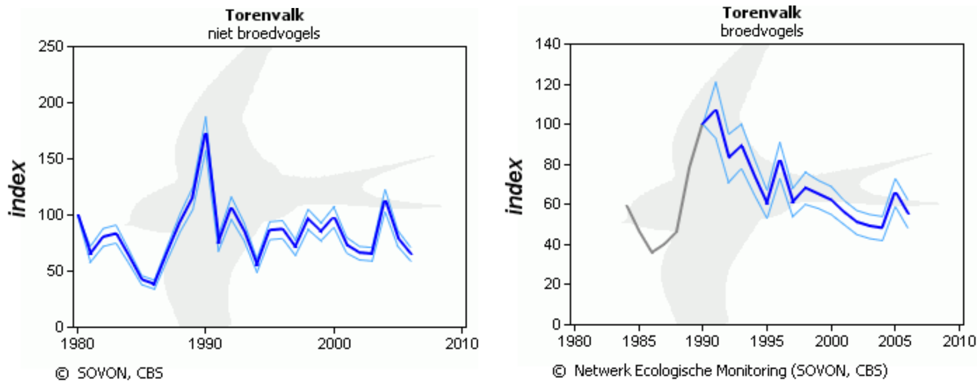


Figure 10. Index of Non-breeding (left) and breeding (right) Kestrel in The Netherlands (taken from www.SOVON.nl)

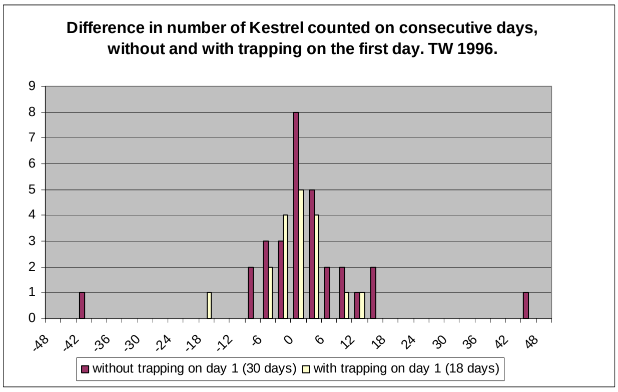
Despite the erratic, over the long term more or less stable numbers of non-breeding Kestrel the breeding numbers in The Netherlands are decreasing (figure 10). The only slight increase in Kestrel numbers in late summer on LWD could therefore mean that only local/regional birds are involved. The large increases in late summer Kestrel numbers on TW and VKL on the other hand, cannot be induced by local breeding birds only but suggest that dispersion movements from over a much wider source area are involved. This is supported by the fact that the trapped birds on TW that were already ringed not only originated from The Netherlands but also from Belgium (8), Germany (4) and Sweden (1). Furthermore, the Swedish ring suggests that also southwest oriented migrating birds are partly responsible for the increase during late summer. Nevertheless, the 8 Belgium rings (originating from the southwest, contrary to the migration direction) support the idea that dispersion movements are dominant. Also the seasonal pattern (figure 5) points in this direction. On both VKL and TW the seasonal increase starts at the end of June, peaks in the 3rd week of July and is over by the end of September. This is a month earlier than the known migration pattern of the Kestrel in The Netherlands (LWT/SOVON 1992). The fact that most of the trapped Kestrels on TW were immature and that only 4.8% of the relocated returned to the airbase also supports the conclusion that the late summer peak consists mainly of non-resident birds which are dispersing non-directional from a large area.

Kestrel strikes

Its aerial flying hunting behaviour does make the Kestrel a very strike prone bird species. In addition, prey fixation is so strong that evasive manoeuvres to avoid a strike are seldom seen. It is not surprising therefore that the majority of the Kestrel strikes occur in the months July to September (figure 7) when numbers are at its peak (figure 5). Nevertheless the presumption that more strikes will occur when more Kestrels are present is belied if we consider the fact that for none of the three airbases there is a significant relationship between the yearly mean number of Kestrels per count and the number of bird strikes per year. The same applies when only the peak period July – September is taken into account. This is underlined in figure 6 which shows that the number of Kestrel strikes is stable from the year 2000 onwards despite the fact that the mean numbers per count (fig. 4) do not follow that pattern.

The apparent absence of the expected relation between numbers of Kestrels present and Kestrel strikes is not unique. A study of Lapwing numbers versus strikes did not reveal a simple straight forward relation either (Dekker & Buurma 1988). Behavioural aspects like flocking and flight activity of the Lapwing were thought to be the explanation. Flocking does not play a role in the case of the Kestrel but it is conceivable that variation in flight activity is the key factor. The availability of prey might be an important factor. In years when voles are abundant and competition low, Kestrels need to hunt less and therefore fly less than in years with low vole density and/or high competition. These circumstances would weaken the expected positive relation between numbers and strikes. Another factor that might influence the relationship is the fact that 52% of the Kestrel strikes were not reported and only based on carcasses found alongside the runway. It is uncertain how complete these incidents are noticed and documented. Taken all these considerations into account, and in the absence of information on vole density we have to assume that, without knowing the quantitative nature of the relationship and all circumstances equal, more Kestrels mean an increased strike risk.

Trapping and relocation of Kestrels
Although labour intensive, the work at TW airbase showed that trapping of Kestrels is very well possible. In good years 150 to 200 Kestrels were trapped during the summer peak. On days with trapping activity on average 3.8 (SD 2.7) Kestrels were trapped. Relocating the trapped Kestrels over only 10 Kilometres was successful in the sense that 95.2% of these birds did not come back to the airbase.
To assess the effectiveness of relocation in decreasing the number of Kestrels on the airbase a comparison is made of the number of Kestrel on two consecutive days, with and without trapping on the first day. This is done for the years in which the most Kestrels were trapped, 1996 and 2001. The results for 1996 are given in figure 11.



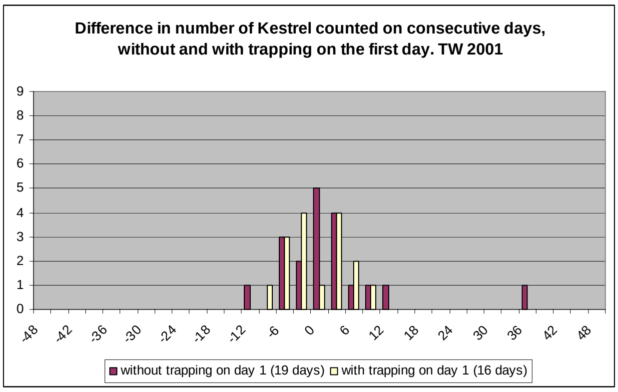


Figure 11. Difference in number of Kestrel counted during peak presence (July – September) on TW in 1996 (left) and 2001 (right) on consecutive days, with and without trapping on the first day.

It is clear that, independent of trapping activity on the first day, the presence of Kestrel on the second day can be the same, higher or lower along a normal distribution. This was not only true for 1996 but also for 2001. This indicates that trapping does not decrease the number of Kestrels on the next day and that Kestrel presence is very dynamic due to dispersion movements as well as migration.
Attempts to reduce raptor numbers on airfields are not new. Already in 1965 raptors, mainly short-eared owls (*Asio flammeus*) and Barn owls (*Tyto alba*), were trapped on Vancouver International Airport and relocated over 20 miles (Anonymous 1965). Also it has been shown already that trapping and relocating raptors is not always effective. In a study on Toronto International Airport in 1976 it was stated that " *The present control method (trap and removal) for raptors was judged to be rather ineffective, for although none of the removed birds returned, most were almost immediately replaced by others.*" (Brooks et al 1976). Based on the experience on TW airbase the conclusion is that the effect of trapping is very limited in time but does satisfy the call for action.

Number of Buzzards
Buzzard numbers on LWD airbase have increased dramatically since 2002 while on TW and VKL airbase numbers are more or less stable. If we consider this in relation to the National Census data from figure 12 this is surprising. On a National level both the non-breeding and breeding numbers of Buzzard increased significant and almost doubled compared to the late eighties and early nineties. This means that the increase on LWD airbase is in line with the national trend while the stable numbers

on TW and VKL airbase are relatively low when considered in relation to the National trend.

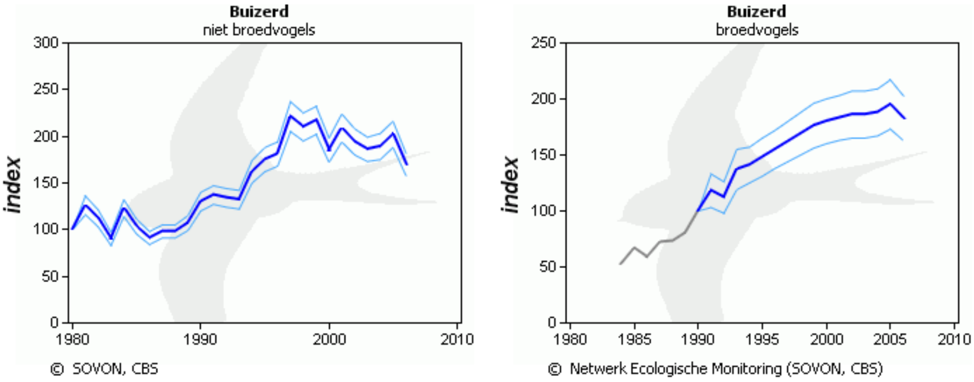


Figure 12. Index of Non-breeding (left) and breeding (right) Buzzard in The Netherlands (taken from www.SOVON.nl)

The positive trend for the Buzzard in The Netherlands from fig. 12 is supported by a similar population trend for Europe (figure 13). Buzzards breeding in The Netherlands are non-migratory, while Buzzards from more northerly regions do migrate south, some as far as Spain and North Africa but also to wintering grounds in The Netherlands (SOVON/LWVT 2002). At the major concentrating point in SW Sweden, among other raptors, 10,000 migrating Buzzards pass in the autumn (Zalles & Bildstein 2000). Autumn migration over The Netherlands starts end of August while spring migration lasts until early May (LWVT/SOVON 2002). The seasonal pattern for the Buzzard on LWD airbase shows increasing numbers from week 33 (end of August) up to week 15 (end of March). This suggests that the increase during the winter months is due to an influx of migrating Buzzards from Northerly regions. Since the Buzzard in Europe has increased in numbers with about 70% since the eighties (fig. 13) it is not surprising that numbers of wintering Buzzards on LWD have increased. It is on the contrary surprising that wintering numbers on TW and VKL did not increase but remained more or less stable (figure 4).

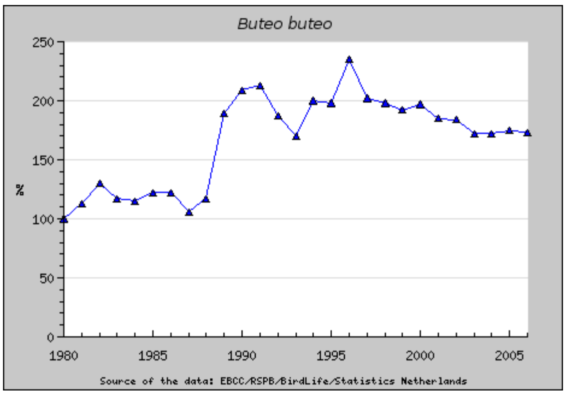


Figure 13. Trends in European Buzzard population according to the European Bird Census Council (taken from www.EBCC.info)

Buzzard strikes

Through the years the total number of Buzzard strikes does not show a significant trend; and varies between 0 and 4 strikes per year (figure 6).
Buzzard strikes do occasionally occur in all months of the year but on LWD airbase are concentrated in the months August – November, corresponding with an influx of migrating Buzzards from more Northerly origin (figure 7).

The period in which high numbers of Buzzard are present on LWD lasts from the end of August to the end of March (figure 5). Based on these increased wintering numbers one would expect that strikes also would occur more frequently during the late winter months, up to March. It is unclear why Buzzard strikes are absent in these months. A possible explanation could be the learning effect of the wintering birds. Also the decrease in good thermal conditions in the second half of the winter could play a role since this leads to less flying activity of the Buzzards. On the other hand, during late winter Buzzards are very active when establishing their territory (Bijlsma 1993).

Voles (Microtus arvalis) as the main food source for Kestrel and Buzzard.
Both Kestrel and Buzzard heavily rely on voles as their main food source. The population of voles in The Netherlands does follow a three yearly cyclic pattern but unusual cold, wet or snowy winters, which influence mortality and reproduction, do disturb this pattern. The cycles are synchronous within regions but may differ between regions (Apeldoorn of 2005). These dynamics probably form the main underlying factor for the very variable number of raptors from year to year. Vegetation length is determining the attractiveness of habitats for voles. Lowest densities occur in intensively exploited, short grasslands that offer hardly any cover, while in vegetations of 10-30 centimetres higher densities are registered than in real long vegetations of 30-60 centimetres (Apeldoorn 2005). This implies that any long grass policy, although effective against many bird species, has a downside of being attractive for voles and their dependent raptors. Even more so if clippings from mowing are left, which form an attractive thatch in which reproduction thrives (Jacob & Halle 2001).In line with this, early experience in grass management on LWD airbase showed that mowing without immediately taking away the clippings resulted in a situation where more Kestrels were counted then when clippings were taken away immediately after mowing (Dekker & van der Zee 1996). In addition, in a study on the erosion resistance of river dykes, van der Zee (1992) found that vole densities always were higher in long grass than in poor grass conditions.

The fact that different airbases with the same grassland management may show very different raptor densities is surprising. If we assume that this is correlated to different vole densities we have to conclude that the same grassland management may lead to different vole densities. These differences in vole density may be related more to the soil structure than to the grassland management. Although soil type (clay, sand, lowland peat) is not determining whether a vole population might explode to a plague, the permeability (hardness) of the upper 20 cm of topsoil is an important factor for the possibility to build burrows (Apeldoorn 2005). This probably explains why on three other RNLAF airbases (Woensdrecht, Gilze-Rijen and Soesterberg), situated on course sandy soils which support only very low vole densities, raptors only occur in very low numbers that never increase to unacceptable levels.

Changing grassland management to intensively managed short grass and thus reducing vole densities is likely to undo the positive effect of the present management towards recognised other problem species (gulls, waders, pigeons etc). This leaves no other options than direct and specific measures against voles as the main attractant for raptors. The use of rodenticides in The Netherlands is very strictly regulated and inhibits the exposure of poison to other than the target organisms. This means that spreading rodenticides in the open air over large areas is no option.

Another potential measure against voles is flooding the terrain. This proved to be very effective when, as a consequence of malfunctioning of the drainage system, on LWD airbase large areas of the runway environment unintentionally became extremely wet in the winter of 2005/2006. This resulted in a temporary decrease in the number of raptors, suggesting a drastic decrease in vole densities. As a standard measure against voles it is not recommended since extreme wet or flooding circumstances do attract other problem species like gulls and waders.
An interesting new development in vole control is the use of a combination of special traps and fences; enhancing the hunting success of natural predators (Malevez & Schwizer 2005). Although primarily designed for agricultural purposes it could well be efficient for airfields.

Unfortunately we did not have a monitoring system for voles in the past years and had to rely on raptor numbers as an indirect indication for vole density. From 2008 onward vole densities are spatially monitored using the “renewed burrows method” (Liro 1974). Hopefully this method will help us to establish the nature of the relationship between voles and raptors in the particular airfield environment. It also might lead to a better insight in factors determining vole density, thus opening a way to preventive measures.

IMPLICATION FOR BIRD STRIKE PREVENTION

In addition to the discussion above, this analysis leads to a number of general conclusions in relation to bird strike prevention on airfields:

- Concerning bird numbers on airfields figures 3 and 4 demonstrate that for recognising trends, long time series are needed. Depending on the species, numbers may naturally fluctuate through the years;
- Decreasing numbers of a problem species will increase the relative importance of other remaining species;
- Numbers of birds on airfields are not only a reflection of the attractiveness of the airfield but have to be considered in relation to regional, National or Supra National trends;
- The poor grass regime, based on depletion of the soil fertility, is effective against most traditional problem species. Although it proved not effective against raptors there is no evidence that it is more attractive to raptors than conventional long grass habitat management.
- The relation between numbers of raptors on an airfield and the number of raptor strikes is not unambiguous but in general terms the chance to have a raptor strike is higher when more raptors are present.
- Controlling raptor influxes due to migration or dispersion movements is extremely difficult;
- Trapping and relocating raptors is feasible and successful in the sense that displacement over just 10 kilometres proved to be enough in the case of Kestrels;
- Trapping and relocating does not automatically mean that the numbers present on the airfield will decrease. The dynamics in bird movements might well mean that removed birds will be immediately replaced by others, making this control method ineffective. A trapping and relocating scheme may therefore just satisfy the call for action;

- In circumstances in which trapping and relocation is ineffective the same holds for lethal measures;
- There is a great need for environmentally accepted techniques to control vole populations.

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Appendix 1. Frequency of detailed bird counts used in this paper