A quantified species specific Bird Hazard Index

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Abstract
To assess the bird situation at airfields a risk assessment matrix, which indicates the risk that bird species pose to an airport, is often used. For a given period, bird species are positioned in this matrix according to the frequency with which they were involved in bird strikes and the percentage of strikes resulting in damage. The matrix is a tool to evaluate the bird hazard management program, enabling the management to take appropriate measures. For day to day purposes it does not provide the possibility of calculating a hazard level at any given moment, based on birds present in the runway environment. Therewith it does not provide a decision tool for bird control units to prioritize bird control measures. This requires a quantified species specific Bird Hazard Index which enables the estimation of the hazard level at any specific time.

We have developed such a quantified species specific Bird Hazard Index by combining the species specific bird strike sensitivity and damage sensitivity. Strike sensitivity is calculated using the discrepancy between the local RNLAF bird strikes per species and their presence on an airbase (using 15 years of systematic bird counts on 7 RNLAF airbases). The damage percentages from EURBASE represent the species specific damage sensitivity. Combining those two a species specific Bird Hazard Index is generated.

In this project the Bird Hazard Index is calculated for 20 prominent bird species, covering more than 80% of the total number of birds present at RNLAF airbases. With this quantified species specific index it is possible to objectively assess the hazard of the local bird situation at any moment during any bird count at any airbase. This enables the development of a bird control decision support system. In addition, this method can be used as an audit tool based on bird counts only, without the use of bird strike statistics (which often are inconsistent and/or are based on low numbers on small airports).

1. Introduction

On-airfield bird strike prevention is based on assumption that birds that stay in the runway environment will sooner or later fly and then may interfere with starting or landing aircraft. Bird control on airfields is therefore focussed on the reduction of the number of birds present, using habitat management schemes and scaring techniques. Since bird free airfields will never be accomplished, bird control should be prioritised according to the hazard levels presented by the birds present at any moment. There is no point in aiming resources at bird species that are present in significant numbers but hardly form a threat while at the same time neglecting birds species that, despite their small numbers pose a real threat to flight safety. All bird controllers know by experience that one bird species is more likely to be involved in bird strikes then another. Based on this experience they create their own frame of reference and act according to it. In the RNLAF this acting not only consists of prioritising scaring operations but also means that bird controllers issue a *bird status*. Depending on the level of the *bird status* flight operations are affected. Despite the fact that an analysis of issued bird statuses showed that there is a large common agreement between airbases (bird controllers), a quantified, species specific Bird Hazard Index (BHI) is needed. Such a BHI would help to even out personal interpretations and help bird controllers to establish the bird status at any given moment. Apart from establishing an ad-hoc assessment of the hazard at any moment, a BHI could also be used to evaluate in hindsight the hazard level at certain periods; thus acting as an audit tool.

The need to identify the risk level inherent to a bird species has lead to a number of systems in which bird species are ranked according to their involvement in bird strikes and the proportion of those strikes that result in damage.
Dolbeer et al (2000) used the FAA civil bird strike database 1991-1998 and ranked 21 species or species groups with ≥ 17 strikes according to a composition that includes damage, major damage and effect of flight. They suggested using this ranking in conjunction with site specific surveys to enable the management to reduce the strike hazard. Although the overall ranking does make sense it does not provide the quantitative difference between the successive rankings. The fact that the system is based on bird strike statistics only further introduces uncertainties. Linnel et al (1999) showed that pilot reports only cover 25% of all bird strikes. Furthermore, Dolbeer et al (2000) points out that from less than 50% of the bird strikes in his database the bird species involved is known. It is unknown whether the species composition from the unidentified bird strikes reflects that of those strikes of which the bird species is know. This adds some further uncertainty to the ranking system.
Zakrajsek and Bisonette (2005) made a similar study using the USAF bird strike database for the period 1985-1998. Unlike Dolbeer et al (2000) they also calculated a Hazard Index for each species (group), providing a relative distance between the rankings. This study does reflect the overall situation for the United States Air Force. Unfortunately they did not make a selection for on/near airfield bird strikes only. This means that they included the en-route bird strikes. In contrast to civil aviation, bird strikes during military low flying activity could make up over 50% of all bird strikes. This may explain the differences with the ranking from Dolbeer et al. (2000).
Morgenroth (2003) choose a completely different approach and used 11 criteria to calculate a numerical index. For each criterion he defines values in qualitative (expert opinion) or quantitative classes. Some of the criteria are site specific and therefore the index is species and site specific.
Allan (2006) introduces the well known probability-severity risk assessment matrix for bird strike risk assessment. For a given airport the bird strikes per bird species over a given 5 year period are a measure of strike probability. The proportion of strikes with each species that – in the national database - results in damage is a measure of likely severity. This risk assessment matrix is used as auditing tool for the bird strike prevention activities of airfields. It is a simple tool which shows for which bird species further action is needed. Since it is

based on bird strikes only it does suppose that there is an adequate reporting system that provides complete and consistent information; a situation that is not always the case (see also Linnel et al 1999). Since bird strikes are a relatively rare event it uses 5 year periods to avoid statistical noise. For smaller airfields with fewer aircraft movements the method is too coarse and needs adaptation (Hansen 2009).

All described ranking methods are aimed to provide insight in the unquantified relative hazard of species and do not give information with regards to the number of individuals connected to this hazard. These rankings are therefore unsuitable for use within a Decision Support System in which the number of individuals per species has to play a key role.
Our BHI is different; it is a species specific, quantified measure for the hazard posed by an individual bird. The BHI uses the discrepancy between the strike involvement and the strike opportunity to calculate the *strike sensitivity* of a bird species. As a measure of severity the percentage of damaging bird strikes for a species is also included. Since the BHI incorporates behavioural and physical properties without site specific information we believe the BHI for a species to be valid for the entire range of the NW European population.

2. Material

In order to calculate a BHI, information is needed about the presence of bird species on airfields as well as the presence of bird species in bird strike statistics. Since the likelihood of a bird strike is also dependent on the intensity of aircraft operations, also the aircraft movements are needed. With the need for reliable data from these various sources we selected the 15 year period 1995-2009 as a starting point.

2.a Bird strike statistics used for calculating the strike involvement.

We used the RNLAF bird strike database. Due to the military discipline and the long time attention to bird strike prevention within the RNLAF this database is very complete and contains pilot and ground crew reported bird strikes (irrespective of aircraft operator) as well as unreported strikes based on carcasses found on/near the runway. In order to reduce the heterogeneity of the material we selected bird strikes with fix-wing aircraft only. We further excluded all the non-local bird strikes which occurred en-route and do not have any relevance for the BHI. This left us with a database of 836 bird strikes from 7 airbases over a period of mostly 15 years (Leeuwarden (LW 1995-2009), Twenthe (TW 1995-2007), Soesterberg (SB 1995-2008), Volkel (VK 1995-2009), Eindhoven (EH 1995-2009), Gilze-Rijen (GR 1995-2009) and Woensdrecht (WD 1995-2009). From 93.7% of the 836 bird strikes the bird species involved was known up to species level.

2.b. Bird strike statistics used for calculating the percentage damage.

The dataset of 836 on-airfield bird strikes of RNLAF is not large enough to reliably establish the severity as percentage damaging strikes per species. We therefore used the European Military database EURBASE and selected on-airfield strikes with fix-wing aircraft from German, British, Dutch, Belgian and Danish Air Forces which are known to have similar reporting standards. This increased the number of available bird strikes per species considerably, numbers per species varied from 7 to 401.

2.c. Aircraft movements

Calculating the strike sensitivity for a bird species by only using the presence of that species in both the strike statistics as well as the bird counts for a combination of 7 airbases does not take into account the variation in air traffic intensity between those airbases. A species might be present on an airbase in huge numbers but when there are hardly any aircraft movements the chance that the species is involved in a bird strike is very small. Since we are dealing with military airbases there is no holiday peak in aircraft movements in the summer months.

This was tested for an available detailed subset sample for five years. So it is safe to assume that military aircraft movements are more or less evenly spread throughout the year.

2.d. Bird counts

Knowing which bird species at what time of the year are present on an airfield in which numbers is vital information for bird strike prevention programs and bird controllers. In the RNLAF it is therefore common practice for several decennia to make systematically executed standardised bird counts. For trend analyses and as input for habitat management decisions these counts per species and per plot on the airfield are carried out in the morning between 8 and 10 am. These so called "GORS" counts are executed 2 to 3 times per week. In addition, for the years from 2000 onwards there is information from runway inspections that are carried out with a minimum of 4 times a day. These quick inspections contain the total number of each bird species in the runway environment (up to 100m each side of the runway) in abundance classes. We used the GORS counts for calculating the presence of a species on an airfield and corrected this for time of day effect by using the day pattern from the inspections.

For the various analyses a total of 14,192 GORS counts and 116,414 inspections were available from 7 airbases.

2.e. Species selection

A BHI can only be calculated for those bird species for which enough information is available about their presence on airfields and in the bird strike database. The accumulative and relative presence of the 20 most present bird species during the 15 years 1995-2009 on the 7 RNLAF airbases is given in figure 1. From this figure it is clear that only a few bird species dominate the avifauna of the airbases. Eight species make up 80% of the total number of birds counted and 15 species add up to 90%. Figure 2 presents the real and accumulative relative involvement in bird strikes of the top 20 bird species. As in figure 1 the distribution is dominated by relative few species. Seventeen bird species cover 80% of all bird species involved in bird strikes.

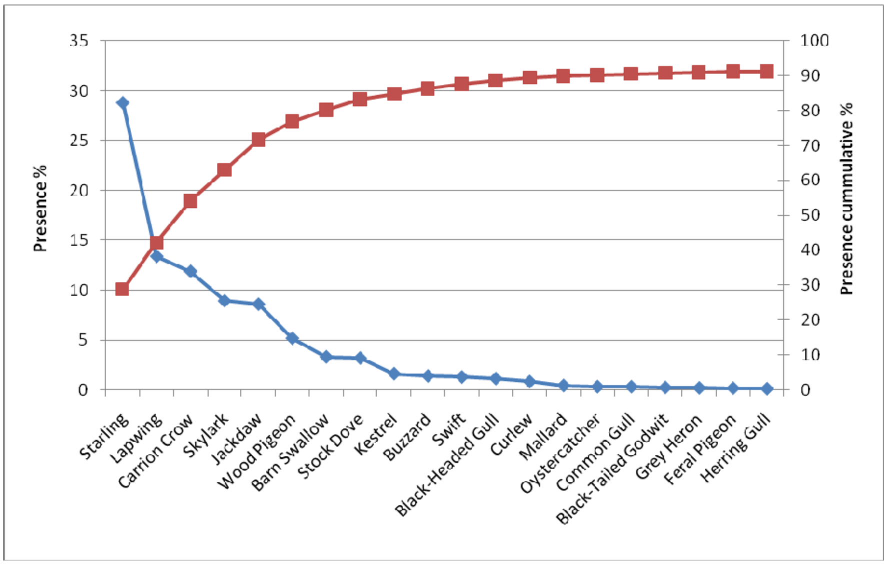

Figure 1: Percentual and accumulative percentual presence of the 20 most common bird species on 7 RNLAF airbases during standardised counts in the years 1995-2009.

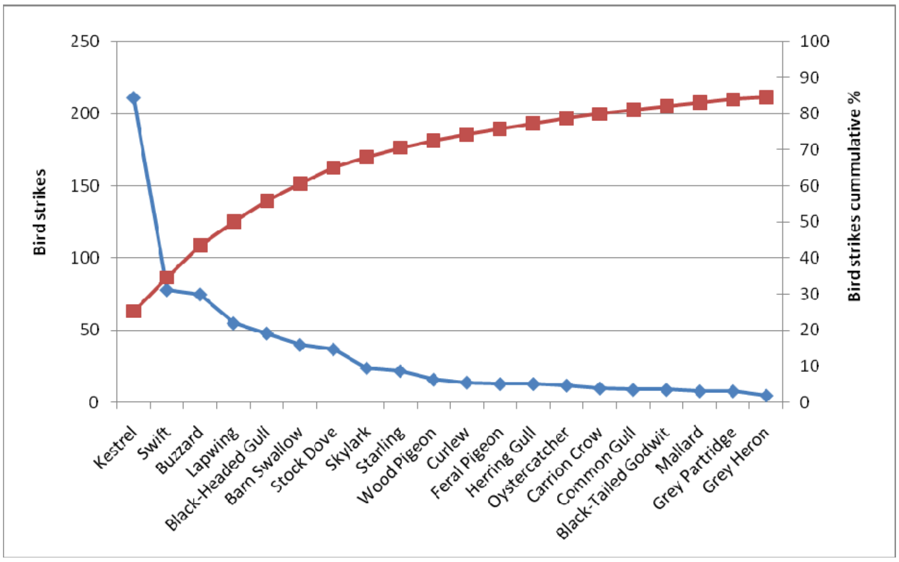

Figure 2: Real and accumulative percentual involvement of 20 bird species in bird strikes on 7 RNLAF airbases during the years 1995-2009.

The set of bird species in figure 1 and 2 is very similar; of both figures 19 species overlap. Out of figure 1 and 2 we composed a set of 20 relevant bird species which is given in table 1.

Herring Gull	*Larus argentatus*
Kestrel	*Falso tinnunculus*
Grey Heron	*Ardea cinerea*
Buzzard	*Buteo buteo*
Feral Pigeon	*Columba livia*
Common Gull	*Larus canus*
Black-headed Gull	*Larus ridibundus*
Oystercatcher	*Haematopus ostralegus*
Mallard	*Anas plathyrhynchos*
Curlew	*Numenius arquata*
Swift	*Apus apus*
Stock Dove	*Columba oenas*
Wood Pigeon	*Columba palumbus*
Swallow	*Hirundo rustica*
Lapwing	*Vanellus vanallus*
Carrion Crow	*Corvus corone*
Skylark	*Alauda arvensis*
Starling	*Sturnus vulgaris*
Jackdaw	*Corvus monedula*
Black-tailed Godwit	*Limosa limosa*

Table 1: Selected 20 species for which the Bird Hazard Index is calculated. The order of the species is as in other tables and annexes and is in decreasing order according to the calculated Bird Hazard Index

3. The calculation of the Bird Hazard Index

The Bird Hazard Index (BHI) equals the product of the relative strike sensitivity and the damage probability:

BHI_i = Relative Strike Sensitivity$_i$ * Damage Probability$_i$ (1)

In which:

BHI_i = Bird Hazard Index for species i
Relative Strike Sensitivity$_i$ = The relative risk that species i is involved in a bird strike
Damage Probability$_i$ = The percentage of damage for species i from EURBASE

We defined the relative strike sensitivity as the discrepancy between strike involvement and strike opportunity. The relative strike sensitivity is calculated in two steps:

$$\text{Strike sensitivity}_i = \frac{\text{Relative strike involvement}_i}{\text{Relative strike opportunity}_i} \quad (2)$$

$$\text{Relative strike sensitivity}_i = \frac{\text{strike sensitivity}_i}{\max(\text{strike sensitivity})} \quad (3)$$

In equation (2) the ***relative strike involvement*** for a bird species is the proportion that that species makes up of the total number of strikes.

The ***strike opportunity*** for a species is calculated according to equation 4

$$\text{Strike opportunity}_i = \sum_{v=1}^{7}\left(\sum_{j=1}^{15}\left(\text{presence}_{ijv} * \text{N Aircraft movements}_{jv}\right)\right) \quad (4)$$

In which:

Strike opportunity$_i$		= The strike opportunity for species i
Presence$_{ijv}$		= The presence of species i in year j on airbase v
N Aircraft movements$_{jv}$		= The number of aircraft movements in year j on airbase v
v		= Airbase
j		= Year

The ***relative strike opportunity*** for a species is the proportion that the strike opportunity for that species makes up of the total strike opportunities from all species. Although both the strike involvement and strike opportunity per species are relative, they are not subject to the selection of the 20 bird species because fractions are calculated using the total dataset of birdstrikes and present species, including the non selected species (see annex 1).

In equation 4 the presence of a bird species is calculated for each year and airbase as the summed weekly mean numbers. Weeks with missing data are interpolated taking into account the yearly pattern and the long term trends in summed weekly mean numbers. Years with missing data for 10 weeks or more were excluded for the establishment of the long term trend. The process of interpolation was executed using the function “pchip” (Piecewise Cubic Hermite Interpolating Polynomial) in MatLab® and for each bird species resulted in the presence as a year sum for each airbase and year.
Since GORS bird counts are executed between 8 and 10 am, the presence as calculated represents the morning situation only. Bird species might however show distinct daily patterns of presence, if only due to bird control operations. Therefore the presence was corrected, using day patterns derived from the frequent runway inspections. Figure 3 demonstrates this process for the Lapwing. The day pattern in the inspections shows a gradual decline in numbers through the day and an increase from late afternoon onwards. The mean number of Lapwing between 8 and 10 am as derived from GORS counts is 10.13 while the overall mean of all inspections throughout the day is12.45. The fraction 12.45/10.13 = 1.23 is used to correct the year sum of the Lapwing on this particular airfield and year.

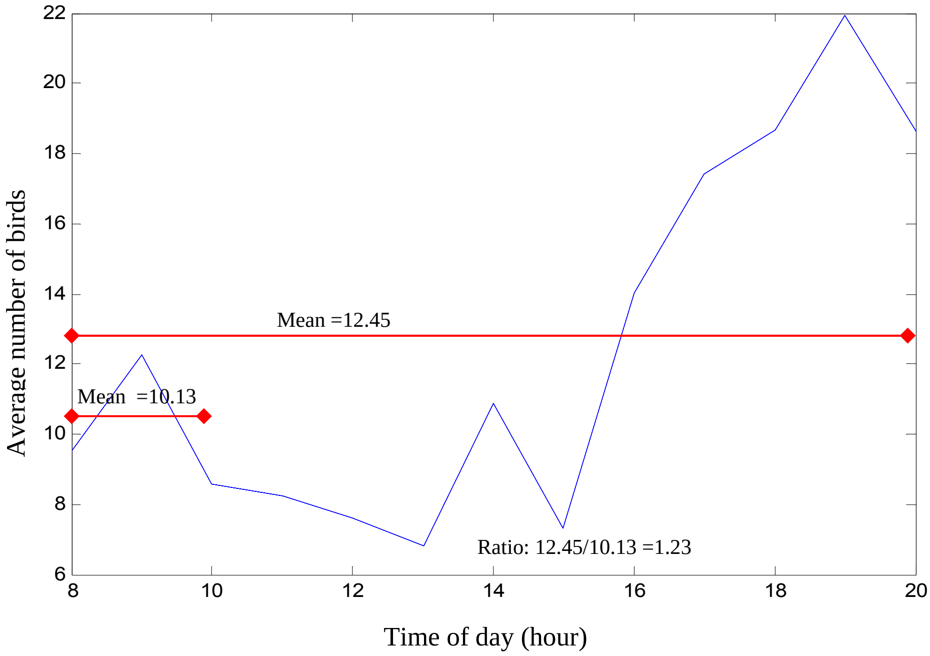

Figure 3:
Correction for day pattern of the Lapwing. Average number over the day according to multiple inspections = 12.45 while the average number of the standardised counts between 08:00 and 10:00 is 10.13. This results in a correction factor of 12.45/10.13=1.23.

4. The resulting Bird Hazard Index

The resulting values for relative strike involvement, relative strike opportunity and relative strike sensitivity for the 20 selected species are presented in figure 4 and given in annex 1.

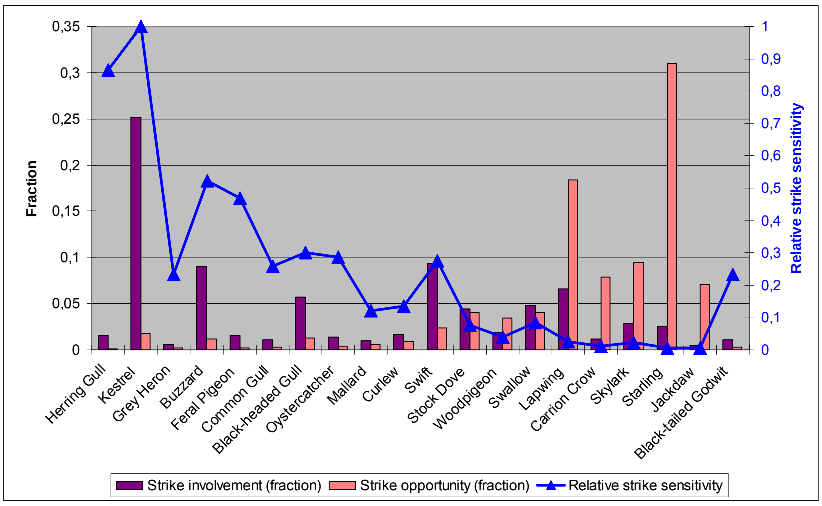

Figure 4:
Relative strike involvement, relative strike opportunity and resulting relative strike sensitivity for 20 selected bird species.

From the EURBASE selection we calculated the percentage of strikes resulting in damage for each of the 20 selected bird species. The number of strikes for each species varied from 7 (Jackdaw) to 401 (Lapwing) and is presented in figure 5 and the accompanying data is given in annex 2.

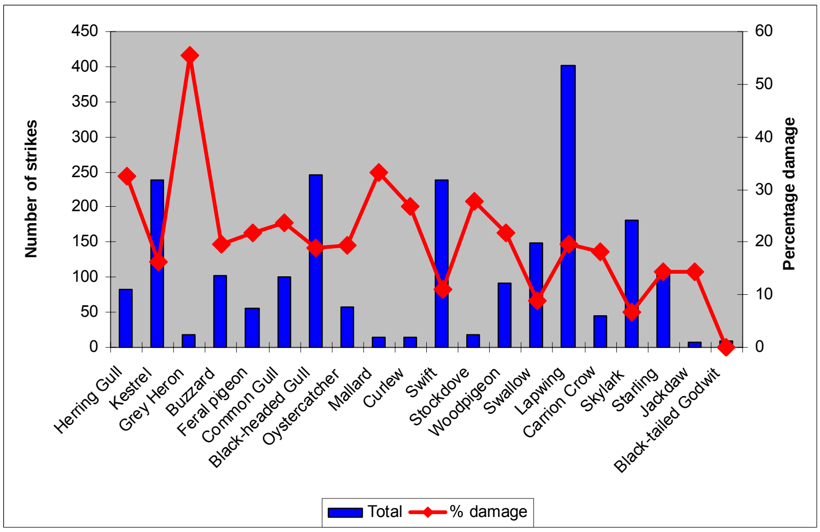

Figure 5:
Percentage of damage per bird species and the number of strikes on which this is based (EURBASE).

By multiplying the relative strike sensitivity and the damage probability we calculated the bird hazard index for each species (see figure 6 and annex 3).

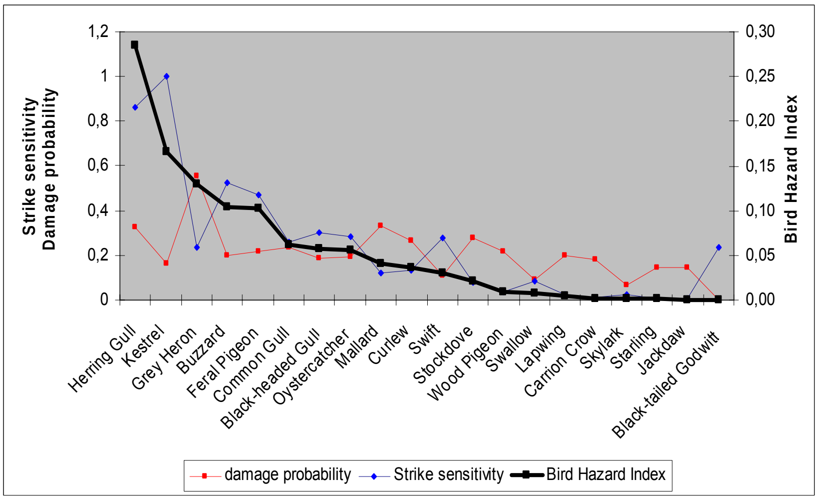

Figure 6:
Damage probability and strike sensitivity for 20 most common bird species (left Y axis) and resulting Bird Hazard Index (BHI) (right Y-axis).

As is clear from figure 6 and annex 3 the BHI varies from 0,0002 for the Black-tailed Godwit to 0,2846 for the Herring Gull. For the interpretation of these figures it is important to realize that the BHI represents the hazard level for one single bird.

5. From Bird Hazard Index to Inspection Index.

As indicated before, the BHI can be used to calculate at an ad-hoc basis the hazard level on an airbase or used as an audit tool. For both these purposes the results of inspections have to be transformed into inspection indexes using the BHI. We calculated the Inspection Index by first multiplying the numbers per species during an inspection by their BHI value and sum the resulting values. In fact, the BHI enables us to use an integrated approach towards the hazard imposed by the avifauna of an airbase.

The Inspection Index values vary enormously in a skewed distribution. They are therefore transformed to a normal distribution using the following equation:

Inspection Index $= \ln\left[\left(\sum_{i=1}^{i=s}(n_i \times BHI_i)\right) \times 1000 + 1\right]$

In which:
S = the total number of bird species in the inspection
n_i = number of birds from species i
BHI_i = BHI from species i

In table 2 an example is given of how the inspection index is calculated.

Bird species	**Number**	**BHI**	**Index =** **n_i x BHI_i**
Grey Heron	8	0.1301	1.0408
Kestrel	4	0.1660	0.6640
Black-headed Gull	9	0.0567	0.5103
Jackdaw	11	0.0007	0.0077
Carrion Crow	22	0.0020	0.0440
Starling	102	0.0009	0.0918
$\sum_{i=1}^{i=s}(n_i \times BHI_i)$			2.3586
Inspection Index	$\ln\left[\left(\sum_{i=1}^{i=s}(n_i \times BHI_i)\right) \times 1000 + 1\right]$		**3.3728**

Table 2: Calculation of the inspection index for the inspection on LW airbase 29-11-2009 at 11:00 am.

6. The Inspection index and the Bird Status

For the subset of 49,186 day time inspections we calculated the inspection index. The inspection index varied from 0 to 12, mean value was 6.75 (SD 1.25). On arbitrary grounds and for the application in a Decision Support System, inspections belonging to the 5% highest values (n=2491) and thus indicating the most hazardous situations should be assigned a critical bird status. Therefore we put a threshold at an inspection index of 8.37. To compare this with the assigned bird status by bird controllers the distribution of inspection indexes is visualised in figure 7. The threshold for the 5% highest indexes is indicated with the blue line and the proportion of inspections defined critical by bird controllers is shown in red. Although there is no complete match the results are encouraging:

- Of the 1274 inspections that were assigned by bird controllers to bird status critical, over half (57%) had an index value higher than the threshold of 8.37.
- Inspections with an index value of 6 or lower were never assigned the bird status critical by bird controllers.
- Of the 2491 inspections with an index above the threshold, 29.2% were also assigned critical by the bird controllers.

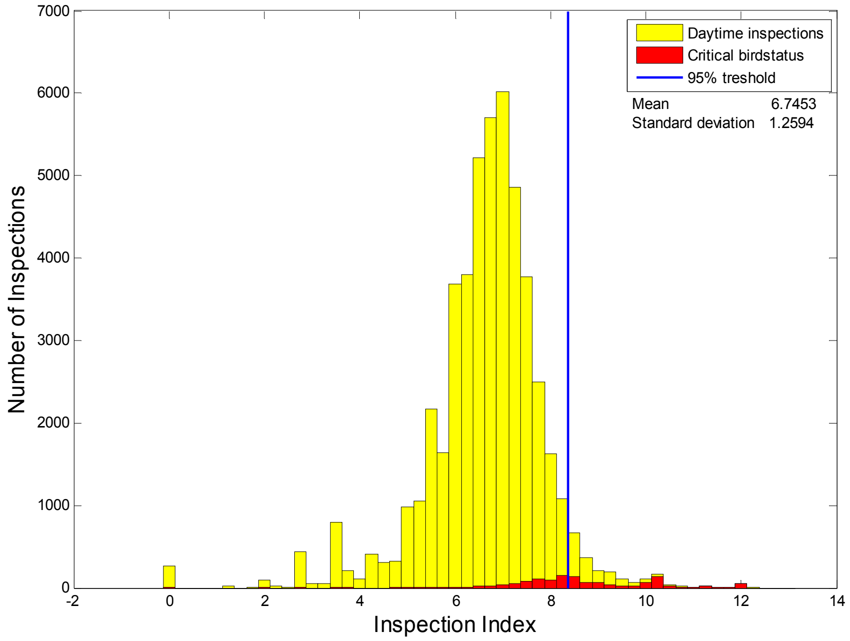

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Figure 7:
Distribution of day time inspection indexes from 7 RNLAF airbases, including 95% threshold and (in red) the inspections that bird controllers assigned bird status critical.

In order to get a better, more detailed insight in the inspection index and the relation with the bird status assignment by bird controllers we looked at each airbase separately. The results are given in table 3.

Airbase	N inspections	N inspections with Index >= 8,37		N inspections with Index >= 8,37 & bird status critical	
LW	4,632	808	(17.44 %)	34	(4.21 %)
TW	2,334	59	(2.53 %)	1	(1.70 %)
SB	6,373	12	(0.19 %)	1	(8.33 %)
VK	4,143	442	(10.67 %)	203	(45.93 %)
EH	18,062	704	(3.90 %)	174	(24.72 %)
GR	6,407	92	(1.44 %)	3	(3.26 %)
WD	7,253	374	(5.16 %)	312	(83.42 %)
Total	49,186	2491	(5.06%)	728	(29.22 %)

Table 3: Number of the subset of inspections during the day per airbase, number and proportion with values above the threshold as well as the number and proportion assigned bird status critical as well as being over the threshold.

From table 3 it is clear that both LW and VK airbase have an avifauna that more frequently produces higher inspection indexes; 17.4% and 10.7% of the inspection indexes respectively above the chosen threshold.
At the same time TW, SB and GR airbase hardly ever produce inspection indexes above the threshold while EH and WD airbase take an intermediate position. Table 3 actually summarizes that the hazard level of the different airbases is - according to the inspection indexes - quite different. This is nicely illustrated in annex 4 for each airbase separately. This very much reflects the non quantified expert opinion about these airbases.

7. Discussion

Having used high quality data on both bird strikes and bird counts we do believe that the calculated BHI is indicating the real hazard a species poses to flight safety. The ranked list of species with their BHI might at first impression seem odd since species that have been considered as hazardous, like Starling and Lapwing, are ranked low. It has to be taken into account though that the BHI is a value that is valid for an individual bird. Our intuitive higher ranking for these species is based on the experience that these species often do occur in large flocks. Once Inspection Indexes are calculated the bird numbers are introduced and the contribution from each species to the hazard level of the inspection becomes clear.

Calculating inspection indexes based on the BHI does provide a good insight in the hazard level at any given moment. This calculated hazard level does only partly coincide with the bird status as assigned subjectively by bird controllers. From table 3 and annex 4 it shows that on WD airbase more than 80% of the inspections that resulted in an index >8.37 were also assigned a raised bird status by the bird controllers but for all other airbases this overlap was (much) smaller. Despite the high proportion of inspections with raised indexes the bird controllers on LW airbase hardly ever translate these in a raised bird status while on VK airbase almost half of these inspections with high indexes result in a raised bird status. However, this does not mean that the chosen method for calculating the hazard level is incorrect; it merely means that bird controllers do sometimes disagree. Reasons for this mismatch could be:

- Inspections during non operational periods did not trigger bird controllers to raise the bird status due to lacking aircraft movements.
- The fact that we based the threshold (Insp. Index 8.37) on the combined set of data. This of course is a reference that is not available to the bird controllers. They unconsciously use their subjective knowledge and experience of their own airbase as a reference.
- The inspections also include overflying birds. These have been included in the calculation of the Inspection Index using the BHI. Since the BHI is based on birds counted on the airbases this is not correct. For overflying birds different rules apply.
- The BHI does not account for individuals or small groups that show atypical response to scaring operations; nor does the BHI include a hazard level for the exact location of the birds in the runway environment. (e.g. a few swallows foraging above the runway will never increase the inspection index above 8.37 while these birds could pose a real threat due the combination of location and the fact that they can’t be scared away easily)
- During the inspection bird species could have been seen for which no BHI is available. This option is further investigated. Figure 8 gives an impression of the completeness of the inspection index with regards to the number of species for which a BHI was missing. From the total set of inspections during 1995-2009 most inspections (46,088) did not include bird species for which no BHI was available while the remaining 45.7% (38,329) of the inspections included one or more bird species for which no BHI was calculated. In the majority of the cases this involved 1 – 3 species. The number of individual birds for which no BHI was available was almost always very low:

    - 99.3% less than 100 birds
    - 0.6% between 100 and 200 birds
    - 0.1% more than 200 birds

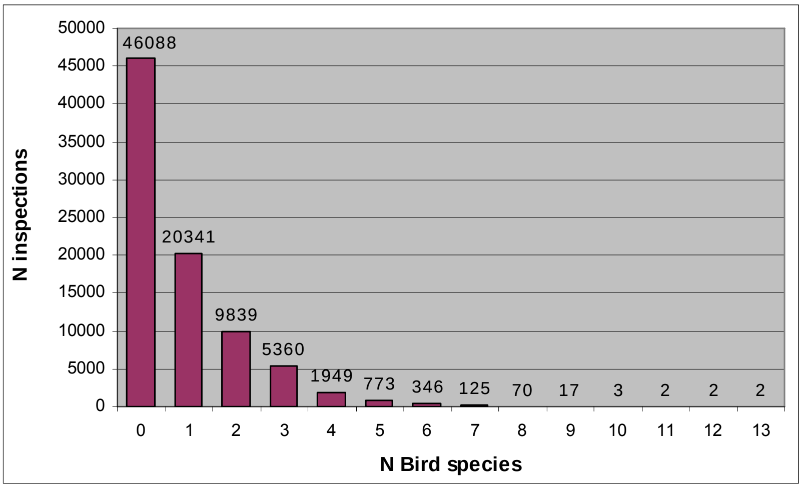

Figure 8: Completeness of the inspection index with regards to the number of species for which a BHI was missing.

The BHI is species specific and valid for the species within the North West European population range and based on a wealth of detailed data about both the presence of birds and bird strikes. It can therefore be used to calculate the hazard level during any bird inspection on any NW European airfield and can be the basis for audits. Contrary to the risk matrix used by Allan (2006) no information on bird strikes is needed for this, it is solely based on the risk that the avifauna on an airfield poses at any given moment. Especially for smaller airfields on which very few bird strikes occur this is a big advantage (Hansen 2009). Also when bird strike data are lacking or deemed unreliable the BHI enables auditing on the basis of bird counts.

8. Conclusions

The BHI provides an objective quantitative measure of the hazard posed by one individual of a bird species. The BHI as we calculated is an intrinsic value for a bird species; it is therefore valid throughout the range of these species in NW Europe.
The BHI should be used to calculate an Inspection Index which in turn gives an overall measure of the hazard posed by birds on an airfield at any given time. This derived Inspection Index can serve two distinct purposes: it can be part of a Decision Support System (DSS) for Bird Controllers and it can be a tool for auditing.

A DSS for Bird Controllers can be realized using modern on-board computers in the BCU vehicle as they are already on the market for logging operations. Simultaneously with entering the observed birds during an inspection the DSS can calculate the Inspection Index. Using thresholds at predetermined levels the DSS then produces output to the bird controller on the hazard level, the bird species that have most contributed to the hazard level and the birds for which no BHI was available. This would enable the bird controller to make a sound decision on the bird status and to prioritize his actions towards the birds most contributing to the hazard level. The DSS as depicted is not geared to deal with overflying birds.

For audit purposes the BHI can be used in the same way as in a DSS. All inspections should yield inspection indexes. These then can be used to compare with other airfields and for analyses which provide insight in the most hazardous species, most hazardous season, most hazardous time of day etc. Inspection Indexes can even be used in relation to scaring operations.

9. Acknowledgements

The work in this paper fully depends on the high quality data on the presence of birds and on bird strikes. Without the perseverance and discipline of the Bird controllers of the RNLAF this data would not be available. The contribution of Belgian, German, British, Danish and Dutch Air Forces to the European Military Bird Strike Database (EURBASE) meant that we had a substantial set of data available on which to base the damage probability for each bird species.

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Annex 1: Number of local, fix-winged bird strikes, relative strike involvement, relative strike opportunity and relative strike sensitivity for 20 selected bird species in the dataset for 7 RNLAF airbases over the years 1995-2009

Bird Species	N Bird Strikes	Relative strike involvement	Relative strike opportunity	Strike sensitivity = Rel. strike involvement / Rel. strike opportunity	Relative strike sensitivity = strike sensitivity / max. strike sensitivity
Herring Gull	13	0,0156	0,0013	12,2965	0,8651
Kestrel	211	0,2524	0,0178	14,2135	1,0000
Grey Heron	5	0,0060	0,0018	3,3191	0,2335
Buzzard	75	0,0897	0,0121	7,4332	0,5230
Feral Pigeon	13	0,0156	0,0023	6,6515	0,4680
Common Gull	9	0,0108	0,0029	3,6919	0,2597
Black-headed Gull	48	0,0574	0,0135	4,2566	0,2995
Oystercatcher	12	0,0144	0,0035	4,0573	0,2855
Mallard	8	0,0096	0,0056	1,7026	0,1198
Curlew	14	0,0167	0,0087	1,9207	0,1351
Swift	78	0,0933	0,0238	3,9138	0,2754
Stock Dove	37	0,0443	0,0404	1,0951	0,0770
Wood Pigeon	16	0,0191	0,0345	0,5553	0,0391
Swallow	40	0,0478	0,0405	1,1815	0,0831
Lapwing	55	0,0658	0,1844	0,3568	0,0251
Carrion Crow	10	0,0120	0,0794	0,1506	0,0106
Sky Lark	24	0,0287	0,0936	0,3066	0,0216
Starling	22	0,0263	0,3096	0,0850	0,0060
Jackdaw	4	0,0048	0,0711	0,0673	0,0047
Black-tailed Godwit	9	0,0108	0,0033	3,3047	0,2325
Remaining species	71	0,0847	0,0499	-	-
Total	836	1,0000	1,0000	-	-

Annex 2: Number of strikes for each of the 20 selected bird species and the proportion resulting in damage. Data from the European Military Bird Strike Database (EURBASE). Only local bird strikes with fix winged aircraft from Belgian, British, German, Danish and Dutch Air Forces up to 2008.

Bird species	N strikes in Eurbase	N damaging strikes	Damage probability (fraction)
Herring Gull	83	27	0,325
Kestrel	239	39	0,163
Grey Heron	18	10	0,556
Buzzard	104	20	0,192
Feral Pigeon	55	12	0,218
Common Gull	101	24	0,238
Black-headed Gull	245	46	0,188
Oystercatcher	57	11	0,193
Mallard	15	5	0,333
Curlew	15	4	0,267
Swift	239	26	0,109
Stock Dove	18	5	0,278
Wood Pigeon	92	20	0,217
Swallow	146	13	0,089
Lapwing	401	79	0,197
Carrion Crow	44	8	0,182
Skylark	181	12	0,066
Starling	112	16	0,143
Jackdaw	7	1	0,143
Black-tailed Godwit	9	0	0,000

Annex 3: Strike sensitivity, damage probability and resulting Bird Hazard Index (BHI) for 20 20 selected bird species in the dataset for 7 RNLAF airbases over the years 1995-2009.

Bird species	Strike sensitivity	Damage probability	Bird Hazard Index
Herring Gull	0,865	0,325	**0,2846**
Kestrel	1,000	0,163	**0,1660**
Grey Heron	0,234	0,556	**0,1301**
Buzzard	0,523	0,196	**0,1046**
Feral Pigeon	0,468	0,218	**0,1020**
Common Gull	0,260	0,238	**0,0619**
Black-headed Gull	0,300	0,188	**0,0567**
Oystercatcher	0,286	0,193	**0,0552**
Mallard	0,120	0,333	**0,0400**
Curlew	0,135	0,267	**0,0360**
Swift	0,275	0,109	**0,0300**
Stock Dove	0,077	0,278	**0,0214**
Wood Pigeon	0,039	0,217	**0,0086**
Swallow	0,083	0,088	**0,0074**
Lapwing	0,025	0,197	**0,0049**
Carrion Crow	0,011	0,182	**0,0020**
Skylark	0,022	0,066	**0,0015**
Starling	0,006	0,143	**0,0009**
Jackdaw	0,005	0,143	**0,0007**
Black-tailed Godwit	0,233	0,001*	**0,0002**

* replaced by 0,001% otherwise the BHI would become zero

Annex 4: Distribution of Inspection Indexes for seven RNLAF airbases over the period 2000-2009, including the overall 95% threshold (blue line).