Ministerie van Verkeer en Waterstaat

stuvwxyz

Programmadirectie Ontwikkeling Nationale Luchthaven

Bird control at airports

An overview of bird control methods and case descriptions

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Inhoudsopgave

1 Introduction

1.1 Background and aim of the study

The Dutch government is currently studying the possibilities of expanding the national airport. For the future development, two locations have been selected: the existing location of Amsterdam Airport Schiphol and a new location in the North Sea off the Dutch coast. The project organisation 'Ontwikkeling Nationale Luchthaven' (ONL; Development National Airport) was founded to investigate the possibilities and prepare middle an long-term decisions. Rijkswaterstaat, Directie Noordzee, co-ordinates the various projects. The ONL project comprises several components, one of which is birds and safety. With regard to the sea location, birds may be a serious problem. As a part of this, an overview was required of the methods of bird control currently in use (nationally as well as internationally). Early next year (2000), two of the selected exemplary airports will be visited by a Rijkswaterstaat delegation, in order to exchange knowledge and experiences. Rijkswaterstaat, Directie Noordzee, assigned Ingenieursbureau 'Oranjewoud' b.v. to carry out this study. The underlying report contains the results.

The study comprised gathering and analysis of international literature and publications on bird control, in order to obtain an overview of the 'state of the art' of bird control at airports (chapter 2). Furthermore, a number of airports were selected for case studies. Similarities in airport-design, location, bird species or bird problems, compared to an airport in open sea, served as selection criteria. The case studies, described in chapter 3, focus on the practice of bird control under similar or comparable circumstances. Conclusions and recommendations are presented in chapter 4, containing summary and analysis of the bird control methods (section 4.1), recommendations for bird control at an island in sea (section 4.2), a review of the described airports and recommendation of two relevant examples (section 4.3).

1.2 Aviation, bird hazards and bird control

Birds pose a serious threat to aviation safety. Since the early days of aviation, collisions of aircraft and birds have taken place, sometimes with fatal consequences. Generally, the damage increases with size en weight of the bird species involved and the aircraft's speed and impact location. Also, the behaviour of bird species influences the risks, for instance flocking or certain migration patterns and flying altitudes [4, 22, 1, 6, 13, 30]. Development of larger, faster and quieter aircraft, jet engines and intensification of air traffic caused an increase in the number of incidents [4, 22, 24, 16]. Military exercises involve flying at high speed an low altitude, and are exposed to a more serious risk [4].

Also, large flocking birds, considered to be the greatest threat to aircraft, have increased in numbers in both Europe and North America. Often, these are species that are able to adapt to human activities and land use, such as gulls and geese [24, 21]. World wide, gulls represent the most significant hazard to aircraft [13, 13]. In the United States and Israel, raptors are also a hazardous group of importance [21, 25]. In some cases, mammals can also cause serious problems. Because this is not likely to be the case at sea, control measures with regard to mammals will not be taken into account in this study.

In the case of an island in the Dutch North Sea, four categories of birds can be mentioned that will be important because of their behaviour and movements (bird species, distribution and behaviour will be treated in separate studies within the ONL-project):

- birds using the island for breeding
- birds using the surrounding sea for shelter or foraging
- foraging birds from the coast migrating birds using the island as an 'aiming point', resting place or shelter

Most of these bird movements will be in the lower altitudes, especially in windy conditions and severe weather. Migration in fine weather conditions may also take place at higher altitudes.
Civil aviation experiences most bird strikes (over 80%) during take-off, climb, final approach, taxiing and landing. In this view, the basic starting-point of diminishing the risk of bird strike is to counteract and prevent the presence of birds at airports and their vicinity [24, 16]. In reduction of bird strike hazard, there are four categories:

- awareness
- bird control
- bird avoidance
- aircraft design [13]

Awareness means that the presence, problems and danger of birds at and around an airport are recognised. It does not only apply to birds but also on, for instance, land use and activities in the vicinity of the airport. Awareness will (or should) lead to a careful study of the ecology and behaviour of the relevant species, the problems they cause and possible measures and solutions. Measures and solutions may be found in bird control, bird avoidance and aircraft design [13, 24].
Bird control comprises active and passive measures in order to diminish the number of birds at an airport and/or their threat to aircraft. Bird control focuses on how bird attractants can be minimised (including design and lay-out of the airport), how the birds can be prevented from using attractants and in what ways birds can best be chased away, captured or killed if necessary [6, 24].
Bird avoidance models are being developed to describe migration patterns and flyways, in order to prevent bird strike outside airports on a larger scale. Development of such models consist of a combination of observations, bird distribution data and factors influencing migration patterns and is aimed at predicting dangerous flight conditions. It is particularly useful in military aviation, which has much more possibilities to adjust flight schemes, heights and areas compared to civil aviation [1, 25].
Aircraft design may contribute to a reduction of the damage of a bird strike event. Special attention to the design of vulnerable aircraft components (engines, windshield, leading edges) with respect to collisions, makes the aircraft more resistant to impact by birds [4].

In this study, bird avoidance and aircraft design are not taken into account. More information on these topics may be found in [1, 4, 25, 14] and [4] respectively.

In the past, several institutions were founded in order to investigate and tackle the problem of bird strike. There is considerable co-operation between civil and military aviation. Amongst these are Bird Strike Committees in Europe, Canada and the USA. With the founding of the International Bird Strike Committee, co-operation and knowledge exchange took on a more global level. The International Bird Strike Committee organises a conference yearly and it is the main authority in the field of bird control, comprising the knowledge of bird strike experts world wide.

2 Bird control methods

2.1 Introduction

This chapter presents an overview of the various methods of bird control found in literature. If available, information on their success is included. In the Netherlands, the amount of publication on bird control is fairly limited; the bigger part of the literature treated in this study originates from the United States and Canada. Much information resides with experts world wide and in unpublished literature. Most references are of recent date; a few dated but relevant sources were used as well. Due to the limited amount of time available, it has not been possible to compile a complete overview of everything that has been published on this subject. Nevertheless, the complete field of bird control is covered and a good overview of the current state of the art has been achieved.

Generally, bird control methods vary with location, species, bird behaviour, season, climate etc. [22]. The success of certain methods also differs between airports. There appears to be no single success formula that can be applied at all circumstances. As a result of this, airports have a bird control programme that is based on local experience and/or fits best to the local situation [23]. In turn, the bird hazards may change with varying local conditions, for instance changes in land use [13].
In literature sources, bird control methods are divided into categories in several different ways, for instance ecological and technical methods [23], active and passive methods [13] or habitat management, chasing and elimination [17]. Not all classifications offer a clear distinction between control methods; in fact, there will always be methods that may be placed in more than one category. In this study, a comprehensive classification is used in which three main perspectives in bird control at airports are distinguished (after Blokpoel [4] and Cleary [6]):

- habitat modification
- resource protection
- population management

In this chapter, bird control methods are subdivided according to these three perspectives. Habitat modification (section 2.2) means creating, adjusting or altering the environment to make it less attractive to the problem birds. Resource protection (section 2.3) means making the area or resource unattractive or inaccessible to birds, comprising exclusion, dispersal and repellent techniques. Population management (section 2.4) includes capturing, breeding control and elimination methods [6].

These methods are actually confined to the airport and perhaps its immediate vicinity. They deal with bird problems at and around the airport in the lower altitudes (i.e. 0 – 300 m), where the risks of bird strike are highest. These control techniques have remained relatively unchanged over the last 25 years [19]. A fourth and relatively new perspective in reducing the risk of bird strike is formed by trying to predict the presence of birds on a larger scale, outside airports and at higher altitudes. Predictive models are being developed, combining computer, radar and satellite technology, bird distribution data and factors influencing migration patterns (such as season, geography an meteorology) [1, 19, 25]. This is actually not a type of bird control, because it does not affect the presence of birds. However, it is a potentially successful way of preventing bird strike, that is currently an object of study and research.

2.2 Habitat modification

All birds need food, cover (including shelter, safety, places to nest, rest and roost) and water to survive. Design and management of the airport habitat in such a way that these elements are eliminated or minimised (aimed at the locally most hazardous species), will reduce the local population of birds [4, 22, 6]. Habitat modification should be aimed at the problem species. Because habitat modification will not only affect the target birds, but also other bird species and animals, it is not highly selective. It is also important not to create circumstances that are attractive to other species. Habitat modification is considered to be a very effective and enduring way of preventing the presence of birds. Measures should be based on ecological research of the airport area and its surroundings; every airport offers a unique situation. Continued and properly specialised maintenance of vegetation and water is an important condition to success [4, 6, 13].

2.2.1 Food

In urban as well as in rural areas there are many food sources that usually attract birds, especially gulls, pigeons and starlings. A single bird having found food can attract others quickly. It may act as a decoy to other birds [13] or attract con-specifics by food calls [17]. Rodents and insects are other examples of potential food sources, for instance attracting birds of prey or flocks of passerines [16]. If the attracted bird species is hazardous, control of the prey population is a possible solution. In many cases, however, food attractants are the result of human activities.
Examples of food attractants are: open water, trash bins, trash containers storage areas (especially when improperly handled), worms on runways during rain, fishing vessels (these may occur on an island at sea). Other examples are fish or meat industries, landfills, sewer treatment plants or lagoons, birds being fed in parks, grain storage and agricultural activities (these not will apply to an island at sea). Awareness of such food sources at and around the airport is very important. Proper cleaning up, handling of trash, supplemental bird control measures and adjustment of land use are vital methods to prevent attraction of birds [4, 6, 13, 20].

Sewage lagoons or treatment plants and on-base landfills should be situated as far from the runways as possible and situated in such a way that food flights of attracted birds do not cross the runways. A small working surface, overnight waste dumping and immediate covering, combined with exclusion and repellent techniques are advisable [13]. High trees around landfills, the presence of dogs and continual harassment at landfills have proved to discourage gulls from feeding there [20, 17] (see also section 2.3.1).

Insects and other invertebrates are an important food source for many species of birds. Gulls and waders are known to feed on worms that appear on runways during rain. Measures are large scale sweeping of runways after rain, repelling or killing worms in the grass strip along the runways with chemicals (for instance Benomyl, Thiodan (Endosulfan)) [4]. Awareness of the development of certain insect populations that form a food source can be obtained by careful observation of bird species and their feeding behaviour. If necessary, insect control measures can be taken, if possible through or in combination with vegetation management [13]. Chemical control is practised, for instance Clorpyrifos on craneflies (Tipulidae) [23].

Agricultural land use attracts birds, depending on the type of crop and the agricultural methods. Examples of relatively unattractive crops are hay, cotton and flax [13]. Expelling agricultural land use at Schiphol Airport resulted in a significant decrease of the numbers of birds present [16].

2.2.2 Cover

Many types of habitat can be used by birds for cover or resting. At airports such habitats are:

- vegetated areas, such as fields, dunes (gulls, waders), shrub and trees (pigeons, passerines);
- bare areas, such as runways and other hard surfaces (gulls, waders) and buildings (gulls, terns, pigeons, Starling);
- water bodies, such as lakes and ponds (gulls, waterfowl).

Another important factor is that airports often offer relatively undisturbed areas. When landscaping areas at airports, attention should be paid to bird-attracting aspects of the created habitats. Eliminating existing habitats or making them unattractive or inaccessible (exclusion) can solve many bird problems. Examples are: long-grass management, prevention of seed or fruit-carrying plants, thinning trees at roost sites, drainage of wet and swampy areas, wiring of water bodies and modifying buildings (see section 2.3.1) [4, 22, 7, 6, 13, 16].

Because most of the vegetation at an airport consists of grass, long-grass management is a widely used and effective method. Whether long or short, grass is attractive to certain species. Short grass attracts the more hazardous bird species (mainly gulls, plovers, pigeons, Starling) and long-grass management is generally considered the right approach in Europe [1] [4]. Allowing the grass to grow to 15-20 cm height strongly diminishes the attraction to foraging or resting birds. The availability of food is less, there is no open view for predators and flock integrity and communication are reduced [22, 13, 16]. Mowing should start adjacent to runways moving towards the outermost grass areas (insect and other animals will move away from the runways) and should preferably coincide with periods of low flight activity. Long-grass management should be practised up to 1 kilometre away from the runways [22].
The higher grass will attract more rodents than short grass, resulting in a higher number of raptors or herons. Also, some birds may find a more suitable place to breed (for instance Pheasant, Grey Partridge). In general, these birds are less hazardous because they are more secretive, do not occur in large flocks and fly relatively little. Thus, an increase of these species does not greatly diminish the positive effect of long-grass management [13, 16].

Weeds and seed or fruit-carrying plants (often pioneering on bare soils) limit grass growth and attract birds. To minimise these plants, specific herbicides or growth retardants may be used and grass growth stimulated.
Also, bare soil itself can be attractive as a feeding or resting site. Planting grass on such areas and using fertilisers to stimulate grass growth is recommended [13].

Shrubs, trees and hedgerows at or nearby airports will attract birds and influence their numbers and movements. Currently, tree rows and wooded areas are used as noise and exhaust barrier; this may increase bird strike risk [23].Trees and bushes provide food, shelter and nesting opportunities. Attraction can be reduced by selecting plants and trees that do not produce fruit (especially in winter). Management should consist of thinning and pruning to open the canopy. This prevents the formation of roosting sites. Individual trees are frequently used as perches by raptors. Gradual transitions in vegetation, e.g. from grass via weeds and shrubs to trees, are attractive to birds. Management should be aimed at keeping vegetation transitions abrupt [13]. High trees may make open areas and fields unattractive as a roosting site for gulls. This will however be difficult at airports, but may be effective at roosting sites in the vicinity [17].

[1] However, two examples are known of short grass offering a safer situation, because of ducks and hawks nesting in long grass (Winnipeg, Canada) or hawks feeding on grasshopper in long grass (Mackay, Australia) [4].

In one case, a gull roost at an airport was successfully moved by making a site just outside the airport more attractive [Laty, 1975 in 17; this source does not mention how this was achieved]. Other practice examples of luring birds away by creating more attractive sites nearby have not been found.

2.2.3 Water

Especially in coastal or arid sites, fresh water is very important to many birds. Apart from (sewage) ponds, basins and canals, rain pools can be attractive drinking and preening sites. They also support a potential food source when they contain amphibians, fish and insects. Gulls and waterfowl in coastal areas will show a strong preference for such locations [13,17]. Gulls and other bird species often flock to temporary pools of fresh water at airports after heavy rains [4, 11].
Standing (fresh) water at and around airports should thus be eliminated to the greatest extent possible. Areas remaining wet after rain can be filled, leveled and if necessary (re)planted with grass. If elimination is not possible, resource protection can also be a good solution. Drainage ditches should be deep (unattractive to waders and herons), banks should either be steep (no shallow water) or graded (mowing up to the water possible) [7, 6, 13, 17]. Vegetation, either emergent or submerged, should be removed (unattractive to wildfowl) [13].

In periods of severe frost, salt water becomes an important attractant to some bird species if most of the fresh water inland has frozen over. Under such conditions, water birds (ducks, grebes, gulls) may move to coastal areas, resulting in increased movements (frost migration) and numbers (wintering flocks) of birds off the coast. Being a type of migration, this phenomenon can not be counteracted by bird control measures. However, the circumstances leading to such movements are fairly predictable.

2.2.4 Zoning

In conclusion, habitat management at airports ánd the surrounding environment is very important. Nearby land use practises that attract birds can reduce the effectiveness of on-airport control measures considerably [22, 20]. Care should be taken in developing nearby reserves aimed at keeping birds, especially gulls and Cormorants, away from the airport [17]. Zoning regulations are common practice in most countries. At Schiphol Airport, there are three zones (indicated 1, 2 and 3): the airport itself, 1 kilometre and 5, 5 kilometres around the runways. Within these zones, development of nature reserves or forest is unacceptable (see figure 1) [22]. Such regulations limit the possibilities for certain types of land use around the airport, such as landfills, agriculture or nature refuges. Zoning prevents the build-up of hazardous wildlife populations near airports [22, 29, 20].

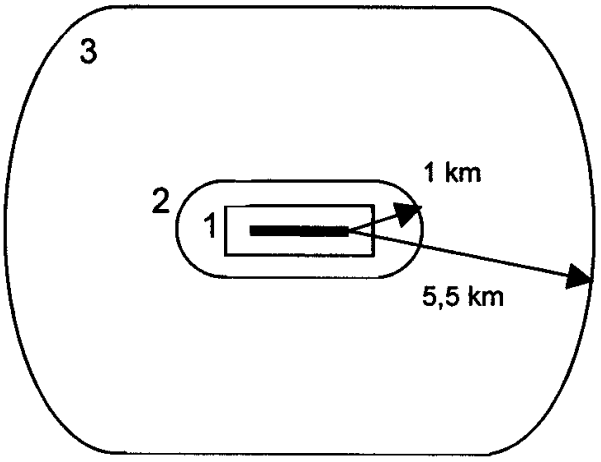


Figure 1. Three protection areas around a runway (bold bar) [WVAVCL, 1997 in 22]

Canada uses an extensive zoning system for land use, regulating natural, agricultural, recreational, commercial, industrial and municipal activities in three zones from the airport reference point. The zones are concentric circles of respectively 2, 3 and 5 miles wide (see figure 2) [23].

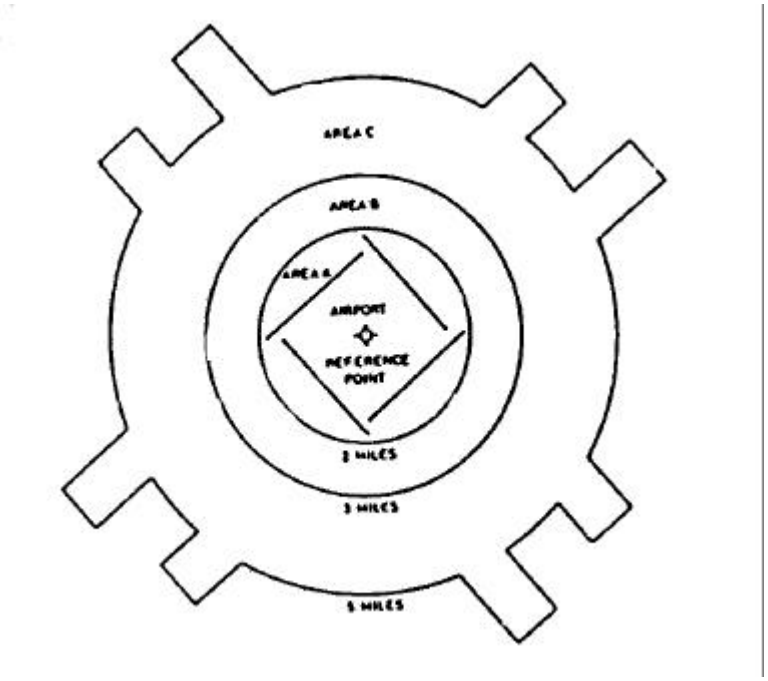


Figure 2. Standard zoning of land use at Canadian airports [23]

Although zoning regulations work well, they usually do not reach beyond several kilometres from the airport, which is much less than the distances covered by food or roosting flights of some bird species [20], especially gulls [17]. Currently, adjustment of the Dutch aviation regulation is considered (towards the Canadian system), to install protection areas within the zones [22, 23].

2.3 Resource protection

Resource protection comprises all activities that make areas inaccessible or less attractive to birds. Apart from food, cover and water, airports often offer relative 'quiet' conditions, because there is little disturbance apart from engine noise. This is attractive to birds and can be an important factor in their presence [22]. Resource protection measures include 'passive' (e.g. wires across ponds, spikes on ledges) and 'active' (harassment with chemical, audio or visual means) methods, hereafter called exclusion and repellents respectively [6]. The success of active harassment depends not only on the methods and bird species, but also on the shape the target birds are in. When breeding, tired or hungry, gulls for example are harder to chase away. Also, the availability of alternative sites for birds in the vicinity determines the success [17]. This may be especially important in case of an island in sea. Due to the adaptive abilities of birds, habituation to repellent techniques is a serious problem in bird control [29, 6, 13, 17 a.o.], addressed in section 2.3.5.

The results of audio and visual repellents vary greatly. Similar methods used at different airports may yield completely different or even contradictory results. Therefore, it is nearly impossible to judge effectiveness of most visual and audio repellents from experiences. At many airports, the effectiveness of repellents is assessed by testing in the field.

2.3.1 Exclusion

Access to attractive areas can be denied or discouraged by using physical barriers. Such barriers are mainly used for buildings and for open water, but also for landfills.
Buildings are used by birds as roosting (or even breeding) sites, for example Starling and pigeons on ledges or in hangers, gulls on open water or on rooftops. Favoured areas, such as ledges, setbacks and flat surfaces can be closed off with netting, screening, spikes, wires or sticky substances (the latter only having a temporary effect). On flat ledges, metal strips can be applied with an angle greater than 45o. Using curtains of heavy plastic sheets will prevent the use of openings or doorways; making a ceiling with nets or cloth will prevent birds to roost under roofs or shelters [4, 6].
Water bodies such as ponds or lakes can be made inaccessible with wire systems. The grid of the wire system depends on the target species. For gulls, a grid of 6 x 6 meters proved to be useful, for waterfowl a smaller grid (3 x 3 meters) is needed. Exclusion of water is also possible with nets [6].
Exclusion of landfills as a food source (mainly important for gulls) is best done by daily covering of the waste. Wire systems have also been successfully used on landfills. Waste sites at meat- or fish-processing industries should also be carefully covered [Drury, 1965 in 17]. Gulls appear to use several feeding sites spread out over a large area. It is therefore important to take measures at all potential feeding grounds in wider surroundings than just the close vicinity [Cogswell, 1969 in 17].
Large, horizontal nets have been described by Herzig [in 17] as a means of keeping birds away from airport fields. However, such nets make maintenance of the terrain difficult.
Experiments have been conducted with heated surfaces, based on the assumption that gulls prefer warm surfaces for roosting or loafing. No positive results were obtained [4].

2.3.2 Chemical repellents

In the Netherlands, amongst other countries, chemical repellents are not used nor are experiments conducted. A number of chemical repellents are currently used in the United States and Australia [6, 23]. In many cases, experiments with chemicals to harass birds (mainly tried on gulls) have often been unsuccessful and if it was, a combination with other techniques was necessary to chase birds away [17, 23]. Having a moderate climate with a lot of rain, chemicals are not expected to be successful in the Netherlands [17]. The use of potentially toxic chemicals may also have legal (and ethical) complications.
Consequently, testing and use of chemicals as bird repellents is not recommended.

Reta

In Israel, surface spraying with Reta (aluminium ammonium sulphate) caused a decrease in the number of gulls; but the gulls did not disappear completely until this was combined with other measures. Although the gulls seemed to have become more uneasy and more susceptible to sounds, the use of Reta was not considered a sufficient method. In several other countries (Denmark, Switzerland, France), tests with Reta failed to produce good results [17, 23].

Polybutene

The chemical repellents discussed below are registered in the United States.
For keeping birds of roosting surfaces, a number of repellents containing polybutene or polyisobutylene are available. The are applied to the favoured surfaces in liquid or paste form and make birds feel uncomfortable when they land. In order to displace the birds effectively, all potential surfaces should be treated. Application should be repeated every half a year or year, but much more often if the surfaces are very dirty. Examples are Bird Stop, Roost-no-more, Bird-X, 4-The Birds, all of them non-toxic [6, 23, Internet].

Methyl anthranilate

Methyl anthranilate is the non-toxic active compound in ReJeX-iT, to which birds have a strong aversion. It is applied on golf courses, landfills, standing water and temporary pools to keep away gulls, waterfowl or Starling [6]. Although the effectiveness of methyl anthranilate has been demonstrated on several bird species (Ring-billed gull, Mallard [11]), experiments on (captive) Canada geese foraging on turf showed no evidence that ReJeX-iT was effective as a grazing repellent. It may be more effective in higher doses and on wild Canada geese, particularly in combination with other forms of harassment. The effectiveness may also depend on the surface that is being protected; food demands higher concentrations of methyl anthranilate than water, for instance [2, 11].

Naphthalene

This repellent, working on the sense of smell, was tested at airfields in the United Kingdom. It was applied to the field as 'moth balls'. Results were contradictory [4].

Aminopyridine

Avitrol is an example of a toxic repellent. Bait (preferably grain) is treated with Avitrol and subsequently eaten by the target birds (for further information on baiting see section 2.3.3). They react on the active compound (4-aminopyridine) with distress behaviour, in turn frightening other birds in the vicinity. A sufficient dose will be lethal; by using limited amounts of bait, a flock of birds can be chased away with minimum mortality [6].

2.3.3 Audio repellents

Birds can (temporarily) be chased away with sounds by using pyrotechnics, propane gas cannons or bioacoustics. In general, loud noise itself does not seem to bother birds [4]. Experience with and results of audio repellents varies greatly between countries [23].

Pyrotechnics

Pyrotechnics are noise producing devices such as scare cartridges, shell crackers, fireworks, alarm pistols, shotguns and electronic alarms (the latter being little used). They are often effective, easy and safe to use and are thus widely used, nearly always in combination with bioacoustics, visual scaring or shooting. Additional development of smoke is occasionally used [4, 23]. Flares are not widely used but tend to have a good effect [4, 16, 23]. Apart from the audio effect of the explosion, there is also a visual effect of light and smoke. Flares are normally fired from a Very pistol. At Schiphol, the Very flares have been replaced by shell crackers that do not leave debris (dangerous on runways) [4]. The effect of shell crackers varies, due to habituation. Birds can be dispersed in a desired direction by carefully locating the sound source or firing in a certain direction (cartridges) [6, 13]. Sirens on

vehicles are used with some success. Automatic noise generators along runways are used successfully on Lapwing, gulls and pigeons [23].

Gas cannons

Propane, carbid or acethylene gas cannons are less widely used, probably because habituation can occur comparatively quickly. They can be very effective on gulls, waterfowl and other game birds (the latter being hunted and associating the noise with danger), especially when used when (migrating) birds come in to feed or roost. Frequent relocation, varying the frequency of detonations and combination with other harassment techniques will prevent habituation and improve the effect [4, 13, 23].

Bioacoustics

Bioacoustics work through broadcasting of pre-recorded bird distress calls. These calls are specific to a bird species, although Godsey mentions that non-specific distress calls are the most effective [13]. Experiments with synthesised versions of calls have been successful as well [4]. The birds will interpret the calls as an alarm signal and fly away, perhaps enhanced by group behaviour. However, other responses, such as flying towards the source to check out the 'danger', have been reported, creating a potential momentary hazard (gulls, Corvids [4]). Distress tapes are (preferably) played from a sound system on a vehicle, producing 90 to 100 decibel. Fixed systems have proved to become ineffective in time in several countries [23]. After the birds have been identified and the tape is selected, the birds are approached to a minimum of 100 to 200 meters (depending on the local situation) and the call is played for a short interval (15 to 20 seconds, to prevent habituation). In the Netherlands, an automatic randomising system is used to broadcast distress calls. Gulls, starlings and crows can be dispersed with distress calls. Not all species react to bioacoustics (Lapwing, Oystercatcher and Starling appear to be difficult); several calls may be tried. The response may also depend on the birds' behaviour or state (hungry, tired or breeding birds showing less response) [4]. In practice, bioacoustics are very often used in combination with other measures to prevent habituation. Combination with pyrotechnics, hunting or incidental killing provide good results in many countries [4, 13, 23]. In Britain, the main problem species react to their distress calls [4]. Before using distress calls, investigations are needed into the problem species, their calls, the circumstances in which the calls should be used, the required quality and equipment and the best way of reinforcement [4].

Ultra-sound, infra-sound, radar

These sound sources are generally regarded as not effective in scaring birds. Tests at various locations and under various circumstances have, in some cases, provided contradictory results. However, there is no hard proof for any positive effect.

Generally, ultra-sound (using very high frequencies) has appeared to be unsuccessful in chasing away birds [4, 6, 13, 23]. The hearing range of birds is assumed to be narrower than the human range (proven for Pigeon, House Sparrow and Starling), so sounds inaudible to humans are inaudible to birds [6]. Moreover, ultrasound requires much power and quickly loses strength with distance.
Contrastingly, one record of successful use of ultrasound was found in literature: at Venice airport in Italy ultra-sonic equipment has reportedly been used with success on gulls. The experimental circumstances in which these results were obtained are not mentioned [23].
According to some sources, birds species may be sensitive to infra-sound (low frequency) and use it for navigation. The same may be true for modulated radar, as several observations indicate. According to other sources, however, radar does not seem useful for scaring birds [4, 17]. Studies are underway to test this possibility [6]. The noise of aircraft engines is being studied to determine if certain frequencies are suitable for scaring birds. There may be overlap in frequencies between engine noise and distress calls. Studies to investigate these subjects are currently underway [19].

2.3.4 Visual repellents

Carcasses or models of dead birds

This method of agricultural origin is widely practised, with varying results. Dead birds 'wear out' quickly; their use can be extended by conservation with formaldehyde. Plastic models (dummies) or mounted specimens are more durable, but the effect seems to less compared to carcasses. Incidentally, problems with animals or birds of prey, attracted to carcasses, occur [17,23].

At Schiphol, many experiment with both mounted or model gulls have been conducted [4]. Various gull reactions, ranging from virtually no effect to a very strong reaction, have been noted. Posture and placing of the model appear to be important factors. Sitting or standing models do not deter gulls. Lying birds, with or without spread out wings, provoke a reaction similar to distress calls; flying towards the model, circling and flying away. The frightening effect may last 1 – 3 months [17]; other sources report effectiveness lasting only one to a few days [23]. Birds may settle down again within 50 meters of the dead bird. Models hung up are more frightening than when laying on the ground, probably because of the additional movement [4]. Especially a nodding head-tail movement has been successful [17, 23].

Falconry

The results with falconry vary in practice. Success of falconry depends on many factors; more analysis is needed to establish the effectiveness under various circumstances [10].

Several species of falcon (Peregrine, Gyr, Lanner or Saker Falcon or Merlin) and Eurasian Goshawk can be trained effectively for bird dispersal at airports. Not only low altitude hunting flights but also high altitude patrolling flights of raptors are successful in chasing away birds. An advantage is that the falcon is less vulnerable than when hunting. In this respect, falcons are more useful than goshawks, because the latter preferably uses fast low altitude flight [10]. Falconry was or is practised in some countries with good results (e.g. Scotland, Canada [4], Spain [10]).

At JFK Airport, falconry was tested to supplement (and eventually replace) the gull-shooting programme. Peregrine, Peregrine x Gyr falcon-hybrid and Harris' hawk were flown, typically in flights simulating hunting. Gulls will react mainly with formation flight [17]. Additional pyrotechnics and distress calls were used. During overlap of shooting and falconry, less gulls were shot. When shooting was stopped and falconry was continued (received positively by public and media), there was, however, no significant reduction of bird strikes compared to the period prior to shooting.

In other cases, falconry did not appear to be (cost)effective after testing. In the Netherlands, falconry was tested at Schiphol airport, in combination with model aircraft. It was used at Vliegbasis Leeuwarden until 1974 [23].

An advantage is that habituation does not occur, because a real danger is involved. However, there are several limitations: training and maintenance is difficult, a full-time team is required, the birds can only be flown during daylight and good weather and flying is not possible just after feeding or during moult [4, 13, 17]. In many cases, falconry was abandoned because of these limitations. When considering use or testing of falconry, the local situation and limitations should be taken into account.

Models of birds of prey

Overhead silhouettes of raptors have been successful to some degree. However, habituation quickly occurs when there is no actual danger associated with them [6, 17].

Model aircraft

Remote-controlled model aircraft, shaped in the silhouette of a bird of prey, have been tested with success (on gulls in the Netherlands, on Dunlin in Canada). The small aircraft are flown across or towards the target birds by remote control, in such a way that a raptor is imitated. Tests in France showed that shape, colour and noise of the model did not influence results, but that the way the model was piloted was most important [23]. Maneuvering the aircraft is said to be difficult, especially in windy circumstances and in busy aviation traffic. There is no information on habituation [4, 17].

People, vehicle

Slow arm weaving has been tried successfully on gulls, perhaps because the movement imitates the flight of a large raptor (e.g. White-tailed Eagle) [17]. There will be many variations on this theme, such as imitation wings fixed on a vehicle etc. However, little information was found in literature. The mere presence of people or the bird patrol vehicle is enough to scare away some species.

Persons holding shotguns (or even models) are successful, especially where hunting is common practice. In some cases it is noted that habituation to this way of visual scaring is much less than to other dispersal techniques [23].

Dogs

One literature source mentions the use of Border Collies to disperse geese. This was reported to be successful under certain circumstances, but the nature of these circumstances is not explained [13].

Mylar-tape

In agriculture, mylar tape is used as a 'scarecrow' to keep birds out of crops. Twisted strands tied to sticks move in the wind and flash in the sun, and they appear to have a frightening effect. Fences of Mylar tape are also used in agriculture. Although the use of Mylar-tape is mentioned in relation to bird control, no examples of use at airports were found [6].

Eye spots

With eye spots on flags, balloons or doors no positive results are obtained. There may be an initial reaction, but birds get used to them very quickly [6, 23]. Eye spots on aircraft (e.g. engine spinner) are studied with various outcome: negative [13] to a 20% reduction of bird strike [23].

Lights

Various types of light source (search, rotating, flashing, laser or strobe lights) are tried and/or used, sometimes in combination with mirror systems [13].

Flashing ('anti-collision') lights are commonly used on aircraft; birds are better able to detect an approaching plane and avoid it. Flashing lights are also used on bird patrol vehicles. The flashing frequency should be less than 100/sec.

Search lights have shown to have some effect in darkness. A strong light beam can scare gulls at a distance up to 800 m. Tests have indicated that blue light may be more effective than other colours, perhaps due to a higher sensitivity of the bird's visual senses to 'blue' wavelengths.

Fixed strobe lights have been successful inside buildings, but they are not practical outside [4, 23].

Laser is considered not very successful, although there have been good results with a portable helium-neon laser in France [17,23]. However, test results also showed that the required laser intensity would be dangerous to animals and man [4].

It has been concluded that the approach-lights alongside landing-strips reduce bird strike (during day light) by 50%. Probably, they improve a bird's timely detection of an approaching plane [Thorpe, 1977 in 17].

Care should be taken with the use of lights, because migrating passerines are known to be attracted by lights at night. Especially during falls, increased numbers of passerines have been recorded at or around lighthouses, lightships or illuminated large industrial areas along the coast.

Windmills

Mobile windmills have a medium effect. Regular shifting is necessary, the method is susceptible to habituation. This technique is only known from the Netherlands [23].

Unsuccessful visual repellents
Many things have been tried out without any success at all. Stuffed or plastic owls are being advertised for use in buildings, but are generally considered unsuccessful [13]. Moreover, they are known to attract passerines and crows when used outside. Rubber snakes are said to keep birds out of buildings, but they do not seem to work in practice [13]. Other examples are blue balloons, coloured smoke, dyeing of grass, brightly coloured panels [4].

An important disadvantage of visual repellents is that they are only effective during daylight.

2.3.5 Habituation

Habituation will eventually occur to any audio or visual repellent that does not pose a noticeable threat or danger to the birds themselves. Birds generally react to 'new' objects, explaining the (initially) good results of a repellent. Repeated use without additional reinforcement will in time make any effect disappear because the birds will learn that there is no actual danger involved. Frightening techniques should only be used after careful study and planning; indiscriminate use will accelerate habituation [4, 29]. Varying use and location, switching between different techniques and combining pyrotechnics and distress calls with other control measures is necessary to keep harassment successful [6, 13]. As long as an attractive site is still present and accessible, birds will keep returning to them. In this view, habitat modification and exclusion compares favourably to audio and visual repellents [6].

2.4 Population management

Generally, population management can be a very effective control method. Three perspectives can be distinguished:
- reduction of the (local) population of target birds
- ad hoc elimination of individual birds that constitute an acute danger
- harassment of groups or reinforcement of other control techniques

Population management consists of capturing or killing target birds. Negative aspects of population management are that (apart from killing birds) the large-scale effect is non-permanent, the (public) reputation is poor and high costs can be involved [6]. In most countries, a large number of birds is under protection, although permits can be obtained for specific purposes. Killing birds is generally considered as a 'last resort', only used when other techniques fail. In practice, however, there is often a need for quick and adequate action [4].

2.4.1 Capturing

Physical capture
Physical methods are trapping and netting. Live trapping is a selective method and may offer a solution for birds that are hard to scare. For instance, Snowy and Great Horned Owls are trapped at Canadian airports in winter, banded and released elsewhere [4]. Trapping cages can work well, especially when provided with food, water, cover and decoy birds (for instance on Corvids or raptors [4, 33]). They need to be moved regularly and checked at least daily. Capturing small flocks is possible with cannon or rocket nets [6]. Cannon netting takes considerable preparations: cannons and net must be carefully installed, target birds must be feeding (or trained to by baiting) right in front of the net. The

net size may be varied according to the expected number of birds. The cannons fire projectiles which pull the net over the feeding birds [pers. obs.]. Rocket nets are smaller but can be launched from the shoulder and are thus suited for ad hoc use on individual bird or small flocks. In the United States, a number of live capturing devices for individual raptors are used, such as 'bal-chatri', noose carpets or sliding padded pole traps [6]. Traps are generally little used [23]. Capture and removal of birds is time-consuming and costly. Also, displaced birds may return or other con-specifics may take their place. Useful results with displacement are generally only achieved in the case of individual raptors [4].

Chemical capture

Chemical capture works by feeding target birds with bait treated with a sedative or immobilising toxicant, after which the birds can be captured. Recommended baits are corn (for groups of pigeons or waterfowl) and bread (individual birds). Alpha chloralose (A-C), for example, is used in the United States [6] and on Herring Gulls in Denmark (here, however, in a lethal dose) [23]. Birds become capturable within 30 to 90 minutes, recovery occurs within 8 to 24 hours. Pre-baiting is necessary to ensure the success of this method (see section 2.4.2).

2.4.2 Killing

Population management aimed on an actual reduction of the total numbers of a bird species (other than on a local scale) implies that the killing rate must be higher than the natural death rate. Most target species tend to be very numerous or the numbers are increasing (e.g. gulls, waterfowl, Starling), so killing will show little effect in terms of numbers, unless practised on a very large scale. However, it has shown to be effective at local breeding colonies. Killing great numbers of birds is, apart from difficult an expensive, generally not an acceptable control method. Moreover, it may have an adverse effect. Decreasing numbers result in less competition between the surviving birds for resources, so the remaining population may well be 'healthier' [6]. In the Netherlands, population management at gull colonies is hardly practised, also because gulls generally do not cause many problems in the breeding season [17].

In the case that birds are an acute danger, killing or capturing is used to immediately eliminate the threat. This method is widely used, often as a 'last option' in bird control [16, 23]. Captured birds are either relocated (birds of prey) or killed. There are various methods for killing or capturing which will be discussed below. The use will depend on the local situation, the applicable regulations and on social or political aspects.

Killing individual birds as a reinforcement of repellent techniques is widely used and has proved to avoid habituation and to stimulate the scaring effect. This is mainly done by shooting. Leaving a carcass after shooting has proved to be very effective, the effect lasting 24 hours. However, care should be taken not to leave carcasses on or close to runways because they may attract predators or scavenging birds, or the carcass may itself be ingested in engines of passing planes [23].

Lethal means of population management are shooting, lethal trapping, poisoning and destroying of eggs or nests. One example of introduction of predators was found. Relevant methods are discussed below.

Shooting

Shooting eliminates the target bird, frightens the rest of the flock and reinforces other repellent techniques. Surviving birds will be scared by the noise and the death of one bird, and will associate this with the other repellents. It can be very effective; at JFK International Airport for instance, bird strike was reduced to 90% by shooting gulls flying over the airport. These birds were mainly Laughing gulls, originating from an expanding breeding colony nearby; during a six year shooting period, 52,235 gulls were killed [10]. Observations indicated that shot local breeders were replaced by birds immigrating from

other (expanding) colonies [20]. Apart from the disadvantage of killing many birds, shooting is expensive and demands a lot of effort. Professional use of fire arms, study of regulations and notification of local authorities are important aspects of this control method [6].
For waterfowl, hunting is a good way of reducing the local population as well as repelling ducks or geese [6]. Gulls tend to learn very quickly and will soon react to approaching vehicles or people by keeping a safe distance, out of shooting range (this behaviour causes the reinforcing effect of shooting on harassment). Thus, shooting gulls may soon become very difficult, unless it is practised on birds flying overhead on a sleeping or feeding fly-route [10, 17].
Occasional shooting of individual birds is practised in many countries, depending on the applicable regulations. In the Netherlands, shooting at civil airports is only used as reinforcement of the usual techniques and to reduce the number of hazardous breeding species (Oystercatcher, Lapwing, Grey Heron, Pheasant) [23].

Trapping

Lethal traps are little used. An (American) example is a snap trap for woodpeckers damaging utility poles [6]. Woodpeckers are generally not a problem species on airfields. Eurasian species of woodpecker are not likely to use poles and are rare around airports because of the lack of trees.

Poisoning

For poisoning target birds, oral and contact toxicants are used, a.o. in the United States [6] (they are not used in the Netherlands [23]). Experience with toxicants mainly has an agricultural background, but they are also used at airports. Oral toxicants are applied by baiting, contact toxicant by treating perches. They require a careful study of the target birds' behaviour, favoured sites, carefully designed pre-baiting, careful handling and controlling of toxicant and bait. Pre-baiting is the determining factor for success. Location and timing of pre-baiting should be adjusted to the birds' feeding behaviour and daily routine, and should be conducted for two to three weeks before applying the toxicant. The bait should be of good quality and of fine, uniform structure (higher surface-volume ratio). It should not be applied before it is made sure that only target birds feed on the bait. Unused bait and dead birds should be properly removed [6].
An example of an oral toxicant (registered in the United States) is 3-chloro-p-toluidine hydrochloride, that is a.o. used for gulls at colonies to reduce predation of nearby nesting colonies of other species. It metabolises quickly, the metabolites are not toxic and there is no secondary toxicity to animals eating killed birds. An example of a contact toxicant (registered in the United States) is fenthion ('Rid-a-Bird' perches). It is used for Starling, pigeons and sparrows and applied on or in (farm) buildings, power plants, bridges etc. Secondary toxicity occurs so dead birds should be properly removed. It is not recommended to use perches outside building because non target birds may become a victim [6].
There is an example of successful application of a strong sleeping drug in a gull colony in New Zealand, after which many birds were captured [Caithness, 1969 in 17].

Destruction of eggs and nests

Nearby breeding populations of waterfowl or gulls can be a problem. Breeding of gulls can be discouraged by removing their eggs and nests. As soon as clutches are complete, all eggs and nests should be removed from the colony every two to three weeks, continuing until all breeding efforts stop [6]. Another possibility is to spray the eggs with an emulsion of oil in water containing 10% formaldehyde. The eggs will die of without decomposition (which may induce laying of a second clutch). Kuyk [17] mentions that this method is only workable in smaller colonies, although it was used effectively at a large Herring Gull colony near the airport of Copenhagen [4, 23]. Egg-shaking is also used. Shaking should start after the clutch is complete and breeding begins. When incubating is already progressed, shaking loses its effect. To determine the state of incubation, the flotation test is suitable. Eggs and nests should not be destroyed after shaking before another period of incubation have gone by (three weeks for waterfowl). After that period, birds will generally not attempt to re-nest [6].

Predators

In the United States, Herring Gull colonies on small islands have been eliminated by introduction of fox and racoons within 2 – 4 years (predation of both birds and eggs). However, these predators were not able to survive without additional feeding. In contrast to colonies, the presence of predators at gull-roosts does not appear to be effective, because roosting birds will fly sooner than breeding birds.

To prevent escape of predators and colonisation of adjacent terrain, areas where predators are introduced should be completely fenced of. In practice, this will be very difficult (except on islands). A general problem with introduction of predators is that they themselves have to be controlled, in order to maintain a certain population density. Also, the predators themselves may pose a strike risk to aircraft [17].

3 Case descriptions

3.1 Introduction

The previous chapter provided an overview of the international 'state of the art' of bird control. It appeared that methods and effects of bird control may vary greatly between circumstances and locations. In order to obtain a more practical view, concentrating specifically on the situation of an airport in open sea, five exemplary airports have been selected for a more detailed description of situation, bird hazards and bird control. In selecting the airports, the following criteria have been used:

- location of the airport:
- in or at sea/fresh water or otherwise isolated and attractive to birds
- in important migration routes
- close to important breeding colonies
- problem species, status and (seasonal) dynamics
- extent to which birds constitute a problem
- extent to which bird control measures are practised
- number of civil aviation movements

The airports are comparable with or relevant to the situation of an airport in the North Sea for at least a number of criteria. The following airports have been selected (main reason between brackets):

- John F. Kennedy International Airport, New York, U.S.A. (close to sea; gulls)
- O'Hare International Airport, Chicago, U.S.A. (close to large fresh water lakes; gulls, waterfowl)
- Ben Gurion Airport, Tel Aviv, Israel (nearby landfill, important migratory flyway)
- Kansai International Airport, Osaka, Japan (island at sea)
- Copenhagen Airport, Denmark (close to sea; gulls on nearby island; north-western European situation, comparable problem species)

Amsterdam Airport Schiphol is also included, to get a view on the current situation at the Dutch national airport. Moreover, Schiphol has pioneered in bird control and many of its measures have been 'exported' abroad to other airports (e.g. Israel, Japan; A. Klaver, pers. comm.).

The 1998 passenger numbers and flight movements of the selected airports are shown below. Comparing the number of bird strikes between airports is difficult, because countries differ in their ways of reporting bird strike events. Comparable figures have not been found for all airports.

	# passengers	*# flight movements*	*# strikes per 10,000 flight movements*
Chicago O'Hare	72,369,951		
Amsterdam Schiphol	34,420,143	360,000	5
New York John F. Kennedy	31,295,000	356,000	2
Osaka Kansai	19,512,147	121,355	
Copenhagen	16,670,511	280,000	2.5
Tel Aviv Ben Gurion (1997)	7,359,092	53,044	

[27, 35, 36, G. van Es pers.comm.]

3.2 Amsterdam Airport Schiphol

3.2.1 Bird hazards

Gulls (Black-headed, Common and Herring Gull), Lapwing and Golden Plover are the most dangerous species because of their erratic behaviour and sudden peaks in numbers (mainly outside the breeding season in winter). Numbers of Lapwing and Golden Plover can be considerable, depending on season. Long-grass management has strongly reduced the hazards of these species. Grey Heron forages at the airport in increasing numbers. They are dangerous because of their size, weight and erratic behaviour. Control takes places through continuous harassment with flashlight and flares. Research of their ecology and experiments with prey control (rodents) did not yield any necessities to adjust the habitat management. Shooting was intensified over the last few years. Mute Swan is rare but observed in increasing numbers. They are immediately chased away when present. Persistently returning birds are shot. The surrounding populations are increasing and of growing concern. Great Cormorant has shown a strong recent increase in the Netherlands and observations at Schiphol are becoming more numerous. Because of their size and weight, Cormorants are chased away immediately and occasionally shot. Flocks of Starlings are also a problem, especially when gathering and flying in great numbers to and from roosts. Also, these birds are hard to spot in long grass [31]. When roosts occur in the vicinity of the airport they are disturbed instantly, thus forcing the flocks to move. This has proved to be successful [16]

3.2.2 Bird control

At Schiphol, the precautionary methods consist mainly of habitat management. These are:

- exclusion of agricultural activities in the late eighties
- adjusted mowing of fields ('long-grass management')
- no dumps or landfills within 5-6 km of the airport boundaries
- no berry-carrying shrubs in airport vegetation
- trees only at a certain distance from airstrips
- no coniferous trees in the vicinity

The starting point has always been to make the airport as unattractive as possible to the species most dangerous to aircraft. Bird control started in the late sixties, when the ecology of birds was monitored and conditions were formulated for habitat and agricultural management. Following studies focussed on the distribution and preferred habitat of gulls, Lapwing and Grey Heron at Schiphol and its surroundings, vegetation, soil and invertebrate fauna and harassment. Bird control at Schiphol was based on the results of these studies (A. Klaver, pers. comm.).

Abandoning agriculture and long-grass management have proved to be very effective in reducing the number of strikes. Allowing the grass to grow to 15-20 cm height strongly diminishes the attraction to foraging or resting birds. The availability of food is less and there is no open view for predators. With Lapwing, Golden Plover and several species of gull being the most threatening species, abandoning of agricultural land use and long-grass management strongly reduced the number of bird strikes. Long-grass management has got some negative side effects. The long grass now hosts larger numbers of small rodents, in turn attracting other bird species such as Kestrel, Grey Heron and owls. Also, it is a more attractive breeding habitat for Lapwing, Pheasant and Grey Partridge. The densities of these species, however, are much less and the positive effect remains [22, 16].
Experiments of controlling voles with chemicals did not show an effect on the numbers of birds [31]. Due to the high costs involved with removing mowed grass, the flight intensity, fertilisation by deposition of nutrients and the regular replacement with new grass strips, no efforts are made to create a scantier vegetation. However, a pilot project that investigates the effect of such management on fauna is under consideration [16, 31].

The following repellent techniques are used:

- flares and distress calls
- noise using gas cannons
- mobile windmills and gull dummies

Breeding attempts of gulls are disrupted immediately. Incidental breeding of Lapwing is tolerated. Wintering and migrating groups of these species are constantly harassed with distress calls, flares and flashlight. Gas cannons are used to prevent habituation, shooting only takes place incidentally (10-20 birds per year).
Round-the-clock patrol is the core of bird control at Schiphol. Nowadays, the bird control team consists of about 12 people (A. Klaver, pers. comm.). Apart from a number of daily foraging birds, the presence and movement of birds around Schiphol appears to be rather unpredictable. By constantly monitoring and identifying the birds present, appropriate measures can be taken instantly [22]. Patrol takes place using a four-wheel-drive vehicle with search light, loudspeakers to play distress calls and several types of flares. Mobile windmills and gull dummies are used as well, but tend to be more susceptible to habituation. Flexibility and knowledge of bird behaviour as well as air traffic are key factors [16].

Incidental shooting in the case of persistent breeding, flocking or sleeping attempts remains to be successful (in a number of around 100 gulls are shot on a yearly basis). In the past, pre-roosting gathering of gulls resulted in the presence of 5 – 10,000 gulls in large flocks. Shooting several individuals scared off the flocks, which did not return after repeated action. Repressive shooting is further used to support the harassment techniques (preventing habituation), when large groups of birds are present and harassment is dangerous, or when there are threats at different locations at the same time. It is noted that shooting has decreased with 50% since long-grass management was taken into practice [16].

3.3 JFK

3.3.1 Bird hazards

The airport is situated on the eastern part of Long Island, New York, shortest distance to sea being 4 kilometres. Long Island is a peninsula, parted from the sea by a lagoon and a string of islands. The airport borders urban areas in the north and east. A large recreation ground (approximately 9000 ha), consisting mainly of open water with islets, lies to the south-west [10]. Jamaica Bay Wildlife Refuge, an important wetland with mudflats, marshes, open salt and fresh water, borders directly to the airport. It is a part of Gateway National Park and houses large numbers of water birds (gulls, ducks, herons, waders, mainly during migration) and a large breeding colony of Laughing Gull. Herring and Great Black-backed Gull are breeding in low numbers. Gulls are the most hazardous species, responsible for about 50% of all strikes. Geese are uncommon, but to be counted with because of their size and weight. Most bird strikes occur at daytime and in low altitudes (0 – 30 m). Tidal movements are mainly confined to the Jamaica Bay area [34].

3.3.2 Bird control

The bird control team consists of six people, two of which full-time. Bird control at JFK has the following elements:

- daily routine on-base harassment
- management of fields along runways
- management of attractants such as fresh water ponds, waste and garbage dumps
- shooting (gulls)
- gas cannons
- falconry

Grass management has been altered from short to long-grass management in the past. However, long grass houses more benthic fauna and insects, on which Laughing Gulls feed. Moreover, the vegetation has an open structure because of the poor soil quality (sandy). The grass management is currently under review .
Two nearby garbage dumps have been closed and covered in the past, resulting a decrease in the number of gulls.
Special attention is paid to low level areas after rains, in order to reduce pools of standing water.
Gas cannons are used to disperse gulls that use the runways for cracking shellfish during low tide. Due to habituation, the effectiveness is diminished. Bioacoustics are regarded as ineffective and are not used [34].

From 1985 onwards, a colony of Laughing Gull developed quickly, causing a dramatic increase of strikes at JFK. A shooting programme has been started in 1991. Bird strike was reduced to 90% by shooting gulls flying over the airport. These birds were mainly Laughing gulls, originating from an expanding breeding colony nearby; during a six year shooting period, 52,235 gulls were killed [10, 34]. The number of breeding pairs dropped from 7,000 (1990) to 2,500 – 3,000 (1996 – 1999). Observations indicated that shot local breeders were replaced by birds immigrating from other (expanding) colonies [20].

At JFK Airport, falconry was tested to supplement (and eventually replace) the gull-shooting programme. Peregrine, Peregrine x Gyr falcon-hybrid, Saker and Harris' hawk were flown, typically in flights simulating hunting. Additional pyrotechnics and distress calls were used. During overlap of shooting and falconry, less gulls were shot. When shooting was stopped and falconry was continued (received positively by public and media), there was, however, no significant reduction of bird strikes compared to the period prior to shooting [10, 34].

3.4 O'Hare

3.4.1 Bird hazards

O'Hare International Airport, the main airport for Chicago, Illinois, USA, is situated close to the Great Lakes.
Within the boundaries of the airport, a number of water bodies are present for drainage purposes. The largest is Lake O'Hare, (42.5 ha). The lake is generally shallow and does not have steep shores. Water levels fluctuate; it is only completely filled after heavy rains and maximum depth is 4 m. Being drained as much as possible (nowadays), at least half of the lake is dry and the remainder has a maximum depth is 1 – 2 m. There are two retention ponds (1.3 ha each) and a stream (10 m wide) that runs across the airport area for about a mile [7].

The Great Lakes are inhabited by large numbers of waterfowl and gulls. Canada goose and Ring-billed gull are on the increase [24]. Gulls roost on rooftops in the city of Chicago. The on-base water bodies, especially Lake O'Hare, are attractive to birds, in particular Canada geese, dabbling ducks and (Ring-billed) gulls. These are also the main hazardous species, that were causing problems before the wildlife management started. The lake regularly attracted large flocks of water birds. Gulls were also attracted to garbage bins at the parking lot. Starlings and waders occur as well, but not in great numbers and they are not considered a problem.

3.4.2 Bird control

Wildlife management by (two) biologists of the US Department of Agriculture, Animal and Plant Health Inspection Service (USDA) started in 1992. They assisted in tackling the problems with Canada geese, ducks and gulls that the airport was experiencing at that time. The biologists design the general policy and measures, carry out monitoring and part of the bird control. They also trained Airport Operations personnel to carry out bird control, mainly pyrotechnics. Lethal measures, if necessary, are carried out by the biologists. The following measures have been taken:

- adjusted water level management of Lake O'Hare
- exclusion of the ponds and the stream
- exclusion of lampposts and garbage bins
- harassment and shooting

The lake is kept drained as much as possible, up to nearly half of the total surface at maximum. Changes in water levels are large, which probably prevents the development of plants and invertebrates that might serve as food for ducks and makes the lake less attractive as a roost for gulls. Pyrotechnics are used for harassment; bioaucoustics are not considered effective. Ducks are immediately harassed or shot. Canada geese, locally increasing as a breeding bird, meet with a zero-tolerance approach and are consequently little observed at the airport. The combination of water level management with regular harassment and shooting strongly reduced the presence of birds and, consequently, the number of bird strikes.
At the retention ponds, a grid of Kevlar lines is used to make the water inaccessible to birds. The lines have a black plastic coating and are spaced 7.5 m apart. A part of the stream is close to a runway. At this point Kevlar lines are used as well, spaced closer together and only across the stream. The Kevlar lines are sufficient to keep water birds out of the ponds and stream [7].

3.5 Tel Aviv

3.5.1 Bird hazards

At a distance of 4.5 km of Ben Gurion Airport a large landfill is situated (fig. 3). This landfill, known as Hiriya garbage dump, was established in 1952. By this time, it measures about 170 acres and is more than 80 metres high. The dump causes severe safety problems at the airport. During the wintering season (October to March) it houses ten thousands of birds: gulls (especially Black-Headed), White Stork, Black Kite, egrets (especially Cattle Egret) and Hooded Crow. The total population of wintering gulls is estimated on 350,000 birds, with day totals up to 130,000. Numbers vary with time of day, weather and food availability. Five kilometres east of the airport, another dump is located (Modi'in); movements between the dumps occur regularly. Flying and soaring birds are thus present within the take-off/landing area and above the airport during one half of the year. Collisions caused by gulls account for 4 – 20% off the total number of bird strikes per year.

In the near future, Hiriya garbage dump will be closed, after long years of campaigns and discussions [35].

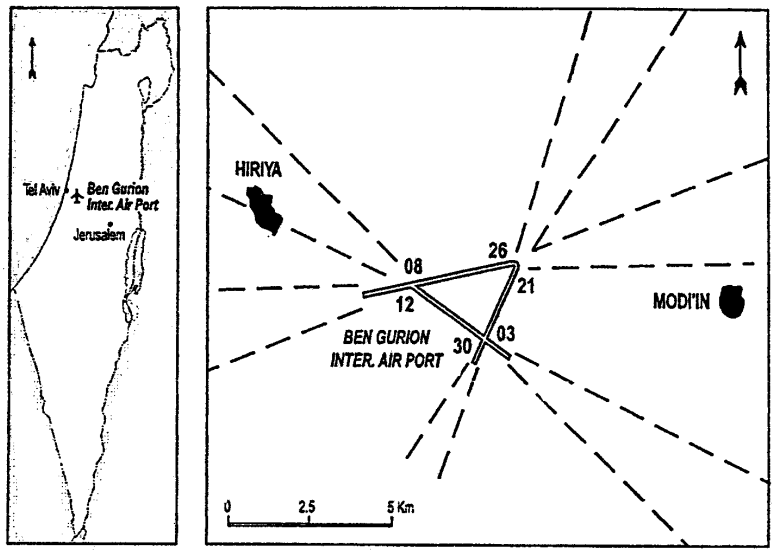


Fig. 3 Ben Gurion International Airport location and the location of the Hiriya and Modi'in dumps, including the high risk area of take-off/landing

Migration

Israel is situated on the very land bridge between Europe and Asia and Africa. As a result of this huge numbers (estimated 500 million) of migratory birds pass the country in autumn on the way south and in spring on the way north. Migration takes place during both night and day and mainly above land. Especially large birds like raptors, pelicans and stork, which use thermal rising air streams to gain height, are hazardous to aircraft. For instance, their main flying height (1,000 m) coincides with the training height of airforce fighters (due to Israel's political situation, low level military training flights are an important part of the country's defensive system) [25].

3.5.2 Bird control

Bird control at Ben Gurion Airport is designed after the example of Amsterdam Airport Schiphol (Y. Leshem & A. Klaver, pers. comm.). A bird control team consisting of two people use a vehicle and equipment when required. Within the airport, specific laws regulate land use. Outside the airport, regulations control elevated object or constructions, including shrubs and trees.

Distress calls, noisy rifle shots and gas cannons are successfully used to disperse birds. 'Scare models' are or have been used, with unknown results. Lights and laser are not used.

There have been extensive experiments with the chemical repellent Reta. Results were negative and the use of Reta has been abandoned [23].

Migration
The problem with large migratory species is not directly related to airport features and bird control measures. As a result, most (research) efforts in Israel are aimed at monitoring migration (counts, radar, satellite) and developing predictive avoidance models. This extensive research on bird avoidance has taken on a large scale at international level. Because it is outside the reach of this study, this issue will only be very briefly addressed to here.
Count and radar observations showed strong correlation. Data analysis has shown that atmospheric conditions determine the migrational flyways and altitudes, allowing indicative predictions of when and where which bird species will arrive.
As these models themselves do no deter the birds from choosing their way, measures must be taken when potentially dangerous situation are detected. The only measure available in this case is a temporary stop on flight movements. As a result of the real-time warning system, based on detailed information of thermal migration, the number of bird strikes with military aircraft have been reduced with 88% [25].

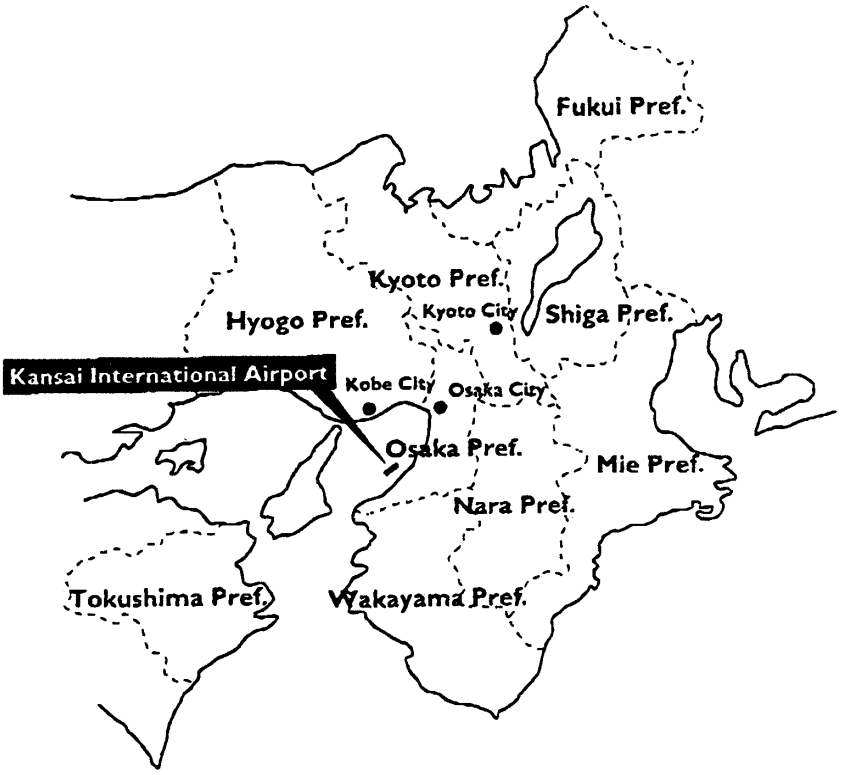
Thermal migration does not occur above sea. Moreover, migration of large birds at the scale of Israel does not occur in north western Europe. However, some raptor and passerines species may cross seas when migrating. Other bird species migrate mainly or solely across sea (pelagic birds divers, grebes, ducks, geese, gulls, terns). This is, of course, not thermal migration and it usually takes place at low altitudes below 50 metres. This phenomenon is addressed more in detail in other studies.

3.6 Osaka

3.6.1 Bird hazards

Kansai International Airport is situated 5 km off the coast. A bridge connects the airport to the shore. There is one runway for both landings and take-offs (3,500 x 60 m), construction of a second runway is under preparation. The runway is 5 m above sea level, the tidal range is 1.5 m and the sea is 18.5 m deep. The airport was opened fairly recently, in September 1994 [26]. In the past, Schiphol Airport served as an example, for the development of bird control measures in Japan (A. Klaver pers.comm.).

Hazardous birds are gulls, Grey Heron and cormorants, as they regularly fly across the approach lights of a particular runway, at the altitude between 200 and 300 feet. Other birds occurring at the airport are Black Kite, Osprey, Cattle Egret, Little Tern, Japanese Wood Pigeon and Skylark; only the latter two are breeding. Of these, Black Kite, Grey Heron and Cattle Egret are attracted by grasshoppers that have been occurring in large quantities. Osprey, Black Kite, Grey Heron, gulls and Little Tern catch fish in the surrounding waters (where commercial fishing is prohibited up to a distance of some 400 metres from the airport, and fish is abundant).
In the entire country of Japan, approximately 600 bird strikes per year have taken place in recent years [36].



3.6.2 Bird control

Any land use on airports is prohibited. In a zone of 400 metres around the airport, fishing is prohibited. These waters being abundant with fish, however, attract birds [36]. Generally (in Japan), grass is mowed twice a year and kept short [23]. Puddles and marshes are removed by the maintenance department. Fruitless trees are chosen along the street in the airport, with good results. The recent explosive occurrence of grasshoppers has been countered by dusting the grass with insecticides, which proved to be effective [36].

The bird control programme is carried out by a team of five people. Guns (for firing shell crackers), smoke and fire, distress calls and explosion devices (gas cannons) are used to warn off and disperse birds from the airfield. Shooting to eliminate birds is needed as a reinforcement, but it is only practised when necessary and as little as possible.
Shell crackers are effective, but need reinforcement by shooting birds.
The main targets for shooting are large birds such as Black Kites, herons and gulls.
Fireworks are shot from a special launcher. They explode noisily with a bright flash and are sometimes used at night. Care is taken with respect to grass catching fire. Distress calls are used from Black Kites, gulls, herons, crows and ducks. The broadcasting unit is installed on patrol vehicles. The gas cannons are installed near the touch-down zones at both ends of the runways. At regular intervals, propane gas is exploded by a timer [26, 36]. Falconry, bird models and chemical repellents are not used [23].

3.7 Copenhagen

3.7.1 Bird hazards

Copenhagen Airport is the main airport in Scandinavia. The airport area measures approximately 12.4 square kilometres and has three runways (a fourth runway is planned). The two main runways, where approaching and departing flights are over water, is used in approximately 97% of all flights [28].

At a distance of 5 km from the airport lies the island Saltholm which houses a large breeding colony of Herring gull. Breeding gulls are difficult to disperse because they have a strong relation to the colony site [17]. In 1970, it contained about 37,000 pairs, declining to 8-9,000 in 1989 after measures were taken. This resulted in a much reduced number of gull strikes and presence of Herring gulls at the airport [23].

Since long-grass management is practised (1974), Kestrels have become more numerous on the airport and strikes have been increasing significantly since 1978. So far these strikes did not cause serious damage and this effect of long-grass management is accepted [23].

Large flocks of Oystercatcher (from nearby breeding grounds) are present in spring and summer, resting or feeding on earthworms or Tipula-larvae. This species accounts for 5% of the strikes, no serious strike has occurred until 1990 [23].

3.7.2 Bird control

In Denmark, civil airports have regulations on vegetation management and planting programmes. Long-grass management is practised in order to reduce attraction to gulls, Lapwing and Starling. Construction of landfills, gravel pits or lakes is prevented within 6.5 km from airports. The possible overhead flying routes (feeding flights) from such sites to breeding sites are taken into account. Existing nearby landfills may even be removed [23].

Every year since 1970, the nests of the Herring gull colony have been sprayed with an emulsion of MIDOL difencryl oil in water (60%) to reduce the size of the colony. In this way, embryos are killed but the parents continue incubation. The colony thus produces very few young birds, resulting in a decrease in gull strikes (moreover, young birds are more likely to cause collisions than adults). Also, the breeding colony was reduced to 20,000 pairs after 4 – 5 years. At that stage, additional measures were necessary for a further reduction of risks. Adult birds were removed by baiting at the nest with herring, containing a lethal dose of chloralose. The combination of these measures reduced the colony to 8-9,000 pairs in 1989. Reduction of Herring gull has lead to an increase of other gull species on the island, however, it did not cause more strikes with these species [23].

In 1977 experiments were carried with Reta on short cut-grass. The effects were minimal. Because of anxiety of environmental damage as a result of chemicals, no further experiments with chemicals have been conducted [23].

A mobile bioacoustics-unit is used for harassment with distress calls. Recordings of the following species are used: Herring, Black-headed and Common gull, Lapwing, Starling, Rook, Jackdaw. Results are good except for Starling and Lapwing. Scaring of

Oystercatchers is difficult, no satisfying solution for this species has been found yet. Bioacoustics are combined with pyrotechnics, visual scaring (with shotguns) and regular incidental killing by shooting to prevent habituation. As a result, habituation to visual scaring with shotguns is much less than to other dispersal devices [23].

4 Conclusions and recommendations

4.1 Effectiveness of bird control methods

The literature study yielded a good overview of the current state of the art of bird control, despite that it has not been possible to compile a complete overview of everything that has been published on this subject. It has become apparent that much information resides with experts and in unpublished literature world wide. The International Bird Strike Committee is the main authority in this field.

It must be concluded that there is no 'blue print' for successful bird control at any location. None of the current methods is perfect. The underlying overview shows that results of bird control methods vary greatly with location, bird species and environmental circumstances. One of the main reasons seem to be that no two airports are (a.o. ecologically) the same. Examples of bird control methods for the specific situation of an island at sea were not found. Airports have a bird control programme that is based on local experience and preferences and fits best to the local situation. A lot of bird control methods are based on 'trial and error' testing in the field. The same method applied on different locations (even on the same species) may yield completely different results. The results can be biased by many factors, such as habituation, preference for certain methods by the personnel, perseverance, specific circumstances at and around the airport. It is therefore very difficult to judge and compare control methods on their results. Most of the described methods have been successful to some extent. However, the literature study produced sufficient information to provide some conclusions.

Generally, habitat management and zoning of land use around the airport are successful and most durable, because attractants are eliminated or reduced. To a lesser extent, this is also true for exclusion measures (the attractant still exists but is made inaccessible). These bird control methods are not susceptible to habituation. However, there is a limit to the achievements of habitat management, and many birds have a way of getting through or around exclusions, as long as the attractant is strong enough.
Several resource protection measures have proved to be successful. Chemical repellents have proved successful in some cases, but they are hardly used in Europe because of legal and ethical considerations. Bioacoustics and pyrotechnics are the most widely used audio repellents; lights, people, models or carcasses of dead birds are the most used visual repellents. Among the visual repellents, falconry is least susceptible to habituation because a realistic threat is involved. Because of several practical constraints however, it is not widely used.
Population management is generally considered a last option, when other measures fail. Nevertheless, (incidental) killing of birds is inevitable as well as successful. It is widely (and successfully) practised on a small scale basis, for reinforcement of other measures, for eliminating (individual) sick or weakened birds or persistent breeders or birds that constitute an acute danger. This is mainly and most successfully done by shooting.

Table 1 presents an overview of the current application of bird control at airports. Scores are added, expressed in + or -, indicating current use and success of each measure, as well as the applicability of each measure to the situation of an airport-island at sea (the latter will be addressed in section 4.3). Given that differences between published material and practice experience may occur, the remarks should merely be treated as indications. Moreover, regarding the relatively unexplored situation of an airport at sea, experts may develop new ways of bird control specific to this ecological situation.

Table 1: overview of the current application of bird control at airports

Method	Use	Success	Applies to island
Habitat modification			
handling potential food sources	++	++	+
management of vegetation and terrain	++	++	++
fresh water management, drainage	+	++	+
zoning	+	++	-/+ (fishing vessels?)
Resource protection			
exclusion	+	+	+
chemical repellents	-	+/-	-
audio repellents:			
- pyrotechnics	++	+	+
- gas cannons	+	+/-	+/-
- bioacoustics	++	+	+
- ultra-/infrasound, radar	-	-	-
visual repellents:			
- carcasses/models dead birds	+	+/-	+/-
- falconry	+/-	+	+/-
- model birds of prey	-	-	-
- model aircraft	-	+/-	-
- people/vehicles	++	+	+
- dogs	-	+/?	-/?
- mylar tape	-	?	?
- eye spots	-	-	-
- lights	+/-	+/-	-
- windmills	-/+	+/-	+/?
Population management			
physical capture	-/+	-/+	-
chemical capture	-	+	-
shooting	++	+	+/-
trapping	-	+/-	-
poisoning	-	+	-/?
destruction of eggs and nests	-/+	+	+
introduction of predators	-	+/-	-/?

An approach that integrates elements of all control strategies (habitat management, resource protection and population management) will offer maximum effectiveness for the long-term. It will also minimise the need for killing birds [6]. Airports should have a wildlife management plan that is reviewed regularly, personnel should be properly trained. In active bird control, perseverance is also an important factor [29, 13, 20].
Even so, there will always be situations in which no control measures can take away the threat. Migration is an important example. In these cases, if possible, intermittence of flight activities is the only way to prevent dangerous situations [33].

4.2 Developing a bird control programme

4.2.1 In general

It is clear that the design of a bird control programme should be proceeded by a study of ecology and behaviour of problem birds at the local and regional level. Preferably, the results will be taken into account when locating and designing a new airport.
The first step towards effective bird control is answering the question why the birds are (or will be) attracted to the airport. The answer will be provided by identifying to what extent

the environment offers food, cover and water. This implicates knowledge about the ecology of the target birds (and, possibly, their prey), the features of the environment and land use activities in the vicinity [6, 20]. Godsey [13] also stresses the importance of learning about local bird activities, through conducting bird surveys. These surveys should include weather conditions, species, location, flying and other activities and possible attractants.
Cleary [6] mentions questions that should be answered next:

1. Which bird species are causing the damage?
2. What are the birds doing that make it necessary to control them or their damage? The answer to this question will , to a large extent, determine the control methods used.
3. What is the legal status of the problem birds?
4. What are the daily movement patterns of the birds between their feeding, loafing and roosting areas? When are they most vulnerable in their movement cycles?
5. What effective and legal control methods are available?
6. How selective are these control methods? The object is to control only the target birds, not all birds in the area.
7. How much will it cost to apply the selected control methods (also in relation to the costs of the damage)?
8. How does the public feel about the birds, their damage and the control implications? [6]

A number of these questions may be of less relevance, when compared to the risks involved (for instance, the legal status of birds or the public feeling). Bird control measures (and their costs) should be compared to an assessment of the risks to safety.

Several authors stress the fact that, apart from control techniques, monitoring of bird strike is a very important way of gathering information, assessing risks and developing bird control measures fit to the local situation. It is suspected that many strike events remain unreported. Reporting bird strike is being strongly promoted by the several bird strike committees [29, 21]. Using this information will facilitate the assessment and modelling of the risk of bird strike [29].

A guideline for developing a wildlife management plan is under preparation (by J. Hild, D.A.V.V.L., Germany; A. Klaver, pers. comm.). Also, the next revision of the "Green Booklet" will appear as a ‘handbook’ for bird control at airports (expected April 2000, under preparation by B. MacKinnon, Transport Canada; A. Klaver, pers. comm.).

4.2.2 Bird control on an airport-island

When designing an airport island in the North Sea, special attention should be paid to bird hazards from the start. An island at sea will always constitute a strong attraction to many birds. The attraction can be influenced by design, habitat manipulation and exclusion and repellent or dispersal techniques, be it only partly. In order to provide sufficient safe conditions for aviation, bird control should be very strict, for instance including absolute zero-tolerance policy towards (breeding) gulls and Cormorants. However, migrating or sheltering birds can hardly be controlled by bird control measures. An adequate observation and warning system may be necessary. Especially during migration and winter, bird hazards can well be such that flight operations may have to be intermitted.

Zoning around an airport at sea takes a rather different perspective compared to airports inland. Restrictions on ‘land’ use do not seem to apply, however, certain activities, like commercial fishing, require special attention. Large numbers of gulls may follow fishing boats, usually flying at low altitude. An island is very useful as a sheltered look-out for approaching boats. Regulations like a fishing-free zone around the island, after the example

of Kansai Airport, are advisable. Still, it is to be expected that the island will attract fishing birds (gulls, terns, cormorants) in a similar fashion as at Kansai Airport.
At night, an airport-island at sea will also be an island of light. Whereas special lights have been used for repelling birds, they will rather attract birds at sea (whether flashing or not), especially nocturnally migrating passerines.
Vegetation management requires special attention, because the island will start off with bare sand. Sand dunes are dynamic and will shift rapidly under the windy circumstances. Measures will be needed to keep runways and hard surface free of sand, and vegetation will be the most important. In coastal areas, grass ('Helmgras') is generally used. However, Herring, Black-backed and Common gulls use this habitat when breeding in dunes. Pioneer-vegetations on flat coastal sands are generally scanty and short, thus being attractive as roosting and loafing habitat. Creating a closed grass vegetation will be very difficult Thorn scrub ('Duindoorn') grows well in this habitat and may be an alternative, despite its attraction to migrating passerines (for cover and berries). These small migrants are generally not abundant out at sea (except in the occasion of a fall), they tend to stick to cover and do not fly around much, thus being less hazardous than roosting gulls.
Audio and visual repellents that have proven to be effective should be tested in the field situation. Depending on test results, techniques may be adjusted or altered. Chemical repellents may be tested as well, although legal or environmental concerns may arise. Moreover, many chemicals have proven to be unsuccessful and may be especially so in the wet and windy circumstances on an island.

A number of measures can be mentioned as being important and/or potentially useful. Derived from the table in section 4.1 these are:

- design and management of lay-out, vegetation and other terrain on the airport
- management of fresh water (drainage, rain)
- handling of potential food sources and waste disposal
- regulations for commercial fishing around the airport
- exclusion measures
- continuous bird patrol
- pyrotechnics and bioacoustics
- shooting
- discouragement and destruction of breeding attempts (zero tolerance)

With respect to the rather unique situation of an airport-island in the North Sea, several aspects will require more research. Also, other aspects deserve interest that are usually not or less relevant in the case of an airport inland. A number of aspects can be mentioned in this respect (some of which are already subject to current studies):

- preferred distance from the coast with respect to migration patterns and attracting coastal birds
- behaviour of birds (gulls) at and around islands
- sea-migration patterns around islands
- effects of creating nearby islands attractive to birds, to keep them away from the airport island
- design of the island with respect to birds migrating across the sea
- field tests on the development of (preferred) vegetation under coastal conditions
- minimising the creation of sheltered bays or lagoons
- exclusion measures along shores, buildings and at sheltered sites on and around the island

4.2.3 Relevant examples

There are several examples of plans for airports at sea that have not been carried out. For instance, New York City has been considering an airport island five miles out to sea. In Denmark, the island of Saltholm (five miles off Copenhagen) was considered a potential site, but the large Herring Gull colony and the large numbers of wintering waterfowl would constitute a great hazard (a conservation campaign was started to develop the island as a

bird reserve). The mudflats in the mouth of the Thames has been proposed as a location for London's third airport. The great numbers of birds present (Brent Geese, ducks, waders, gulls, passerines) at times (migration, winter) was among the reasons to drop this location, both from the view of environmental impact and bird hazard [4].

It seems that there is no airport in the world situated in circumstances that are comparable to an island in the North Sea. Kansai International Airport is the only airport actually built out in sea, but it is situated only 5 km off the coast, is connected to the mainland by a bridge and there will be ecological differences.
In selecting two airports to serve as an example, the conditions at the selected airports should be comparable to an island at sea to a high extent. Because the ecological conditions of an island in the North Sea will be most strongly related to airports close to sea in north western Europe, at least one of the two airports to be visited should be located in this region. From the airports in north western Europe, Copenhagen Airport in Kastrup, Denmark, is likely to be one of the most useful examples. There is a lot of experience with bird control and problems with the same hazardous species that are to be expected in the North Sea.
Kansai International Airport in Osaka, Japan, is world wide the only airport situated on a completely artificial island. The description shows that the hazardous bird genera do not differ very much from the Dutch situation (gulls, herons, terns). There is a considerable experience with bird attractants and hazards, bird control measures and zoning for fishing activities. Kansai International Airport may therefore serve as a useful example as well.

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Colofon

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