+ Referred to throught the paper as S.A.A.S.

WORLD / BIRD STRIKE COMMITTEE EUROPE

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DEVELOPMENT OF THE THEORETICAL CONSTRUCT OF SYNERGISED ALUMINIUM AMMONIUM SULPHATE+ FOR THE CONTROL OF BIRDS AT AIRPORTS

From the various papers at this and previous similar conferences it can be seen that it is the behaviour of birds at airfields which is the major cause of concern. Therefore, it is the behaviour of birds with which we are concerned and with which I shall deal. We have nothing against the birds themselves: we seek neither to destroy nor to eliminate them; but only to control the type of behaviour which is causing concern. This applies equally to the indiscriminate depletion of food stocks over the world and to the safety of travel by air.

Many species of birds frequent airfields, possibly because large open spaces relatively free from man provide safe resting places affording full visibility against surprise attacks from predators, moreover, permanent pasture areas between runways and pasture, and cereals and vegetables which are often found around the perimeters provide ample feeding grounds and, as in the case of the J.F.Kennedy Airport, New York, further food is found in the small rodents. The location is often near ecologically good food provision, occasionally with municipal refuse dumps nearby. Structure and location of the airports is, therefore, conducive to large accumulations of birds, and any long-term solution to the bird-strike problem may well have to take these ecological factors into consideration and this may involve re-structuring and, possibly, re-siting - a costly proceedure which could not take place within the forseeable future.

For the present, therefore, we have the problem of controlling the numbers of birds which frequent airfields.

Many means of bird-scaring have been used over the years, but they are time-consuming, costly, and have never yet been found to give continuous, overall, control. The ideal answer would seem to lie in the use of an effective deterrent which would control the behaviour of birds, that is, to eliminate the habit of alighting and remaining on and around airfields, providing that such method of control would be economically and ecologically viable and able to give continuous, overall, protection.

This has already been achieved at one airport - the Ben Gurion International Airport, Israel, where, after a history of bird strikes there has been a period of three years without them and, indeed, a reasonable freedom from all birds.

This freedom followed a planned spraying of all feeding areas on and around the airfield (including the municipal refuse tips on the perimeter) with the safe, harmless, chemical S.A.A.S.

Initially, clearance of birds was assisted by the transmission of taped bird distress calls and an exceedingly loud fog-emitter (Pulse-Fog), but, previously, both of these methods had only very temporary effect. (v. Ref.9)

The success of S.A.A.S. in controlling bird behaviour is only just being understood through the results of research into the electrical and chemical control of behaviour in both avian and mammalian species. Identical behaviour has been observed in the domestic hen under chemical stimulation of the brain (Fisher, 1969) during laboratory research, and, recently, in the field in sparrows when chemically stimulated with S.A.A.S. In each case, the behaviour elicited was identical: the birds stopped feeding, shook the head from side to side, then wiped the beak on the ground. The S.A.A.S., a chemical substance taken in from the environment, elicits identical behaviour to the chemical stimulation applied directly to the hypothalamus in the brain of the bird.

This paper provides the theoretical construct of how this is achieved.

THE CONTROL OF BEHAVIOUR

Behaviour, whether of feeding, resting, mating, nest-building or the establishment of social hierarchies is largely under chemical control. Electrical and chemical stimulation of areas within the hypothalamus in the brain have found separate areas primarily concerned with one of the following types of behaviour: fear, anger, feeding, satiety or the inhibition of feeding and many other activities and functions. It is believed that there is a specific "trigger" chemical for the control of specific behaviour. This chemical is within the hypothalamus and it triggers off the needed responses from the endocrine system. Our knowledge of the chemistry of the avian hypothalamic and pituitary hormones is recent and incomplete, whereas, in mammalian species, research has moved apace since the pioneering studies of Walter Rudolph HESS, who obtained the Nobel Prize in 1949 for it. Olds demonstrated the pleasure and pain centre in the hypothalamus in 1956, and Fisher, in 1964, demonstrated the ability to elicit disgust of normal food from the chemical stimulation of a particular area there.- identical behaviour to that obtained from S.A.A.S.

The chemical control of behaviour is affected by the neuro-secretory systems: one centrally situated in the hypothalamusaand one peripherally situated in the endocrine glands which are scattered throughout the animal body. Information reaches the hypothalamus via sensory perceptors and the cranial nerves - the olfactory nerve, one branch of the trigeminal nerve, the nervi terminales and the optic nerve endings in the eyes which are responsive to chemicals, and, possibly, others.

In the first of the systems, hormones are produced which when released act as trigger mechanisms to the peripheral system causing a particular gland to produce its specific chemical and release it into the body, thereby affecting and controlling behaviour (CHEDD 1971)

For example, it has long been known that Quelea quelea birds prefer privacy, each bird maintaining an individual distance within which approach by a companion is not tolerated (Hediger, 1950), and it has now been established by laboratory experiments that this behaviour is controlled by the production of luteinising hormone from the pituitary gland (Butterfield & Crook, 1968), and the trigger release mechanism in the hypothalamus for the luteinising hormone (LFH) structurally identified in 1971 (Guillemin & Burgess, 1972).

The role of chemicals in the control of animal behaviour is only now being recognised: and while there is a great deal yet to learn, the following can be stated with some degree of confidence:

External and internal changes, such as, for example, the external presence of food and the internal need of hunger, stimulate the receptors of animals. This information in the form of nerve impulses may be transferred ultimately to the neuro-secretory cells of the hypothalamus. These, in turn, communicate the information through the chemical system by means of hormone-releasing factors causing the bird to eat (Kobayashi & Wada, 1973). Animals also communicate with each other through chemical means. particularly over time and distance when visual or auditory means could not operate effectively.

This chemical information left by others is perceived by the sensory perceptors of the olfactory system, for example, and communicated to the neuro-secretory cells in the same way. This information may modify or alter the animal's behaviour, as, for example, a bird about to alight and feed may, on picking up a danger signal, fly off without alighting, leaving in its turn a chemical communication of fear. These external chemical communications in animals are termed 'pheromones' by many workers, but possibly a more useful term is 'exocrinology'. This was used by Parkes and Bruce, (1961), following their research on visual and olfactory stimulation in birds and mammals, to denote the expanded view of chemical regulators of behaviour to include, not only the internal chemical information system of endocrinology, but, also, external or exogonous chemical information which also modifies behaviour. The fact that the systems are interlinked helps to explain, in part the self-regulatory nature of population controls and the abnormal behaviour which follows overcrowding (Hall, 1969).

It is only since 1967 that reliable scientific evidence has been accumulating of the importance of the olfactory perceptual sense in avian species, although the anatomical evidence has been known for years. "Anatomical evidence, especially impressive in the case of olfaction, has existed for some time, and convincing electro-physiological and behavioural observations have been more recent contributions"(Wenzel, 1973).

CHEMORECEPTION

Our knowledge at present indicates that the perception of chemical stimuli occurs through the neural routes:

1. the olfactory nerve with receptor endings in the posterodorsal reaches of the nasal cavity,
2. taste fibres in the facial and glossopharyngeal nerves with sense cells on the tongue and buccal lining, and
3. free nerve endings distributed widely over the body surface in the neural network that respond to the several qualities of cutaneous sensation - the common chemical sense, which has had little study.

"Some writers have argued that apparent olfactory or gustatory sensitivity in the bird may actually be due to common chemical sensitivity. This argument need no longer be taken seriously because the modalities of taste and smell do exist, but cutaneous chemo-reception may also contribute". (Wenzel, 1973).

The structure of the olfactory epithelium is consistent for all vertebrates, including the two avian species Black Vulture (Coragyps atratus) and the domestic duck (Anas platyrhynchos) which were studied in detail (Brown & Beidler, 1966, and Graziadei & Bannister, 1967). The only non-mammalian chacteristic is an increase in microvilli on the terminal dendrite knob.

The size of the olfactory bulb, the terminal part of the cerebral hemisphere of vertebrates, from which springs the olfactory nerve (first cranial nerve) running to the organs of smell, varies widely among birds, but "the absence of gross differences between the avian and mammalian olfactory bulbs makes it reasonable to apply descriptions of mammalian bulb ultrastructure to birds, for no direct knowledge is available". (Beidler, 1971)

OLFACTORY PATHWAYS IN THE BRAIN

In 1971, new research techniques used by Lennart Heimer showed for the first time a central pathway for smell in the brain, and although this technique has not yet, as far as I know, been used in bird study, at least one recent study on the pigeon (Rieke & Wenzel, 1973), using electrical stimulation, confirms earlier reports that smell evokes responses in the central areas of the brain of the bird. This would seem to bear out all evidence so far obtained that there is little difference between the olfactory systems of all vertebrates.

SIMILARITY OF SMELL IN BIRDS AND MAMMALS

There is ample research to demonstrate that the sense of smell in at least fourteen different varieties of birds is indistinguishable from that of amphibians, reptiles and mammals. The methods used to demonstrate this are electro-olfactograms (electrical recordings of the olfactory nerve - Tucker, 1965), and extracellular recordings (Shibuya & Tonosaki, 1972). Furthermore, electrical recordings from the olfactory bulb itself have been obtained for fifteen different avian species (v. App. 'A'). Of the latter it was stated that "The wave bursts are very typical of recordings from any vertebrate olfactory system." (Sieck, 1967; Sieck & Wenzel, 1969; Wenzel & Sieck '72

An interesting point is the variation in responses to smell which occurs with different concentrations of the same compound and with different compounds and the variation from one bird to another of the same species (Sieck and Wenzel 1967 - 1972). The fact that the recordings were genuine reflections of the responses to smell was established by showing that the activity disappeared following the cutting of the olfactory nerve.

BEHAVIOURAL EVIDENCE OF SMELL

Even before the above evidence was known, some studies were showing that behaviour was dependent upon taste and smell, and the potential for the use of these senses is now well established.

Several instances of the use of olfaction in normal behaviour have been documented and others have been suggested (Stager, 1967). After extensive studies, Stager concluded that the Turkey Vulture and, possibly the King Vulture, locate general areas of carrion by odour cues, after which, the exact location is pinpointed by vision. (The method for this study was to hide a generator of ethyl mercaptan at the base of a canyon and to release the fumes into the still, morning air. The vultures could not see the generator, but they congregated and circled around the area of the generator repeatedly.)

Stager,1967, also proposed that the African Honeyguides which feed on beeswax, locate hives by the odour of the wax. He found that the birds were even attracted by a lighted candle, while Archer and Glen, 1969, found that Honeyguides "can be netted repeatedly in the immediate vicinity of beehives even ten to twelve days after their abandonment by the bees and when visual and auditory clues would no longer be available." They concluded, "They were able to pinpoint the location of the hives by a distance cue such as odour."

Papi et al (1971-2) reporting that homing pigeons rely on olfaction, stated, "Birds with bilateral olfactory nerve section, with both nostrils plugged with cotton tampons, and with one nerve bisected and the other nostril plugged, were all profoundly disorientated as shown by the very low incidence of returns to the home loft. The few that returned arrived later than the sham operated control birds." They had observed behaviour on six days before the operation and for seven days after, as the result of which they suggest, "pigeons in the loft learn to recognise odours from surrounding areas and to associate them with wind directions."

Johnstone et al (1970), stated, "It (avian reliance on olfaction) may even contribute to the normal operation of physiological systems in ways that are only beginning to be understood for other vertebrates."

Wenzel (1968-72), found that kiwis were completely successful at night in locating which of three feeding stations contained their food.

Grubb (1971/2) produced a variety of evidence to show that Leach's Storm Petrels and Wilson's Storm Petrels, the Greater Shearwater and, possibly, Sooty Shearwater birds accomplish at least some navigation by reliance upon olfactory cues."

Egrets found an island in the Bay of Fundy at night by flying up-wind (Grubb, 1972). Their nesting material served as an effective lure in the darkness. The birds landed through dense trees a short distance down wind from their burrows and they chose an arm of a 'Y' maze which contained the odour of their own nest material rather than the other which had similar control material taken from the ground. Finally, the birds with plugs in their nostrils or with sectioned olfactory nerves, had not returned to their burrows after one week, and Grubb concluded that the evidence supported the hypothesis that Leach's Storm Petrel depends upon olfaction for many aspects of burrow location.

"Not only does olfactory input influence many aspects of reproduction in other (than avian) forms, but it has even been shown to affect certain aspects of general behaviour in both rats and birds." (Avian Biol., 1973) which cites Douglas & Isaacson (1969); Heimer &Larsson (1967); Papi et al (1969) and Hutton & Wenzel (1971).The article continues, "Perhaps its most significant contribution to many avian forms lies in this sphere of influence rather than in the transmission of specific information about odours."

VARIATIONS IN BEHAVIOURAL RESPONSES

The variations in responses of birds and mammals has posed the greatest problems to the commercial development of an acceptable and ecologically viable chemical repellent. The complexity of behaviour is due, partly to the complexity of perceptual response in the individual, and partly, for want of a better term, 'bloodymindedness', or determination to carry out some destructive act.

The degree of variation in responses, both inter and infra species, is, at present, unaccounted for in research studies. Explanations given for it usually include past experience coupled with present nutritional and metabolic need, e.g., past water deprivation may mean that present thirst will overcome the aversion to a particular taste, (Wenzel, 1973) In such cases, a repellent, to be successful, would need the spectrum of repellency necessary for the particular species, together with such potency as to be able to overcome the tolerance limit of any individual. But, although this argument has some cogency, it has yet to be resolved.

RESPONSES TO S.A.A.S.

Evidence of the variations in responses to S.A.A.S. which would appear to have been caused by high incidence of hunger and/or thirst was first demonstrated in the Israeli Government trials by de Wolf and the Volcani Institute (1971-5). Migratory birds of varying species flying South over various farms from Hedera (32°12" N) to Gilat (31°20" N) did no damage to crops sprayed with S.A.A.S., whereas, after a further flight of some 150 miles across mainly barren desert to Neviot (29°00" N) some damage was found on the crops at the agricultural station there.[1]

Individual dislikes and preferences can be comprehended, but the apparent determination to carry out an act despite disagreeable consequences is believed to be unusual. This was first demonstrated by two dogs which shared a kennel and badly damaged it by gnawing, whereupon it was heavily painted with S.A.A.S. in an adhesive. The dogs stopped chewing for two days, but on the third day they tore the kennel to pieces, were violently sick and thereafter refused absolutely to go near any kennel.[2]

In similar vein, the buds and flowers of a row of syringa bushes in a garden were being taken by tits and sparrows and so sprayed with S.A.A.S. There was no damage for three days, but on the fourth and fifth days every bud and flower was found on the ground - not one remained on the bushes - but none of the other plants in that garden, which normally suffered heavy damage, were touched during the remainder of that season.[3]

Similar instances have been noted, but at the moment no work is known to have been carried out in this field to explain them.

CONTROL OF BEHAVIOUR BY S.A.A.S.

Olfactory control of avian behaviour by S.A.A.S. has been well established. Leinati L., followed by field trials in the U.K. and Italy, (4,5,6,7), showed that maize, pea and cereal seed, dressed with S.A.A.S. at up to 5% w/w, and sown up to two inches under the soil surface, were left untouched by pheasants, rooks and crows, whereas, up to 50% of the control seed was taken in some instances at the first sowing, and up to 30% at the second and subsequent sowings in the same control plots during the same season.

In many field trials, however, control by S.A.A.S. can be very difficult to establish scientifically for the reason that the effect of the repellent smell can cover a wide area, including that which was not treated. (For this reason it is recommended that S.A.A.S. be sprayed in strips leaving alternate unsprayed strips so as to minimise cost of material and application) This action was well demonstrated in a trial using the Latin Square method of evaluation, when it was hoped that the young cereal plants in the treated squares would eventually stand proud over the untreated control areas. But, in the event, the first birds to arrive at, or near, a treated square apparently warned the others of something unusual and distasteful and all birds left the field and did not return. To the scientists this was a failure: to the farmer it was a huge success!(8)

Avian response to the repellent involving, possibly, both olfaction and gustation has ample evidence from official trials including:-

Udagawa Y. Ministry of Agriculture, Japan; Japan Botanical Epidemic Prevention and Nippon Shokubutsu Boeki Kyokai, "Published Results of Ministry Trials, 1976", pp 232-5, on the control of pigeons (Columba palumbus) on soybean.(16) Also, private trials' reports of wild boar on bamboo shoots (17), and reports with photographs of sparrows (Passer domesticus) and turtoedoves (Streptopelia turtur) on barley, soy bean and paddy rice (18)

de Wolf Y. Ministry of Agriculture, Israel, Plant Protection trials 1970-74 et seq.: control of damage to various crops by several avian species including goldfinch (Carduelis carduelis & Carduelis elegans), linnet (Carduelis cannabina), pigeon (Columbdae), turtle dove (Streptopelia turtur), sparrow (Passer domesticus and Passer hispaniolensis), lark (Alauda arvensis), greenfinch (Chloris chloris), rock partridge (Alectoris graeca), starling (Sturnus vulgaris) and black-headed gull(Larus ridibundus).(19)

F.A.O. Research into the Control of Grain-Eating Birds. Preliminary, private draft of report of S.A.A.S. in the control of parakeet (Psittacula krameri), parrot (Poicephalus senegalus), buffalo and village weaver (Bubalornis albirostris & Ploceus cucullatus), glossy starling (Lamprotornis chalybacus), grey-headed sparrow (Passer griseus), and others. (20)

Dar G. "Summary of Tests Carried out at the International Ben Gurion Airport (Lod) with Bird-Repellent 'RETA'" (S.A.A.S., BSCE/11, 1976, WP.26, showed control of partridge (Perdrix bartavelle and Alectoris graeca), black-headed gull (Larus ridibundus), lapwing (Vanellus vanellus), starling (Sturnus vulgaris), dove (Streptopelia turtur), pigeon (Columba Palumbus) and swallows (Hirundo rustica and Delichon urbica). (9)

Memory would appear to play an important role in avian and mammalian control by means of chemicals. The chemical information on its route to the hypothalamus being linked up with feed-back loops from the mitral cells within the olfactory bulb which apparently play a role in the memory of previous experience, thereby affecting behavioural responses. But little is known yet of this function.

The memory factor, together with the information given by the release of pheromones, or exogonous chemical factors giving warning messages would appear to be the only possible explanation for the action of birds and mammals in avoiding a treated area for periods of up to several months. This could be due to memory alone if only the creatures experiencing the original treatment were concerned, but newcomers to treated areas have been repelled in a similar manner after the lapse of several weeks and months and even after heavy rain would have washed away most if not all of the repellent material, as, for example, at Ben Gurion International Airport (9) where there are movements of migratory birds, and seagulls were found to arrive daily with the possible object of reconoitering the repellent effect of the S.A.A.S. At Sydney, Australia, (10) no dogs would walk on areas of parks seven weeks after treatment with S.A.A.S., during which time there had been 4-inches (102mm) rainfall and the government drugs laboratory could find no evidence of the chemical remaining on the treated areas. Similarly, rats (11-12) desert rodents (13) and rabbits (14) among the mammalian species to react to the repellent, have been totally repelled for long periods of time from the treated areas.

Response attributable solely to the gustatory effect of S.A.A.S. has been demonstrated empirically in a manner similar to that by Fisher with the hen (v. above) on only one occasion. Twelve sparrows (Passer domesticus) were found happily shredding the petals of crocus flowers with their beaks. The birds left while the petals were sprayed with a mild solution of S.A.A.S. in water but they returned after a few minutes, whereupon one of their number hopped to a flower and commenced to shred a petal as before, when it suddenly stopped, dropped the petal, shook its head several times from side to side and hopped back to its fellows. Shortly after, two others from the twelve then carried out precisely the same actions with identical results. Then, all twelve birds flew off. But, during the remainder of the season, no further damage was done in that garden to any plant by any bird although much damage was done to plants in the adjoining gardens. (15

<u>To sum up</u>, research into the control of behaviour by neuro-physiological means has now reached a stage whereby several control mechanisms are known, both electrical and chemical.

It is suggested that we use our knowledge of the normal avian chemical control of behaviour in order to control behaviour undesirable to man by the development of an ecologically viable chemical repellent.

Such a repellent has been developed and the results of the field trials at Ben Gurion International Airport (now free from most birds for three years) would seem to suggest that it is effectively controlling bird behaviour at present.

I, therefore, submit to this conference that I have demonstrated that S.A.A.S. can have behavioural control over the birds and mammals that, directly and indirectly, can cause damage to aircraft in the course of landing and taking-off at airfields, and that I have correlated the scientific research work showing that this is achieved by neuro-chemical action within the brain.

There is, of course, much laboratory and field research still to be carried out, but, meanwhile, it is suggested that the correct grade of S.A.A.S. correctly applied on areas in and surrounding airports may do much to reduce the incidence of bird-strikes to aircraft in many parts of the world.

A questionnaire is attached to each copy of this paper for the use of any authority wishing to obtain advice as to grade and quantity of S.A.A.S. to use and the method of application.

R.J.STONE.

APPENDIX "A"

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The avian species shown below were used in electrophysiological experiments in olfaction by the methods and the researchers shown

NERVE RECORDING - Tucker D. 1965 in 'Electrophysiological Evidence for Olfactory Function in Birds: Nature: 207. 34-36.

- Chicken (White Leghorn)
- Common crow (Corvus brachyrhynchos)
- Muscovy Duck (Cairina moschata)
- Domestic Goose (Embden)
- Ring-billed Gull (Larus delawarensis)
- American Sparrow-hawk (Falco sparverius)
- Blue Jay (Cyanocitta cristata)
- Common Night-hawk (Chordeiles minor)
- Domestic Pigeon (Columba palumbus)
- Bobwhite Quail (Colinus virginianus)
- House Sparrow (Passer domesticus)
- Black Vulture (Coragyps atratus)
- Turkey Vulture (Cathartes aura)
- Common Yellowthroat (Geothypis triches)

BULB RECORDING - Sieck, 1967; Sieck & Wenzel, 1969; Wenzel & Sieck, 1972)

- Black-footed Albatros (Diomedea nigripes)
- Chicken (White Leghorn)
- Mallard Duck (Anas platyrhynchos)
- Domestic Pigeon
- Manx Sheerwater (Puffinus puffinus opisthomelas)

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