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Toxic Chemicals and Birds of Prey: Discussions at Eilat in 1987

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Discussions about toxic chemicals and birds of prey at the III World Conference on Birds of Prey at Eilat, both in the session "Raptors in Polluted Environments" and informally throughout the meeting, largely fell within 6 principal themes. These themes appear to have a longer-term significance, such that they might be considered as a framework for future activities of the World Working Group's Committee on Toxic Chemicals. Hopefully, this overview paper, written admittedly from my own perspective and presenting particular points of view, will prompt contributions to the programmes of future meetings of the Working Group.

The themes discussed, not necessarily in order of importance, were:

1) A re-interpretation of past events, in the light of recently acquired knowledge and understanding. Not only is this of evident scientific interest, but it provides a sounder basis for conservation policies in areas of the world where particular chemicals are being used;
2) Documentation of now-familiar effects of toxic chemicals on birds of prey, such as eggshell thinning and depressed productivity, in areas of the world which have hitherto received relatively little attention;
3) Priorities for future research and projects;
4) A documentation of effects of new chemicals or of new uses of chemicals;
5) Re-introduction of raptors into polluted enviroments;
6) Implementation of national and international strategies for reducing harmful effects of toxic chemicals on birds of prey.

1) RE-INTERPRETATION OF THE PAST

The DDE-Dieldrin Controversy

A need to re-interpret the conclusions of the past became apparent at the Second World Conference on Birds of Prey, held in Thessaloniki in 1982. Discussion of a resolution urging global curtailment of those chemicals most harmful to birds of prey revealed a divergence of views about the chemicals considered most responsible for the population declines in Great Britain and in North America. The British contingent put forth the view that dieldrin, by causing high levels of adult mortalities, had been the principal factor in the decline of the Peregrine Falcon, *Falco peregrinus*, in Britain and Ireland and in the decline of other species, particularly the Sparrowhawk, *Accipiter nisus*. This view has been restated in a summary of the International Peregrine Conference held in Sacramento in 1985 (WWGBP, 1986). North American workers generally have considered that reproductive failures associated with DDE-induced shell thinning were the principal factor in the population declines (Hickey & Anderson 1968; Cade *et al.* 1971; Peakall *et al.* 1975; Anderson *et al.* 1975; Spitzer *et al.* 1978; Grier 1982; Risebrough 1986; Fyfe *et al.*, in press).

The comfortable dogma of the North Americans received an additional challenge from Ian Nisbet in his summary remarks at the International Peregrine Conference in Sacramento in 1985. Mortalities caused by dieldrin use in North America would provide a better explanation for the rapid disappearance of the Peregrine from eastern North America in the years between 1946 and 1964 than would depressed productivity caused primarily by DDE. Nisbet's written contribution to the Proceedings of the conference (Nisbet, in press) documents extensive use of dieldrin in eastern North America during the years the Peregrines were declining.

We might recall the vigorous debates which took place in the 1960s and until the mid-1970s with a DDT company in the United States and its spokesmen (Jukes 1963, 1971; and numerous letters to editors), who pointed out that any innocuous effects of DDT compounds on birds had been disproved by a demonstrated lack of major effects on chickens and that, moreover, DDT thickened rather than thinned eggshells. Robinson (1969) of the Shell Chemical Company made the case that bird populations had generally increased after the beginning of dieldrin use. Any serious disagreement at the present time among raptor biologists and environmental chemists about which chemical or chemicals was responsible for the population declines could not only revive these debates with the industries on the environmental effects of organochlorines, but also undercut the continuing efforts to restrict their global use, particularly in developing countries. Discussion of this topic was therefore a priority at Eilat.

These discussions showed, I think conclusively, that there is no fundamental disagreement on this issue. As a contribution to the technical basis upon which such a review must depend, David Peakall (this volume) has reviewed the avian toxicology of dieldrin and the relevant aspects of the toxicology of other organochlorines. The primary effect of dieldrin is mortality, and the primary effect of DDE is depressed productivity, at sufficiently high environmental levels.

In a contribution to the Proceedings of the Sacramento conference, we have examined the possible relative contributions of DDE and dieldrin to the decline of Peregrine populations (Risebrough & Peakall, in press). Initially, we modified a population model of Peregrine populations that had been presented at the Madison conference in 1965 (Young 1969) to include a "floating" non-territorial and non-breeding component of the population, and to take into account some aspects of the biology of the species. Particularly, we considered it more likely that in a highly territorial species such as the Peregrine, a bird would be more likely to remain in the territory upon the death of a mate rather than abandon it in search of a new mate. We assumed that a "normal" level of productivity was 1.5 young fledged per active nesting (Hickey & Anderson 1969), and adopted a figure of 0.3 young as a typical level of depressed productivity, based on observations by Rice in Pennsylvania in 1947-1952 (Rice 1969) and supported by data provided by Ratcliffe (1972) on productivity in England in 1962.

For several years no decrease in the numbers of breeding pairs would occur, because of the buffering action of non-territorial birds which move into the breeding population. After several years, however, the population would begin to decline. Without enhanced mortality, the population of breeding Peregrines in eastern North America would have been reduced to a very low level by 1964 as a result of depressed productivity. Depressed productivity alone, however, could not account for the reduced occupation of sites in both Massachusetts (Hagar 1969) and Pennsylvania (Rice 1969) by 1951-52, before any major use of dieldrin. DDT/DDE is the only plausible cause of enhanced adult mortalitites over this interval.

DDE/DDT alone could therefore have accounted for the disappearance of Peregrines from eastern North America, principally through depressed productivity but with a contribution of enhanced adult mortality. Dieldrin and other toxic organochlorines would have greatly accelerated the decline through further increases in adult mortality. Continuing instances of mortalities caused by organochlorines in the 1980s (Stone & Okoniewski, in press) indicate that mortalities must have been more severe at an earlier time of higher total organochlorine use.

The editors of the Sacramento symposium (Cade *et al.*, in press) furthermore point out that the levels of exposure to organochlorines of a declining population in Alaska were measured during the period of decline, which was associated with high DDE levels, shell thinning and depressed productivity, with no indication of increased adult mortality and with comparatively low levels of dieldrin (Cade *et al.* 1971; Peakall *et al.* 1975). The recovery of this population was associated with decreasing DDE levels (Ambrose, in press).

We suggested (Risebrough & Peakall, in press) that the situation in Britain could be considered in equivalent terms, not only for the Peregrine but for the Sparrowhawk as well. Over the initial years of DDT use we would anticipate that populations of both species were severely stressed because of depressed productivity. Although the numbers of breeding populations might be maintained or in exceptional cases even increase, the numbers of non-territorial, floating birds would be greatly diminished. Populations were very likely beginning to decline locally at the time dieldrin use was begun. The introduction of a chemical such as dieldrin under these circumstances would be expected to have a much greater impact than it would otherwise have had, hence the association of the population decline primarily with dieldrin rather than with DDE or a combination of DDE and dieldrin.

Future considerations of effects of toxic chemicals on raptor populations might consider separately effects on productivity and effects on adult mortality, within a population model such as that developed by Grier (1979, 1980).

The Scottish Golden Eagles

A certain clarification of the relative contributions of DDE and dieldrin to population declines of raptors does not explain everything, and one of the most intriguing examples is provided in the paper by Dr. Furness and his colleagues (this volume). Why should productivity of Golden Eagles, *Aquila chrysaetos*, breeding on the island of Rhum in Scotland, be depressed in association with a seabird diet?

Furthermore, why should productivity of the eagles in the Western Highlands continue to be depressed (Dennis *et al.* 1984)? The major study of the relationships of the Golden Eagle in Scotland with its food supply (Brown & Watson 1964) had found major differences in food supply among the several habitat types occupied by Golden Eagles, but concluded that in all areas the available food was in excess of requirements.

Golden Eagles in the Western Highlands of Scotland provided one of the first examples of a pollutant effect on raptors. Ratcliffe (1967, 1970) recorded reductions in shell thickness index in the order of 10% in eggs from this area of Scotland. Depressions in productivity in the early 1960s were attributed primarily to dieldrin, then in use as a sheep dip, and were associated with a high incidence of egg breakage (Lockie & Ratcliffe 1964). Productivity later increased as dieldrin levels declined (Lockie *et al.* 1969).

The major inconsistency in this story is that dieldrin is now discounted as a significant contributor to shell thinning (Lehner & Egbert 1969; Mendenhall *et al.* 1983). Prior to the use of dieldrin as a sheep dip, however, DDT had been used in a similar capacity in the late 1940s (Lockie & Ratcliffe 1964) and could account for the thinning; DDE levels in eggs collected in 1963 were low (Lockie & Ratcliffe 1964), too low to be associated with shell thinning of this magnitude. The thickness index of these eggs, collected for analysis and therefore broken, was apparently not estimated. Analysis of remnant lipid on the membranes of the eggs measured by Ratcliffe from the Western Highlands in the late 1940s or early 1950s and found to have reduced thickness indices might bring some light to this question; determination of the ratios of dieldrin to DDE would be comparatively easy.

How then can the high incidence of egg breakage be explained? Was this a behavioural response induced by dieldrin, supporting Ratcliffe's views that the eating of eggs by Peregrines, presumably after breaking them, represented abnormal behaviour rather than the response of the bird to an egg already broken because of shell thinning?

Does this provide an example of a primary effect of dieldrin upon productivity, upsetting somewhat the dogma stated above that the primary effect of dieldrin was an enhancement of mortality? Experiments and observations of the effects of the similar compounds heptachlor epoxide and endrin have shown that productivity was depressed in American Kestrels, *Falco sparverius*, and Screech Owls, *Otus asio*, by these compounds without increasing the mortality of adults (Henny *et al.* 1983; Fleming *et al.* 1982). The principal effect of dieldrin upon a breeding colony of Barn Owls, *Tyto alba*, however, was the mortality of adults rather than a depression of productivity (Mendenhall *et al.* 1983).

The depressed productivity of the eagles of Rhum also raises the question of the contributions, if any, of the PCBs and mercury to population declines of raptors. The literature does not support, nor does it rule out, a PCB effect on the eagles of Rhum. A suggestion of a mercury effect comes largely from high levels of mercury in Sea Eagles, *Haliaeetus albicilla*, of the Baltic (Henriksson *et al.* 1966), although Sea Eagles in the Baltic also have high levels of the organochlorines (Jensen *et al.* 1972; Helander *et al.* 1982). Evidence for an increase in mercury levels in food webs of the Baltic during the industrial era comes from the analysis of feathers of Guillemots, *Uria aalge* (Jensen *et al.*, 1972) and of Sea Eagles (Berg *et al.* 1966) obtained in the pre-industrial era and in modern times. Moreover, the analysis of museum specimens has shown that Sea Eagles naturally accumulate higher levels of mercury than do species such as the Peregrine because of generally higher levels of mercury in fish than in birds (Berg *et al.* 1966). Would an increase in environmental levels of mercury caused by human activities affect a species such as the Sea Eagle that has evolved in an environment where it is exposed to relatively high levels of mercury? An extensive literature has demonstrated that a mercury-selenium protective mechanism has evolved in marine mammals feeding principally on fish. Would a species such as the Golden Eagle, which has evolved in an environment with low mercury levels in its food supply, be more sensitive to higher levels of mercury, such as those encountered by the eagles on Rhum that feed principally on sea birds?

Hopefully we might have more insight on some of these questions for discussion at the next meeting of the Working Group.

The Dose-Response Relationships

Shell thickness and productivity change with increasing DDE levels. The earlier studies of the relationships between shell thickness (or thickness index) and DDE levels in eggs found that the logarithm of the DDE provided a reasonable fit to the data (Hickey & Anderson 1968; Anderson *et al.* 1969; Blus *et al.* 1972; Risebrough 1972) at good or high levels of statistical significance. Such a model predicts a sharp drop in thickness with the lowest levels of DDE. It could be represented as a group of sensitive sites, such as a finite number of enzymes which assist in the transport of calcium across the eggshell membrane. There is no excess, and blocking of any of these sites by DDE would decrease the total calcium transport, leading to a reduction in shell thickness, or, as suggested by Cooke (1979), increase the calcium-magnesium imbalance, resulting in both thinning and structural change. As DDE levels increase, more DDE molecules would be associated with a sensitive site, but the proportion of the total DDE associated with sensitive sites would decrease, hence the logarithmic relationship.

More than 10 years ago already, while we were working with Richard Fyfe of the Canadian Wildlife Service on an extensive data set of contaminant concentrations and shell thickness indices of eggs of Prairie Falcons, *Falco mexicanus*, and Merlins, *F. columbarius*, from Alberta, Ian Nisbet suggested that we use a function that would assume an initial surplus of sensitive sites. Such a model would show no, or only a slight, decrease of thickness over a range of DDE concentrations, but after a critical level, when all of the 'excess' sites had been blocked, thickness would decrease rapidly in an approximately logarithmic fashion. The function, called here the 'S' function or informally the 'nisfunc', did provide a better fit to the Prairie Falcon and Merlin data than did the logarithm; after a full decade, these data have finally been published (Fyfe *et al.* in press). The relationship is shown by a set of data on American Kestrels obtained by Jeff Lincer in his doctoral studies (Lincer 1972, 1975; Figure 1).

It is appropriate that these proceedings provide an opportunity for Ian Nisbet to publish his description of this function and its application to a set of Bald Eagle data provided by Stan Wiemeyer of the U.S. Fish and Wildlife Service (Nisbet, this volume).

The thickness-DDE relationships may be of more academic than practical interest, but the relationships between productivity and DDE, and between productivity and shell thickness, are of immediate interest to raptor biologists studying species affected by the DDE-thin eggshell syndrome. Wiemeyer *et al.* (1984) reported a logarithmic relationship between productivity and DDE levels, predicting a rapid decrease in numbers of young fledged at the lowest levels of DDE. Nisbet's analysis (this volume) shows that the 'S' function better describes the relationship between DDE levels and the productivity of Bald Eagles. Thus, there is a range of DDE levels at which productivity is not significantly depressed. Relationships between productivity of Prairie Falcons and thickness index (Figure 2), and between DDE levels and productivity of Prairie Falcons and Merlins (Figure 3), follow similar patterns.

In these two species, productivity falls from normal levels to zero over a relatively small range of DDE and thickness levels. Conversely, productivity would improve rapidly within this critical range of DDE levels if environmental DDE levels were generally decreasing. The rapid recovery of Peregrines in a number of localities (Cade *et al.* in press) has indicated that when Peregrine Falcon populations recover, they may do so rapidly. A relatively small decrease in environmental DDE levels, through the critical range, could explain a rapid increase in productivity.

Figure 1 Reduction of thickness index of eggs of American Kestrels, normalized to estimated pre-DDT value of 1.06, with increasing levels of DDE. Data of J.L. Lincer from field and experimental studies. 1: logarithmic function; 2: 'S' function. Reproduced from Fyfe *et al.* 1988 with permission of the Peregrine Fund.

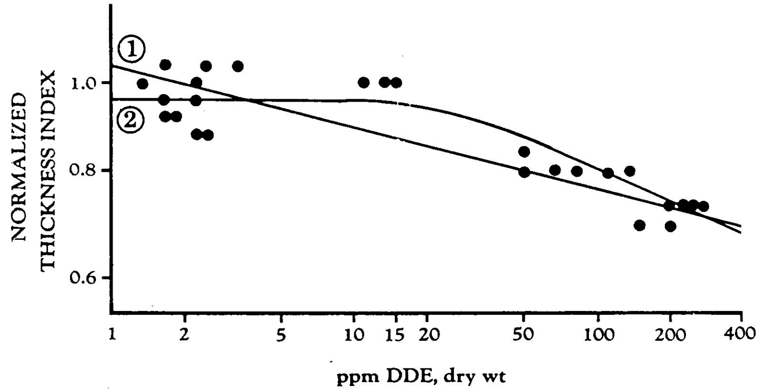


Figure 2. Productivity of Prairie Falcons as a function of normalized shell thickness index. One egg from each clutch removed for analysis. Means of thickness indices with 95% confidence intervals. Reproduced from Fyfe *et al.* 1988 with permission of the Peregrine Fund.

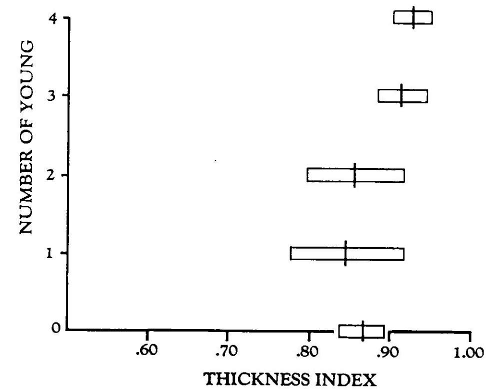
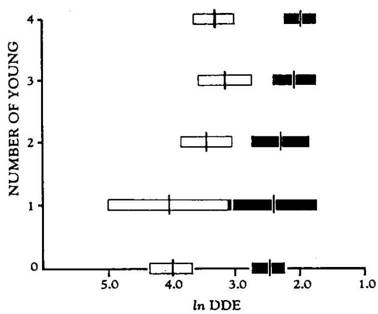


Figure 3. Productivity of Prairie Falcons (shaded) and Merlins (unshaded) as a function of DDE concentrations in one egg per clutch removed for analysis. Means of 1n DDE concentrations with 95% confidence intervals. Reproduced from Fyfe *et al.* 1988 with permission of the Peregrine Fund.



The California Condor

A re-interpretation of data and observations leads not only to a change in our scientific assessment of both past and present events but, as Lloyd Kiff relates in his account of the history of the Condor programmes (this volume), may also change our historical perspective of the human factors involved. The late Carl Koford and Fred Sibley have been two of the most competent and respected American field biologists of the century. Koford, whose earlier studies of the Condor are now a classic (Koford 1953) was severely critical of Sibley's field studies, believing that they resulted in egg breakages. Sibley, who was the first Fish and Wildlife Service Biologist in the Condor programme, is not exactly a roadside biologist, and made extensive forays into the Condor country on foot. We now know that the Condor eggshells were weakened during that era through a DDE effect. Moreover, Sibley had entered the nesting cavities well after the eggs had been broken. It is ironic that the DDT industry had similarly criticized the biologists studying the Brown Pelicans, *Pelecanus occidentalis*, on nearby Anacapa Island, acusing them of causing the pelicans to break their eggs before the arrival of the biologists on the island!

The 20% Thinning Syndrome

Many of us have come to consider that 20% thinning is a critical level, associated with depressed productivity and declining populations. This assumption had come largely from the reports of Hickey and Anderson (1968) and Anderson and Hickey (1972) on declining Peregrine populations. We have seen, however, that a "threshold" level of thinning, above which productivity declines, is about 8% for Prairie Falcons and about 15% for Merlins (Fyfe *et al.* 1988). Interspecific variability is evident.

2) FAMILIAR EFFECTS IN NEW PLACES

The majority of the documented effects of toxic chemicals on raptorial birds have taken place in western Europe or in the U.S. and Canada. Uses of the chemicals responsible have either ended or have been restricted in these countries. Uses of these chemicals continue, however, in many other areas of the world; assessments of impacts upon local raptor populations would determine if major conservation efforts are necessary.

We are therefore pleased to have a report on Fish Eagles, *Haliaeetus vocifer*, from southern Africa (Davies & Randall, this volume), and a report of preliminary studies undertaken by the laboratory of Lilia Albert in Mexico. Neither suggests the existence of problems on the scale of those in Europe and North America in the 1950s and 1960s, but we hope that additional surveys will be given a high priority and that the next meeting of the Working Group will see a number of additional reports. Mexico is of special interest to North Americans, and efforts there deserve all the support we are able to provide. Elsewhere in the world, India is a country with a long and distinguished ornithological tradition, where pesticide use is heavy. Encouragement of a report from India should be a priority for the next meeting. Other areas of the world to which especial attention might be paid, in addition to continuing studies in southern Africa and Mexico, include Brazil, other areas of Africa, and south-east Asia. Hopefully, it will not be too long before we establish working contacts with interested persons in the Soviet Union and China.

3) PRIORITIES FOR FUTURE RESEARCH AND PROJECTS

Some of the priorities for future programmes have just been mentioned. A parallel approach to the problems of toxic chemicals and raptors in developing countries is that taken by Eduardo Iñigo (this volume). Documentation of the kinds and amounts of pesticides used will provide a preliminary indication of possible problems. Surveys can therefore be designed and undertaken in those areas of greatest use of the most dangerous chemicals. Since major problems have occurred near the sites of factories manufacturing DDT, dieldrin and endrin, it seems reasonable to look for comparable problems near such factories elsewhere in the world.

It is embarrassing at this stage to admit that it is not possible to point to the exact mechanism whereby the DDE-thin eggshell syndrome affects productivity. Egg breakage is not the only factor involved, particularly when productivity of Prairie Falcons can be depressed by a relatively low level of thinning.

The transplant experiments of Osprey, *Pandion haliaetus*, eggs (Wiemeyer *et al.* 1975) between Maryland and Connecticut had shown, for those populations of Osprey at least, that factors intrinsic to the egg, rather than some abnormal behaviour of the adults, were associated with a low hatching rate. DDE toxicity to the embryo seems unlikely, in view of the generally low toxicity of DDE and the wide range of DDE levels found, for example, among the falcons (Fyfe *et al.* in press). A promising topic for future investigations would appear to be scanning electron microscopy studies of eggshell structure in populations of birds experiencing low productivity. Applications of this technique have demonstrated structural changes within the eggshell in addition to thinning, including a reduction in the number of pores that traverse the eggshell (Garrett 1974; Fox 1976; Peakall *et al.* 1973; Kiff *et al.* 1979). The first egg laid by Bald Eagles re-introduced to Santa Catalina Island in southern California (Garcelon *et al.* this volume) was of normal thickness (L. Kiff, pers. comm.), yet visually the fragments appeared to be abnormal.

The most important immediate cause of failure may therefore be abnormalities in the exchange of gases and water through the eggshell. Although several authors (Peakall *et al.* 1973; Fox 1976; Cooke 1979) have shown that thin-shelled eggs of several species, including the American Kestrel and the Peregrine, lose water less rapidly because of a reduction in the number of pores, Brian Walton (pers. comm.) has indicated that fertile, thin-shelled eggs of Peregrines lose water more rapidly than do normal eggs during artificial incubation. Further studies are needed to resolve this apparent discrepancy.

Not well understood is the role that the PCBs have had in the population declines. Feeding experiments generally have shown little effect on productivity, but there have been a number of experiments that have demonstrated behavioural effects (reviewed by Risebrough, 1986). Very few experiments have used combinations of chemicals that approximate natural mixtures. Several studies indicate that PCBs and DDE may act together to produce an enhanced effect on productivity (Lincer 1972; Risebrough & Anderson 1975; Greenburg *et al.* 1979).

I have consulted with both Dan Anderson, who measured many thousands of eggs during his doctoral studies with Professor Hickey, and Lloyd Kiff, who is curator of the extensive egg collection of the Western Foundation of Vertebrate Zoology, on the report by Davies and Randall that Fish Eagles in coastal areas have thicker eggshells than do those in the interior. Neither could provide any other examples, but Professor Anderson considers it a problem worthy of his attention in his retirement years. There is a report in the literature (Dyck & Kraul 1984) of an association between decreasing salinity and eggshell thinning of Guillemots. These investigators found no significant relationship between thinning and DDE residues, but in the area of the Baltic where their investigations were carried out DDE levels were higher in areas of lower salinity. Changes in thickness could therefore have been associated primarily with DDE rather than salinity, in spite of the lack of statistical significance in the data set available.

The salt gland of birds shares a feature with the shell gland in that both have high concentrations of the enzyme carbonic anhydrase for regulation of the carbonate-bicarbonate balance. An early report in the German literature that DDT concentrations could be measured by the level of inhibition of carbonic anhydrase (Keller 1952) led to speculation that inhibition of this enzyme might be the immediate cause of shell thinning (Risebrough *et al.* 1970). Although inhibition of carbonic anhydrase by DDE in the shell gland has been measured (Peakall 1974), it is not now considered a significant factor in shell thinning.

As raptor populations recover, many of these questions become increasingly academic and it is likely that some will never be answered. Preservation of habitat is much more crucial to raptor conservation. We remain obliged, however, to look out for new threats of chemicals to raptor populations.

4) NEW CHEMICALS; NEW USES OF OLD CHEMICALS

The contribution of Shutt and Bird (this volume) indicates that fluorosis could be a potential problem in areas of environmental exposure to fluorides. Although the ingestion of lead shot by raptors consuming crippled waterfowl has long been recognized as a problem, resulting in deaths of species such as the Bald Eagle, which frequently feeds on crippled waterfowl, the threat to carrion eaters of ingestion of lead fragments from bullets has only recently been recognized. The contribution by Pete Bloom and his colleagues (this volume) demonstrates that fragments of bullets may be ingested by carrion feeders such as the Golden Eagle, resulting in extreme cases in lead poisoning. The recent deaths of several of the last California Condors remaining in the wild through lead poisoning can be attributed to the ingestion of bullet fragments.

Not included in the written proceedings, pending further investigations, is the contribution by Marjorie Gibson and her colleagues which indicates that atmospheric levels of organophosphates in California may be responsible for changes in the blood chemistry of Golden Eagles. Continuing investigations of this phenomenon appear to be of high priority.

There are recent literature reports on deaths of raptors through secondary poisoning by "newer-generation" pesticides such as famphur and carbofuran (Balcomb 1983; Franson *et al.* 1985; Henny *et al.* 1985). We might consider two aspects of such mortalities. The unnecessary death of any raptor is deplorable. From a conservation perspective, however, such mortalities are significant only if populations are affected, measured primarily as the number of breeding birds.

5) RE-INTRODUCTION OF RAPTORS TO POLLUTED ENVIRONMENTS

It is evident that the re-introduction of the Peregrine to eastern North America, one of the most striking of the recent success stories in conservation, would have failed had environmental levels of DDE been too high to permit successful breeding in the wild. Such is still the case in Central California, where DDE levels are high and with shell thinning exceeding critical levels. Nevertheless the coastal Peregrine population has regained its former numbers as a result of a programme of active manipulation by the Santa Cruz Predatory Bird Research Group (Walton & Thelander, in press). The assumption has been that environmental levels of DDE will eventually decrease to acceptable levels.

Re-introduction of Bald Eagles to the marine environment of southern California may confront a similar problem - that environmental levels of DDE remain too high (Garcelon *et al.* this volume). The question must therefore be faced, whether it is worthwhile at the present time to proceed with the programme or to wait, perhaps several decades. Once a breeding population is established, it is a relatively minor effort at a relatively low cost to replace unhealthy eggs with eggs from other areas, or to bring in chicks if eggs should break. The major effort and cost are in the early years of the programme.

Environmental levels of DDE in the marine environment of southern California have not gone down over the past decade because there has been a continuing source in the sediments off Los Angeles which contain in the order of 200 tons of DDT compounds. It may indeed take several decades for the environmental input to decline sufficiently. The Bald Eagles would therefore serve as a living reminder of what a careless technology has done. For educational reasons alone, it would appear worthwhile to continue the Bald Eagle programme on Santa Catalina Island. Only when they are able to reproduce successfully would the environment be considered sufficiently "cleaned" of this contamination.

Re-introduction of California Condors to the wild at the earliest possible time is the working premise of the Condor Recovery Plan. Although the last breeding pair in the wild laid a thin-shelled egg with high levels of DDE (Kiff, this volume), most of the eggs laid over the past several years were not adversely affected by DDE to a significant degree. DDE would therefore be only a minor threat to the Condors re-introduced to the wild, but it would nevertheless be worthwhile to determine the source or sources of the high levels of DDE in that egg. The lead problem appears to be much more serious. If indeed, as the evidence strongly supports, the ingestion of fragments of lead bullets caused the deaths of several birds during the period they were all radio-tagged, lead from this source will continue to be a major threat to Condors in the wild. It is not politically possible at this time to consider closing the deer-hunting season over a wide area. Expanded archery seasons might, however, reduce the threat to Condors on a local scale.

6) STRATEGIES FOR REDUCING HARMFUL EFFECTS OF TOXIC CHEMICALS ON RAPTORS

The continuing use of organochlorine insecticides in many countries of the world threatens local populations of sensitive raptor species. What can the contributors to the Toxic Chemicals Committee of the Working Group do to reduce this threat?

The considerations are:

- continuing use of DDT is of particular concern because of the effects of the DDE derivative on reproduction of many species ;
- any use of aldrin/dieldrin, endrin, and heptachlor can be expected to cause raptor deaths and/or to lower reproductive capacity;
- occasional mortalities caused by any other environmental chemical are of potential concern if the local population is already stressed by lowered reproduction and/or unnatural mortalities;
- since progress is rarely made in a political vacuum, local economic, social and other political factors must be considered in attempting to change pesticide use practice.

A suggestion:

- to appoint national correspondents of the Toxic Chemicals Committee, whose tasks might include:

1) the compilation of data and information on the status of potentially sensitive species;
2) the initiation whenever possible of programmes that obtain residue data;
3) the compilation of data on the total use, manufacture, import and export of these several chemicals, as well as of the PCBs and of other chemicals that are potentially harmful;
4) compilation of information on local economic and other factors that might be considered in effecting change.

Such reports might be published, at least in summary form, in future newsletters or other publications of the Working Group.

Over the past twenty years there has been a major global shift in the use patterns of chemicals that are deliberately introduced into the environment or which enter the environment in consequence of the way they are used. The dimensions of this technological change have been enormous, affecting not only what kinds of pesticides are used but also which chemicals are used across the entire economy. The rationale for these changes is evident - human health is threatened by any toxic, persistent chemical which will accumulate in our food, in the air we breathe, or in our drinking water. Nevertheless it was the sensitive species of birds of prey which provided the early warning which prompted these massive changes in our technology. It is therefore appropriate that the World Working Group on Birds of Prey and Owls, through the monitoring of unexpected changes in raptor populations, should serve to provide the early warnings of any future deleterious change in our chemical environment.

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