



## Summary

- 1) Mean DDE levels in grackle samples from Arizona, south Texas, northern Tamaulipas, Chiapas and Tabasco were all greater than 2 ppm suggesting a possibility for reproductive failure.
- 2) DDT appeared to be the source of DDE in Mexico, but in the U.S. the source is unknown.
- 3) Where severe eggshell thinning has occurred, in Veracruz Mexico, grackles showed the lowest DDE levels of the areas sampled.
- 4) One particularly contaminated spot (DDE = 6.3 ppm) was near the town of Zapata, Tabasco, in the heart of one of the densest breeding populations of aplomado falcons known.

## Introduction

The northern aplomado falcon (*Falco femoralis septentrionalis*) was once a common resident in the desert grasslands of the southwestern United States according to naturalists describing wildlife in the early 1900's (Bendire 1887, Smith 1910, Strecker 1930). Today the species is essentially extirpated from the U.S. (Hector 1980). There have been no nesting records since the mid-1950's and there is no documentation of its existence in northern Mexico (Grainger Hunt, pers. comm.). The fact that aplomado falcons disappeared in the U.S. approximately when other predatory birds were experiencing their dramatic declines suggests that DDT (and possibly dieldrin) may have been a factor in their loss.

Specimen records reveal that aplomados existed in the Mexican states of Tamaulipas, Veracruz, Chihuahua, Durango, Sinaloa, Jalisco, Guerrero, Yucatan, Campeche, Tabasco, Chiapas, Coahuila, Sonora and San Luis Potosi (Fig. 1) (Hector 1981). Today aplomados are known to breed only in the states of Veracruz, Campeche, Tabasco,

Chiapas, and San Luis Potosi (Fig. 1). Status estimates for this region and the extirpation of the aplomado farther north have resulted in the species being listed as endangered in 1986 by the U.S. Fish and Wildlife Service. Aplomado falcon reintroductions in south Texas have been underway since 1985.

DDE contamination could be a serious threat to remaining aplomado falcon populations. Aplomado falcons in Veracruz, Mexico are heavily contaminated with residues of DDT, with eggshells 24% thinner than pre-DDT eggshells from the same region (Kiff et al. 1977). Mexico is still using large quantities of persistent pesticides which could seriously affect recovery of the species in the United States and Mexico. In addition, high levels of DDE are still present in portions of the falcon's historic range in the United States, so reintroduction sites need to be carefully evaluated.

There is no reason to assume that aplomado falcons are not still declining. To assure the continued existence of the aplomado falcon, productivity and contaminant levels need to be determined so that restoration can be made possible in the U.S. and Mexico.

Organochlorine contamination, particularly DDE, has had many undesirable effects on falcon species, however, eggshell thinning has been the effect most widely studied and quantified. In this study, DDE levels in a major prey item of aplomado falcons are evaluated in terms of their relationship to reproductive failure resulting from eggshell thinning. However, it should be kept in mind that high DDE levels in falcon species are also associated with direct mortality of adults, failure or inability to breed, addled eggs, death of embryos or young, abnormal behavior such as egg eating, and starvation of young. All of these factors would affect productivity (Fyfe et. al. 1989).

Although the effect of DDE contamination on eggshell thinning and population declines is well established with regard to peregrine falcon populations (Lincer 1975, Wiemeyer and Porter 1970), there are weak correlations between the timing of the

population declines and the introduction of chlorinated hydrocarbon pesticides and between the areas of decline and areas of pesticide use (Hickey 1969). Convincing support has appeared for the hypothesis that one, several, or a complex of organochlorine compounds have caused reproductive failures, low productivity, population declines and local extinctions of peregrine populations (Fyfe et al 1989).

In spite of the 1986 ban (SEDUE pers. comm.) on DDT use in Mexico there is evidence that the chemical is still being used, and therefore could be affecting many neotropical and migrant birds that breed in the U.S.

I chose the great-tailed grackle (*Quiscalus mexicanus*) for pesticide monitoring in this study because it is often associated with agriculture, it is considered to be nomadic, and therefore it will represent contamination over a large area for this study. The great tailed grackle is insectivorous and is abundant throughout aplomado falcon habitat in both the U.S. and Mexico. Moreover, it is a major prey item of aplomado falcons in southern Mexico, Great-tailed grackles were the most frequent item of the observed prey remains (16.7%) and were the fourth most common (8.1%) of the prey observed being taken in the Chiapas/Tabasco and Veracruz areas of Mexico (Hector 1980). Grackles also appeared to be the most abundant prey item in these parts of Mexico (Hector 1980).

This goal of this investigation was to: 1) give further insight on the extent to which the continued presence of DDT in Mexico is affecting aplomado falcon populations. 2) and aid in selecting suitable habitat for reintroduction in the U.S. and northern Mexico.

## Hypotheses

- 1) Grackle contamination in portions of Mexico where aplomados breed is not greater than 1 ppm DDE, and therefore can not be assumed to indicate that reproduction will be threatened.
- 2) Organochlorine levels in a major prey item (grackles) of aplomado falcons is no different at the south Texas reintroduction site than it is in Veracruz, Mexico where eggshell thinning is a problem.

## Objectives

1. Determine the organochlorine levels in the avian prey of aplomado falcons in currently occupied breeding territories - where eggshell thinning is a problem.
2. Determine the local "hot spots" of contamination by comparison of prey tissue levels between pooled samples within each of the areas where grackles were collected.

## Methods

### Collecting Activity

We determined occupancy of aplomado falcon nesting territories at previously documented nest sites, and found additional sites by exploring areas where birds were spotted from the road. We collected 3 - 4 samples of 7-10 great-tailed grackles in each of 2 areas (Fig. 2) where aplomado falcons are known to breed:

Area #1 . . . .northern Chiapas, eastern Tabasco.

Area #2.....northern and central Veracruz.

For examination of conditions at proposed release sites, similar collections were made in the following areas (Fig. 2) (3-4 pooled samples/area):

Area #3.....South Texas and Northern Tamaulipas where aplomado falcon releases are now in progress.

Area #4... .Historical range of aplomados in southeastern Arizona.

Samples were collected during the month of April, which coincides with the beginning of the breeding season for aplomados in Mexico and the U.S. (Romeo Dominguez pers. comm; Bendire 1887, Strecker 1930). Whole body samples were scanned, in composites of 7-10, for the following organochlorine residues:

p,p'-DDE	Dieldrin
p,p'-DDD	PCB's (total)
p, p'-DDT	Heptachlor epoxide
o,p' DDE	Oxychlordane
o,p'-DDD	alpha-Chlordane
o,p' DDT	gamma-Chlordane
Hexachlorobenzene-(HCB)	trans-Nonachlor
alpha-BHC	Endrin
beta-BHC	Mirex
gamma-BHC (Lindane)	Toxaphene
delta-BHC	

We collected only mature grackles which we determined by examination of plumage and gonad development. We chose to collect mature grackles because they represent prey items with a greater potential for bioaccumulating compounds over time, thus giving a better indication of what levels are possible for an area. Collecting was done using an air rifle in Mexico, and a shotgun in the U.S. Specimens were plucked, eviscerated, and the head and feet were removed, and the remainder was wrapped in clean aluminum foil, then frozen on dry ice (Risebrough, Bodega Bay Institute, pers. comm.). In Mexico whole bodies were homogenized by grinding with a hand powered meat grinder, and an aliquot of the resulting homogenate was then frozen in glass vials that had been cleaned with acetone. Aluminum foil was placed under the plastic caps before capping them.

#### Analyses of Grackle Specimens

Levels of 25 organochlorine residues were determined at the Mississippi State Chemical Lab. Ten gram tissue samples were thoroughly mixed with anhydrous sodium sulfate and soxhlet extracted with hexane for seven hours. The extract was then concentrated by rotary evaporation; transferred to a tared test tube, and further concentrated to dryness for lipid determination. The weighed lipid sample was dissolved in petroleum ether. Residues were partitioned into petroleum ether which was washed, concentrated and transferred to a glass chromatographic column containing 20 grams of Florisil. The column was eluted with 200 ml 6% diethyl ether/85% petroleum ether (Fraction II). Fraction II was concentrated to appropriate volume for quantification of residues by packed or capillary column electron capture gas chromatography. Fraction I was concentrated and transferred to a silicic acid chromatographic column for additional cleanup required for separation of PCB's from other organochlorines. Three fractions were eluted from the silicic acid column. Each was concentrated to appropriate volume for quantification of residues by packed or megabore column, electron capture gas chromatography. PCB's were found in Fraction II (USDI-FWS report form No. 2010007). The lower limit of detection for chlorinated pesticides was 0.01 ppm and for PCB's and Toxaphene 0.05 ppm and the range of recovery was 80 - 90 % for dieldrin and DDE. Accuracy, as measured by

spike recovery, was generally acceptable. The precision, as measured by duplicate sample analyses, was acceptable for all analytes (USFWS Patuxant Analytical Control Facility, Quality Assurance Report 1992).

DDE is the primary chemical of concern in this study, as well as dieldrin due to their strong association with reproductive failures in falcon species. Mean levels from proposed reintroduction sites in the U.S. were compared (using an ANOVA and a Bonferroni test for mean separation) to occupied habitats in Mexico where eggshell thinning is a problem. In addition, mean organochlorine levels were compared between pooled composites within each of the areas sampled, in order to determine local "hot spots" (areas with high residue levels) that may affect the long term viability of the species in both the U.S. and Mexico.

## Results

### Arizona

Grackles were collected from agricultural areas north of Wilcox, around Kansas Settlement and from the cotton growing areas surrounding Safford, Arizona on the Gila River. Kansas Settlement grackles had DDE levels of 3.0 ppm (Table 1) and an incidental sample of red-winged blackbirds also from this area had DDE levels of 2.7 ppm. The grackle composite from Safford had 3.0 ppm DDE, and the Wilcox composite had 0.76 ppm DDE. Mean levels for Arizona grackles were 2.25 ppm (Table 1, Fig. 2) indicating potential for reproductive failure when compared to that level (1 ppm) which has been associated with poor reproduction in peregrine falcon (*Falco peregrinus*) populations (Enderson 1982). DDT and DDD were not detected (Table 1) in any of these samples suggesting that recent application of DDT is not a likely source for the DDE. However, compositing samples in groups of 7 - 10 grackles could have prevented the detection of trace amounts of DDT in certain individuals. Dieldrin levels were low ranging from 0.01 - 0.09 ppm among the four composites (Table 1). Other contaminants detected at low levels were: oxychlordan, heptachlor epoxide, and t - Nonachlor (Table 2). Cotton appeared to be a predominant crop in the Safford and Kansas Settlement areas; also lettuce and pecans were grown.

## Tabasco/Chiapas

This area had the highest mean DDE levels of the four areas sampled ranging from 0.36 - 6.3 ppm (Fig.2). The composite with the highest DDE levels (6.3) was taken near the town of Zapata, Tabasco. DDT was present in all four composites (0.02 - 4.6 ppm), representing 6%, 73%, 7%, and 51% of the total DDT's detected. DDD was detected in three of the four composites (0.10 - 0.53 ppm) indicating recent application of DDT (Table 1) and possibly very recent application near Zapata and Cardenas (73% and 51% DDT). Other compounds detected at low levels were alpha-BHC, beta-BHC, and gamma BHC (Table 2).

These results falsified my original hypotheses. That is, 1) DDE levels in the U.S. were greater than 1 ppm, suggesting that reproductive problems are possible near the proposed and current reintroduction sites. 2) Mean DDE levels from South Texas were higher than the Veracruz area where severe eggshell thinning has occurred in recent times ( $F = 3.01$  3,15 df  $P = 0.1086$ ).

## Discussion

In this study highly contaminated individual grackles that would be particularly dangerous for aplomados to consume are masked in the composite samples because of the technique of compositing several grackle bodies into one analysis aliquot. This masks the variation in residues between individuals causing the concentration per aliquot to approximate the arithmetic mean residue of all individuals within the composite.

## South Texas/Northern Tamaulipas

The abundance of great-tailed grackles appeared to be as great or probably greater in south Texas and northern Tamaulipas than in southern Mexico where it is a common

prey item of aplomados. Therefore it would be reasonable to assume that grackles might also be taken frequently as prey in this area.

DDE levels in grackles from this area could be high enough to affect aplomado reproductive performance if selected as prey on a regular basis. Previous studies have indicated that DDE levels in this area were still elevated in biota, and bottom sediment in 1985, 1986 (White et al. 1983, USFWS unpubl. report 1988, Wells et al. 1987). Areas closest to the coast had the highest DDE levels (Arroyo Colorado 3.2, East Rio Grande 3.2), and the Mexican side of the border showed lower levels in grackle composites than the Texas side. Current use of DDT in Mexico seems unlikely since the only crop observed in the northern part of Tamaulipas was sorghum, and many residents claimed that cotton, and citrus haven't been grown for up to 20 years.

Composite samples from south Texas were 100% male grackles, however female grackles appear to be the sex that is commonly taken as prey in southern Mexico (Hector 1980). Studies of the gizzard contents of grackles (Davis and Arnold, 1972) indicate that males and females have different feeding habits. Thus, samples from this area may not be strongly representative of what an aplomado would be exposed to. Although the female grackle's annual diet is 81% animal matter, whereas, the male grackles' annual diet is only 53% animal matter in south Texas (Davis 1972), it is still difficult to say which sex would concentrate more DDE residues, as the male diet may be more varied.

### Arizona

Arizona represents a desert grassland portion of the aplomado's historic range rather than a coastal lowland habitat. Grackle distribution in this area as well as that of red-winged blackbirds are limited to irrigated agricultural lands and human settlements. These agricultural areas may compose a relatively smaller portion of the available habitat for aplomado falcons, compared to coastal lowland habitats. Since no data

exist on aplomado feeding habits in desert regions, it is difficult to predict how often an aplomado would encounter a highly contaminated resident prey item. In order to fully assess the potential for bioaccumulation in aplomados it would be necessary to know to what degree they would feed on birds from these contaminated agricultural areas, and what levels would be encountered by aplomados when eating other prey items in areas remote from agriculture. Previous studies indicate that much of the avifauna in remote desert areas are highly contaminated with DDE (USFWS unpubl. report 1987, Ellis et al. 1989) These studies indicate that the highest pesticide loads are likely to come from migratory shorebirds, followed by migratory insectivores, while nonmigratory species typically will have lower contaminant levels except for those in known DDE "hot spots" (Ellis et al. 1989; Deweese et al. 1986).

### Tabasco/Chiapas

Most of the sample locations in the states of Tabasco and Chiapas are pastureland rather than agricultural, however sugarcane, corn, and rubber were observed near Zapata, and oranges, sugar cane, sorghum, and beans were observed near Cardenas, Tabasco. The amount of pastureland in this area is declining (Dominguez pers. comm.) as many areas are being converted to croplands between the towns of Zapata and Tenosique. This area has been a recent stronghold for aplomado falcons, with some of the highest densities of aplomados being observed there (Jenny pers. comm.). The Zapata sample site (approximately 16 square kilometers), which contained the highest DDE levels, represents a possible threat to this population and should be monitored carefully in the future.

### Veracruz

Grackles from the Veracruz area had the lowest mean DDE levels of the samples collected. This was different from what would be expected as Aplomado eggshells from this region were 24% thinner in 1977, and eggshells from 1954-1967 were

25.4% thinner than normal (Kiff et al. 1980). In addition, there seemed to be a larger variety and proportion of crops being grown near the sample sites of this state. Agricultural crops observed near Tecolutla were oranges, beans, bananas, and corn which correspond to the highest DDE level detected in the state of Veracruz (1.3 ppm). Near Nautla the primary land use we observed was cattle ranching, which corresponds to the lowest DDE levels for this state (0.37 ppm), The Chachalacas site, where sugarcane was prominent, had low levels of DDE with trace levels of DDT also showing up. and. Near Alvarado there were extensive fields of pineapple and pecans, which corresponds to a relatively low DDE level of (0.69 ppm), but had the highest DDT and DDD levels of the four sites.

#### Implications of Grackle Consumption

DDE residues in grackles, in all cases, formed the major part of the total organochlorines scanned (Table 1). It is important to know the extent to which grackle prey might serve as a source of DDE residues in aplomado falcons. The DDE levels reported in this study may be substantially below those found in certain birds with particularly high organochlorine residues. For example, residues in birds collected by Hunt et al. (1986) in West Texas had variable DDE levels, with pools of western kingbirds (*Tyrannus verticalis*) containing 170, 190 and 270 ppm (dry weight), redwinged blackbirds (*Agelaius phoeniceus*) contained 17, 190 and 250 ppm; killdeers (*Charadrius vociferus*) contained 71 ppm, and great-tailed grackles ranged from 31-79 ppm. The highest levels in the U.S., typically, can be expected in migratory and insectivorous species (Baril et. al. 1990, Enderson, et. al 1982, Monk 1981, Deweese et. al. 1986, Ellis et. al. 1989). Grackles are omnivores, eating a large portion of insects during particular times of the year, in additon to a large portion of grains (Davis and Arnold 1972). Extensive examination of contaminant levels in various avifauna indicate that, generally, primary insectivores were greater than four times more contaminated with DDE than were omnivores (Deweese et al. 1986). These results suggest that grackles may not accumulate the high levels that some other

species might. Aplomado falcons may therefore receive much higher doses of toxicants from prey sources other than grackles. In this study, grackle residue levels are most useful for representing the "relative" proportions of DDE contamination across various aplomado habitats rather than a prey item from which bioaccumulation rates can be estimated.

### Suspected Bioaccumulation Rates for Aplomados

I will attempt to clarify the relationships that have been established thus far with respect to DDE, population declines, eggshell thinning and levels in prey items. 1) Levels of eggshell thinning greater than 15% have been associated with population declines in peregrine populations (Enderson 1982), and no North American raptor population has maintained itself while experiencing 18% or more eggshell thinning (Stickel, 1975, Lincer 1975; Anderson and Hickey 1968). 2) Eggshell thickness is inversely related to the logarithm of DDE concentrations in shell membranes (Blus et al. 1972). 3) Levels of DDE in peregrine falcon eggs at which hatching failure occurs is 15-20 ppm wet weight (Peakall 1975). 4) In peregrine falcon eggs, DDT and its metabolites are typically found in concentrations 15-30 times greater than the whole-body levels found in small samples of prey (Cade et al. 1968; Enderson and Berger 1968).

Although no data exists on the level of thinning associated with egg breakage for aplomados, previous data on peregrines and other raptor species make it reasonable to assume that thinning over 18% will likely result in reproductive failure, primarily from egg breakage. Though a limited number of aplomado eggshells from Mexico have been examined (n = 20, 11 clutches) they had a 24% reduction in thickness from the estimated pre-1947 (pre- DDT) measurements, and eggshell membranes had a geometric mean DDE concentration of 296.8 ppm (31 - 1280 ppm) lipid weight (Kiff et al. 1977).

Aplomado falcons are thought to be relatively sensitive to DDE (Fyfe et al. 1989). Estimates of the degree of thinning at various levels of DDE exposure have shown that bat falcons (*Falco ruficularis*) are the most sensitive among species examined, and of the falcons, the American kestrel is the least sensitive. The peregrine appears to be intermediate in sensitivity. The aplomado appears to be relatively sensitive to DDE at higher levels; and is comparable to that of the bat falcon (Fyfe et al. 1989)

It has been determined that any whole body DDE residue level in prey in excess of 1 .00 ppm (wet weight) may yield elevated residue levels in peregrine falcons consuming such prey during the breeding season, and this concentration is also correlated with an 18% reduction in shell thickness (Enderson et al. 1982). This 1 ppm concentration is applied as a minimum harmful level for aplomado falcons in this study since the apparent sensitivity of aplomados is as great or greater than peregrines (Fyfe et al. 1989). Three of the four sample sites had mean DDE levels exceeding this 1 ppm level, indicating potential for reproductive problems. Because prey selection by aplomados is subject to many vagaries, and because of the great variation of DDE in prey, it is very difficult to correlate residues in prey with DDE and shell thinning.

All evidence presented in Lincer's paper (1975) suggests that a causal relationship exists between the ingestion of prey highly contaminated with DDE and the consequent thinning and breakage. Breeding failure and consequent declines of several raptor populations is straightforward, logical and well documented (Lincer 1975).

#### Potential sources of DDE residues in South Texas and SW Arizona

The absence of DDT or DDD in grackle tissue from the United States indicates that there may be an alternative source for the DDE that was present. Studies imply that in insectivorous animals living in areas treated with one DDT application, DDT

represents a large proportion of the body burden for a few months up to about 2 years; thereafter DDE constitutes nearly all of residues (Dimond et al. 1970; Henny et al. 1982).

The fact that DDT and DDD were virtually absent in grackles from the U.S., and that levels of DDE were comparable to those in Mexico where DDT composed from 6-73% of total DDT's implies that an alternative source is possible. It was recently concluded that technical dicofol is the source of a significant fraction of the abnormally high DDE levels reported in Arizona, New Mexico, West Texas and South Texas (Clark and Krynitsky 1983, Hunt et al. 1986, White 1976).

Dicofol is an organochlorine compound that is still registered for use in the U.S. It is used as an acaricide or miticide primarily for the cultivation of cotton, citrus, and other fruit trees. The principal commercial dicofol product, Kelthane, is made from DDT and DDE they have been identified as a metabolite of dicofol. Further analyses may be necessary to determine whether dicofol is present in the grackle samples.

#### Potential for Successful Reestablishment of Aplomado Falcons

Because of the relative distribution of agriculture in the desert grassland areas as opposed to coastal lowland areas, it is difficult to know how widespread DDE residues are in avian prey items. However, the fragmentation of their U.S. range by "DDE hot spots" (areas of high DDE contamination), in combination with habitat loss and elevated DDE levels in migratory prey, may still serve as an obstruction to their recolonization. Previous studies have shown that contamination is still a problem in many portions of the southwest (Clark and Krynitsky 1990, Fleming and Cain 1985). Areas that deserve special attention due to evidence of recent DDE contamination are: West Texas; the Gila River valley downstream of the New Mexico border; the Verde River; the Kansas Settlement area south of Wilcox, Arizona; the Pecos river drainage south of Roswell, New Mexico; the Carlsbad area; the Rio Conchos in northern

Mexico; and most of the entire Rio Grande valley (Clark and Krynitsky 1990, Fleming and Cain 1985, White et al. 1983, White and Krynitsky 1986, USFWS unpubl. report 1987).

### Management and Research Recommendations

1. Aplomado falcon reintroduction sites should be carefully chosen with respect to areas that still maintain high DDE residues.
2. The degree of DDE exposure to aplomado falcons should be determined through analyses of a wider variety of prey items prior to continuing aplomado releases in south Texas.
3. Status and food habits information should be determined for aplomado falcons in the U.S., as diets of aplomados may differ from southern Mexico due to differences in the availability of avifauna, reptiles, and small mammals.
4. Aplomado productivity and contaminant levels should be monitored in south eastern Mexico on a long term basis.
5. The source(s) of DDE contamination in the U.S. should be determined due to their well known effects on wildlife populations.

Table 1. Organochlorine residues in 16 composite samples of great-tailed grackle tissue Collected in Mexico and the U.S. in 1991.

compounds in ppm, wet weight basis:					
<u>Veracruz</u>	<u>p'p'DDE</u>	<u>p'p'DDD</u>	<u>p'p'DDT</u>	<u>Dieldrin</u>	<u>% Lipid</u>
Nautla	.37	ND	ND	ND	7.66
Tecolutla	1.3	ND	.02	ND	6.14
Alvarado	.69	.05	.31	ND	6.93
Chachalacas	.45	ND	ND	ND	6.15
<u>Chiapas/Tabasco</u>					
Palenque	.36	ND	.02	ND	6.26
Zapata	6.3	.53	4.6	ND	6.34
Tenosique	3.8	.10	.28	ND	6.65
Cardenas	.43	.11	.22	ND	5.28
<u>Texas/Tamaulipas</u>					
N. Tamaulipas	2.0	ND	ND	.01	6.47
N. Tamaulipas	2.3	ND	ND	.03	5.74
Arroyo Colorado	3.2	ND	ND	.19	5.83
Rio Grande W.	2.0	ND	ND	.01	6.96
Rio Grande E.	3.2	ND	ND	.10	5.69
<u>SE Arizona</u>					
Safford	3.0	ND	ND	.04	5.74
Kansas Set.	3.0	ND	ND	.09	7.12
Wilcox	.76	ND	ND	.01	7.00

Lower level of detection = 0.01 ppm for tissue, those chemicals indicated by a ND were not detected.



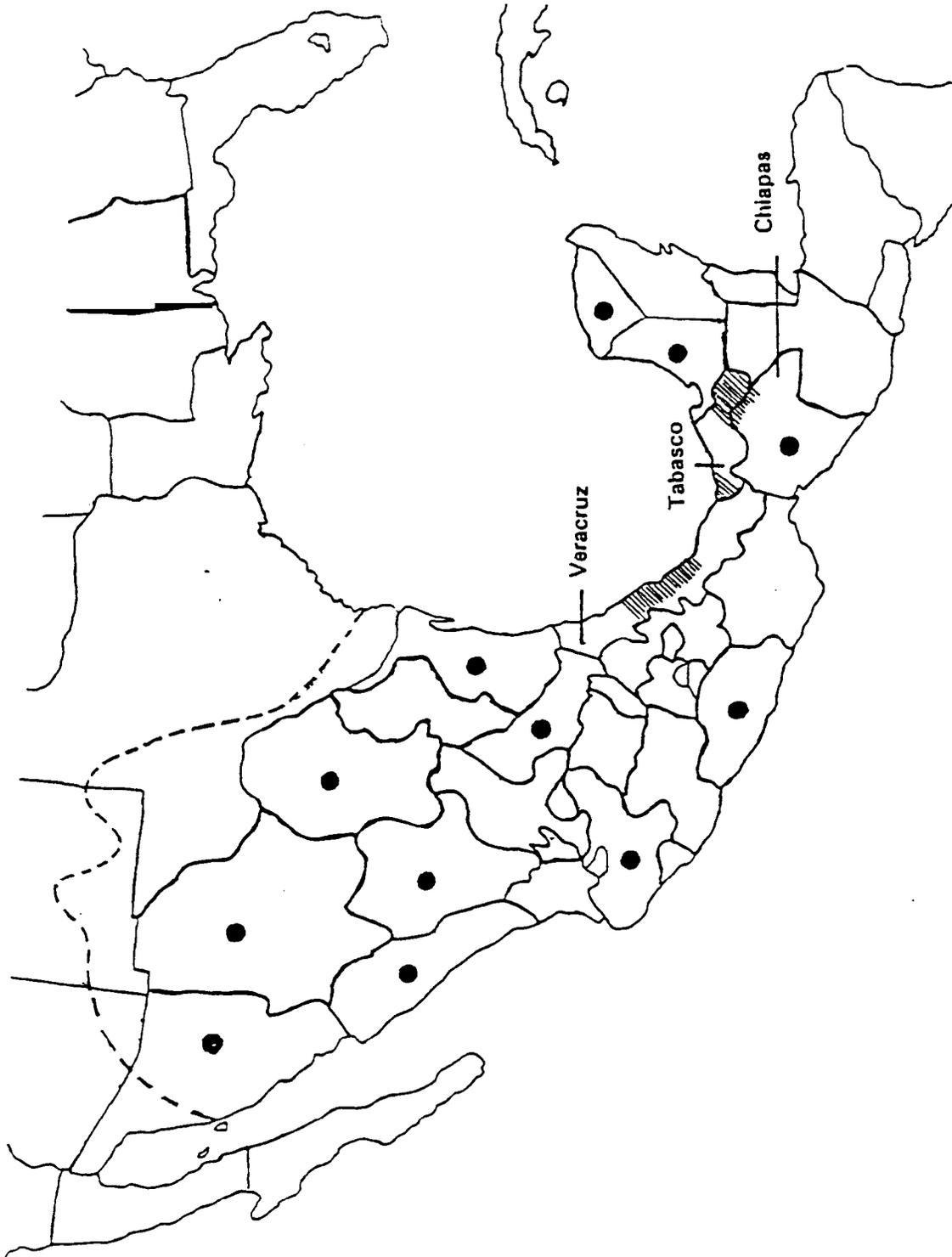


Figure 1. The Northern Range Limit of the Aplomado Falcon (dashed line), the Mexican states containing at least one specimen record (states with dots), and the current breeding populations of aplomado falcons (cross-hatching); adapted from Hector (1987).



Figure 2. Mean and range of DDE levels found at 4 sample sites.

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