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Breeding Biology and Pesticide-PCB Contamination of Western Grebe at Bear River Migratory Bird Refuge

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BREEDING BIOLOGY AND PESTICIDE-PCB CONTAMINATION OF WESTERN GREBE AT BEAR RIVER MIGRATORY BIRD REFUGE

by

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of the requirements for the degree

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Mark L. Lindvall

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Of Western Grebe at Bear River

Migratory Bird Refuge

by

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Utah State University, 1976

Major Professor: Dr. J. B. Low
Department: Wildlife Science

The breeding biology of western grebe was studied at Bear River Migratory Bird Refuge, Utah in 1973 and 1974. More than 300 nests were located and data gathered on nesting habitat and success. Western grebe at Bear River selected nest sites for nearness to open water of approximately 30 cm in depth. At least one young was hatching in 21 percent of the nests. Avian predation and abandonment of nests following drops in water levels caused the greatest loss of nests. Chlorinated hydrocarbons monitored in western grebes showed DDE, DDD, PCB, 1260, and PCB 1254 levels in 24 breast muscle samples (wet weight) to average 12.8, 0.8, 3.8, and 3.5 ppm respectively. Contaminant concentration was found to be correlated to the condition of the bird as determined by visceral fat content. A significant ($p < .01$) 2.3 percent decline in western grebe eggshell thickness between pre- and post-DDT use periods was found. DDE was significantly ($p < .05$) negatively

correlated with eggshell thickness in western grebe. Contaminants were not linked to any reproductive failure in western grebe at Bear River MBR.

(105 pages)

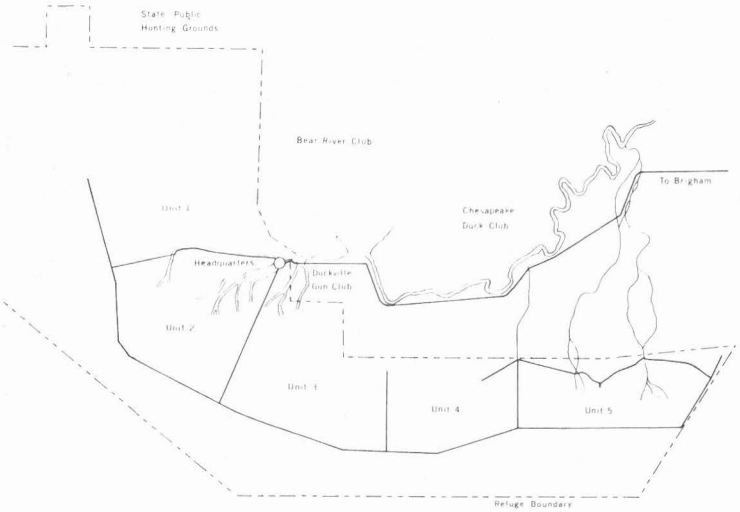
INTRODUCTION

The western grebe (Aechmophorus occidentalis) is a fish-eating diving bird inhabiting western North America. The breeding range encompasses northern Mexico, the western United States, and western Canada. Nesting is primarily colonial in emergent vegetation. Wintering areas for this migratory species are found along the coasts of California and British Columbia.

Because the breeding biology of western grebe has received little attention in the past and because reproduction in fish-eating birds has been shown to be affected by pesticide contamination, the objectives of this study were to: (1) investigate the breeding biology of the western grebe and (2) monitor chlorinated hydrocarbons in western grebe. The first objective was accomplished through examination of nesting habits, nesting success, and brood production. Western grebe tissues and eggs were examined via gas chromotography to meet the second objective.

DESCRIPTION OF STUDY AREA

Bear River Migratory Bird Refuge (Bear River MBR) is located 15 miles west of Brigham City, Utah on the northern edge of the Great Salt Lake (Figure 1). Waters from the Bear and Malad Rivers are divided and held in five large impoundments by a system of dikes and canals. The refuge contains 26,263 hectares (64,895 acres) of which 9,268 hectares (22,900 acres) are open water, 5,811 hectares (14,360 acres) marsh, and 10,878 hectares (26,880 acres) mud flats. The marsh most nearly fits the Class IV (semipermanent ponds or lakes), D (brackish), cover type 4 (open water or bare soil on 95 percent of the wetland area) classification of Stewart and Kantrud (1971). Narrowleaf cattail (Typha angustifolia), hardstem bullrush (Scirpus acutus), alkali bullrushes (Scirpus americanus and S. paludosus), saltgrass (Distichlis stricta), and pondweed (Potamogeton spp.) are the predominant vegetation types. Water depth in the five units ranges from a few cm at the heads of the units, to approximately 50 cm in the unit center, and to over 2m along the dikes and in the canals. The climate is characterized by hot dry summers and cool dry winters. Average annual precipitation is 33.8 cm (13.3 inches). Average minimum temperature is 19°C (-2°F) and average maximum temperature 37°C (99°F). The surrounding area is classified as the cold desert, subclass salt desert, by Shelford (1963).



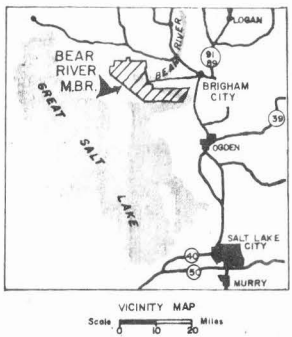


Figure 1. Area and location for western grebe studies, Bear River MBR, Utah.

REVIEW OF LITERATURE

Western grebe nesting habits have been described by several authors. Bent (1919) gives the most complete description. He describes colonies in North Dakota, California, and Saskatchewan, as being characterized by floating nests in emergent vegetation. Finley (1907) visited several colonies in Oregon and found three to four eggs in a floating nest, the usual situation. He also documented large scale market hunting of this species by plume hunters. Davis (1961) surveyed colonies in northern Colorado where he believes the western grebe is pioneering. Yocum (1958) lists known colonies of Oregon and describes one of the colonies in detail. Munro (1941, 1954) characterizes the western grebe as chiefly a transient in interior British Columbia and describes one colony. Nero (1959) and Nero, Lahrman, and Baird (1958) describe an unusual nesting situation for the western grebe. Due to an increase in water level and subsequent loss of emergent vegetation, western grebes were forced to nest on dry land. Nero, Lahrman, and Baird (1958) believe nesting success was low for these unusual colonies. Lee (1967) reported western grebes winter breeding in southern California. He considered this an unusual occurrence. The most complete natural history for the western grebe is contained in Palmer (1962). Courtship behavior, winter and breeding ranges, plumage characteristics, nesting habits, and food habits are covered.

Several authors have investigated food habits of western grebe to determine the possible impact of the species on sport fisheries. Food habits of the western grebe on the breeding grounds are discussed in detail by Lawrence (1950), who found fish made up 81 percent and insects 17 percent of the yearly diet based on 27 stomachs. Based on 19 stomachs, collected from various locations throughout the range of the western grebe, Bent (1919) concluded that fish make up 100 percent of the diet. Munro (1941) and Phillips and Carter (1957) collected western grebes along the Pacific coast to determine winter food habits. These studies found fish, particularly herrings, to be the major food items. Munro (1941) also found crustaceans in his samples. Herman, Garret, and Rudd (1969), as part of their study of the impact of DDD on the western grebe, conducted food habits analyses on birds collected at Blear Lake and Topaz Lake, California. They found western grebes were taking small centrarchids and cyprinids. Of 114 western grebe collected, only 18 had recognizable food items. Herman (1974) studied feeding and weight fluctuations in captive grebes.

Storer (1965) found two races, a light and a dark phase, of western grebe at Bear River Migratory Bird Refuge, Utah. He found 12 percent light phase and 86 percent dark phase birds in the population. Storer found birds selectively mated with birds of the same color phase and described a clinal variation with light phase birds dominating in the southern end of the breeding range and dark phase birds dominating in the northern breeding areas. Sibley (1970) examined 700 western grebe and, as Storer, found two races. Dickerman (1963, 1973),

on the basis of western grebe examined in Mexico, proposes that these light phase birds be classified as a racially distinct subspecies, Aechmophorus occidentalis clarkii.

Field and laboratory studies on the effects of chlorinated hydrocarbons on birds are numerous. Discussion here will be limited to field studies which have concentrated on fish-eating birds.

Biological concentration of pesticides in fish-eating birds is well documented. Robinson et al. (1967) documented it in marine fish-eating birds. Woodwell, Wurster, and Isaacson (1967) demonstrated it in the double-crested cormorant (Phalacrocorax auritus) and red-brested merganser (Mergus serrator) by sampling various trophic levels. Moore and Walker (1964) found higher levels of DDT and metabolites in raptors and fish-eating birds than in herbivorous birds. Greichus, Greichus, and Emerick (1973) found biological concentration of pesticides and PCBs occurring in double-crested cormorants and white pelicans (Pelecanus erythrorhynchos). Zitko and Choi (1972) found concentrations of PCB to be 44 to 100 times greater in cormorants than in their fish food. They also found levels in the cormorant greater than levels in black ducks collected from the same area.

Direct mortality of fish-eating birds from pesticide poisoning has been reported in two instances. J. O. Keith (1966) documents die-offs of fish-eating birds at Lower Klamath Refuge, California following application of toxaphene to nearby lands. Western grebe, white pelican, common egret (Casmerodius albus egretta), black-crowned night heron (Nycticorax nycticorax hoactli), and

California (Larus californicus) and ring-billed (Larus delawarensis) gull were among the species affected. High levels of DDT and DDD were recorded but toxaphene was judged the toxicant responsible. Die-offs of western grebe have been reported at Clear Lake, California and attributed to poisoning by DDD (Rudd 1964).

The relationship of pesticides to eggshell thinning has been investigated by many workers. Field studies, laboratory studies, and physiological studies related to the eggshell thinning problem are reviewed in an excellent article by Cooke (1973). Field studies on shell thinning in fish-eating birds are extensive. Many authors have compared shell thickness or indexes of shell thickness between pre- and post-DDT use periods and found significant decreases in thickness (Faber, Risebrough, and Pratt, 1972) in the great blue heron (Ardea herodias) and common egret (Casmerodius albus), Gress et al. (1973) in the double-crested cormorant, Anderson et al. (1969) in the double-crested cormorant and white pelican, Hickey and Anderson (1968) in the osprey (Pandion haliaetus) and herring gull (Larus argentatus), Blus et al. (1972) in the brown pelican (Pelecanus occidentalis), and Rudd and Herman (1972) in the western grebe. Other authors have compared shell thickness with DDE content of eggs and found a negative correlation (Blus et al., 1971, 1972) in the brown pelican, Anderson et al. (1969) in the double-crested cormorant and white pelican, Hickey and Anderson (1968) in the herring gull, Schreiber and Risebrough (1972) in the brown pelican, and Gress et al. (1973) in the double-crested cormorant. Blus et al. (1971), using stepwise linear regression to analyze their data on

brown pelican eggs, concluded that, of the contaminants measured, DDE had the greatest impact on shell thickness. Whether these correlations offer irrefutable proof of a cause and effect relationship between DDT and its metabolites and eggshell thinning is still a matter of controversy.

Measuring the overall impact of contaminants on avian reproduction in field studies is difficult. A problem with field studies on the impact of toxicants is, as with shell thinning, the acceptability of a correlation as proof. Added to this problem is the extreme complexity of the toxicant-effect relationship. Keith (1969) states:

> The biological vulnerability to insecticides of an individual bird, a species, or a species population is a function of interacting relationships that include: 1) the behavior of insecticides in the environment, 2) the life requirements or ecological niche of the species, 3) the incidence of the ecological coalescence of individual birds with environmental contaminants, 4) the degree of residue accumulation in individual birds, 5) the innate behavior of the species in relation to such physiological processes as lipid turnover, 6) the population dynamics of the species, and 7) variations in these relationships brought about by differences in environmental factors such as food availability, weather, and habitat conditions. These relationships produce an extremely complex situation. (pp. 38-39)

Several studies have shown correlations between high pesticide contamination and reproductive failures in fish-eating birds. A series of articles by Rudd (1964), Herman, Garret, and Rudd (1969), and Rudd and Herman (1972) address the problem of trophic concentration of pesticides in a marsh ecosystem. As part of this overall study, the correlation between the pesticide DDD and western grebe mortality and reproductive failure has been investigated. In 1949, 1954, and 1957 DDD was applied to Clear Lake in large amounts to control gnats. Die-offs of western grebes followed each application of the

pesticide to the lakes waters (Rudd 1964). Levels of DDD in western grebe tissues and eggs were still high ten years after the last application of the pesticide (Herman, Garret, and Rudd 1964). A complete cessation of breeding by western grebes also followed the application of DDD. Ten years after application breeding was initiated, but reproductive success was low. Hatchling mortality, caused by high levels of DDD, is believed to be one cause of low reproductive success (Herman and Rudd 1972). Levels of chlorinated hydrocarbons found in western grebe tissues and eggs at Clear Lake are considerably higher than those found in this study.

Faber, Risebrough, and Pratt (1972) concluded that lowered production in a common egret colony could be attributed to eggshell thinning. Gress et al. (1973) reached similar conclusions in their study of the double-crested cormorant and also found a negative correlation between DDE levels and shell thickness.

Keith, Woods, and Hunt (1970) found the same pattern; thin eggshells, reproductive failure, and a negative correlation between DDE content and shell thickness, in the brown pelican. This study also showed that the greatest eggshell thinning occurred in aggregations of pelicans containing the highest DDE residues.

Other field studies of fish-eating birds have found no apparent ill effects of toxicants on avian reproduction. Presst and Jefferies (1969) compared production of the great crested grebe (Podiceps cristatus) in England in areas of high and low DDT use and could detect no differences in breeding success. No

detectable population declines were found with the advent of DDT use. They considered levels found in great crested grebes low for a fish-eating bird in England. Kury (1969) could find no apparent effect on reproduction of double-crested cormorants contaminated with DDT. Levels incurred in his study were lower than in Grees's et al. (1973) study on the same species where reproduction was suffering.

PCB's (polychlorinated biphenyls) are now widespread in the environment and causing increasing concern. Risebrough et al. (1968) surveyed many species and trophic levels including fish-eating birds, and found PCB's present in all. Zitko and Choi (1972) demonstrated trophic concentration of PCB's in double-crested cormorants. Johnston (1973) found PCB's in two tern species and one species of booby. Interestingly, no DDT or DDT metabolites were detected. Many other studies have detected PCB's in fish-eating birds (Blus et al. (1971) in the brown pelican, Greichus, Greichus, and Emerick (1973) in the white pelican and double-crested cormorant, Faber, Risebrough, and Pratt (1972) in the great blue heron and the common egret, and Presst and Jefferies (1969) in the great crested grebe). The impact of PCB's on shell thickness is yet to be determined but initial investigations suggest a lesser effect than DDE (Blus et al. 1971, Cooke 1973). Heath et al. (1972) in laboratory experiments, found toxicity and effects on reproduction of PCB's lower than DDT. Dustman et al. (1971) reviewed chemistry, occurrence, biological concentration, toxicity, and physiology of PCB's. They concluded that PCB's must be viewed

as a potential problem until further data are gathered. The strong positive correlation between DDE and PCB content of samples along with the problems encountered in field studies makes assigning cause to either pollutant difficult.

METHODS

Nesting study

Western grebe nests were located by driving along dikes and observing birds or by rowing a small boat along edges where nests were suspected. Most nests were built along the water's edge and were generally easily located. Located nests were marked at the site by placing masking tape marked with the nest number on nearby vegetation. The location was also noted on a map and on the nesting form (Appendix Figure 1). Nests were visited every 3 or 4 days and information gathered on surrounding vegetation, nesting materials, distance to open water, distance to nearest nest, distance to land, moving or stagnant water, depth of nearest open water, number of eggs, condition of nest, condition of eggs, and whether a colony or a non-colony nest. Any nest over 100 from the next nearest nest was considered a non-colony nest. In 1974 data on nest diameter, percent overhead cover, nest floating or non-floating, and the depth of the deepest water within 1.5 m of the nest were gathered in addition to the forementioned parameters. Fate of eggs was determined by examination of egg fragments and the presence or absence of yolk in the nest.

In 1973 colony nests were observed from a small portable blind. The blind was placed on a dike overlooking the colony under observation and left in place. Notes were taken on nest attentiveness, nesting activities, and nest predation.

Brood counts and population surveys

Brood and adult counts were made throughout the summer at weekly intervals. Counts were made by driving all dikes on the refuge. In 1974 stops were made at all spillboxes on the outside unit boundaries and a 15 to 60 X variable power spotting scope used to scan the upper ends of the refuge units. This resulted in higher counts in 1974 than in 1973.

Birds were classified as adults, class 1 young (on parents back), class 2 young (free swimming downy), and class 3 young (showing black on the head and neck). Location as to refuge unit was also noted. Class 1 and class 3 birds are difficult to identify. Class 1 young are often concealed under the parent birds wings and at a distance are difficult to detect. Often birds were known to have young on their back but no estimate of how many young could be made. Class 3 birds, especially at later stages of development, resemble adults and are also difficult to classify at a distance. Class 2 birds are the most conspicuous and, thus, present the best estimate as to trends in breeding.

The western grebe exhibits two color phases as described by Storer (1965). Two surveys were conducted in 1973 to determine the percent of the population that exhibited each phase and whether selective breeding was taking place. Birds were classified as dark phase if the black of the crown extended below the eye or passed through the eye and as light phase if the black of the crown ended at a level above the eye. Birds were counted as pairs if swimming in close association with no other birds nearby. All single birds and birds in

flocks where pairing was not evident were counted as unpaired. Birds were observed with a 15 to 60 X variable power spotting scope from dike roads.

Banding

A total of 35 western grebe were leg banded in late August and early September 1973. Nineteen flightless juveniles and 16 adults were captured using night lighting techniques as described by Bishop and Barratt (1969). Grebe were often not greatly affected by the spotlight and proved difficult to capture. Seven nights of approximately 11 hours each were taken to capture the 35 birds. The most efficient method of capture proved to be to move up quickly on a bird and net it as it passed by the side of the airboat.

In 1975 seven adult and four juvenile western grebe were captured in a drive banding operation. One net was placed across a borrow ditch and another net used to drive. All birds were leg banded. Adults were also color marked with a green dye and had blood samples drawn before being released.

State survey

Letters of inquiry were sent to 17 state and federal waterfowl management areas in Utah. One area on the Utah-Idaho border and one area on the Utah-Colorado border were also contacted. Managers were asked to estimate the number of western grebe which breed and summer on their areas.

Pesticide analysis

Three species of fish (Gavia atria, Ictalurus melas, and Cyprinus carpio)

were collected by seining. Fish were sorted as to length and species and placed in acetone rinsed jars with aluminum foil lined lids. Samples were then frozen until analyzed.

Western grebe eggs collected for analysis were placed in egg cartons and frozen. At a later date eggs were thawed and then cut with a scissors. Contents were placed in acetone rinsed jars with aluminum foil lined lids and refrozen until analyzed.

Western grebe collected in the field were immediately frozen. At a later date the birds were thawed and tissues dissected out. Tissues were wrapped in aluminum foil and refrozen until analyzed.

Five ml or larger blood samples were drawn from live birds with a syringe. Blood was immediately transferred to a centrifuge tube. The sample was then taken to the lab and centrifuged 20 minutes and then allowed to settle 8 hours to separate serum and cells. One ml of serum was then transferred to a glass pipet and frozen until analysis. All glassware was acetone rinsed.

Analyses of samples were made at the Denver Wildlife Research Center, Division of Chemical Research and Analytical Services. Samples were prepared for analyses via gas chromatography in the following manner: tissues were first weighed and then ground with granular anhydrous sodium sulfate in a ratio of one part sample to 5 parts sodium sulfate. An extraction solvent of 20 percent (v/v) acetone in iso-octane was added to the sample which was then shaken for 10 minutes. After settling an aliquot of the extract was drawn off and centrifuged for 10 minutes.

The sample was then divided into two portions. One portion was used to determine lipid content in the following manner. Five ml of the extraction solution was placed in a preweighed beaker and the acetone in iso-octane allowed to evaporate leaving the lipids. The difference between the empty beaker weight and beaker plus lipid weight was used to calculate lipid content.

The second portion of the sample was reduced to dryness by placing it in a hot water bath and applying a gentle stream of filtered air. This dry residue was then taken through a liquid-liquid partition in the following manner. acetonitrile saturated iso-octane and iso-octane saturated acetonitrile were added to the dry residue and the mixture shaken for 5 minutes. The mixture was then centrifuged and the acetonitrile (lower) phase drawn off. Iso-octane saturated acetonitrile was then added to the iso-octane (upper) phase. This was then shaken for 5 minutes and then centrifuged. The acetonitrile (lower) phase was then removed and added to the first acetonitrile phase. The following were then added to the combined acetonitrile portions; iso-octane, sodium sulfate-saturated distilled water, and distilled water. The resulting mixture was shaken for 4 minutes and centrifuged. The iso-octane layer was then drawn off and saved for later injection into the gas chromatograph. Blood samples only were treated with fuming sulfuric acid before being injected.

Analysis was performed on a Varian Aerograph Model 2740 gas chromatograph equipped with tritium electron capture detectors and dual columns. The gas chromatograph was operated under the following conditions: detector

foil temperature 215 C, injection port temperature 125 C, column temperature 190 C, column dimensions of 6 feet x 2 mm I.D., column packings of 3 percent OV-1 on 80/100 mesh chromsorb W,AW,DMCS, and 5 percent QF-1 on 100/200 mesh chromsorb @,AW,DMCS, and nitrogen carrier gas with a flow rate of 40 ml/min.

Amounts of DDE and DDD present in samples were calculated by comparing sample peak heights with peak heights of standards. Amounts of PCB 1260 and PCB 1254 present in samples were calculated by comparing peak area of samples with peak area of standards. Because of peak overlaps, both DDD and PCB 1254 are quantity estimates. That is, area or peak height of underlying PCBs was estimated and then deducted from the observed height or area to obtain the actual peak height due to DDD or the actual peak volume due to PCB 1254.

Eggshell measurements

Eggs collected in the field were immediately frozen in egg cartons. At a later date they were removed and allowed to come to room temperature. Vernier calipers were used to measure the length and width (at widest point) of the eggs to the nearest mm. The egg was then cut at the waist with a scissors and the contents removed. The inside of the shell was then rinsed with water and the shell allowed to dry for a minimum of two weeks before any further measurements were made. Six equally spaced measurements of shell thickness were taken at the waist of the egg using a Starrett Model 1010 micrometer.

Thickness was recorded to the nearest 0.01 mm. Shells were then weighed to the nearest 0.01 g on a Torsion Balance, Model DL-T2-1.

Eggs examined at museums had length, width, and weight measured using the same techniques as those described above. Eggs with a 7 mm or larger blow hole were not measured.

Morphological measurements

Wing and tarsus measurements were made according to methods described by Baldwin, Oberhleser, and Worley (1931). Culmen was measured from the anterior edge of the nostril to the bill tip. Bill depth was measured at the anterior edge of the nostril. Culmen and bill measurements were taken with a Vernier caliper.

RESULTS AND DISCUSSION

Status of western grebe in Utah

The status of western grebe in Utah appears stable. Of the 5 areas in which more than 100 western grebe summer and breed, 4 are presently state or federal waterfowl management areas. The Utah Lake population is the only large breeding flock not protected by refuge status. Of the 17 areas contacted 4 reported no western grebe, 8 reported populations between 1 and 100 birds, and 5 reported populations in excess of 100 birds (Table 1). The largest reported summer population is the Bear River flock.

Adult population at Bear River MBR

Western grebe arrive at Bear River MBR in March. Numbers steadily increased throughout the spring and summer. Based on survey data collected in 1974 the adult population is estimated at 680 birds. This figure represents the average number of adult birds present on weekly counts between 11 June and 30 July, the period when breeding is most intense. The highest count recorded in this period was 845 birds, thus 680 is admittedly a conservative estimate.

In August and September, following breeding, western grebe population again rose with the inclusion of young in the adult class and the arrival of migrants from other areas. The peak count for 1973 (742 birds) was recorded on 21 August and for 1974 (1273 birds) on 18 September. Higher counts in 1974

Table 1. Reported occurrence of western grebe in Utah in 1974.

Lake or Marsh	Nearest town	Estimated summer population	Breeding status
Browns Park Waterfowl Mgmt. Area	Greystone, Co.	0	--
Browns Park National Wildlife Refuge	Greystone, Co.	3-10	No record of breeding
Public Shooting Grounds and Salt Creek Waterfowl Mgmt. Area	Tremonton, Ut.	0	--
Locomotive Springs Waterfowl Mgmt. Area	Snowville, Ut.	0	--
Farmington Bay Waterfowl Mgmt. Area	Farmington, Ut.	450	Breeding reported
Lake Powell	Glen Canyon, Ut.	0	(Possible winter area)
Desert Lake Waterfowl Mgmt. Area	Price, Ut.	18	Possible breeding
Clear Lake Waterfowl Mgmt. Area	Fillmore, Ut.	8-10	Breeding reported
Strawberry Reservoir	Fruitland, Ut.	0	--
Ogden Bay Waterfowl Mgmt. Area	Hooper, Ut.	125-150	Breeding reported
Flaming Gorge Reservoir	Dutch John, Ut.	present	unknown
Grays Lake and Bear Lake National Wildlife Refuge Complex	Soda Springs, Id.	400	Breeding reported
Ouray National Wildlife Refuge	Vernal, Ut.	2-3	No record of breeding
Cutler Reservoir	Logan, Ut.	50	Breeding reported
Fish Springs National Wildlife Refuge	Dugway, Ut.	0	--
Bear River Migratory Bird Refuge	Brigham City, Ut.	680	Breeding reported
Utah Lake	Provo, Ut.	500-750	Breeding reported

than in 1973 are a result of different survey methods. Many birds remained on the refuge until mid-October. In late-October and early-November western grebe left the refuge for their wintering areas on the west coast. By the end of November only a few stragglers remained. Occasionally a few western grebe remained through the winter at Bear River MBR. Adult counts for 1973 and 1974 are summarized in Figure 2 and Appendix Table

Brood production

Immediately upon hatching, young downy western grebe crawl onto the adults back. As soon as all eggs have hatched the adults with broods leave the colony site. Both the male and female share in incubation and brood rearing activities. Broods are reared in large open water areas and in ditches. Brood data were collected irrespective of color phase.

Parents feed the young until they are almost adult size (4-5 weeks). Adults feed the larger young both fish and feathers. Adults have been observed feeding the smaller young grebe feathers and small particles, possibly insects, which were picked off the waters' surface. After a week to 10 days, the young begin to spend more time off the backs of the adults. The young remain near the parent birds and may climb on the back of the parent when alarmed. The downy young are quite conspicuous at this stage and offer the best opportunity for evaluating brood numbers and sizes.

At 25-35 days of age the young began to resemble the adults in size and plumage. Development of dark plumage color is slower in the light phase than in the dark phase birds. At this stage the young are often seen away from the

Figure 2. Adult numbers of western grebe at Bear River MBR in 1973 and 1974.

adults and broods become hard to distinguish. Adults still feed the young but the degree to which young are dependent on this food source was not determined.

The first young were seen on 1 June in 1973 and on 28 May in 1974. This means nesting must be initiated in the first part of May, even before most birds have arrived on the breeding grounds. Broods, however, do not become common until a much later date. Brood rearing is not seriously underway until late July (Figure 3). Young were classified as class 1 (on parents back), class 2 (free swimming downy), and as class 3 (showing black on the head and neck). In 1973 the peak count for class 1 broods was 31 July, the peak count for class 2 (probably the best indicator of production) was 21 August, and the peak count for class 3 was 4 September. In 1974 the peak counts for classes 1, 2 and 3 were 28 August, 6 August, and 1 October respectively. Counts for 1973 fit the development pattern for young fairly well. The peaks for classes are in the proper sequence (i.e. the class 2 peak follows the class 1 peak by approximately 14 days, and the class 3 peak follows the class 2 peak by approximately 15-25 days) and the time between peaks at least somewhat compatible with the class designations. The 1974 brood count data do not fit the class designations. The peak for class 1 follows the class 2 peak when one would expect the opposite order. Furthermore, the peak for class 3 is almost two months after the class 2 peak when one would expect only a 15 to 25 day lag. These discrepancies may in part be due to the difficulties associated with counting class 1 and class 3 young (see methods).

Brood rearing continues late into the summer. The last class 1 young were seen on 21 September in 1973 and on 18 September in 1974. The fate of

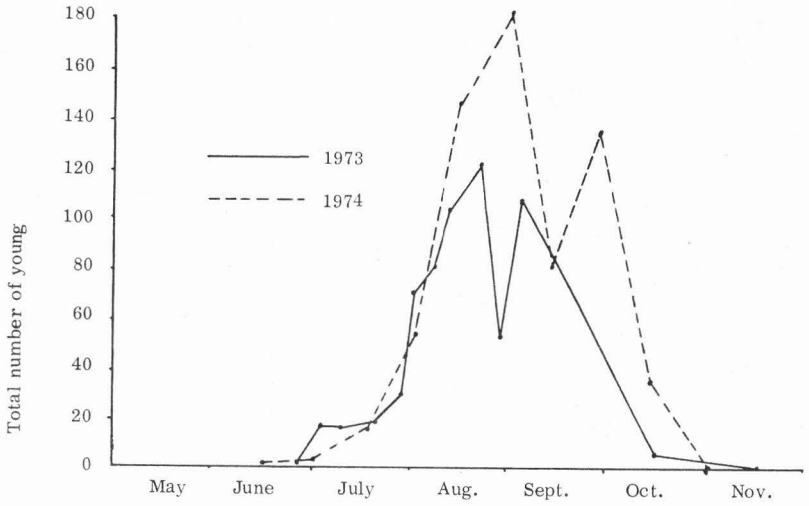


Figure 3. Brood numbers of western grebe at Bear River MBR in 1973 and 1974.

young brought off this late is unknown, although occasionally a few western grebe will become icebound at the refuge. Whether these birds are injured or young unable to fly is unknown.

Total production of class 2 young can be computed from the weekly survey data in the following manner. Young remain in the class 2 designation for approximately two weeks. By adding the actual counts from every other survey week minus a correction factor (for those birds that may be counted twice) an estimate of class 2 production was obtained. The correction factor for a weekly survey was one seventh of the class 2 total from the survey that preceded by two weeks the survey being corrected. One seventh was used because if a class 2 young were to be counted twice it would have to become a class 2 on the day of the first survey. It was assumed that due to probability one seventh of the young on each survey were just entering class 2. A weekly count thus equals the actual count minus one seventh the actual count of the survey preceding the corrected count by two weeks.

Using this method two estimates of total class 2 production were obtained for each year, one if computation was started from the first week class 2 young were seen and one started the second week class 2 young were seen. In 1973 the totals for class 2 young produced were 124 and 158, and in 1974, 218 and 269. Higher totals were obtained when the second week in which class 2 young were seen was used as a starting point because these counts included the peaks in both 1973 and 1974. Higher counts in 1974 are due to the differences in survey method.

Several indexes to success were computed. One was the number of young per adult. If total class 2 young produced (the most easily observed class) and the number of adults present at breeding time were used, this index was 0.3 for 1973 and 0.4 for 1974. Another indicator of success was the average class 2 brood size. In 1973 average class 2 brood size was 1.6 and in 1974, 1.8.

Average class 2 brood size was similar to the index of young per mated pair used by Rudd and Herman (1972). Rudd and Herman found 1.7 young per mated pair in what they considered a normally reproducing population. In the population at Clear Lake, where they believed DDD to be affecting reproduction, they found one young per mated pair. Average class 2 brood sizes for 1973 and 1974 from Bear River MBR compare well with those from what Rudd and Herman (1969) considered a normally reproducing population.

Nesting

Both male and female western grebe shared incubation duties. Eggs were incubated for 21 to 28 days with the average being 24 days for 14 clutches where day of laying and hatching were known. The average clutch size of 70 clutches judged complete was 2.6 and ranged from one to four. Herman, Garrett, and Rudd (1969) found a model clutch size of three for western grebes. Nero (in Palmer 1962) states eggs to usually number three to four. All nesting data in this study were gathered irrespective of color phase.

Davis (1961) found many four, five, and six clutches in a Colorado colony. I found no clutches larger than four which I did not consider a dump nest. Only three dump nests were seen among the nests I examined. Bent (1919)

and Finley (1907) also reported dump nests for western grebe. Two western grebe nests under observation had one western grebe egg added to the nest after incubation was well under way.

Western grebe at Bear River build nests of three basic types: emergent vegetation nests, open water nests, and dry land nests. Nests in emergent vegetation are typical for the western grebe (Finley 1909; Bent 1919; Wetmore 1924; Lawrence 1950; Munro 1954; Yocum, Harris and Hansen 1958; and Herman, Garrett, and Rudd 1969). Dry land nesting has been reported by Nero (1959) and Nero, Lahrman, and Bard (1959). They believed dry land nesting to have occurred in this area due to the loss of emergent vegetation. No such situation existed at Bear River.

Fifty-four percent of 386 nests located were in emergent vegetation. Nests of this type were located in hardstem bullrush (51 percent), cattail (16 percent), and alkali bullrush (24 percent), and a combination of cattail and hardstem bullrush (2 percent). Nests were nearly always constructed of the same type of vegetation surrounding the nest. Nests were located near to open water (average distance 0.4 m) and were either floating (24 percent), built on a snag, or built in shallow water and resting on the bottom (76 percent). The average depth of the nearest open water, often at the nest rim, was 30 cm. Nests were constructed in stagnant water (59 percent) and moving water (41 percent). The average distance from land to emergent vegetation nests was 55 m. Nests of this type and other types, were conspicuous (Figure 4).

Figure 4. Western grebe emergent vegetation nest.

Open water nests (Figure 5) made up 41 percent of nests located, they were found in both 1973 and 1974 in Unit 5 (Figure 5). Raft like nests of this type were constructed of pondweed (Potamageton spp.) in areas with no emergent vegetation. Potamogeton was used exclusively to form a floating nest about 70 cm across and extending 30 cm below the waters surface. The nest platforms were approximately 10 cm above water level at the edges and 5 cm in the center. In 1973 western grebes nested in the dense pondweed beds approximately 0.8 km from shore in 56 cm of water. Nests were held in place by the dense mat of sago pondweed surrounding them. Waves moving through the colony area caused nests to gently rise and fall with no apparent harm. In 1974 pondweed was not as dense as in 1973 and the colony was located only 200 m from shore in 29 cm of water. Nests were not anchored in or surrounded by pondweed. Nests were smaller (average diameter 24 cm) and held in place by contact with the bottom. This type of nesting has not been reported for the western grebe.

Dry land nests made up 5 percent of the nests located (Figure 6). Dry land nests were found in saltgrass (37 percent), hardstem bulrush (16 percent), with no surrounding vegetation (16 percent), in cattail (11 percent), and in cattail saltgrass mix (11 percent). Materials used in nest construction, often sparse, were the same as the surrounding vegetation. Most nests were located near to flowing water (89 percent) and close to open water (average distance to open water was 4 cm). The average depth of the nearest open water was 21 cm. Tables 2 and 3 summarize nesting data for colony and non-colony nests for 1973 and 1974. Figure 7 shows colony locations.

Figure 5. Western grebe open water nest.

Figure 6. Western grebe dry land nest.

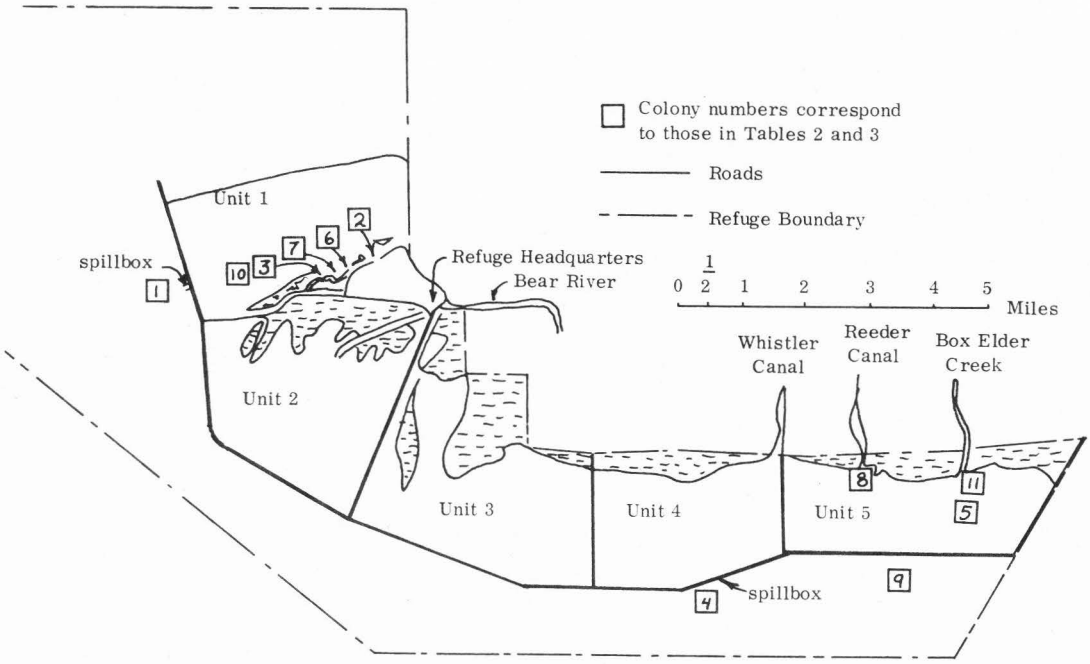


Figure 7. Western grebe colony locations at Bear River MBR in 1973 and 1974.

Western grebe appear to be selecting nest sites for nearness to open water of greater than 20 cm in depth. Nests were usually also located in sparse or no emergent vegetation. The average percent (visual estimation) overhead cover for 202 nests located in 1974 was only 1.3 percent. Many nests had no overhead cover. Density of vegetation may be inversely correlated with nearness to open water. No other factors measured were consistently seen in all three nest types. Davis's (1961); Sturling's (1964); Wetmore's (1924); Bent's (1919); and Yocum, Harris, and Hansen's (1958) observations also suggest western grebe prefer to nest near open water. Nearness to open water could allow for early detection and rapid escape from predators.

Both colony and non-colony western grebe nests were found at Bear River MBR. Non-colony nests made up 5 percent of the 386 nests located. Colony nests were more easily located and thus non-colony nests may be under-represented in this sample. Non-colony nests differed little from colony nests in the factors measured. Non-colony nesting has not been previously reported for the western grebe. McCartan and Simmons (1956) reported both colony and non-colony nesting for the great crested grebe.

The majority (95 percent) of western grebe nests at Bear River MBR were colonial. Colonies ranged in size from 5 to 88 nests. Colonial nesting is the usual situation encountered in the western grebe. Colony sites were highly variable. Channels with emergent vegetation, channels without emergent vegetation, edges of large open water areas, and open water areas devoid of emergents were all chosen for colony sites. Several colony sites used in 1973 were

Table 2. Summary of 1973 data on nest characteristics and nesting success of western grebe at Bear River MBR.

Colony Number	Totals	Non-colony	1	2	3	4	5
Location	--	--	Unit 1	Unit 1	Unit 1	Unit 3	Unit 5
Date colony located	5/29	--	5/29	5/29	7/11	7/2	8/2
Total nests	184	25	6	51	22	10	70
Surrounding vegetation							
hardstem bullrush	62	14		40	7	1	
cattail	27	3		10	13	1	
hardstem bullrush-cattail	5	3			2		
saltgrass	10	3		1		6	
none	73		1			2	70
hardstem bullrush-saltgrass	1	1					
alkali bullrush	5		5				
cattail-saltgrass	1	1					
Nesting materials							
hardstem bullrush	59	13		39	7		
cattail	22	1		8	13		
hardstem bullrush-cattail	11	5		4	2		
saltgrass	10	3				7	
none	0						
hardstem bullrush-saltgrass	2	1				1	
alkali bullrush	8	2	6				
cattail-saltgrass	2					2	
sago pondweed	70						70
$\overline{X}$ distance to open water (m)	.2	0.1	0.0	0.2	0.7	0.0	0.0
$\overline{X}$ distance to nearest nest (m)	13.7*	100+	46.3	15.2	9.7	34.9	8.1

Table 2. Continued.

Colony Number	Totals	Non-colony	1	2	3	4	5
$\bar{X}$ distance to land (m)	354.3	1.6	2.8	4.0	3.5	0.0	800
Moving water	76	6	6	36	18	10	
Stagnant water	105	19		15	1		70
$\bar{X}$ depth nearest open water (cm)	40	38	24	31	28	20	56
Fate							
hatched	35	11	1	22	1		
avian predation	66	12	3	23	20	8	
abandon	2	1		1			
flooded and wave action	10	1	2	4	2	1	
unknown but lost	1			1			
drop in water level and abandon	0						
unknown	70						70

*Non-colony not included

Table 3. Summary of 1974 data on nest characteristics and nesting success of western grebe at Bear River MBR.

Colony Number	Totals	Non-colony	6	7	8	9	10	11
Location		--	Unit 1	Unit 1	Unit 5	Willard	Unit 1	Unit 5
Date colony located			6/2	6/20	6/6	6/22	6/27	7/2
Total nests	202	7	17	21	9	55	5	88
Surrounding vegetation								
hardstem bullrush	47	3	13	20	8		3	
cattail	9	3	4				2	
hardstem bullrush-cattail	0							
saltgrass	0							
none	90			1	1			88
hardstem bullrush-saltgrass	1	1						
alkali bullrush	55					55		
cattail-saltgrass	0							
Nesting materials								
hardstem bullrush	49	3	13	21	9		3	
cattail	9	3	4				2	
hardstem bullrush-cattail	0							
saltgrass	0							
none	0							
hardstem bullrush-saltgrass	1	1						
alkali bullrush	32					32		
cattail-saltgrass	0							
sago pondweed	88							88

Table 3. Continued.

Colony Number	Totals	Non-colony	6	7	8	9	10	11
$\bar{X}$ distance to open water (m)	0.4	0.3	0.5	0.6	0.0	0.8	0.7	0.0
$\bar{X}$ distance to nearest nest (m)	7.1*	100+	5.0	3.5	4.8	2.0	30.0	11.0
$\bar{X}$ distance to land (m)	142.6	3.7	6.0	2.9	1.2	200.0	2.3	200.0
Moving water	11	3	2		2		4	
Stagnant water	191	4	15	21	7	55	1	88
$\bar{X}$ depth nearest open water (cm)	29	38	32	28	29	24	36	29
$\bar{X}$ percent overhead cover	1.3	1.0	5.0	4.0	0.5	0.8	6.0	0.0
$\bar{X}$ nest diameter (cm)	39	46	54	47	51	51	55	24
Floating	119	4	6	2	7	9	3	88
Non-floating	83	3	11	19	2	46	2	
Fate								
hatched	12	3	2	5		1	1	
avian predation	23	2	7	5	7		2	
abandon	8		2	4	2			
flooded and wave action	1		1					
unknown but lost	10	1	3	6				
drop in water level and abandon	56			1		55		
unknown	92		2				2	88

* Non-colony not included

not used in 1974. A colony was located in an area in 1974 where no colony existed the previous year. Three colonies located in 1973 were again active the following year.

Larger colonies were more dense than smaller colonies. Three of four colonies with ten or fewer nests had an average distance to nearest nest of greater than 30 m. All colonies larger than ten nests had an average distance to nearest nest of 15 or less meters. Burger (1974) described a similar situation for the Rolland's (Rollandia Rolland) and silver grebes (Podiceps occipitales).

Nesting activity was underway in late May but did not peak until the first half of July (Figure 8). Nests started in the peak period of 1 to 15 July are probably a combination of first nests and renests. Some western grebe are still arriving at Bear River in late June and have not yet had an opportunity to nest. Other birds, which arrived earlier and failed in the first nesting attempt, may be renesting. Palmer (1962) states replacement clutches to be common in western grebe. Some evidence of renesting was observed at Bear River MBR as eggs destroyed by avian predation were often replaced.

Other workers have also found western grebes to nest in June, July, and August. Nero (in Palmer 1962) gave first nesting dates ranging from late May in California and Utah, to 1 June along the Canadian border, and 10 June in the northern limits of the range. He stated viable eggs were found well into July. Herman, Garrett, and Rudd (1969) gave June as the peak nesting time for western grebe at Clear Lake, California. Lawrence (1950) found western grebe breeding in July and August at Clear Lake. He gave no peak date. Munro (1941) found

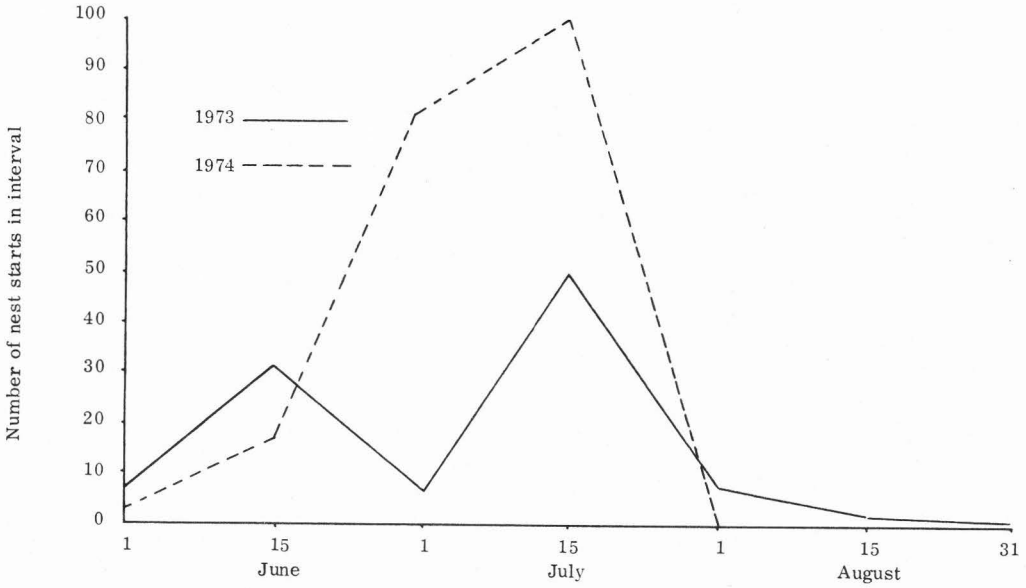


Figure 8. Nesting activity of western grebe at Bear River MBR in 1973 and 1974.

western grebe breeding in June and July in British Columbia. He postulated that July nests were renests. Nero, Lahrman, and Bard (1958) reported nesting in June, July, and August in Saskatchewan.

Nesting success

The fate of 221 emergent and dry land nests was determined. No open water nests were monitored for success. Twenty-one percent of nests observed were successful in bringing off at least one young. No other studies have determined success for western grebe via nest examination. Disturbance of the nest while checking was undoubtedly a factor which lowered success. To what extent disturbance affected success was not determined, but some avian predation and abandonment were due to my presence. Western grebe rarely cover their eggs upon departure from the nest thus making an already conspicuous nest even more visible to predators.

Avian predation accounted for the loss of 40 percent of the nests under study. Coots (Felica americana) and California gulls (Larus occidentalis) were the main nest predators. Egg predation was observed on three occasions, once from a blind and twice from a dike overlooking a nest. In the first instance, observed from a blind, human disturbance was not a factor. In the other two instances observed from a dike, human disturbance was a factor.

Coots were common in the nesting areas and were often seen swimming among the nests of the colony. In the instance observed from the blind, a coot jumped on the untended nest and pecked several times at one of the two eggs in the nest. After breaking one egg open the coot consumed a small part of the

contents and left. Upon returning to its nest the grebe mounted the nest and examined the eggs. It then picked up the broken egg in its beak and left the nest depositing the broken egg in the water approximately 2 m from the nest. The grebe then left the area to return an hour later. In this hour the coot returned and pecked at the remaining egg but was unable to break the shell. Upon returning the grebe mounted the nest and continued incubation of the one remaining egg.

In the first observation from a dike a coot was again responsible for the destruction of eggs. The coot jumped up on the nest rim and pecked holes in eggs in the nest. After consuming a small portion of the egg contents, the coot left the nest.

The final observation involved the destruction of an egg by a California gull. The gull made several aerial passes at the nest before landing and removing an egg. With the egg in its bill the gull then flew off a distance and dropped the egg to the ground.

Yocum et al. (1958) found evidence of nest predation on western grebe by ring-billed gulls. McCartan and Simmons (1956) observed predation on great crested grebe nests by coot. It is believed that some form of disturbance was necessary for predation to occur as western grebe were seen to defend their nests against both coots and gulls. Disturbance from human activity such as cars, planes, or helicopters sometimes caused birds to leave the nest and swim nervously about the colony. Birds also left the nest for short periods to chase other western grebe from the nest area and to add vegetation to the nest. On rare occasion birds would leave the nest for extended periods.

Abandonment of nests, following a drop in water level, accounted for the loss of 25 percent of the nests studied. The loss of one large colony accounted for almost all of this type loss. This colony was located outside Unit 5 in an area where water level is not managed. In less than three weeks the water level in the colony area dropped 38 cm, exposing mudflats. Western grebe, unable to swim to their nests, abandoned them.

Five percent of nests examined were lost to wave action and flooding. Burger (1974) reported nest losses due to flooding in the Rolland's and silver grebe. Losses to flooding at Bear River MBR were probably minimized due to management practices designed to stabilize water levels.

Abandonment of nests accounted for a loss of 4 percent of the nests monitored. This figure may be low because abandon nests may have been destroyed by predation before I checked the nest again. The loss would then be counted as avian predation rather than abandonment.

Success of open water nests was not monitored because of their open situation and subsequent vulnerability to predation. Some predation by California gull was known to have occurred. A California gull colony and loafing area was located near the western grebe colony in 1973 and any disturbance of grebes from their nests resulted in substantial egg losses. Some nests in sparse pondweed appeared to have been destroyed by wave action. Whether these nests were abandoned and then washed out or simply washed out is not known.

Discriminant function analysis was used to compare habitat variables between successful (n=46) and predated nests (n=86). Only emergent and dry

land nests were considered. Habitat variables considered were surrounding vegetation, distance to open water, distance to nearest nest, distance to land, depth of nearest open water, and whether the nearest open water was flowing or stagnant. No significant differences between successful and predated nests were seen with any of the habitat variables considered.

Color phases

The color phases of the western grebe were first described by Lawrence (in Baird 1858) and later by Storer (1965). Dark phase birds are most easily identified by the black of the crown extending below the level of the eyes and the lores. In light phase the black of the crown ends above the level of the eyes and lores. Bill color in dark phase birds is somewhat darker than that of the light phase. Light and dark phase birds of both sexes are shown in Figure 9. There is also some difference in the body plumage, with the light phase birds having a paler more dappled black color on the back than the dark phase birds.

Young western grebe can be classified as to color phase. The young of the dark phase began showing black on the head, neck, and back at a much earlier age. One dark phase brood, where date of hatching was known, began to show dark color after 12 days. Light phase young do not show black on the head, neck, or back until almost fully grown. One brood of two light phase birds had little dark plumage at four weeks of age. After five weeks only one young remained, and it began to show black on the head and neck.

In the 1974 population at Bear River MBR 103 (12.6 percent) of 717 birds observed were light phase and the remainder dark phase (Table 4). Of 160 pairs

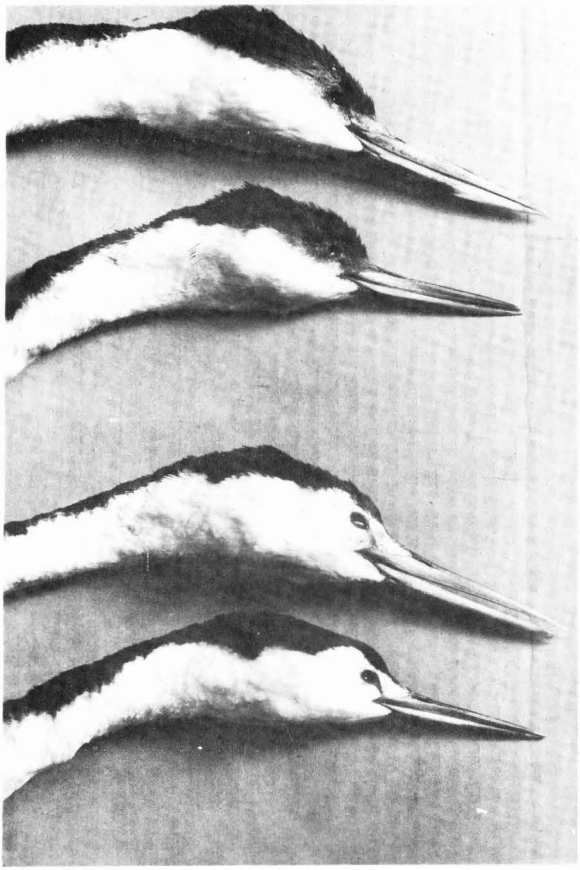


Figure 9. Color phases of western grebes, (from top to bottom; dark phase male, dark phase female, light phase male, light phase female).

observed on two different days, only one pair was observed in which a light and a dark phase bird were paired. If the birds were mating irrespective of color phase 35 of the 161 pairs observed should have been dark-light pairs. This discrepency indicates selective breeding, as to color phase, to be taking place. A summary of color phase data is contained in Table 4.

Table 4. Occurrence and pairing in dark and light phase western grebe at Bear River MBR. (Surveys conducted on 9 July and 17 July 1974)

Unpaired		
light	62	
dark	463	
Pairs		
both dark	140	
both light	20	
dark male-light female	0	
dark female-light male	1	
Totals		
dark	717	87.4%
light	103	12.6%

Storer (1965) conducted color phase surveys at the Bear River Migratory Bird Refuge with similar results. He also documented a latitudinal variation in the species with the dark phase birds dominating in northern areas of the range, and light phase birds dominating in southern areas. Storer postulated that color phase differences function to improve individual recognition in colonies. This

explanation is inconsistent with the distribution of the two phases, however, since one would expect light and dark phase birds to be equally distributed throughout the range.

A more plausible hypothesis, and one that is consistent with the distribution of the two color phases, is that color serves as a mechanism for thermo-regulation. The lighter birds living in the southern hotter climates would absorb less heat from the sun than the dark birds living in the cooler more northern climates. Dark birds living in cooler climates could show a net energy advantage over the light phase birds. Heppner (1970) conducted energy use studies in the laboratory and found that because black birds lose less heat during light periods, they have a net energy advantage over a similar but non-black bird. He also hypothesized that white or whitish birds would be expected to receive a lesser net energy advantage from the sun but would also be less subject to high heat loads where insulation is at a high level. This hypothesis could be applicable to western grebe.

Dickerman (1963, 1973) has proposed a classification of Aechmophorus occidentalis clarkii for a population of light phase birds breeding in Mexico. All other western grebe would then be classified as A. occidentalis occidentalis. Dickerman's A. o. clarkii collection from Mexico differ in all parameters considered (length of tarsus, wing, and culmen) from my Bear River MBR collections (Table 5). Birds Dickerman examined and considered A. o. occidentalis, the group into which my collections should have fallen, also significantly differed in several parameters from my Bear River MBR collections. Dickerman's

Table 5. Comparison of morphological measurements of western grebe from three areas.

		A. o. clarkii (from Dickerman 1973)		
		wing	culmen	tarsus
		t values		
A. occidentalis (from Bear River MBR)	males	2.7*	20.8*	4.0*
	females	2.9*	8.8*	6.0*

		A. o. occidentalis (from Dickerman 1973)		
		wing	culmen	tarsus
		t values		
A. occidentalis (from Bear River MBR)	males	0.4	9.3*	0.6
	females	1.7	5.4*	2.9*

* Indicates significance at a = .05

A.o. clarkii were the smallest, his A.o. occidentalis intermediate, and my Bear River MBR collections the largest of the three groups considered (Table 6). This variation is an example of the problems encountered when trinomials are used to emphasize small differences between populations. Selander (1971) points out the difficulties and general uselessness of the subspecies concept in birds, especially when only a few morphological characters are considered.

My observations suggest that future consideration should be given to the possibility that the dark and light color phases of the western grebe are reproductively isolated and thus merit species status. Behavior, resource use, and biochemical variation, as well as morphological characters should be considered in determining the taxonomic relationship between the two color phases of western grebe.

Sexual dimorphism

Sexual dimorphism in the western grebe has been demonstrated by several authors (Palmer 1962, Dickerman 1973). Measurements of wing, bill, tarsus, and culmen from Dickerman (1973) and this study are summarized in Table 6. Tarsus, culmen and bill measurements of males from this study are significantly larger than the same measurements of females (Table 7). No significant difference in wing length was seen between male and female. This could be explained by the variability in the stages of growth of the primaries following molt, as birds were collected at various times throughout the summer both preceding and following the molt.

Table 6. Morphological measurements of western grebe from three areas.

	No. specimens	Range (mm)	$\bar{X}$ (mm)	SD
A.o. clarkii (from Dickerman 1973)				
Males				
wing	16	172-188	180.8	4.5
culmen	17	49-60	55.1	2.6
bill	14	9.7-11.9	11.1	0.5
tarsus	14	69-77	73.1	2.2
Females				
wing	12	164-172	168.2	3.5
culmen	11	45-50	46.7	1.4
bill	13	7.4-9.4	8.6	0.6
tarsus	13	63-69	65.6	2.1
A.o. occidentalis (from Dickerman 1973)				
Males				
wing	27	188-208	197.2	5.6
culmen	25	50-67	59.4	3.8
bill	22	11.0-13.8	12 5	0.7
tarsus	23	74-81	77.4	2.2
Females				
wing	17	173-196	183.4	5.7
culmen	12	49-58	53.1	2.4
bill	12	8.3-10.7	9.5	0.8
tarsus	16	67-75	71.9	2.1
A. occidentalis (this study)				
Males				
wing	10	183-197	190.4	4.55
culmen	10	61.8-76.0	71.6	4.57
bill	10	10.9-12.3	11.6	0.54
tarsus	10	75-84	79.9	3.03
Females				
wing	13	172-195	181.8	7.06
culmen	13	59.7-67.8	62.7	2.66
bill	13	8.0-10.0	9.2	0.61
tarsus	13	66-79	72.7	4.33

Table 7. Comparison of four morphological measurements between male and female western grebe from Bear River MBR.

	Males		Females		t
	$\bar{X}$ (mm)	SD	$\bar{X}$ (mm)	SD	Value
wing	190.4	4.55	181.8	7.06	1.3
tarsus	79.9	3.03	72.7	4.33	2.8*
culmen	71.6	4.57	62.7	2.66	38.5*
bill	11.6	0.54	9.2	0.61	402.3*

*Indicates significance at a = .05

Food habits

Stomachs of 13 western grebe collected live and 11 found dead were examined for food items. Of the 13 birds collected live 8 contained food items. None of the 11 birds found dead contained food items. All of the stomachs examined contained a stained mass of feathers making up from 50 to 100 percent of the total contents by volume. Lawrence (1950) postulates that this feather mass serves to both speed digestion and protect the stomach and intestinal walls from sharp fish bones.

Fish are the main food item for western grebe at Bear River. Only one other food item, a nymph in the order Odonata, was found and this only in one instance. Carp (Cyprinus carpio) from 3.3 to 6.3 cm in length were most frequently taken by grebes. Of the 13 recognizable fish found in stomachs, 10 were carp, 1 was a black bullhead (Ictalurus melas), and 2 were Utah chub (Gila atratulus) (Table 8). Small carp are abundant in the late summer when most of

Table 8. Food items in 8 western grebe stomachs collected at Bear River MBR.

Date Collected	Field Number	Item	Weight	Condition of contents
3 Dec. 1972	14	feathers	8.7g	green mass
		Gila atratulus	6.0g	8 cm long
		Gila atratulus	1.0g	head only
		fish parts	1.3g	unidentifiable
29 Aug. 1973	2	feathers	45.6g	brown-green mass
		Cyprinus carpio	4.1g	6.3 cm long
		Cyprinus carpio	2.8g	5.4 cm long
		Cyprinus carpio	2.0g	4.3 cm long
		Cyprinus carpio	1.4g	4.0 cm long
		Odonata	--	tarsal claws and terminal segments
29 Aug. 1973	1	feathers	30.9g	brown-green mass
		Ictalurus melas	1.0g	3.5 cm estimated live length
		fish parts	11.4g	unidentifiable
31 Aug. 1973	3	feathers	26.5g	green mass
		fish parts	0.5g	unidentifiable
12 Aug. 1974	24	feathers	15.3g	brown mass
		fish parts	3.2g	unidentifiable
12 Aug. 1974	23	feathers	16.5g	brown mass
		Cyprinus carpio	1.1g	4.8 cm long
		Cyprinus carpio	1.5g	4.5 cm long
		Cyprinus carpio	0.8g	3.8 cm long
		Cyprinus carpio	0.8g	3.3 cm long
		Cyprinus carpio	1.9g	3.3 cm long
		Cyprinus carpio	0.8g	head only
12 July 1974	8	feathers	36.0g	green mass
		fish parts	1.0g	unidentifiable
2 July 1974	6	feathers	34.0g	green mass
		fish parts	1.0g	unidentifiable

the birds were collected and thus may be over represented in this analysis. Utah chub, which are also abundant, may be an important food in early summer and again in fall when the small carp are less numerous. Since no birds were collected in the spring and only one late in the year (it contained only Utah chub), the Utah chub may be under represented as a food source in this sample. Wetmore (1924) lists the stomach contents of three western grebe collected at Bear River before 1924. One stomach contained two carp and one mullet sucker (Catostomas ardens), another eight carp, and the last stomach four Utah chub. Other workers (Bent 1919; Wetmore 1924; Munro 1941; Lawrence 1950; Phillips and Carter 1957; and Herman, Garrett, and Rudd 1969) have also found small fish to be the main food of the western grebe.

Contaminant levels in western grebe

Breast muscle, visceral fat, blood, and whole eggs of western grebe were examined for chlorinated hydrocarbons. DDE, DDD, PCB 1260, and PCB 1254 were found in various concentrations of four tissues examined (Table 9). Means for PCB's in blood and in eggs were not computed because most observations in these categories were below the level (1 ppm) at which PCB's were quantifiable with the method used.

Levels of contaminants showed great variability in all tissues, and thus averages have limited value. Keith (1969) also found great variability in pesticide content of western grebe at Tule Lake National Wildlife Refuge. DDE was the predominant contaminant found at Bear River MBR. PCB's, 1260 and 1254, were found in lower levels than DDE but higher levels than DDD.

Table 9. Contaminant levels in western grebe tissues collected at Bear River MBR in 1973 and 1974.

Tissue	n	Contaminant	Basis	$\bar{X}$	90% CI	Range
Breast Muscle	24	DDE	wet	12.8	8.1	<0.1-115.2[a]
			lipid	513	280	3-3287
		DDD	wet	0.8	0.5	<0.1-6.0
			lipid	29	13	2-171
		PCB 1260	wet	3.8	2.1	ND-17.6[b]
		PCB 1254	wet	3.5	1.8	ND-17.6
Visceral fat	18	DDE	wet	61.5	23.0	5.4-213.0
		DDD	wet	5.2	2.0	0.5-16.4
		PCB 1260	wet	22.4	13.0	<1-147.1
		PCB 1254	wet	16.7	8.2	<1-84.0
Blood	16	DDE	wet	0.55	0.26	.04-2.00
		DDD	wet	0.07	0.04	ND-.20
		PCB 1260	wet	<1	--	ND-1.0
		PCB 1254	wet	<1	--	ND-1.1
Whole eggs	40	DDE	wet	6.6	1.6	1.0-21.4
			lipid	76.5	17.7	20-275
		DDD	wet	1.3	0.3	0.3-4.7
			lipid	14.9	3.1	3-52
		PCB 1260	wet	<1	--	<1-5.4
		PCB 1254	lipid	<1	--	<1-3.8

ND = none detected, counted as 0 in averages
b = <1.0 ppm counted as 0.5 ppm in averages
a = <0.1 ppm counted as 0.05 ppm in averages

DDE (1,1-dichloro-2,2-bis (p-chlorophenyl) ethylene) and DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene) are chlorinated hydrocarbon pesticides. Both DDE and DDD are also products of the metabolic degradation of the pesticide DDT (1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane). DDT, DDE, and DDD are all widespread in the global ecosystem. PCB 1260 and 1254 are polychlorinated biphenyls with 60 and 54 percent chlorine that have recently become widespread in animal tissues. PCB's are used in plasticizers in diverse materials, as electrical insulators and impregnators, as grinding and cutting oil, as hydraulic fluids, as high temperature lubricants, and as heat exchange media (Heath et al., 1972). The method by which PCB's have entered the environment is little understood. Industrial leakage, flushing or dumping of PCB wastes, and refuse burning have been suggested as possible entry methods (Heath et al., 1972).

Comparison of contaminant levels between species to evaluate effect is of limited value. Laboratory studies have shown interspecific differences in the vulnerability of birds to pesticides. Comparisons of contaminant levels are somewhat useful in evaluating qualitative and quantitative differences in contamination between species.

Dustman et al. (1971) reviewed PCB contamination patterns and concluded that PCB levels of 10 or more ppm in eggs were high by todays standards and that populations showing contamination at these levels should be investigated for population problems. By this standard PCB contamination in western grebe at Bear River appear low (averages in eggs of PCB 1254 and 1260 were both <1 ppm).

Levels of DDE and DDD in eggs of western grebe from Bear River MBR compare favorably with those seen in studies of fish-eating birds. Levels of DDTR (sum of DDT, DDD, and DDE) in the range of 1 to 10 ppm wet weight basis are often encountered. The average DDT in eggs of western grebe at Bear River MBR is 7.9 ppm. Several studies, including the only other one done of western grebe, have shown much higher contamination levels. Levels of DDTR in eggs of herring gull as high as 227 ppm wet weight basis were recorded by Keith (1966). DDT, DDE, and DDD levels found in eggs of fish-eating birds are summarized in Table 10.

DDE was, as in my samples, the predominant pesticide found in all but one study. DDD was predominant in Rudd and Herman's (1972) study on the western grebe. The predominance of DDD in this case is due to the direct application of DDD to the lake where the study was conducted. The absence of DDT in western grebe from Bear River MBR may be a result of the breakdown of DDT into its metabolites. Several laboratory studies have shown that birds can breakdown DDT into its metabolites (Jefferies and Walker, 1966; French and Jefferies 1969). Herman, Garrett, and Rudd (1969) also found an absence of DDT in western grebe from Clear Lake. No DDT was found in 62 breast muscle samples and in only one of 18 visceral fat samples. Furthermore no DDT was found in fish collected at Bear River MBR, thus ruling out this as an input source of DDT.

Levels of total DDE and DDD encountered in western grebe at Bear River MBR are much lower than those found in the studies conducted on western

Table 10. Pesticide levels in eggs of fish-eating birds (ppm wet weight).

Study	Bird	Total DDT	DDT	DDE	DDD
Anderson et al. (1969)	double-crested cormorant	10.6	0.2	10.4	Trace
	white pelican	1.8	0.1	1.7	0.4
Greichus, Greichus, and Emerick (1973)	double-crested cormorant	11.5	0.7	10.4	0.5
	white pelican	2.3	0.1	2.1	0.2
Presst and Jefferies (1969)	great-crested grebe	6.6	0.6	5.9	0.1
Risebrough et.al. (1967)	Cassin's auklet	10.8	0.3	10.4	0.1
	western gull	6.5	0.2	5.3	0.5
Keith, J. A. (1966)	herring gull	227	19	202	6
Kury (1969)	double-crested cormorant	8.4	1.5	6.2	0.7
Schreiber and Risebrough (1972)	brown pelican Florida	1.7	not given		
Blus, Belisle, and Prouty (1974)	brown pelican California	79.0	2.0	75.6	1.4
Rudd and Herman (1972)	western grebe (1967)	445.8	not given	147.1	298.7
(all values lipid weight)	western grebe (1969)	165.3	not given	47.9	117.4
Knopf and Steel (1974)	white pelican (wet, yolk only)	17.32	not given	13.6	3.7
Bear River (this study)	western grebe (wet)	7.9	none detected	6.6	1.3
	(lipid)	91.4	none detected	76.5	14.9

grebe at Clear Lake, California (Rudd 1964; Herman, Garrett, and Rudd 1969; Rudd and Herman 1972). Western grebe eggs (n=17) collected in 1967 at Clear Lake averaged 147.1 ppm DDE and 298.7 ppm DDD. In 1969 DDE averaged 47.9 ppm and DDD 117.4 ppm in eggs (n=28) (all figures lipid basis) (Rudd and Herman 1972). Western grebe eggs (n=40) collected at Bear River in 1973 and 1974 averaged 76.5 ppm DDE and 14.9 ppm DDD (lipid basis) (Table 9).

Rudd and Herman (1972), on the basis of their Clear Lake study, conclude "Direct accumulation of residues in eggs followed by toxic manifestations as the yolk sac is absorbed in young birds are the presumed bases of hatchling mortality." (p.477) Levels of DDE and DDD encountered in western grebe eggs at Bear River MBR do not seem to be causing hatchling mortality. One fully developed unhatched dead embryo collected had low levels. No indication of hatchling mortality was found in the nesting study and production of young, as measured by brood counts, appeared normal.

No direct mortality from pesticide poisoning was documented at Bear River MBR. No residue levels in brains, the best indicator of mortality resulting from pesticides, were monitored. Much higher levels in breast muscle and fat have been seen in live western grebe from other areas (Keith 1969; Herman, Garrett, and Rudd 1969). Rudd and Herman (1972) collected two birds at Clear Lake, with 41.1 and 47.9 ppm DDD wet weight in brains, that they believed had died of pesticide poisoning. Levels of DDD in breast muscle for these same birds were 23.0 and 45.9 ppm wet weight. Both birds were emaciated and had brood patches. No levels of other contaminants were

mentioned. Five emaciated dead western grebe from Bear River MBR had comparable levels of DDE in breast muscle with the DDD levels in the two birds from Clear Lake. Since no brains were examined and live birds with higher residue values have been collected, no mortality can be attributed to pesticide poisoning. High levels in breast muscle of emaciated birds do, however, suggest future consideration should be given to residue analysis of brain tissue from birds found dead at Bear River.

Contaminant levels in fish

DDE was the only contaminant detected in the three fish species sampled at Bear River MBR. Samples consisted of five fish, of the same species and in the 7.5 to 11.5 cm size range, ground together. DDE was found at 0.01 ppm in Cyprinus carpio, 0.02 ppm in Gila atratulus, and 0.02 ppm in Ictalurus melas (all wet weight basis). No PCB's or DDD were detected. Smith (1973) sampled larger fish in other areas in Utah and found DDT, DDE, DDD, and PCB's. No samples were taken from the Bear River drainage or from small fish.

PCB's could be picked up by western grebe on the wintering grounds along the California coast. Examination of Christmas bird counts show large concentrations of western grebe along the west coast of North America. Also, two western grebe banded in the 40's at Bear River were later recovered in the winter on the California coast. Risebrough et al. (1968) have suggested that the ratio of total DDT to PCB contamination may be useful in determining the location in which a bird has picked up contaminants. They found DDT to PCB ratios between one and two for west coast bay feeding birds. This same ratio

was between 9 and 10 for birds collected in areas remote from PCB contamination. Western grebe collected at Bear River MBR have average DDT to PCB ratios of 1.8 for breast muscle and 1.6 for visceral fat. These ratios suggest that most PCB's and possibly DDE in western grebe at Bear River are picked up on the wintering grounds along the Pacific Coast. Further supporting this hypothesis is that of all western grebe collected at Bear River, the only one that contained no PCB's was a juvenile which had not yet visited the wintering grounds. This bird also had low levels of DDE and DDD.

Tissue-contaminant level relationships

Of the tissue examined visceral fat contained the highest levels of all four contaminants. Herman, Garrett, and Rudd (1969) sampled eight tissues in western grebe and found pesticide concentration to be highly positively correlated with lipid content. They also, as can be expected by the high lipid content of visceral fat, found the highest residue levels in this tissue. Breast muscle from western grebe from Bear River MBR contained average residue loads from 83-87 percent lower than the average levels in visceral fat. Lipid levels in breast muscle are considerably lower than lipid levels in visceral fat. I found the average percent lipids in breast muscle to be 4.2 percent and Herman, Garrett, and Rudd (1969) found average lipid levels in visceral fat to be 73.3 percent. Blood contained the lowest levels of all contaminants. Levels of DDE in blood were 1 percent of those found in visceral fat and 4 percent of those found in breast muscle. The same figures for DDD were 4 and 8 percent respectively.

Table 11 presents correlations (r^2 values), within tissue from the same bird, for the four contaminants detected. The similar compounds, PCB 1260 and PCB 1254, and DDE and DDD, were highly correlated in all but one case.

Table 11. Coefficients of determination (r^2) comparing contaminants within tissue of western grebe from Bear River MBR.

		DDD	DDE	1254	1260
Eggs n=40					
	1260	0.1	0.1	0.7	1
	1254	0.4	0.2	1	
	DDE	0.4	1		
	DDD	1			
Breast n=24 muscle					
	1260	0.1	0.2	0.8	1
	1254	0.2	0.5	1	
	DDE	0.7	1		
	DDD	1			
Visceral Fat n=19					
	1260	0.1	0.2	0.8	1
	1254	0.2	0.5	1	
	DDE	0.7	1		
	DDD	1			

High correlations was seen between PCB's 1254 and 1260 in all three tissues. DDE and DDD were highly correlated in visceral fat and breast muscle but not in eggs. One would expect 1260 and 1254 to be highly correlated and DDE and DDD to be highly correlated.

Table 12 presents coefficients of determination (r^2) for comparisons between tissues of the same bird.

Table 12. Coefficients of determination (r^2) for contaminants between tissues of the same western grebe.

Visceral Fat with Breast Muscle n=19	
DDE	0.5
DDD	0.4
1260	0.4
1254	0.7
Visceral Fat with Blood n=8	
DDE	0.1
Breast Muscle with Blood n=9	
DDE	0.8

Contaminant levels in breast muscle are correlated with levels in visceral fat but are only highly correlated in PCB 1254. Levels of DDE in blood were well correlated with DDE levels in breast muscle but not with DDE levels in visceral fat. Herman, Garrett, and Rudd (1969) compared pesticide levels in nine tissues

from 10 western grebe and found residue levels in breast muscle the best predictor of levels in other tissues.

Three female western grebe were collected live off nests for comparison of residue levels found in eggs and in the adult. Figure 10 compares residue levels in females and their eggs. Levels of all contaminants in eggs compare favorably with levels in the breast muscle of the females. Levels in breast muscle were generally lower than those in the eggs. Herman, Garrett, and Rudd (1969) found a similar relationship in their Clear Lake study.

Condition-contaminant level relationships

Pesticide concentrations in blood, visceral fat, and breast muscle are related to the visceral fat content of the bird. Western grebes with sparse or no visceral fat have higher levels of DDE in breast muscle, blood, and fat than those birds with abundant visceral fat. Significant differences, between birds with sparse or no and abundant visceral fat, were also seen with DDD in visceral fat, with PCB 1260 in visceral fat and breast muscle, and with PCB 1254 in breast muscle (Table 13).

The interaction of lipids and pesticides has been studied in the laboratory. Findlay and Defretas (1971) introduced DDT into pigeons and then starved them. They found that DDT moved from fat into muscle but not into brain, liver, heart, or blood. They also found fatty acids to move out faster than DDT. Ecobichin and Saschenbrecker (1969) found that restriction of food to cockerels resulted

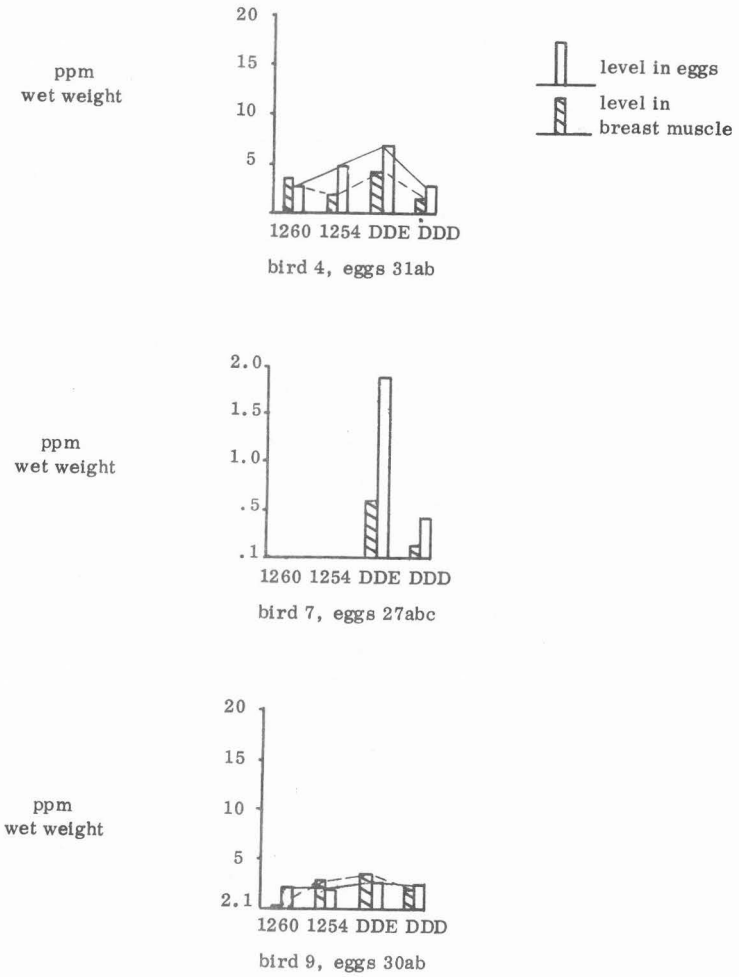


Figure 10. Residue levels in three female western grebe and their eggs, from Bear River MBR.

Table 13. Residue averages and Mann Whitney U values for differences between samples with sparse and no visceral fat and abundant visceral fat in western grebe from Bear River MBR.

	DDE	DDD	1260	1254
Visceral Fat n=19				
$\bar{x}_a$ (ppm)	30.6	3.3	8.6	7.1
$\bar{x}_s$ (ppm)	83.9	6.7	32.5	23.6
U	19*	21*	19*	25
Breast Muscle n=23				
$\bar{x}_a$ (ppm)	2.6	0.5	0.6	1.2
$\bar{x}_{s_n}$ (ppm)	19.2	3.0	19.3	12.5
U	17.5*	35	15.5*	31*

* indicates significance @ a=.05
a- abundant visceral fat
s- sparse visceral fat
sn-sparse or no visceral fat

in loss of lipids and increased residue levels in plasma, brain, liver, and heart. Donaldson, Sheets, and Jackson (1968) found increased DDT levels in blood from starved chicks.

Keith (1969) suggests that during stress periods or periods of fast DDT is mobilized from fat into other tissues. These stress conditions could exist for western grebe at Bear River during migration, breeding, and periods of fast, starvation, or disease. Herman, Garrett, and Rudd (1969) kept western grebe in captivity with an unrestricted food supply. Even with unrestricted food, the

grebes showed cyclic fluctuations in both feeding activity and weight. Western grebes also fast when nesting. One bird tends the nest and the other goes out to forage. Western grebes collected dead usually contained sparse or no visceral fat and were assumed to have been subject to some stress, possibly disease or starvation. Some form of stress could account for the utilization of lipids and the subsequent transfer of contaminants to other tissues. The greater concentration of residues in sparse visceral fats could be explained by the more rapid movement of fatty acids than residues out of the lipid tissue, as suggested by Findlay and Defretas' (1971).

DDE residues in blood from western grebe with sparse or no visceral fat are significantly ($t=2.13$, $p<.05$) higher than levels of DDE in birds with abundant visceral fats. Average DDE in blood from birds with abundant visceral fat ($n=4$) was 0.63 ppm and in birds with sparse visceral fat ($n=5$), 1.14 ppm. It appears that as lipids are utilized DDE is transferred from fat into blood. There is also a significant difference in DDE levels in blood between breeding and non-breeding western grebe. Four western grebe (3 females and 1 male) collected off the nest had significantly higher ($t=5.5$, $p<.05$) DDE levels in blood than nine nonbreeding western grebe collected by shooting and drive banding. Average DDE for breeders was 0.65 ppm and for non-breeders 0.29 ppm (wet weight basis). The difference in DDE levels may again be related to lipid metabolism. Breeding birds, attending the nest and fasting, could be metabolizing fat, and in the process, increasing DDE levels in blood.

Eggshell thickness

Ratcliffe (1967) was the first to use an index to eggshell thickness rather than a directly measured thickness. His thickness index equals the egg weight divided by the product of egg length and egg width. This index has gained wide acceptance as it is useful in measuring museum specimens in which a direct thickness measurement cannot be obtained. The eggshell thickness index is a good estimator of shell thickness in the western grebe. The thickness index and average thickness (as determined by six equally spaced readings around the egg waist) of 93 eggs collected at Bear River MBR were highly correlated (r^2=.7).

The average eggshell thickness index of 93 eggs collected at Bear River MBR in 1973 and 1974 is significantly smaller than the same figure for 389 pre-1940 eggs measured in museums ($F=25.6$, $p<.01$). The average and standard deviation of the index for 93 Bear River MBR eggs was 1.898 ± 0.015 and for 389 pre-1940 museum eggs, 1.989 ± 0.008. This is a decrease of 2.3 percent from pre-1940 to present. Pre-1940 eggs were used in the comparison because they represent a sample obtained before the widespread use of DDT. No difference was seen between pre-1940 eggs collected in California and Utah, and thus the two groups were pooled to make the comparisons. A small but significant decrease in eggshell thickness between pre- and post-DDT use periods is indicated.

The average eggshell thickness (direct measurement) and standard deviation of 93 eggs collected at Bear River are 0.38 ± 0.03 mm. Rudd and Herman (1972) give 0.33 mm as the average eggshell thickness of eggs

collected at Clear Lake. Eggs at Clear Lake had higher levels of contaminants than those I collected at Bear River. Rudd and Herman (1972) also took direct measurements from pre-1940 eggs and found an average thickness of 0.389 mm, a thickness 3.1 percent greater than my Bear River collections.

The small amount of eggshell thinning seen in western grebe eggshells at Bear River MBR appears to have no effect on reproduction. No crushed, cracked, or broken eggs were seen during this study. It also appears that western grebe eggs can contain a relatively high load of contaminants with only a small amount of eggshell thinning.

Multiple regression with stepwise deletion was used to test the relationship of the various contaminants to eggshell thickness and eggshell thickness index. This method quantifies the reduction in variation between actual and predicted values of each dependent variable (eggshell thickness or thickness index). The equation is of the form $\hat{Y} = b_o + b_1X_1 + b_2X_2 + \ldots b_nX_n$ where $\hat{Y}$ is the predicted value of the dependent variable (eggshell thickness or thickness index), $X_1, X_2, \ldots X_n$ are the independent variables (logarithms of the various contaminant concentrations), b_o the intercept, and $b_1, b_2, \ldots b_n$ the partial regression coefficients. In stepwise multiple regression all the independent variables are included in the model initially, then the variable which contributes the least amount to the model sum-of-squares is deleted. A new model is formed with the remaining variables and again the independent variable which contributes the least to the model sum-of-squares is deleted. This continues until there is

only one independent variable remaining. Once a variable has been deleted it will not be considered in a subsequent model.

The original model, with all contaminants included explained 45 percent of the variability in eggshell thickness index and 51 percent of the variability in eggshell thickness. In this model the contribution of DDE was significant at the a=.05 level, and the contribution of PCB 1260 at the a=.1 level. The deletion of PCB 1254 and DDD from the model did not lower the predictive power. The model containing PCB 1260 and DDE explained 50 percent of the variability in eggshell thickness and 45 percent of the variability in thickness index. The contribution of DDE in this model was significant at a=.01 and the contribution of PCB 1260 at a=.025. This model proved to be the best predictor of both eggshell thickness and thickness index. Deleting PCB 1260 from the model and forming a model with only DDE resulted in a loss of predictive power. A model with only DDE explained 37 percent of the variability in eggshell thickness and 33 percent of the variability in thickness index. The contribution of DDE was significant at a=.01. Table 14 summarizes the various models discussed.

The best multiple regression model for predicting both eggshell thickness and eggshell thickness index is the one which includes DDE and PCB 1260. Interpretation of this model can be aided by examination of the correlation coefficients (r values) which are given in Table 15. DDD is significantly negatively correlated with both eggshell parameters. Multiple regression analysis suggests, however, that DDD's relationship to eggshell thickness and index is spurious; that is a result of its correlation with DDE. Correlations between both PCB's

Table 14. Multiple regression models for predicting eggshell thickness and thickness index using contaminant concentration.

Model	Variable	F Ratio	r^2 for model
$\hat{Y}_1 = 2.15 + .10X_1 + .01X_2 - .16X_3 - .04X_4$	1*	3.1	.45
	2	<0.1	
	3**	5.7	
	4	0.3	
$\hat{Y}_1 = 2.18 = .11X_1 - .18X_3$	1**	7.3	.45
	3***	29.0	
$\hat{Y}_1 = 2.10 - .13X_3$	3***	18.9	.33
$\hat{Y}_2 = 42.89 = 1.82X_1 = .45X_2 - 3.21X_3 - .83X_4$	1*	3.8	.51
	2	0.2	
	3***	8.4	
	4	0.5	
$\hat{Y}_2 = 43.45 = 2.19X_1 - 3.58X_3$	1***	9.4	.50
	3***	35.6	
$\hat{Y}_2 = 42.02 - 2.62X_3$	3***	21.3	.37

Y_1 = predicted value of eggshell thickness index

Y_2 = predicted value of eggshell thickness

X_1 = log of PCB 1260 concentration, values <1.0 ppm counted as log 0.5

X_2 = log of PCB 1254 concentration, values <1.0 ppm counted as log 0.5

X_3 = log of DDE concentration

X_4 = log of DDD concentration

significant at *.1, **.05, ***.01

Table 15. Correlation coefficients (r) comparing contaminants concentration and eggshell parameters for western grebe at Bear River MBR, Utah.

	DDE	DDD	PCB 1254	PCB 1260
Thickness	-.60*	-.58*	-.25	-.01
Thickness Index	-.58*	-.56*	-.27	-.03

*indicates significance at a=.01

and eggshell thickness and thickness index were not significant. The contribution of PCB 1260 to a multiple regression model was, however, significant. Interpretation of the multiple regression relationship between PCB 1260 and eggshell thickness or thickness index is difficult because of this lack of correlation between PCB 1260 and either eggshell parameter. One multiple regression model was also tested in which the log of the sum of the PCB isomers was used. This model differed little from the model in which I considered the PCB's separately. No conclusion on the effect of PCB 1260 on eggshell thickness can be drawn from this analysis. The fact that PCB 1260 can explain variability in eggshell thickness and thickness index does, however, suggest that consideration should be given to a possible interaction between PCB 1260 and DDE.

DDE is the only contaminant which was both correlated with and can explain variability in eggshell thickness and eggshell thickness index. Experimental studies have shown DDE in diet can cause decrease in eggshell thickness (Porter and Wiemeyer 1969; Heath, Spann, and Kreitzer 1969; Peakall 1970; Wiemeyer and Porter 1970; and Longcore, Samson, and Wittendale 1971). Experimental studies in which birds have been subject to PCB's have not shown reductions in eggshell thickness (Tucker and Haegle 1970, Peakall 1971). These experimental results are in support of the relationship of contaminants to eggshell thinning seen in the western grebe; that is DDE is correlated with shell thinning but PCB 1260 and PCB 1254 are not.

Incubation stage appears to have no measurable effect on eggshell thickness or index. Eggs were divided into four classes according to the amount of development present and analysis of variance used to test for differences

between the incubation stages. Groups 1, 2, 3, and 4 contained 50, 19, 8, and 19 eggs respectively. No significant differences between groups was detected in either eggshell thickness or index. Rothstein (1972) and Kreitzer (1972) both reported a decline in eggshell thickness as incubation progressed. Vanderstoep and Richards (1970) also found a decrease in eggshell thickness with incubation but suggested that eggshell thickness is a much less sensitive measurement than that of deformation or eggshell crushing strength.

Clutch size and thickness index of 389 pre-1940 eggs examined in museums were compared via analysis of variance. Clutches ranged in size from one to seven eggs and groups contained 2, 8, 78, 176, 100, 18, and 7 eggs respectively. Clutch size was found to be significantly related to thickness index ($F=6.2$, $p<.05$). Figure 11 shows thickness index plotted against clutch size. No discernable pattern is present. Rothstein (1972) found eggshell thickness greater in three egg than four egg clutches in cedar waxwing (Bombycilla cedrorum). Further confounding the problem is the apparent selection of larger clutches by museum collectors. The average clutch size for museum collections was 3.9, whereas I found the average complete clutch size 2.6 for western grebe at Bear River MBR. Some of the five, six, and seven egg clutches in museum collections are probably dump nests.

Ten two-egg clutches, in which order of deposition was known, were collected. A paired difference test using students was implemented to test for differences between the first and second egg of a clutch. No significant differences in residue concentrations between first and second eggs were seen.

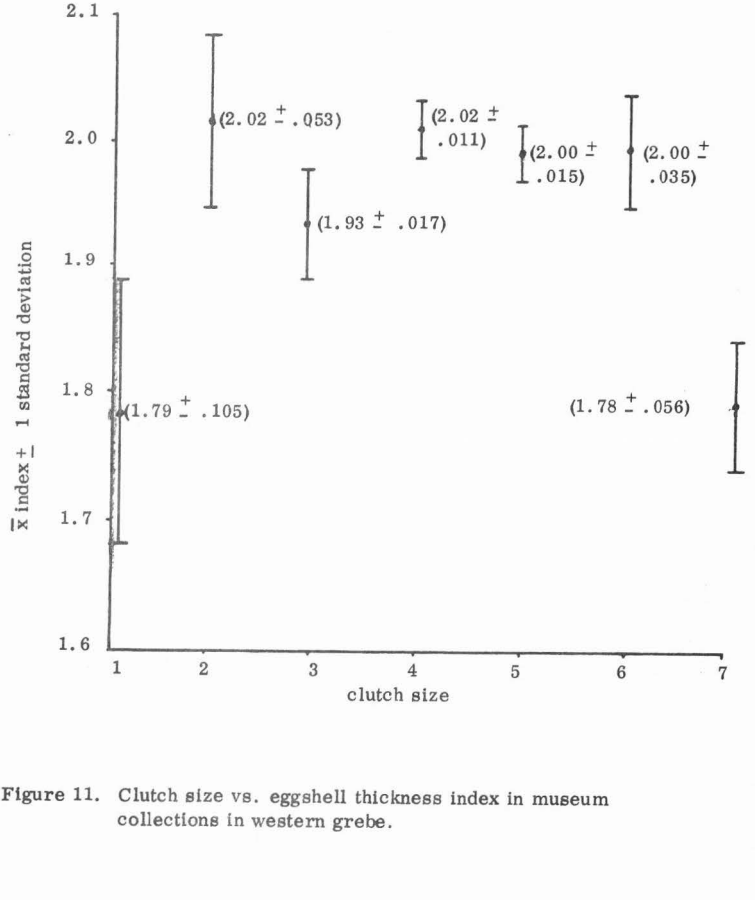


Figure 11. Clutch size vs. eggshell thickness index in museum collections in western grebe.

There was also no difference in eggshell thickness or the thickness index between the first and second eggs of a clutch. Sample size was admittedly small.

RECOMMENDATIONS AND CONCLUSIONS

1. Water level fluctuations in nesting areas should be kept at a minimum during June and July (the period of greatest nesting activity for western grebe) to prevent flooding and abandonment of nests.
2. Human disturbance in colony areas should be kept at a minimum to prevent abandonment of nests and destruction of nests by predators.
3. Any rough fish control program should consider the impact on fish-eating birds as the western grebe.
4. Pesticide and PCB analyses should be made on brain tissues of western grebe found dead at Bear River MBR to further investigate the possibility of contaminant induced mortality.
5. Contaminants, especially PCB's, should be monitored in western grebe at Bear River MBR to delineate long term trends in contamination patterns.
6. Future consideration should be given to the possibility that dark and light phase western grebe are separate species.
7. The status of major western grebe breeding grounds in Utah appears stable.
8. Western grebe at Bear River build nests in emergent vegetation, on dry land, and in open water in both colony and non-colony situations but in all cases grebes select nest sites near to open water.

9. Avian predation and water level fluctuations are the greatest causes of nest failure.

10. No differences in nest habitat variables were seen between successful nests and nests destroyed by avian predation.

11. Western grebes selectively mate with respect to color phase.

12. Chlorinated hydrocarbon concentrations in western grebe are related to the condition of the bird as determined by visceral fat content.

13. Eggshell thickness index of western grebe has decreased 2.3 percent between pre-and post-pesticide use periods.

14. DDE concentration in western grebe eggs was negatively correlated with eggshell thickness.

15. Pesticide and PCB contamination in western grebe at Bear River MBR was not linked to any reproductive failure.

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APPENDIX

Nesting for Western Grebe
Nest #_____

Location

Surrounding vegetation

Nesting materials

Distance to open water

Distance to nearest nest

Distance to land

Moving or stagnant water
depth or nearest open water

Form Utah Coop. Wildlife Research
Unit #1

Unhatched eggs collected Yes No

Other details:

Date	# Eggs	Water Depth	Condition of Nest	Condition of Eggs	Fate of Eggs

Figure 12. Nesting form used in western grebe study.

Table 16. Counts of adult and young western grebe at Bear River MBR in 1973.

Date	Adults	Young Class 1	Young Class 2	Young Class 3	Total
2 May	188	0	0	0	0
26 June	345	4	0	0	4
3 July	477	18	0	0	18
10 July	585	17	0	0	17
17 July	627	11	7	0	19
24 July	372	20	12	0	32
31 July	617	38	20	10	68
7 Aug	507	31	4	44	79
14 Aug	634	19	46	41	106
21 Aug	742	17	70	36	122
28 Aug	543	25	15	14	54
4 Sept	673	20	38	57	115
21 Sept	662	1	41	22	64
17 Oct	678	0	5	0	5
16 Nov	31	0	0	0	0

Table 17. Counts of adult and young western grebe at Bear River MBR in 1974.

Date	Adults	Young Class 1	Young Class 2	Young Class 3	Total
27 March	48	0	0	0	0
16 April	254	0	0	0	0
23 April	224	0	0	0	0
30 April	232	0	0	0	0
7 May	330	0	0	0	0
14 May	281	0	0	0	0
21 May	345	0	0	0	0
28 May	559	0	0	0	0
3 June	473	0	0	0	0
11 June	472	0	0	0	0
17 June	538	4	0	0	4
24 June	561	2	0	0	2
2 July	616	3	2	0	5
9 July	831	4	5	2	11
16 July	825	13	3	1	17
23 July	845	22	10	1	33
30 July	747	44	4	8	56
6 Aug	792	28	83	7	128
13 Aug	875	25	73	46	144
20 Aug	827	24	79	37	140
28 Aug	1142	45	49	63	157
3 Sept	1141	43	55	84	182
10 Sept	923	24	64	52	140
18 Sept	1273	12	30	38	80
1 Oct	950	0	41	97	138
15 Oct	658	0	0	35	35
7 Nov	308	0	0	0	0
21 Nov	37	0	0	0	0

Table 18. Contaminant levels in western grebe collected at Bear River MBR.

Sample type	Date and place of collection	Condition at collection	Tissue	PCB 1260	PCB 1254	DDE	DDD
western grebe	Bear River MBR,	live	bm	<1	<1	4.8	.5
adult female	Utah Unit 3		bm lip	- -	---	90	9
#1	29 August 1973		(abundant)vf	7.9	13.1	109.2	15.0
western grebe	same	live	bm	<1	<1	1.7	.1
adult female	Unit 3		bm lip	- -	- -	40	2
#2	29 August 1973		(sparse)vf	5.3	2.8	21.9	1.8
western grebe	same	live	bm	<1	<1	<.1	<.1
adult male	Unit 3		bm lip	- -	- -	- -	- -
#3	31 August 1973		(abundant)vf	1	1	.4	.4
western grebe	same	live off	(sparse)vf	52.6	25.2	110.4	8.4
adult female	nest #22	nest	bm	3.4	<1	4.7	.8
#4	19 June 1974		bm lip	61	- -	84	14
			bl	<1	1.1	1.4	.13
western grebe	same	dead	vf	none present			
adult male	Unit 4		(very slim)bm	11.5	3.8	38.7	.7
#5	12 June 1974		bm lip	1667	215	2187	40
western grebe	same	live	(sparse)vf	8.7	4.1	41.1	2.5
adult female	Unit 4		bl	<1	<1	1.3	.1
#6	2 July 1974		bm	<1	<1	2.7	.2
			bm lip	- -	- -	71	5
western grebe	same	live off	(abundant)vf	1.5	1.6	5.4	1.2
adult female		nest	bm	<1	<1	.7	.1
#7	18 July 1974		bm lip	- -	- -	11	2
			bl	ND	ND	.1	Tr
western grebe	same	live off	(sparse)vf	25.7	9.0	42.5	7.8
adult male	nest #99	nest	bm	<1	1.1	1.8	.5
#8	12 July 1974		bm lip	- -	40	66	18
			bl	<1	<1	.1	.1

Table 18. Continued.

Sample type	Date and place of collection	Condition at collection	Tissue	Residues PCB 1260	PCB 1254	DDE	DDD
western grebe	Bear River MBR,	live	(abundant)vf	21.6	20.3	34.8	3.4
adult female	Utah, Nest #57		bm	<1	2.3	2.6	.5
#9	27 June 1974		bm lip	- -	33	38	7
			bl	<1	<1	.7	.2
western grebe	same	live	vf	none present			
adult female	Unit 1		bm	1.7	1.4	7.9	.4
#10	3 June 1974		bm duplicate	1.7	1.4	7.9	.4
			bm lip	72	59	314	17
			bl	<1	<1	2.0	.2
western grebe	same	live	(sparse)vf	34.4	16.8	125.0	12.3
adult female	Unit 3		bm	1.3	1.2	3.4	.7
#11	12 June 1974		bm lip	42	38	109	22
			bl	Tr	Tr	.6	.2
western grebe	same	dead	(sparse)vf	5.8	<2	20.2	6.2
adult female	Unit 5		(slim)bm	1.5	3.1	8.0	1.3
#12	11 June 1974		bm lip	93	191	494	80
western grebe	same	dead	(sparse)vf	34.5	34.1	148.8	7.2
adult male			bm	4.0	3.2	13.4	.5
#13	31 May 1974		bm lip	62	50	207	8
western grebe	same	live	(abundant)vf	24.7	12.8	50.2	1.6
adult female			bm	1.1	2.2	3.4	.4
#14	3 December 1972		bm lip	20	41	63	7
western grebe	same	dead	vf	none present			
juvenile of	Unit 3		bm	ND	ND	.3	.2
unknown sex	14 August 1973		bm lip	- -	- -	26	17
#15							

Table 18. Continued.

Sample type	Date and place of collection	Condition at collection	Tissue	Residues PCB 1260	PCB 1254	DDE	DDD
western grebe	same	dead	vf	none present			
adult male	Unit 1		(slim)bm	1.0	1.0	5.1	.3
#16	19 June 1973		bm lip	84	84	429	25
western grebe	Bear River MBR,	dead	(sparse)vf	31.3	35.0	62.8	1.7
adult male	Utah Unit 5		(slim)bm	13.6	5.7	30.3	.2
#17	4 May 1973		bm lip	388	162	864	6
western grebe	same	dead	(sparse)vf	10.9	44.8	213.0	16.4
adult male	pond near headquarters		bm	8.6	17.0	115.2	6.0
#18	29 May 1973		bm lip	245	485	3287	171
western grebe	same	dead	(abundant)vf	2.4	3.7	15.8	2.2
adult female	outlet Unit 1		bm	<1	<1	.2	1.7
#19	3 August 1973		bm duplicate	<1	<1	.2	1.6
			bm lip	- -	- -	3	28
western grebe	same	dead	vf	none present			
adult male			(slim)bm	24.8	17.6	24.5	.6
#20	unknown		bm lip	1407	998	1390	34
western grebe	same	dead	(sparse)vf	.9	3.5	15.1	.5
adult male	Unit 1		bm	<1	<1	6.4	.3
#21	3 June 1973		bm lip	- -	- -	534	25
western grebe	same	dead	(sparse)vf	147.1	84.0	122.5	8.7
adult male	Unit 5		(slim)bm	13.1	16.5	23.8	1.9
#22	8 June 1973		bm lip	670	851	1228	98

Table 18. Continued.

Sample type	Date and place of collection	Condition at collection	Tissue	Residues PCB 1260	PCB 1254	DDE	DDD
western grebe	same	live, one	(abundant vf	4.1	4.1	17.1	1.0
adult female		of a pair	bm	<1	2.8	7.6	.5
#23	12 August 1974	with no	bm lip	- -	81	220	14
		young	bl	<1	<1	1.5	.2
western grebe	same	live, one	(abundant)vf	6.2	.6	11.6	1.3
adult female	Unit 4	of a pair	bm	<1	<1	1.1	.2
#24	12 August 1974	with no	bm lip	- -	- -	36	7
		young	bl	Tr	Tr	.2	.1

bl-blood, wet weight basis; vf=visceral fat, wet weight basis; bm=breast muscle, wet weight basis; bm lip=breast muscle, lipid basis.

Table 19. Contaminant levels in western grebe eggs collected at Bear River MBR.

Sample type	Place and date of collection	Condition at collection	Field number		Residues* PCB 1260	PCB 1254	DDE	DDD
eggs	Bear River MBR, Utah 12 July 1974	all eggs in first incubation stages	28	a	1.9	3.5	21.4	3.5
				a1	20	37	228	37
				b	2.1	2.9	20.0	3.0
				b1	29	40	275	41
				c	2.3	5.2	20.9	2.8
				c1	29	65	263	35
	same 17 July 1974		18	a	1.9	<1	2.1	.8
				a1	22	- -	24	9
				b	1.6	<1	2.0	.9
				b1	17	- -	21	10
				c	1.6	<1	2.0	.8
				c1	17	- -	21	8
	same 17 July 1974		26	a	<1	<1	1.7	1.0
				a1	- -	- -	23	13
				b	<1	<1	2.0	1.2
				b1	- -	- -	23	14
				b duplicate	<1	<1	2.3	1.1
				b1 duplicate	- -	- -	28	13
				c	<1	<1	4.0	1.3
				c1	- -	- -	51	17
				d	<1	<1	2.0	.9
				d1	- -	- -	27	12
	same 18 July 1974		27	a	<1	<1	2.0	.5
				a1	- -	- -	20	5
				b	<1	<1	1.7	.3
				b1	- -	- -	43	8
				c	<1	<1	1.9	.4
				c1	- -	---	23	5

Table 19. Continued.

Sample type	Place and date of collection	Condition at collection	Field number		Residues* PCB 1260	PCB 1254	DDE	DDD
eggs	Bear River MBR, Utah 2 July 1974	all eggs in first incubation stages	29	a	1.8	1.4	7.9	1.0
				al	20	15	87	11
				b	1.9	1.5	7.2	1.0
				bl	25	20	97	13
	same 27 June 1974		30	a	1.8	1.1	2.3	.5
				al	23	14	29	6
				b	1.8	1.3	2.6	.6
				bl	19	14	28	6
	same 19 June 1974		31	a	3.3	2.6	5.2	1.0
				al	80	63	125	24
				b	3.4	3.7	6.7	1.3
				bl	33	36	65	13
	same 12 June 1974		32	a	<1	<1	5.5	1.7
				al	- -	- -	46	14
				b	<1	<1	4.1	1.7
				bl	- -	- -	45	19
	same 3 June 1974		33	a	<1	<1	1.0	.3
				al	- -	- -	13	4
				b	<1	<1	4.0	.5
				bl	- -	- -	35	4
	same 26 July 1974		34	a	1.1	1.2	10.9	4.7
				al	12	13	120	52
				b	<1	1.3	9.8	3.8
				bl	- -	17	127	49

Table 19. Continued.

Sample type	Place and date of collection	Condition at collection	Field number		Residues* PCB 1260	PCB 1254	DDE	DDD
eggs	same		35	a	<1	<1	7.4	1.0
	1 August 1974			al	- -	- -	172	23
				b	1.0	<1	8.2	1.6
				bl	14	- -	112	22
	Bear River MBR, Utah	all eggs in first incubation stages	36	a	1.6	2.4	10.5	1.3
	6 August 1974			al	12	19	81	10
				b	1.2	<1	6.0	.5
				bl	26	- -	131	11
	same		39	a	<1	<1	1.2	.4
	11 June 1973			al	- -	- -	10	3
	same		43	a	2.3	1.9	20.9	1.7
	20 July 1973			al	16	14	149	12
				a duplicate	2.1	2.1	22.1	1.8
				al duplicate	14	14	148	12
				b	1.0	3.0	9.9	1.0
				bl	12	37	122	12
				c	1.3	2.6	19.6	2.1
				cl	9	17	128	14
				d	<1	1.6	1.9	.5
				dl	- -	30	36	9
	same		44	a	<1	1.0	3.6	1.1
	23 July 1973			al	- -	10	36	11
	same		47	a	3.9	3.2	8.1	.9
	23 July 1973			al	36	30	75	8

Table 19. Continued.

Sample type	Place and date of collection	Condition at collection	Field number		Residues* PCB 1260	PCB 1254	DDE	DDD
eggs	same		48	a	5.4	3.8	9.2	1.0
	21 August 1973			al	40	28	68	7
				b	<1	<1	2.5	.9
				bl	- -	- -	25	9
	same		49	a	<1	<1	1.5	.6
	27 July 1973			al	- -	- -	15	6
	same		46	a	<1	<1	3.5	.8
	2 July 1973			al	- -	- -	41	9
	Bear River MBR, Utah 1973	fully developed unhatched embryo	100	a	<1	<1	2.9	1.0
				al	- -	- -	34	9
	same	ova of yolk	6	a	8.6	7.3	33.7	2.5
	2 July 1974	only		al	26	22	101	8
		ova white		b	3.6	3.4	15.9	1.7
		developed		bl	24	23	107	11
	same	ova with shell	9	a	1.3	1.5	2.4	.5
	27 June 1974	started		al	21	25	39	8
		3 ova pooled,		b	6.4	6.9	9.3	1.7
		yolk only		bl	19	21	28	5

*Single letters wet weight basis, letter followed by 1 are lipid basis.

Table 20. Contaminant levels in western grebe blood collected at Bear River MBR.

Field number	Date	PCB 1260	PCB 1254	DDE	DDD
8	5 August 1974 (all)	ND	ND	.11	Tr
9		1	1	.14	.06
10		ND	ND	.2	Tr
10 duplicate		ND	ND	.18	Tr
11		ND	ND	.14	Tr
12		ND	ND	.04	ND
13		ND	ND	.06	ND
14		ND	ND	.07	Tr

Table 21. Contaminant levels in fish from Bear River MBR.

Species	Date of Collection	Size range	Contaminants			
			DDE	DDD	PCB 1260	PCB 1254
Cyprinus carpio	13 Aug 1974	7.5 - 11.5 cm	.03	ND	ND	ND
Gila atratulus	13 Aug 1974	7.5 - 11.5 cm	.02	ND	ND	ND
Ictalurus melas	5 July 1974	7.5 - 11.5 cm	.02	ND	ND	ND

ND - none detected

VITA

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Master of Science in Wildlife Science

Thesis: Breeding Biology and Pesticide-PCB Contamination of Western Grebe at Bear River Migratory Bird Refuge

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