POTENTIAL WESTERN GREBE EXTINCTION ON CALIFORNIA LAKES

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Abstract. The pisciverous western grebe (Aechmophorus occidentalis) nests in the tule marshes bordering several freshwater lakes in California. Historically, plume hunting and the draining of the vast marshes of the Central Valley caused drastic declines in western grebe populations during the 19th century. Recent hydrologic and shoreline development of inland lakes has eliminated or drastically reduced the amount of remaining breeding habitat. The current breeding status of western grebes on the Salton Sea, Sacramento Wildlife Refuge, Topaz Lake, Eagle Lake, Clear Lake, Lake Earl, and Tule Lake is reviewed. Clear Lake, Lake County, provides a unique example of direct and indirect human destruction of breeding western grebe colonies. Environmental pressures at Clear Lake are amplified by three categories of human disturbance: pesticide treatment of the lake (DDD and parathion), reduction in food supply, and loss of breeding habitat. Western grebe colonies on lakes near human population centers suffer the most amount of human disturbance and hence reproductive failure. The number of nesting western grebes in California is dangerously low; furthermore, continued declines are projected unless rigorous land use planning and management efforts are initiated.

INTRODUCTION

Historically, plume hunting and the draining of the vast marshes of the Central Valley caused drastic declines in western grebe (Aechmophorus occidentalis) populations during the 19th century. Today, western grebes nest within the remaining tule (Typhus sp. and Sciurpus sp.) marshes bordering the periphery of several freshwater lakes and artificial impoundments in California. Western grebes are highly visible black and white aquatic birds and are frequently locally abundant colonial nesters. Fall migration usually involves western grebes moving east to west from lakes with severe winter climate to the moderate maritime climate of the Pacific coast. Furthermore, it appears that some populations of resident western grebes are joined by large influxes of grebes migrating from Canada, Nevada, and Utah (Munro 1954; Herman, Garrett, and Rudd 1969; Lindvall 1975); hence, the number of western grebes in California may increase by one hundred-fold during

fall and winter, followed by a dramatic drop in population density during spring and summer. An east-west migration pattern, a few locally abundant breeding populations, and large numbers of winter migrants in California may reinforce the impression of a stable, viable breeding population of western grebes. The casual observer may conclude that western grebes exhibit a dramatic recovery from the persecution of the past century.

Population declines are easily masked under such circumstances as detailed above. The brown pelican (Pelecanus occidentalis) is a case in point (Schreiber and Delong 1969; Gress 1970). Additionally, western grebe reproductive success is significantly influenced by the physical condition of the tule marsh (Neuchterlein 1975); tule marsh habitat has rapidly disappeared in California since the 19th century. Furthermore, western grebes, like other pisciverous avian species, are potentially susceptible to breeding failure induced by pesticide contamination of their food chain (Hunt and Bischoff 1960; Herman, et al. 1969).

These concerns promoted a census of western grebe breeding colonies in California during 1976. This report summarizes the census results with comparison to historical records. Human alteration of the tule marsh is examined in a historical context to establish qualitative correlation with western grebe reproductive success. Clear Lake, Lake County, is focused upon as a unique example of direct and indirect human destruction of nesting western grebe colonies. Management goals and guidelines are then suggested based upon the historical and present evidence.

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METHODS

Several California western grebe populations were censused during the spring of 1976. Observations were made at Clear Lake, Lake County; Topaz Lake, Mono County; Eagle Lake, Lassen County; Klamath Basin National Wildlife Refuge, Siskiyou County; Sacramento Wildlife Refuge, Glenn County; and Salton Sea Wildlife Refuge, Imperial County after spring migration. Notes were taken at each location concerning natural and man-made alterations to the marsh habitat as well as human use and development of the lake. Nesting colonies were searched for when suitable habitat was found.

Observations of the western grebe colony on Clear Lake, Lake County, California were made during April and May of 1975 and June and July of 1975. Nest and clutch counts were taken in the colony and compared to similar data for 1967, 1968, 1969, and 1971. Seven addled eggs, including one complete clutch, were collected and their shells dried. Ten thickness measurements of each egg shell were taken with a "Federal 35" Bench Comparator; data are expressed as mean ± S.E. (Standard Error) thickness for each egg.

RESULTS

Western grebe censuses of California lakes are shown in Table 1. Widespread and continued decline of western grebe nesting habitat has occurred in California. Comments on some specific breeding locations are as follows:

Salton Sea Wildlife Refuge, Imperial County: Western grebes nested sporadically on the Salton Sea (Grinnell and Miller 1944). Salt marsh vegetation

grows in the refuge which would provide some nesting habitat for western grebes. High desert winds are a common occurrence, causing high waves and wind tides which have the potential of disrupting nesting. We found no western grebes in the Salton Sea National Wildlife Refuge in April 1976. Small colonies could have escaped our detection. We have several reports of observations of a young and several eggs. The absence of western grebes at this location could be caused by several factors. The location of the Salton Sea is away from traditional western grebe migration routes. However, a few wintering birds have been reported in early accounts (van Rossem 1911). Although the western grebe is well adapted to wintering in marine environments, the question of high salinity effects on reproduction has not been examined. A pioneering colony of western grebes could thus be inhibited by sub-optimal reproductive and nesting conditions as well as poor dispersion from existing colonies.

Sacramento Wildlife Refuge, Glenn County: This refuge is one of a series of waterfowl refuges in the Central Valley of California. A few western grebes attempt to nest here nearly every year. The pond that supported the western grebe colony was completely drained for repair and subsequently refilled in March 1976. We counted nine western grebes during our visit in May. No nests or young were seen. Some courtship activity was noted, i.e. six of the grebes had formed pair bonds. Subsequently, in August 1976, three western grebe nests were observed and a total of seven birds seen. All three nests were permanently submerged when the pond was flooded (J. Hammernick, personal communication). The breeding colony of western grebes at the Sacramento Wildlife Refuge represents the last known remnant of the once great Central Valley population.

Eagle Lake, Lassen County: Recent estimates of breeding densities of western grebes at Eagle Lake suggest a total population size of 3000 to 4000 birds (Gould 1974). However, aerial counts indicate that the western grebe population may be grossly over-estimated. The large size of Eagle Lake and the disjunct, inaccessible nature of much of the tule marsh continue to hamper making a thorough census.

Water levels of Eagle Lake fluctuate greatly on a yearly basis as a result of variations in seasonal runoff (Gester 1962). In recent times the maximum depth of the lake has varied from 32 m in 1917 to 22 m in 1937. The average yearly water level of the lake is currently rising due to cessation of water draw-off for irrigation. Traditional colony areas of western grebe are flooded. Some additional marsh habitat may eventually stabilize, particularly after some of the areas of the northern portion of the lake are submerged. The net effect is a loss of nesting habitat. The obvious prediction is that the western grebe population in the future will continue to decline on Eagle Lake until the water level stabilizes.

Clear Lake, Lake County: Clear Lake, with a surface area of 17670 ha, is the largest eutrophic lake in California. The lake is in the Upper Sonoran Life Zone, with the Transition Zone appearing on the highest mountains that surround the lake. Clear Lake is relatively shallow, averaging 8 m in depth, with a maximum depth of 18 m. Relatively high winds are common in the afternoons. The human inhabitants of the shoreline are supported largely through the use of the lake by tourists for fishing, boating, and waterskiing. Clear Lake is but a three hour drive from anywhere in the San Francisco-Sacramento metropolis, and the growth of the shoreline community has paralleled the growth of these cities.

Clear Lake historically was an important breeding ground for western grebes. As early as 1910 western grebes were reported as nesting on Clear Lake in "large numbers" (Finley 1911). A. H. Miller (in Hunt and Bischoff 1960) estimated a breeding population in excess of 1000 pairs on Clear Lake during the 1940's. By 1967 the breeding colony was confined to a single tule marsh named Long Tule Point. Despite extensive searches during the 1975 and 1976

Table 1. Western grebe census results for California, 1976.

	LOCATION						
	Salton Sea Wild. Ref.	Topaz Lake	Sacramento Wild. Ref.	Clear Lake	Eagle Lake	Lake Earl	Klamath Basin Wild. Ref.
Colony protection	yes	no	yes	no	no	no	yes
1976 spring population estimate	0	75	7	200	>1000[1]	50	>1100
1976 productivity (number of hatchlings)	0	?	0	0	?	10	?
Historical breeding reference	Grinnell and Miller 1944	Moffitt 1938	none	Finley 1911	Townsend 1887	none	Bailey 1902
Human use of the lake	recreation, wildlife refuge	recreation	wildlife refuge	recreation	recreation	recreation	managed wildlife refuge, i.e. irrigation sump
Degree of shoreline development	none	minimal	none	high	minimal	minimal	none
Spring water level stability	stable; high winds	stable, but dependent upon weather conditions	unstable	usually stable; high winds	stable, but gradually rising	stable	stable

[1] See text.

breeding seasons, we found no nesting areas other than at Long Tule Point.

Two hundred pairs and 49 nests of western grebes were observed on Clear Lake in 1973. One hundred pairs and 36 nests were found in 1975. Chronic low water levels prevented any nesting during 1976.

The average clutch size on Clear Lake dropped from 2.42 to 2.10 (13 percent) from 1967 to 1975. This measurement does not include empty nests since the difference between an active, empty nest and an old, abandoned nest is sometimes difficult to distinguish. Thus, the decline is a conservative estimation. Table 2 amplifies the clutch size observations by showing the frequency of clutch sizes found during different years. The shift toward smaller clutches is significant (X^2, $p<.05$). No clutches greater than three eggs were found in 1975.

Seven addled eggs were collected in 1975, including one complete clutch. The average shell thickness was 0.32 ± 0.03 mm ranging from 0.29 to 0.38. Western grebe eggs are normally 0.39 mm thick (Rudd and Herman 1973). All eggs collected, except one, were significantly thin shelled (t test, $p<.05$).

The activity of the colony was observed during 1975. Reduced tending of nests was noted compared to our observations before entering the colony, and fewer western grebes were seen throughout the colony. No evidence of "moss covering" of eggs by grebes departing the colony was noted in 1975; although this behavior was found in 1967 and 1973.

DISCUSSION

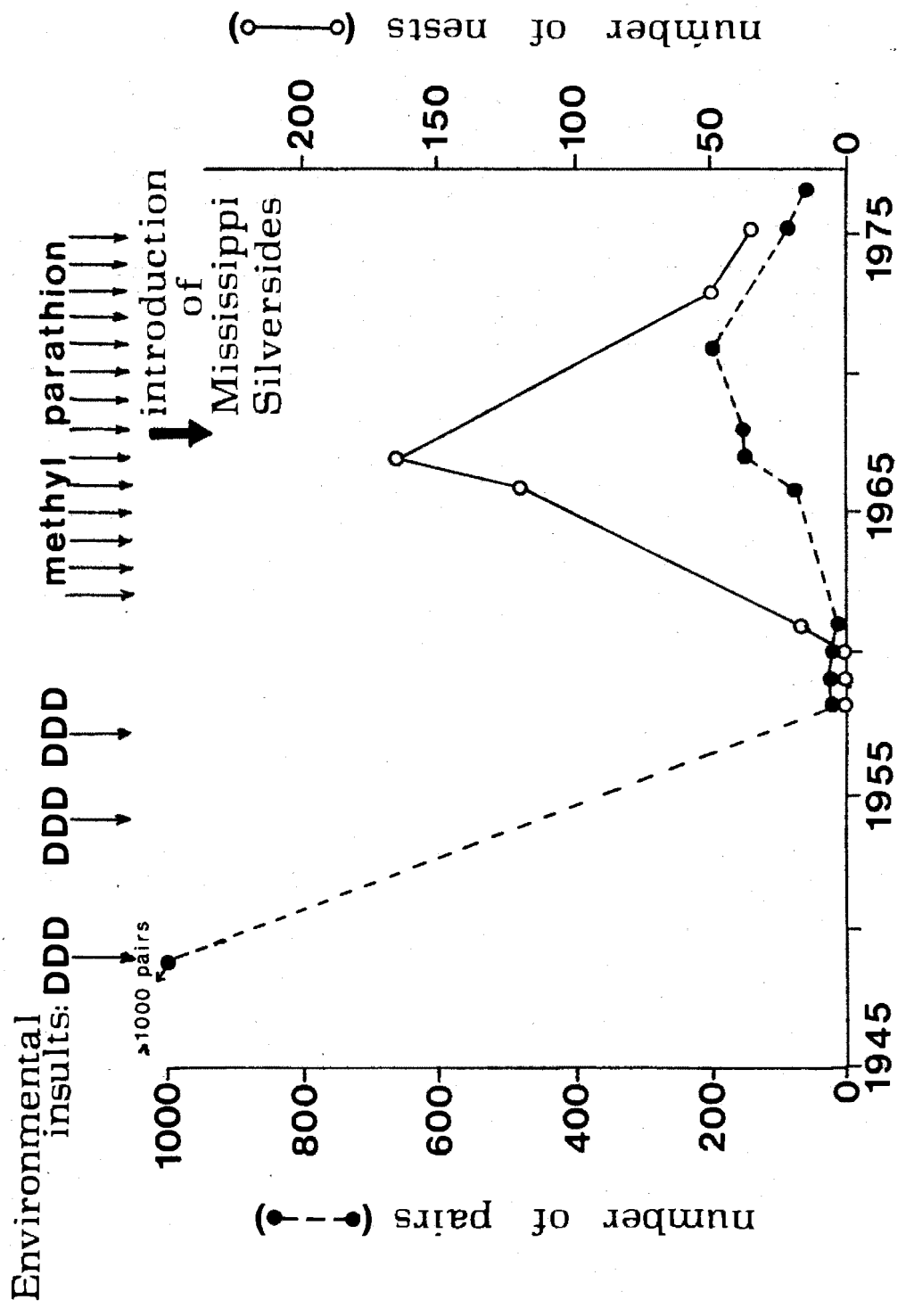
Dessication of the once extensive Central Valley marshland has been well documented (Dasmann 1966, and others). Obviously, the severe reduction in available nesting habitat has eliminated historical western grebe populations in California. After draining of the Central Valley, the distribution of western grebes in California was "limited to the larger freshwater lakes north of 35° latitude" (Grinnell and Miller 1944) by the early part of this century. Commercial development of lakeshore areas and man-made changes in lake hydrology have further restricted the distribution of western grebe colonies. Today, western grebe populations in California are found mainly on scattered wildlife refuges and those few lakes which have escaped large-scale commercial development.

Western grebe colonies are found in tule marshes having several common qualities. First, it is imperative that human disturbance of the colony is minimal. Probability of disruption of the colony is highest on those lakes with extensive commercial shoreline development and no restriction of public access to the tule marsh. The corollary to this statement is that extensive shoreline development means loss of nesting habitat for western grebes. It is not a coincidence that western grebe colonies on lakes near human population centers suffer the most amount of human disturbance and hence reproductive failure. Second, the water level of the tule marsh must be stable during the nesting season. Gradual changes in the water level over a period of years frequently result in loss of nesting habitat.

The status of the western grebe in California is poor. The remaining large colonies are all located in the northeastern corner of the state. Of those populations with greater than 50 individuals, only one out of five is protected in a refuge. The once great Central Valley population is represented by only a handful of individuals at the Sacramento Wildlife Refuge, where their nesting has been inadvertently disrupted. Continued destruction of tule marsh habitat throughout California guarantees a continued decline in nesting western grebes.

We believe that the driving force behind the imminent extirpation of the breeding western grebes on Clear Lake cannot be singly linked to one factor.

Fig. 1. Environmental insults imposed on nesting western grebes at Clear Lake, Lake Co., California.



It is a complex problem, ultimately increasing the environmental resistance to a point beyond which the western grebe cannot adjust. These environmental pressures can be divided into three categories: pesticide treatment of the lake, loss of food supply, and loss of breeding habitat.

Figure 1 summarizes the historical population observations of the western grebe on Clear Lake. The catastrophic reproductive failure of the colony and the disappearance of the breeding western grebe on the lake during the 1950's is well documented. The pesticide spraying of Clear Lake in 1949, 1954, and 1957 to control the Clear Lake gnat, Chaoborus astictophus (Diptera: Chaoboridae), (Hunt and Bischoff 1960; Herman et al. 1969) initiated extirpation of western grebes at Clear Lake. Western grebe reproductive success was absent for eleven years after application. By 1967 the western grebe had recovered somewhat, although DDD residues were still high (Herman et al. 1969). In succeeding years, however, a gradual disappearance of all reproductive characteristics occurred. 1975 evidenced the worst reproductive effort since 1961. Only a fraction of the number of nests found in 1967 were found in 1973 and 1975.

In 1962 the Lake County Mosquito Abatement District began spraying methyl parathion on the lake in a new effort to control the gnat. An average of 26,560 lbs/year of methyl parathion was applied to the lake. In 1976 the gnats became resistant to methyl parathion and were unaffected by treatment of the lake (C. Apperson, 1976, personal communication). New chemical control methods are being planned for 1977.

The watershed surrounding Clear Lake is primarily agricultural. A total of 500,000 lbs of DDT was applied to the watershed during the period 1949-1964 (Cook 1965). A fraction of this had found its way to the lake by means of the major inflowing streams (Herman et al. 1969). The federal ban on DDT usage has stopped legal application to the watershed but the amounts and effects of the substitutes are not known. Local concentrated use of insecticides still persists. A vineyard was planted on land immediately behind the colony in 1974. The owner is spraying with insecticides. The drainage from his land washes directly into a slough which empties within 50 yards from where the breeding grebes forage.

The fact that the pesticide DDD in Clear Lake remained at high levels in the "lipid pool" of the lake ecosystem for 21 years is a unique phenomenon. DDE and DDD are contained in the bottom sediments in significant amounts (Rudd and Herman 1973). The bottom of Clear Lake is soft, organic ooze, and the water level of the lake is static except during periods of high rainfall. The surrounding mountains act as a funnel for the high afternoon winds which cause mixing of the shallow water with the bottom sediment during all seasons of the year. The large, confined, and well mixed biomass of the lake evenly distributes synthetic chemicals added to the lake, rather than the dilution effect of seasonal runoff and binding of synthetic chemicals in the bottom sediment found in most lake ecosystems. It appears that DDD will persist at relatively high levels for some years to come.

Pesticidal induction of eggshell thinning, hence affecting reproduction of avian predators, is well known (Hickey and Anderson 1968; Ratcliffe 1967; Hickey 1969; and others). It appears that the physiological inhibition of reproduction due to pesticides manifests itself as thin eggshells, embryonic death, decrease in clutch size, lack of tenacity on the nest, and reproductive behavior changes. The current reproductive data presented here for the western grebe on Clear Lake strongly suggest that pesticide residues, magnified by the food chain on which the western grebe is the apex consumer, have played a contributing role in the current and continued population decline of western grebes at Clear Lake. In 1967 biological control of the Clear Lake gnat was attempted with the Mississippi silverside (Atherinidae: Menidia audens). It was subsequently shown that the silverside feeds primarily on larger zooplankton (Li, Moyle, and Garrett 1976). The silverside population increased rapidly following its introduction until it became the

most numerous vertebrate in the Clear Lake basin (Cooke and Moore 1970). Western grebes on Clear Lake feed on young centrarchids. Young centrarchids are plantivorous and are now faced with interspecific competition with the silversides for larger zooplankton. Li et al. (1976) showed that the growth rate of young centrarchids has decreased since the introduction of the silversides. The smaller size of young centrarchids implies reduced survivorship of the younger age classes due to predation by the piscivorous fishes in the lake.

At the time of the silverside introduction into Clear Lake it was thought that these fish would provide western grebes with an additional forage species. Unfortunately, this was not the case. Western grebes have not exhibited a switch in prey preference, i.e. to silversides after the apparent reduction of young centrarchids. The current decline of breeding western grebes on Clear Lake began after 1967, the same year that the silversides were introduced into the lake. The implications are that the food supply of the western grebe has been reduced due to the introduction and subsequent success of the Mississippi silversides in Clear Lake.

Destruction of emergent aquatic vegetation along the periphery of Clear Lake has followed commercial development of the shoreline. Emergent tule vegetation is required in the breeding area of the western grebe. The colony at Long Tule Point is no exception; it shifted northward as the land south of the colony was developed for a housing sub-division. Destruction of the emergent vegetation around Clear Lake has precluded the use of alternate nesting areas by the western grebes as the traditional breeding grounds were encroached upon by man. This loss of breeding habitat may be the coup de grace of the western grebe on Clear Lake.

The available evidence strongly supports the notion that breeding western grebes have experienced a rapid decline. Each environmental insult contributes to the total environmental resistance and hence lowers the reproductive capacity of the western grebe colony. The western grebe was eliminated as breeding avian species in the 1950's, yet it began a modest comeback. At this time, however, the ecological conditions are much less favorable.

Western grebe populations in California continue a slow decline which is directly related to habitat loss. Prevention of further population decline hinges on protection and wise management of available nesting habitat. The following management guidelines are suggested:

1) Refuge managers, both state and federal, should be alerted to the regional problems of western grebes. Stable water level in the tule areas of the marsh, about 30 cm deep during the months of April through July, is critical. Access to the colony areas should be restricted until nesting is completed. An abundant prey source, fish between 1 to 3 inches in size, should be a management goal. Thus, a joint management effort by both fisheries and wildlife staff is needed. Management for grebes need not be a special project. If we manage for fish and waterfowl, keeping in mind some of the basic requirements of nesting grebes, the western grebe will survive. Wildlife managers can insure the survivorship of western grebes while managing for game species.

2) All nesting areas should be protected. We applaud the recent formation of the Eagle Lake Basin Interagency Planning Group. Hopefully, positive action will be forthcoming to provide greater protection of the basin's diverse fauna. The situation at Clear Lake is more complicated. We believe that Long Tule Point and the adjacent land require protection in the form of a National Wildlife Refuge. Many species of birds use this marsh as a breeding ground. Protection from hunters, fishermen, boaters, and advancing development is critical.

3) Rational use and control of pesticide spraying is pivotal to the preservation of colonies within agricultural areas and at Clear Lake. The input of pesticides to lakes from the surrounding watersheds compounds the environmental stresses on declining populations of pisciverous birds.

4) Small, pioneering populations of western grebes exist in several areas of California. These colonies should be protected and managed to increase productivity. At Clear Lake both purchase of nesting area and adjacent land and protection of the nesting area during breeding season are urgently needed in order to preserve the nesting marshland of western grebes.

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Table 2. Western grebe clutch size distribution for different years at Clear Lake, Lake County, California.

	No. of eggs per nest						Total nests
	5	4	3	2	1	0	
No. of nests, 1967	2	13	50	34	28	38	165
No. of nests, 1973	1	4	14	9	13	8	49
No. of nests, 1975	0	0	9	4	7	16	36