WESTERN AND CLARK'S GREBE NEST PLATFORMS DESIGNED FOR FLUCTUATING WATER LEVELS

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ABSTRACT: Maintenance of stable water levels during the nesting season is critical for successful reproduction in *Aechmophorus* grebes. Western and Clark's grebes build floating nests that are vulnerable to water level fluctuations and drawdowns, which can cause nest failures. Measures to promote successful grebe reproduction may help offset declines of these birds due to habitat loss, human disturbance at breeding colonies, and environmental contaminants. During this three-year study we developed the first successful artificial grebe nest platforms designed for fluctuating water levels at an inundated, former quarry site that is now used for recreational purposes and aquifer recharge. During the summer months of the nesting season the surface elevation of the lake drops 6.1 meters. Placement of these nest platforms resulted in utilization and nest success rates of 78% and 73%, respectively. Over three years a total of 31 young were produced, resulting in a brood count ratio of 1.41 chicks per adult. Education and cooperation are needed to limit water level fluctuations during the grebe nesting period, but if this is not practical then these artificial platforms may be an appropriate alternative for enhancing grebe production, and may benefit other over-water nesting birds.

TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 45:7-16

Key words: Western and Clark's grebes, nest platforms, fluctuating water levels

Of the 22 grebe species worldwide, two have gone extinct in the past 30 years, two are on the brink of extinction, and three others are considered threatened (O'Donnel and Fjesda 1997). Both the Western (*Aechmophorus occidentalis*) and Clark's (*Aechmophorus clarkii*) grebes were considered color phases of the Western grebe from 1886 until 1985; therefore, the previous literature combined them (Storer and Neuchterlein 1992). Their habitat needs and conservation issues are essentially the same as they occupy the same breeding and wintering areas. They generally nest and forage together but do not interbreed (Storer and Neuchterlein 1992). The prevailing threats to Western and Clark's grebes are loss of habitat, particularly the conversion of shallow lakes into agricultural lands, altered wetland functions, environmental contaminants, water re-allocation, fluctuating water levels in reservoirs, and increased water-based recreation (O'Donnel and Fjesda 1997).

The Western grebe (*Aechmophorus occidentalis*) is a candidate species for listing as threatened or endangered in Washington State, and Clark's grebe (*Aechmophorus clarkii*) is a species of concern in Arizona, Montana, Idaho and Wyoming (Ivey and Herziger, 2006). In California, the Western grebe currently has a conservation priority of "high concern" resulting from water level drawdowns for power generation, which has caused major nest losses (Ivey and Herziger, 2006). Additionally, the Western grebe has appeared on every Audubon Society Blue List (species of concern) from 1973 to 1982 (Tate and Tate 1982).

Aechmophorus grebes breed colonially at large freshwater and brackish marshes, lakes and reservoirs, often bordered by emergent vegetation. Colony selection is influenced by local food constraints, shelter from wind and waves, stem density of nesting substrate, water depth, nest locations of early arrivals, and size of the breeding population (Neuchterlein 1975, Storer and Neuchterlein 1992). Nesting areas are generally isolated from disturbance with adequate open water for rearing chicks. These sites are often used in subsequent years.

Western and Clark's grebes often nest together, sometimes among eared grebes (*Podiceps nigricollis*) and other waterbird species. They build floating nests that consist of a mound of vegetation; rarely do they nest on land with the one exception of Wives Lake in southern Saskatchewan where the water level had recently receded (Nero et al. 1958). Flooded emergent vegetation or rooted submerged vegetation that reaches the water surface is needed to anchor their nests. The structure and nest-anchoring function of vegetation likely is more important than the actual plant species. For example, in the western U.S., colonies are most commonly established in hardstem bulrush (*Scirpus acutus*), but also have been documented in other emergent plants such as alkali bulrush (*S. maritimus*), cattail (*Typha* spp.), giant burreed (*Sparganium eurycarpum*), Baltic rush (*Juncus balticus*), common reed (*Phragmites australis*), reed canarygrass (*Phalaris arundinacea*), saltgrass (*Distichlis spicata*) and water smartweed (*Polygonum amphibium*) (Storer and Neuchterlein 1992, Burger 1997).

Aechmophorus grebes are monogamous with courtship occurring during spring migration and shortly after their arrival to breeding sites (Store and Neuchterlein 1992). These two species are well known for their performance of elaborate courtship displays. Breeding territories only include the immediate vicinity of nests (Palmer 1962); at Eagle Lake, the minimum distance between nests was 1.3 m and averaged 4.9 m (Gould 1974), while in 1996 and 1997 the average distance between nests was 4.1 m and 8.4 m (Shaw 1998). Among several colonies at the Delta Marsh the average distance between nests ranged from 3.4–5.0 m (Neuchterlein 1975).

Males and females participate in nest construction, which takes 1-3 days. New material is continually added to nests throughout the incubation period. In northern California, nests are initiated from mid-June to as late as mid-August (Parmelee and Parmelee, 1997). At Eagle Lake in 1996-97, some Western grebes began nesting 2-4 weeks earlier than Clark's grebes (Shaw 1998). Both sexes incubate, beginning between the laying of the first and second egg, and eggs begin hatching after 24 days (Lindvall and Low 1982). Annual productivity is variable and highly dependent on water conditions, as extreme low and high water levels can limit nesting opportunities. For example, nesting success ranged from 48-80%, and the ratio of chicks per adult in brood counts ranged from 0.53 to 0.88 in Manitoba (Storer and Neuchterlein 1992).

Reservoirs are used for power production, irrigation, public recreation and water supply. The falling water level characteristics of such man-made impoundments generally cause damage to waterfowl nests (Wolf 1955). Fluctuating water levels can have both direct and indirect effects on nesting waterbirds. Direct effects can include flooding of nests by partially or completely submerging the eggs; whereas dropping water levels can dry out grebe nests. Indirect effects may include: spilling or burying the eggs by the adults in their efforts to cope with changes in water level, toppling of nests made unstable by dropping water levels, or isolating the nests and making them inaccessible to adult birds. Fluctuating or decreasing water levels caused by water manipulation or drought can cause serious problems for grebe colonies. For example, at Bear River Migratory Bird Refuge in Utah, after water levels declined 38 cm in a three-week period, 25% of the nests were abandoned (Lindvall and Low 1982). Large colonies of grebes at Tulare Lake and Buena Vista Lake in California were lost from drainage for agriculture (Cogswell 1977). Feerer and Garrett (1977) reported that human disturbance and changes in water level during the nesting season frequently results in the loss of grebe nesting habitat at Clear Lake in Lake County, California. Dropping water levels at Newton Reservoir in Cache County, Utah left grebe and coot nests in such a position that the birds could not reach them, this resulted in nest failures (Wolf 1955). Furthermore, major nest losses were recorded as a result of water level drawdowns for power generation at Lake Almanor in California (Ivey and Herziger, 2006).

Other human factors have caused grebe mortality. Since the majority of individuals migrate east to west from lakes with severe winter climates to the moderate maritime climates of the Pacific Coast (Feerer and Garrett, 1977), they are particularly vulnerable to oil spills where thousands have perished (Smail et al., 1972, Speich and Thompson 1987, Bayer 1988). Recreational boating disturbance has been implicated in the loss of historic nesting areas in British Columbia (Burger 1997), and reduced productivity at several sites in California (Ivey 2004).

Habitat requirements for successfully breeding water birds must provide nest sites, meet their nutritional needs, and provide cover in proper configurations to avoid or reduce predation (Kadlec and Smith, 1992). Artificial nest structures can substitute for a deficiency of natural sites in otherwise suitable habitat. Nest boxes are useful for wood ducks, and various nongame species such as bluebirds, screech owls, kestrels and barn owls. Nest baskets and platforms are readily used by waterfowl. Specifically, Canada geese (*Branta canadensis*) will nest on floating artificial nest structures constructed on a canoe-like platform, which supports a nest box (Will and Crawford 1970). Nesting structures including artificial islands, straw bales, and various types of floating or elevated nest platforms have been used by a variety of wildlife including: Common loon (*Gavina immer*) (Piper et al. 2002), Canada geese, ferruginous hawks (*Buteo regalis*) and Swainson's hawks (*Buteo swainsoni*) (Schmutz et al 1988). Results by Collins et al (2002) demonstrated that Caspian terns (*Sterna caspia*) lacking alternative nesting sites can be attracted to nest on a sand-covered floating platform (barge).

Although many resident nongame waterbirds on lakes are piscivorous, their populations are rarely considered when making resource management decisions (Allen et al 2006). The absence of successful *Aechmophorus* grebe nesting at Quarry Lakes Regional Recreation Area in Fremont, California may have been a result of fluctuating water levels and/or inadequate cover. To enhance the area for grebes, it seemed that nesting structures could benefit the site, but rapidly changing water levels of .5-1 m per week made the establishment of elevated baskets or platforms impractical. Fluctuating water levels, extreme depth, and steep, sloping shoreline (>45°) eliminated the use of elevated structures. Preliminary studies on the use of floating line platforms indicated that considerable drift occurred during low and high water events as they tended to float loose (Brenner and Mondok, 1979). We report here on the development of an artificial grebe nest platform that can accommodate widely fluctuating water levels and discuss management implications for nesting grebes

STUDY AREA

Quarry Lakes Regional Recreation Area (hereafter: "Quarry Lakes") is a 182 ha park located in Fremont, California (37.34678 N Lat., 121.595460 W Long). It has three lakes sculpted from former quarry pits totaling 122 hectares. Two of the lakes offer boating, fishing, and swimming opportunities. The third lake, Lago Los Osos, is set aside for wildlife habitat, and has a surface area of 43 hectares with an average depth of 21.3 meters. Quarry Lakes is part of the East Bay Regional Park District, a two-county special district with about 38,850 ha in Alameda and Contra Costa Counties.

Western grebes (*Aechmophorus occidentalis*) have regularly established breeding colonies on the lake since the late 1990s. Many other nongame piscivorous waterbirds forage or breed at the site including Clark's grebe (*Aechmophorus clarkii*), pied-billed grebe (*Podilymbus podiceps*), common merganser (*mergus merganser*), Forster's tern (*Sterna forsteri*), double-crested cormorant (*Phalacrocorax auritus*), American white pelican (*Pelecanus erythrorhynchos*), great blue heron (*Aredea herodias*), and great egret (*Aredea alba*). Ospreys (*Pandion haliaetus*) are also commonly seen foraging on the lake.

Quarry Lakes is subject to fluctuating water levels. Alameda County Water District manages the lakes' water resources for the purpose of recharging groundwater supplies. The groundwater recharge and annual drawdown cycle was considered in the design and operation of this recreation area. The groundwater recharge cycle peaks with above-sea-level water levels of 10.6 meters elevation in the winter, 7.6 meters elevation in early summer, 4.5 meters in late summer and 1.52 meters elevation by fall. During the summer months of the nesting season the surface elevation of the lake drops on average 6.1 meters. The receding water levels provide little suitable habitat for grebe nesting along the thin fringe of willow (*salix*) and mule fat (*Baccharis viminea*) that border most of the reservoir.

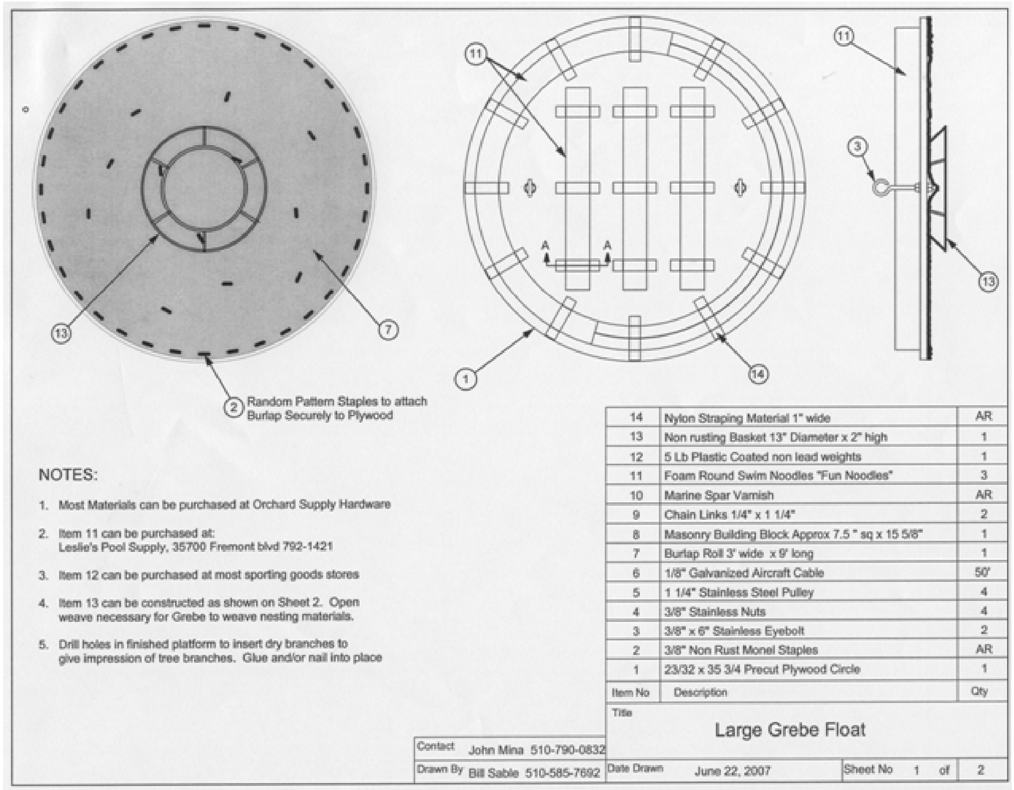
METHODS

We surveyed grebes weekly, using the same observers on Lago Los Osos from February 2006 to August 2008, by walking around the lake until all grebes present had been seen. We conducted the surveys using binoculars and a 15-60x scope during the first four hours of daylight, with the stipulation that visibility was good and that the winds were ≤ 15 km per hour. Viewing distances ranged 75-200m. This survey technique had the benefit of not being intrusive and typically required less than two hours to complete. A record was kept of all grebes observed during each visit to obtain information on number of breeding pairs, platform usage, nest and brood activity. Our survey techniques followed the methods of Dzubin (1969), which has been used to estimate populations of breeding American coots (*Fulica Americana*), pied-billed grebes (*Podilymbus podiceps*) and horned grebes (*Podiceps auritus*) (Arnold 1994).

We used the method described by Wolf (1955) to measure "nesting success" and "hatching success" defined as follows:

Nesting success = 100% minus the nests with egg failure divided by all nests, Hatching success = 100% minus the number of eggs that were not hatched divided by the total number of eggs.

The Mayfield method, which estimates nest success based on days of exposure of sampled nests, and provides statistically testable estimates that are less biased than those obtained using traditional methods (Mayfield 1961 and 1975) was not used



Item No	Description	Qty
14	Nylon Straping Material 1" wide	AR
13	Non rusting Basket 13" Diameter x 2" high	1
12	5 Lb Plastic Coated non lead weights	1
11	Foam Round Swim Noodles "Fun Noodles"	3
10	Marine Spar Varnish	AR
9	Chain Links 1/4" x 1 1/4"	2
8	Masonry Building Block Approx 7.5 " sq x 15 5/8"	1
7	Burlap Roll 3' wide x 9' long	1
6	1/8" Galvanized Aircraft Cable	50'
5	1 1/4" Stainless Steel Pulley	4
4	3/8" Stainless Nuts	4
3	3/8" x 6" Stainless Eyebolt	2
2	3/8" Non Rust Monel Staples	AR
1	23/32 x 35 3/4 Precut Plywood Circle	1

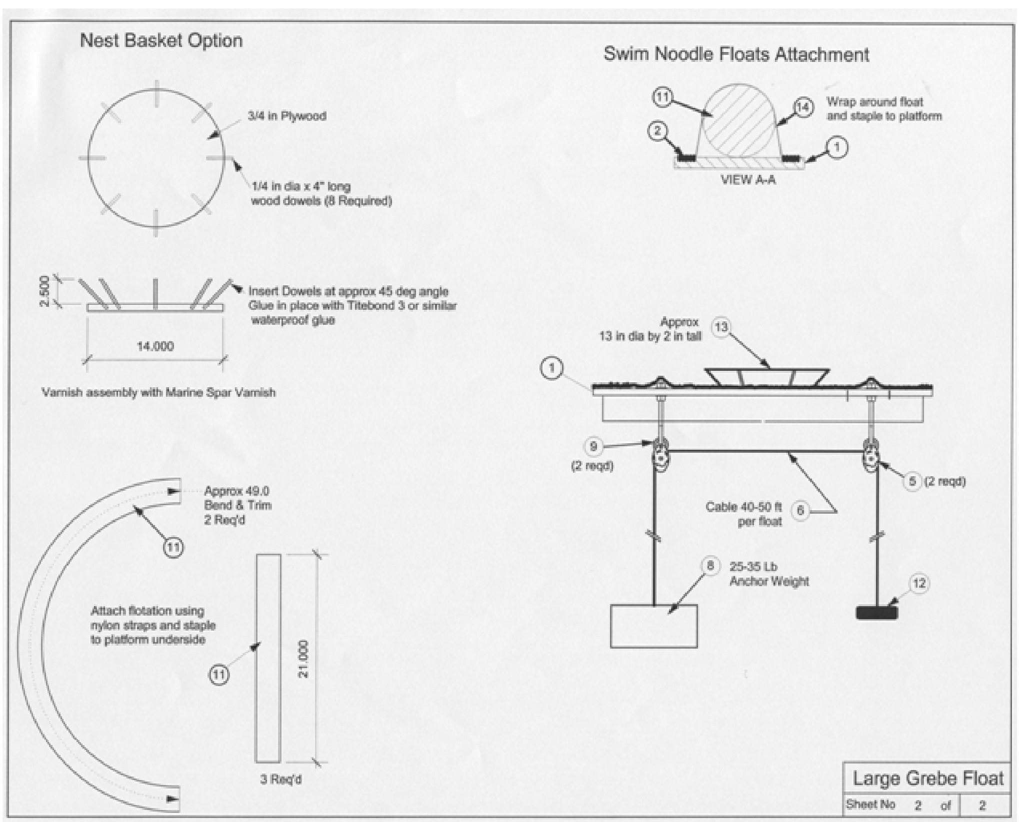


Figure 1. Specifications for constructing grebe platforms designed for fluctuating water levels.

because of inadequate sample sizes (Hensler and Nichols 1981).

The nesting platform consisted of circular 90 cm x 2 cm thick exterior grade plywood covered with a protective coat of satin varnish (Figure 1). To provide traction, a double layer of 5 mm mesh burlap fabric covered the top of the platform. Platform flotation was provided by three cylindrical 6.5 cm x 183 cm Fun noodles™ (Jakks Pacific, Malibu, California) attached to the undersurface of the platform. Shelter over the platform was provided by three arching 1.5-2.5 cm diameter limbs attached to the edge of the platform. Sticks and other natural materials were provided as nesting supplies. A counter-weight anchoring system was designed to allow for fluctuations in water levels. Two anchors, one twice the weight of the other, were attached to the platform by 3 mm galvanized aircraft cable, passed through two 4-5cm stainless steel pulleys. One anchor rested on the bottom, when the lake was maintained at its peak level. If the water level decreased, the smaller anchor would sink while the larger one remained on the lake bottom. This system enabled the raft to adjust to changing water levels. The length of the cable necessary to attach the float to the anchor and the weight of the anchor varied

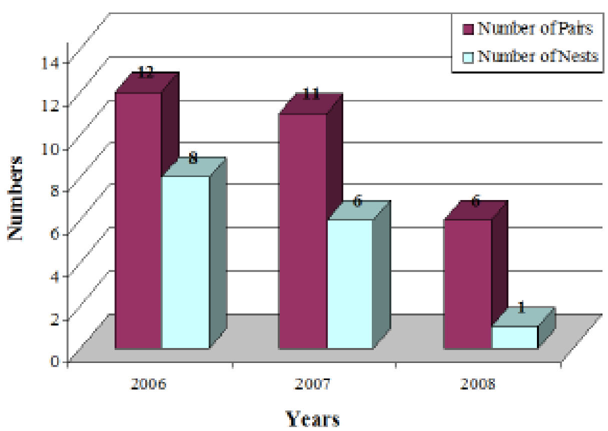


Figure 2. Aechmophorus grebe pairs and nests 2006 to 2008 at Quarry Lakes Regional Park, Fremont, California.

Figure 3. Successful Clark's and Western grebe nests on artificial floating platforms designed for fluctuating water levels.

Table 1. Use of nest platforms by Western & Clark's grebes at Quarry Lakes, Fremont, California.

Number of Platforms					Number of successful grebe nests	Number of eggs	Number of young produced	Chicks per adult ratio
Year	Available	Used by WeGr	Used by ClGr	% use				
2006	4	7_a	1	200	6	29	17	1.41
2007	5	5_b	1	120	5	20	14	1.41
2008	10	1	0	10	0	2	0	0
Total	19	13	2	78	11	51	31	1.41

a. Renesting attempts by other grebe pairs when nesting completed by first occupant.
b. Renesting attempts by other grebe pair when nesting completed by first occupant, which was a Clark's grebe.

depending on the maximum water levels attained at the lake when deploying the platforms. These nesting rafts were in place by the end of January each year.

Our floating nesting platforms were constructed at a cost of $95.00 each, which included the material repair costs required during the 3 years of operation. The platforms were removed in the fall to prevent damage and potential vandalism. See Figure 1 for the specifications for constructing the platforms.

RESULTS

Western grebes were the most abundant piscivorous grebe species on Quarry Lake's Lago Los Osos during all years. Each year large numbers of Western and Clark's grebes began arriving in mid-winter, but by June their numbers typically declined by > 75%. The number of breeding and nesting pairs of *Aechmophor*us grebes showed a general decline over the three years of study (Figure 2). The overall utilization of grebe nesting platforms was 78% (Table 1) with the number of grebes using the platforms decreasing from 200% in 2006 down to 10% in 2008. Over the three years of study, we recorded a total of 11 successful nests on these artificial floating platforms (Table 1 and Figure 3), with Western grebe pairs on two occasions attempting to reuse sites that were previously occupied by successful early nesting Clark's grebes (Table 1). We observed a total of 31 young produced on these artificial platforms with a ratio of chicks per adults in brood counts of 1.41 in 2006 and 2007 (Table 1). The overall nesting and hatching success varied between species and years but averaged 73% nesting and 60% hatching success rate for the three years of study (Table 2). The causes for nest failure ranged from nest depredation by Forster's terns (*Sterna foresteri*) in 2006 to egg dumping by other grebes in 2007 (Table 2). The nest initiation dates varied among years, with the earliest nests starting on April 14, 2006 and the latest on July 9, 2007 (Table 3). The hatch dates also varied among years with the earliest hatching date of May 14, 2006 and latest of August 20, 2007 (Table 3).

Table 3. Grebe Nest initiation and Hatch Dates at Quarry Lakes, Fremont, California.

Year	Number of nests	Nest Initiation date	Hatch date
2006	8	4/17	5/14
		4/30	6/1
		5/8	6/1
		5/8	6/1
		6/1	6/26
		6/1	6/30
		6/9	8/16 abandoned
		6/13	7/10
2007	6	5/28	6/23
		6/22	8/20
		6/29	8/3
		6/29	8/11
		7/9	7/30 social disturbance
		7/9	8/11
2008	1	6/1	7/8 abandoned

Table 2. Summary of Grebe Nest Histories at Quarry Lakes, Fremont, California.

						Causes for failure to hatch		
Year	Species	Number of nests	Average Clutch	Nest Success %	Hatching Success %	Predation %	Social Parasitism %	Unknown %
2006	WeGr	7	3.57	71	56	14[a]		14
	ClGr	1	4	100	75			
2007	WeGr	5	3.2	80	68		20[b]	
	ClGr	1	4	100	75			
2008	WeGr	1	2	0	0			100
	ClGr	0	0	0	0			
Totals	15	2.79	73	60				

a. Western grebe nest failure resulting from Forster's tern nest depredation.

b. Western grebe nest failure resulting from social disturbances of other grebes dumping eggs.

Our best estimation of a total population size for nesting Western grebes at Quarry Lake's Lago Los Osos is eight pairs, the maximum number of active nests found. Renesting is very common in most grebes (Fjeldsa 2004), and eventually eleven pairs successfully hatched young using these artificial platforms in 2006 and 2007. Our shoreline counts were designed to provide a noninvasive index of the relative abundance of nesting resident Aechmophorus grebes. The counts appeared to be capable of detecting the major nesting activities exhibited by Western and Clark's grebes during the study, but should not be considered as census data.

DISCUSSION

Historically, *Aechmophorus* grebes were more abundant and widespread, but habitat loss due to wetland drainage, development, and excessive human disturbance has reduced the number of suitable nest sites. The current global population estimates for Western grebes are 110,000 and for Clark's grebes 20,000 (Kushlan et al. 2002).

Water use as indicated by reservoir storage has increased proportionally to the increase in human population. For example, in 1927, water storage in the San Francisco Bay Area, California was 250,000 acre feet, where today it exceeds 2,000,000 acre feet (Britton et al 1974).These hydrological and shoreline developments in California's inland lakes have eliminated or drastically reduced the amount of breeding habitat for Western grebes (Feerer and Garrett, 1977).

The importance of water as a component of habitat for breeding grebes who build floating nests is obvious. In most areas, however, water levels are not static, and the timing and success of water bird reproduction sometimes depends on the time and extent of water level changes (Kadlec and Smith 1992). Moseley (1930) was one of the first to describe that dropping water levels put marsh nesting birds in danger. Nest failures related to dropping water levels were reported for eared grebe (*Podiceps nigricollis*) and American coot (*Fulica americana*) at Kesterson Reservoir, California (Ohlendorf et al. 1989). Western grebe nests were stranded due to dropping water levels at Swan Lake in Bannock County, Idaho, which resulted in nest failure because the parents were unable to reach the nest (Wolf 1955). These birds are not known for their incubating diligence, and the dampness of the vegetation upon the eggs may be essential for hatching. When the vegetation dries, the incubation process may be interrupted or even stopped (Wolf 1955). Decreasing water depths as the nesting season progresses is the key factor responsible for the high nest losses observed in waterfowl (Jobin and Picman 1997). In areas, where water fluctuations can be controlled, water level should be kept high throughout the nesting season to reduce the possibility of nesting failure due to predation (Jobin and Picman 1997). For Western grebe nesting habitat in California, Feerer and Garrett (1977) recommend that stable water levels be maintained in tule (*Sciurpus sp*) areas of the marsh, at a 30 cm depth during the months of April through July to prevent further population declines. For water impoundments where water levels necessarily fluctuate during the course of water management, our artificial floating platforms provide a key management tool for promoting successful grebe reproduction.

Western and Clark's grebes are foot-propelled, surface diving fish eaters. Fish are captured singly in the bill and may be swallowed either under water or on the surface (Neuchterlein and Buitron, 1989). For foraging, both species require semi-permanent and permanent wetlands, lakes, reservoirs, large rivers, estuaries and open ocean with an abundant supply of small fish generally < 9 cm (Lawrence 1950). A food habit study showed that a vast majority of the fish consumed were non-game species and that the impact of grebes' predation on sport fish was considered negligible (Lawrence 1950). Foraging roles of brood rearing, sexually dimorphic Western grebes have

Table 4. Inland Silverside abundance at Quarry Lakes, Fremont, California.

Year	Total Inland Silverside sampled	Catch per unit effort (# per electrofishing second)	Average length (mm)
2006	1413	0.84	46.69
2007	2021	0.96	63.09
2008	0	0	No fish

shown that the larger males fed larger fish to their young than the smaller females, showing that such behavioral flexibility by parents may be important in buffering offspring from environmental changes in food resources (Forbes and Sealy 1990). In winter, the vast majority of these birds use coastal habitats including salt and brackish bays, estuaries, and the nearshore zone (Store and Neuchterlein 1992).

Population sizes for Western and Clark's grebes at Quarry Lakes over the course of all three nesting seasons, and their nesting successes in 2006 and 2007 were likely related to the abundance of small fish, Inland silverside (*Menidia beryllina*) (Table 4). The nonnative Inland silverside feeds on zooplankton and small invertebrates found in the inshore zone and rarely grow beyond 15 cm (McGinnis 1984). Our systematic surveys showed that densities of Inland silverside and similar fishes were extremely low (x = 0 fish catch per unit effort/ shock seconds) in 2008 (Alexander and Ochikubo-Chan, 2008; East Bay Regional Park District, unpublished data). Although grebes appear well-adapted to changing levels of food abundance, even when associated with major fish kills (Allen et al. 2006), it appears that the Aechmophorus grebes at Quarry Lakes were dependant on sufficient numbers of Inland silverside for successful nesting, and the lack of these fish in 2008 may be responsible for the dismal breeding season. To prevent further population declines of Western grebes in California, one management goal recommends providing an abundant prey source of fish in the 2.5 to 8 cm size range (Feerer and Garrett, 1977).

MANAGEMENT IMPLICATIONS

To our knowledge, this is the first published account documenting successful Western and Clark's grebe nesting on platforms designed for fluctuating water levels. The results of our study suggest additional precautions should be considered when designing reservoirs. Understandably, the primary functions of such reservoirs; whether devoted to aquifer recharge, hydroelectric power, water supply, or for recreation purposes, are economically more valuable than the value of non game wildlife. When practical, the utilization of one resource should not be effected to the detriment of another.

As Herman (2002) suggests, we would do well to remember that management is a delicate thing, demanding skill and sensitivity rather than a formula. Piscivorous birds are important components of aquatic ecosystems. Natural alternatives such as water level manipulation (e.g., maintaining stable water levels through nesting season) would be preferred, but if not practical, our artificial nesting platforms may be an appropriate alternative for enhancing grebe production without compromising wildlife for other water uses.

ACKNOWEDGMENTS

We would like to express our sincere gratitude to the following people and institutions that made this work possible. The Alameda Countywide Clean Water Community Stewardship Program, Alameda County Fish and Wildlife Commission, Alameda County Water Control District, Chevron, Fremont Bank Foundation, New United Motor Manufacturing, and the Regional Parks Foundation together provided more than $50,000 in grant funds and donations to enhance wildlife habitat at Quarry Lake Regional Recreation Area. A special thanks goes to all those listed below who helped with this effort: P. Alexander, D. Bell, N. Baglietto, K. Bloom, G. Bloom, W. Bolden-Ross, R. Cameron, M. Clark, P. Dieanis, K. Goe, K. Hass, C. High, H. High, K. High, S. High, C. Kitting, I. Mena, M. Marrow, E Moon, L. Ochikubo-Chan, B. Pinomaki, R. Pinomaki, T. Pinomaki, B. Pinomaki, M. Riensche, S. Riensche , D. Riensche, N. Riensche, R. Riensche B. Sable, B. Schreuer, M. Schynert, P. Shawen, G. Still, P. Thompson, P. Thompson, S. Wiley, H. Van Austen, and P. Zierman.

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