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COMPENSATION HABITAT PROTOCOL
USFWS
FOR DRAINWATER EVAPORATION BASINS
January, 1995

INTRODUCTION

Two compensation protocols are presented here. Both protocols share a common set of general premises (labeled GP-1 to GP-8 below). The two protocols differ with regard to their risk function premises. One is based on the same eggwise risk function premises (labeled EP-1 to EP-4 below) employed in 1991 (Skorupa 1991a), and the other is based on newly available henwise risk function premises (labeled HP-1 to HP-3 below). Both protocols retain most of the conceptual criteria proposed by the U.S. Fish and Wildlife Service (Service) in 1991 (Skorupa 1991a).

The Service has developed a risk-based approach for compensation to increase accuracy, minimize monitoring costs, and provide incentive to minimize contaminant risk. Compensation protocols based primarily on dead-body counts are inadequate. Adverse impacts to wildlife caused by evaporation basins include both lethal and nonlethal impacts (e.g., Euliss et al. 1989; Barnum 1992; CH2M HILL et al. 1993; White 1993). Nonlethal impacts, by definition, cannot be accounted for by body counts. Body counts for each lifestage (embryonic, juvenile, adult) are extremely expensive to obtain and are inherently biased toward underestimating true impacts (i.e., there are numerous circumstances that result in dead bodies going uncounted, but rarely, if ever, is a dead body counted more than once). The Service prefers a risk-based approach that employs easily verified measures of wildlife exposure to contaminants and exposure-response risk functions. Given adequate risk-functions, not only are measures of exposure more reliable (i.e. less uncertain) than body counts, they are orders of magnitude less expensive to obtain.

Any compensation protocol should be based on clearly stated premises that are amenable to empirical validation and, when applicable, periodic re-evaluation. Furthermore, any compensation scheme must be realistic to implement, that is, it should optimize the certainty/cost ratio by relying on data that can be measured with high certainty and can be collected with relatively low cost. Therefore, the protocols developed here are based on measures of selenium concentrations in the eggs of recurvirostrids (stilts and avocets) and nest densities of recurvirostrids. Selenium concentrations in recurvirostrid eggs and recurvirostrid nest densities can be measured with a high degree of replicability (certainty), and usually require only a day per week during the breeding season (per study site) to obtain the necessary samples and/or data. Recurvirostrid eggs sampled at evaporation basins have generally proven to be reliable indicators of basin-specific contaminant conditions (e.g., Ohlendorf et al. 1993; Skorupa 1994), and there exists a substantial base of scientific data from both laboratory and field studies relevant to estimating risk functions (e.g., Ohlendorf et al. 1986; Heinz et al. 1987; Schroeder et al. 1988; Ohlendorf 1989; Williams et al. 1989; Heinz et al. 1989; Whiteley and Yuill 1989; Skorupa and Ohlendorf 1991; CH2M HILL et al. 1993; Ohlendorf et al. 1993).

RISK-BASED APPROACH

Our approach for compensation is based on the degree of basin contamination and the extent of wildlife exposure. Basins exposing more birds to higher concentrations of selenium require more compensation habitat and vice-versa. Presently, this generally translates into two factors being the primary determinants of compensation habitat obligations: (1) the size of a basin (all else equal, bigger basins attract more wildlife), and (2) the concentration of selenium in water discharged to a basin (as reflected in recurvirostrid eggs). As alternative habitats (see alternative habitat protocol) are established and standard design and operating procedures for evaporation basins are modified to discourage use of the basins by wildlife, these changes will translate into reduced compensation obligations through reduced exposure of wildlife.

GENERAL PREMISES (GP)

Basin Design and Operation

(GP-1) On-shore vegetation control at basins will effectively eliminate most nesting habitat for waterfowl.

One caveat applicable to premise GP-1 is that removal of on-shore vegetation at evaporation basins may have minimal impact on the number of breeding ducks that are foraging at evaporation basins because ducks are commonly known to be capable of nesting long distances (miles) away from the nearest shoreline of their foraging areas. One locally specific example of this is illustrated by the only duck nest (a gadwall nest) monitored by the Service on Kern NWR during the dry breeding season of 1989. The nest was more than 3 kilometers (ca. 2 miles) from the nearest known potential shallow water foraging area, an evaporation pond, and the concentration of selenium in a random sample egg (7.3 ppm, or about 3-4 times a normal background concentration) confirmed that the hen was probably foraging for significant amounts of time at the distant evaporation pond.

(GP-2) In-basin control of submergent aquatic vegetation (e.g., widgeon-grass) will effectively eliminate most nesting habitat for eared grebes (*Podiceps nigricollis*).

(GP-3) Removal of all islands and wave-break levees will effectively eliminate most nesting habitat for terns.

The combined implications of the above premises are a shift in species composition of breeding birds at evaporation basins to nearly complete dominance by shorebirds. Recurvirostrids would be, by far, the primary shorebird taxa of focus for compensation purposes. USFWS 1987-1989 nest records revealed that recurvirostrids comprised about 75% of all breeding birds even prior to complete implementation of the above stated premises (e.g., Skorupa et al. 1993; CH2M HILL et al. 1993). With complete implementation, recurvirostrids are expected to comprise greater than 90% of all breeding birds at evaporation basins. Thus, selenium in recurvirostrid

eggs is the most appropriate standard for assessing wildlife exposure. Accordingly, recurvirostrid exposure-response data will be preferred for estimating wildlife risks associated with the operation of evaporation basins (recurvirostrids are neither the most sensitive nor least sensitive taxa to selenium).

The focus on recurvirostrid data may not be appropriate during the nonbreeding season when waterfowl and species of shorebirds other than recurvirostrids such as sandpipers and phalaropes are more prominent (e.g., Jehl 1988; CH2M HILL et al. 1993). By default, compensation protocols must rely primarily on breeding season data due to a lack of extensive "response" data for nonbreeding birds. Consequently, compensation obligations can be met by providing breeding season habitat. Therefore, true compensation habitat obligations are necessarily underestimated. Presumably, however, the year-round alternative habitat obligations required for effective hazing and for creating a bird safe local landscape around evaporation basins will eliminate the primary risks to nonbreeding birds such as directly fatal poisoning, impaired ability to migrate, impaired ability to avoid predators, immune suppression, and various long-term demographic consequences associated with impaired body condition (e.g., adult longevity, age of first breeding, fecundity, etc.).

Predation Losses

(GP-4) The inherent viability (= hatchability) of a recurvirostrid egg is a probabilistic function of its selenium content at the time of oviposition.

Accordingly, basin operators are obligated to compensate for all selenium-caused inviability of eggs. The fact that a predator "naturally removes" an already "doomed" egg does not release a basin operator from the obligation to compensate for that egg. A chemically inviable egg's fate (and a basin operator's responsibility) has already been determined at the time of oviposition (i.e., when the egg leaves the hen's body). This is more a question of legal liability with regard to definitions of "take" than a question of biology. From a liability perspective, one must distinguish between the number of eggs chemically destroyed and the net biological impact of that destruction. Under statutes such as the Migratory Bird Treaty Act an operator assumes liability for any verifiable "take" without consideration of whether the "take" has population-level impacts or not (i.e., "take" is unconditionally prohibited).

As a matter of biology, some reviewers of the draft Compensation Habitat Protocol advocated releasing operators from compensating for chemically inviable eggs that are subsequently predated up until the normal "background level" of predation is exceeded. The primary problem with that approach is that background levels of predation depend on the quality of the nesting habitat. Recurvirostrids show a very strong attraction to islands as nesting habitat. Such preferred (high quality) nesting habitat would be associated with near-zero background predation rates under undisturbed natural conditions or artificial conditions that mimic historically pristine conditions. For example, H.T. Harvey and Associates (1995) reported for Westlake Farms' section 3 alternative habitat (which possessed continuously isolated islands throughout the breeding season) a 5% nest predation rate and Sidle and Arnold (1982) reported for an island in the Mud Lake Waterfowl Production Area of

North Dakota a 0% nest predation rate. The island they studied was thought to have supported the largest colony of breeding avocets documented in the scientific literature up to that publication date. Subsequently, if the "background level" of nest predation is established based on the good quality nesting habitat that recurvirostrids naturally seek out, the legal and biological perspectives converge on the same outcome, virtually all chemically-induced inviability of eggs should be compensated for.

(GP-5) Eggs lost to predators (or other causes of nest failure) in compensation wetlands do not provide a compensation benefit.

In the extreme case of total loss of eggs to predators in a compensation wetland, it is obvious that no compensation benefit has been provided. The relative habitat utility of compensation wetlands is devalued in direct proportion to predation losses and other sources of nest failure to yield the operational habitat utility. Not only is it important to maximize the attractiveness of compensation habitat to breeding birds (= habitat utility), it is also important to maximize the reproductive output from compensation habitat (= operational habitat utility). Thus, successful efforts to provide predator-safe nesting sites at compensation wetlands will yield higher operational habitat utility and lower compensation habitat obligations.

Relative Habitat Utility

The long-term average density of breeding birds attracted to an evaporation basin or compensation wetland is a measure of the site's attractiveness or utility as nesting habitat (i.e., the degree to which the habitat is utilized for nesting). Relative habitat utility is the attractiveness of one type of habitat, such as evaporation basins, relative to the attractiveness of another type of habitat, such as compensation wetlands. It is important to recognize the distinction between habitat utility and habitat quality. Habitat utility is established by the level of use, whereas habitat quality is established by the outcome of that use. Habitat utility is not a measure of habitat quality.

(GP-6) The primary determinants of habitat utility are predator-safe nesting sites and areas of shallow water supporting at least a threshold density of aquatic invertebrates.

Recurvirostrids exhibit a strong attraction to (predator-safe) islands or perceived islands, such as internal levees of artificial ponds, as nesting sites. Although recurvirostrids are known to utilize a wide variety of nesting substrates (Grinnell et al. 1918; Bent 1927; Johnsgaard 1981), the highest densities of nests occur on islands (e.g., Sidle and Arnold 1982; Salmon et al. 1991).

The densities of birds at saline-sink wetlands are generally believed to be food-limited in some fashion (e.g., Mono Basin Ecosystem Study Committee 1987) and the Service's Waterfowl Management Handbook recommends maintaining a density of at least 100 midge larvae per square meter to "...successfully attract and hold shorebirds." (Eldridge 1992). A study of foraging behavior among black-necked stilts (*Himantopus mexicanus*) at a manmade pond system in

Puerto Rico revealed that abundance of invertebrates was a strong determinant of where the stilts were foraging (Cullen 1994). Cullen's study seems particularly relevant because his focal species (black-necked stilt), study site (manmade salt ponds), and primary aquatic invertebrate (waterboatman) all match-up well with Tulare Basin evaporation basins.

(GP-7) On a unit basis, predominantly shallow compensation wetlands with islands will exhibit about 2.5 times the habitat utility for breeding recurvirostrids as a traditional evaporation basin without islands.

In the first season (1994) of nest monitoring at Westlake Farms' demonstration wetland, it was estimated that 2.0 avian nesting attempts per acre were supported within the intensively monitored area (Cell G; Medlin 1994). Between 1987-1993, traditional evaporation basins without islands supported 0.41 to 1.41 avian nesting attempts per acre with a median of 0.81 (N=9 cases of relatively complete nest monitoring effort in space and time; USFWS, unpubl. data; see exhibit titled, Appendix of Unpublished Data). Additional estimates of habitat utility for compensation wetlands are needed to get a good sense for how variable they might be over time and between different sites, but the first-season data from Westlake Farms' demonstration wetland and alternative wetland currently constitute the best available information. The high habitat utility achieved by Westlake Farms in 1994 appears, to some extent, to be dependent on maintaining predominantly shallow wetlands. By comparison, the Corcoran Sewage Ponds, which are physically more similar to evaporation basins (i.e., offer just a near-shore strip of shallow water) supported only 0.67 nesting attempts per acre in 1989 (Skorupa 1991a). Thus, the relative habitat utility of a predominantly shallow compensation wetland with islands is estimated at (2.0)/(0.81)=2.47 times the habitat utility of traditional evaporation basins without islands.

(GP-8) The relative habitat utility of predominantly shallow compensation wetlands is devalued by about 30% due to nest predation and other causes of nest failure.

In the first season (1994) of nest monitoring at Westlake Farms' demonstration wetland, it was estimated that about 50% of avian nesting attempts within the intensively monitored area survived to hatching (Cell G; Medlin 1994). H.T. Harvey and Associates (1995) reported a nesting success rate of 95% for recurvirostrids nesting at Westlake Farms' alternative habitat in section 3. Accordingly the average nest failure rate for these two sites was about 30%. Additional estimates of devaluation factors for the relative habitat utility of compensation wetlands are needed to get a good sense for how variable they may be over time and between different sites, but the first-season data from Westlake Farms' demonstration wetland currently constitute the best available information. Based on currently available data, an operational relative habitat utility of 0.59:1 for evaporation basins versus compensation wetlands is employed in this protocol.

Actual performance at properly designed compensation wetlands may consistently come closer to the 95% nest success observed in section 3 than to the 50% observed at Westlake Farms' section 16 demonstration wetland in 1994 because anti-predator designs, and water delivery capacity were not completed to

design specifications at section 16 in time for the 1994 breeding season. As actual performance in designing compensation wetlands up to specification on schedule is demonstrated, the predation devaluation factor will be revised. Presumably, over time, improved management techniques for maintaining predominantly shallow wetlands without compromising the predator safety of nesting sites will be developed so that in the future there will be little devaluation of relative habitat utility at compensation wetlands.

EGGWISE PREMISES (EP)

Eggwise Exposure-Response Risk Functions

(EP-1) There is an elevated probability of contaminant-mediated juvenile mortality due to immune dysfunction when eggs contain 3.9 ppm or more selenium (all selenium concentrations are presented on a dry weight basis).

A study of selenium exposure and the ability of mallard (*Anas platyrhynchos*) ducklings to survive a disease challenge (Whiteley and Yuill 1989) led to the suggestion that disease resistance may be affected more by the selenium concentration in a duckling's egg than by dietary exposure to elevated selenium after the duckling hatches. Duckling mortality following a challenge with duck hepatitis virus 1 (DHV1) was twice as high (67%, N=24 vs. 30%, N=37) among ducklings from eggs that averaged 3.9 ppm selenium than among ducklings from eggs with background concentrations of selenium (averaging 0.4 to 1.7 ppm).

(EP-2) There is an elevated probability of direct embryotoxicity, and an elevated probability of contaminant-mediated post-hatch juvenile mortality (due to depressed growth rates) when eggs contain 10 ppm or more selenium.

The logistic regression for eggs of black-necked stilts reported in Ohlendorf et al. (1986) shows that for individual eggs the threshold for embryotoxicity is about 10 ppm egg selenium (Skorupa and Ohlendorf 1991). By comparison, a population-level (geometric mean) threshold of 8 ppm egg selenium was reported by Skorupa and Ohlendorf (1991). For compensation purposes, individual-level risk functions are the most appropriate functions because they directly determine biological impacts.

Embryonic exposure to 10 ppm or more egg selenium was associated with depressed rates of growth among recurvirostrid chicks (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Early growth rates are strong predictors of juvenile survivorship in shorebirds (Cairns 1982). Contaminant-depressed growth rates can be expected to cause increased juvenile mortality.

Because the eggs in the study of recurvirostrid chicks were artificially incubated and the chicks were fed only uncontaminated food after hatching, it was demonstrated that egg selenium alone is sufficient to cause post-hatch growth depression in recurvirostrids (as was also found for mallard ducklings by Heinz et al. 1989) and therefore can serve as a direct predictor for such effects.

(EP-3) **For eggs containing 3.9 to 9.9 ppm selenium it is estimated that the average long-term probability of contaminant-mediated juvenile mortality is about 10%.**

Based on Whiteley and Yuill (1989; see EP-1 for a summary), a minimum contaminant mortality add-on of (67-30%)=37% is the assumed response to a pathogen challenge or similar "stress". It is presumed that this mortality is at least partially compensatory (i.e., compensated for in part by reduced competition and therefore density-dependent increased viability of the survivors; Hill 1988) and that stress "events" are intermittent (not occurring every year). Therefore the effect has been reduced arbitrarily by one-half, or down to 18.5%. Furthermore, it is presumed that not all chicks are exposed to pathogens, parasites, or other stresses during a stress event. Therefore the contaminant-mediated mortality has been arbitrarily reduced again to 10%. Although the resultant "10% premise" is simply an educated guess, a crude guess is still preferable to completely neglecting the empirically demonstrated immunobiological risk for chicks hatched from eggs with 3.9 ppm selenium or more. As more immunobiological research is completed, this educated guess can be revised.

(EP-4) **Between about 10 to 100 ppm egg selenium the central probability of embryotoxicity or juvenile mortality is about 30%.**

Heinz et al. (1989) experimentally demonstrated that when mallard eggs averaged about 11 ppm, 37 ppm, and 60 ppm selenium (from selenomethionine), production of 6-day-old ducklings declined by about 10%, 45%, and 100% compared to eggs that averaged less than 3 ppm selenium (background levels).

Ohlendorf et al. (1986) presented field data showing that as black-necked stilt eggs go from 10 ppm selenium to 60 ppm selenium the production of viable embryos should decline by about 35% to 70%.

In nature, the percent loss of avian production at the lower end of the 10 ppm to 60 ppm egg selenium range will be higher than suggested by the above studies because the above studies do not fully assess the risk associated with the post-hatch to recruitment phase of the reproductive cycle. For example, the Ohlendorf et al. (1986) data are for losses expected to occur between fertilization and hatch, but at Kesterson Reservoir losses occurring between hatch and recruitment were also thought to be substantial (Ohlendorf 1989; Williams et al. 1989).

Also, at evaporation basins, the upper range of egg selenium extends to about 100 ppm (excluding extreme outliers). That is substantially beyond the upper end of 60 ppm in the response curve for Kesterson Reservoir stilts (Ohlendorf et al. 1986).

In light of the studies by Heinz et al. (1989) and Ohlendorf et al. (1986), and their limitations, the "30% premise" proposed here would have to be considered a low estimate of the central probability for embryo or juvenile toxicity. An apparently low estimate was chosen intentionally because reproductive data for American avocets (*Recurvirostra americana*) indicate less sensitivity to selenium poisoning than is typically exhibited by ducks or stilts (Skorupa et. al. 1993; CH2M HILL 1994). Consequently, the "30%

premise" attempts to take that species difference into consideration. Applying a single point-estimate risk function across an order of magnitude of embryo exposure to selenium is imprecise, but is dictated by the imprecision of available eggwise exposure-response data (e.g., see the wide confidence boundaries on Ohlendorf et al.'s (1986) exposure-response curves). As more detailed eggwise exposure-response data for recurvirostrids at evaporation basins become available, this premise could be revised.

COMPENSATION COEFFICIENTS: EGGWISE BASIS

Based on general premises GP-1 to GP-8, and the eggwise risk function premises EP-1 to EP-4, compensation coefficients for each evaporation basin can be calculated using the following equation:

$$CC = HU \times [(F1 \times L1) + (F2 \times L2)]$$

where, CC = compensation coefficient = the multiple of an evaporation basin's acreage that, on average, would be required in predominantly shallow wetland acreage to replace lost production,

F1 = the weighted proportion of randomly sampled eggs at an evaporation basin containing 3.9 to 9.9 ppm selenium, where all species/year estimates are weighted equally (see example below),

F2 = the weighted proportion of randomly sampled eggs at an evaporation basin, containing 10 or more ppm selenium, where all species/year estimates are weighted equally,

L1 = proportion of production lost when egg contamination is from 3.9 to 9.9 ppm selenium (L1 = 0.10 from premise EP-3),

L2 = proportion of production lost when egg contamination is 10 ppm selenium or more (L2 = 0.30 from premise EP-4),

HU = the relative habitat utility of evaporation basins (HU = 0.59; from premises GP-7 and GP-8).

Egg selenium data for stilts and avocets, and from all years sampled at each evaporation basin, are weighted equally to derive the coefficients F1 and F2 for this first iteration of the calculations. Because there has been no compensation for historic impacts of evaporation basins, all available egg selenium data are utilized to reflect average pre-compensation conditions. As compensation calculations are updated at regular intervals, and egg selenium is systematically monitored at all evaporation basins, the calculations can be based on egg selenium data more uniformly matched to a specific compensation period.

Example Calculation of a Compensation Coefficient

If the proportions of contaminated eggs sampled from each taxa were distributed as shown below:

TAXON-YEAR	PROPORTION OF EGGS WITH 3.9 TO 9.9 PPM SELENIUM	PROPORTION OF EGGS WITH 10 PPM OR MORE SELENIUM
Stilts- Year 1	0.25	0.10
Stilts- Year 2	0.30	0.20
Avocets- Year 1	0.05	0.0
Avocets- Year 2	0.25	0.10
Avocets- Year 3	0.35	0.50

then,

$$F1 = (0.25) + (0.3) + (0.05) + (0.25) + (0.35) / 5 = 1.2/5 = 0.24$$

and,

$$F2 = (0.1) + (0.2) + (0.0) + (0.1) + (0.5) / 5 = 0.9/5 = 0.18$$

and,

$$CC = 0.59 [(0.24)(.10) + (0.18)(.30)] = 0.047$$

In this example, an area of compensation wetlands 4.7% the size of the evaporation basin would be required to compensate for estimated contaminant damage (i.e., 4.7 acres of compensation wetlands per 100 acres of evaporation basin).

Tulare Basin Compensation Coefficients: Eggwise Basis

Based on randomly sampled recurvirostrid eggs collected in 1986-1993 the following compensation coefficients have been calculated for evaporation basins in the Tulare Basin:

EVAPORATION BASIN	SAMPLE SIZE	F1	F2	COMPENSATION COEFFICIENT
Souza	--	----	----	---
Lindemann	--	----	----	---
Britz South Dos Palos	--	----	----	---
Sumner Peck	38	0.04	0.96	0.1723
Britz Davenport 5-Pts.	5	0.33	0.67	0.1381
Stone Land Company	18	0.22	0.17	0.0431
Lemoore Naval Air Station	8	0.26	0.0	0.0153
Westlake Farms North	51	0.16	0.02	0.0130
Fabry Farms	9	0.0	0.93	0.1646
Meyers Ranch	2	N/A	N/A	N/A
Barbizon Farms	--	----	----	---
TLDD North	49	0.27	0.0	0.0159
Westlake Farms South	22	0.86	0.03	0.0561
Liberty Farms	18	0.85	0.10	0.0679
Pryse Farms	71	0.57	0.25	0.0779
Bowman Farms	15	0.33	0.67	0.1381
Morris Farms	29	0.24	0.76	0.1487
Martin Farms	10	0.53	0.47	0.1145
Smith Farms	--	----	----	---
Four-J Corporation	15	0.45	0.48	0.1115
Nickell	--	----	----	---
TLDD Hacienda	34	0.70	0.27	0.0891
TLDD South	62	0.30	0.60	0.1239
Westfarmers	286	0.12	0.83	0.1540
Carmel Ranch	10	0.40	0.0	0.0236
Lost Hills Ranch	13	0.27	0.0	0.0159
Rainbow Ranch	68	0.42	0.57	0.1257
Chevron Land Company	--	----	----	---

Tulare Basin Compensation Acreage: Eggwise Basis

From the compensation coefficients listed above, the following acreages of shallow compensation wetlands would be required to balance the loss of avian production on evaporation basins:

EVAPORATION BASIN	EVAPORATION BASIN ACREAGE	COMPENSATION COEFFICIENT	COMPENSATION ACREAGE
Sousa	10	No Data	No Data
Lindemann	100	No Data	No Data
Britz South Dos Palos	50	No Data	No Data
Sumner Peck	100	0.1723	17
Britz-Davenport 5-Pts	25	0.1381	3
Stone Land Company	210	0.0431	9
Lemoore Naval Air Station	80	0.0153	1
Westlake Farms North	260	0.0130	3
Fabry Farms	7	0.1646	1
Meyers Ranch	59	Insufficient Data	Insufficient Data
Barbizon Farms	95	No Data	No Data
TLDD North	301	0.0159	5
Westlake Farms South	740	0.0561	42
Liberty Farms	(160)	0.0679	11
Pryse Farms	(40)	0.0779	3
Bowman Farms	15	0.1381	2
Morris Farms	35	0.1487	5
Martin Farms	13	0.1145	1
Smith Farms	7	No Data	No Data
Four-J Corporation	25	0.1115	3
Nickell	20	No Data	No Data
TLDD Hacienda	1026	0.0891	91
TLDD South	1832	0.1239	227
Westfarmers	542	0.1540	83
Carmel Ranch	180	0.0236	4
Lost Hills Ranch	90	0.0159	1
Rainbow Ranch	100	0.1257	13
Chevron Land Co.	65	No Data	No Data
TOTALS	**6107** (5760 sampled)	---	**525**

NOTES: Evaporation basin acreages in parentheses are for sites that routinely had less than the full system capacity flooded up during most of the study period. Other acreages are from an October, 1994, Regional Water Quality Control Board statistical compilation.

HENWISE PREMISES (HP)

Henwise Exposure-Response Risk Functions

(HP-1) For any given exposure category (egg selenium) the magnitudes of embryonic and post-hatch losses are approximately equal.

Heinz et al. (1987) found that when mallard hens were fed diets supplemented with 10 ppm selenium as selenomethionine and the ducklings they produced were fed the same diet (as would occur in nature), there was both a 47% depression in egg hatchability and a 51% depression of post-hatch juvenile survival as compared to a control group. In a follow-up study, Heinz et al. (1989) fed mallard hens diets supplemented with 1, 2, 4, 8, and 16 ppm selenium as selenomethionine, but fed a clean diet to all the ducklings those hens produced. As would be expected, the embryotoxic effects were about the same as in the 1987 study (i.e. at the 8 ppm treatment level there was a 42% depression in egg hatchability), but the depression in post-hatch juvenile survivorship was much lower (only 18%). Field studies at Kesterson Reservoir suggested that, at high levels of contamination, post-hatch losses may greatly exceed embryonic losses (Ohlendorf 1989; Williams et al. 1989). For recurvirostrids, a depression in egg hatchability on the order of 10% was reportedly associated with a 100% depression in juvenile survivorship. Birds hatched in the wild face many stresses and risks that birds hatched in captivity (such as in Heinz's studies) don't face and that can magnify the post-hatch effects of contaminant exposure. Thus, a 1:1 premise for embryonic versus post-hatch adverse effects likely underestimates total reproductive impairment.

Under the premise that embryonic and post-hatch losses follow similar response curves it is possible to estimate total reproductive losses from embryonic losses alone. For example, if the proportion of embryonic losses is represented as "p" then the proportion of embryos surviving to hatch will be 1-p. If post-hatch mortality is about equal to embryo mortality (= p), then proportional post-hatch mortality will equal $p(1-p)$ or $p-p^2$. Thus, total proportional reproductive losses will equal embryo mortality (= p) plus post-hatch mortality (= $p-p^2$), which together add up to $2p-p^2$. Because a rigorous set of embryonic exposure-response data for recurvirostrids, on a henwise basis, has been collected at evaporation basins (Ohlendorf et al. 1993; Skorupa 1994), a fairly precise henwise-based risk function can be developed.

Henwise-based compensation calculations are presented for comparison to the eggwise-based calculations. The henwise-based protocol is statistically cleaner because only hens (not eggs) are independent data points. It also utilizes more detailed exposure-response data that was actually collected from studies of recurvirostrids nesting at evaporation basins. Additionally, it precisely incorporates the substantial species differences in sensitivity to selenium between stilts and avocets. Another advantage is that henwise compensation is the most appropriate approach from a population genetics perspective. Losses attributable to a given number of genetically distinct hens are replace by an equal number of genetically distinct hens. By comparison, on an eggwise basis, 40 hens that each lost 1 egg could be compensated for by only 10 hens each producing 4 eggs. The disadvantage of the henwise approach is that you cannot compensate for a "partial hen". Any hen that is reproductively impaired, regardless of degree, is compensated for. That disadvantage, however, is counterbalanced by uncertainties regarding effects of selenium exposure on immune dysfunction, adult longevity, and age of first breeding (among other factors), all of which could impose demographic impacts on recurvirostrid populations that this compensation protocol does not take into account.

(HP-2) The long-term ratio of breeding stilts to avocets at evaporation basins is approximately 1:1.

Surveys conducted by the Service during 1987-1989 revealed an overall 1:1 ratio of breeding stilts and avocets (i.e., 2,285 stilt vs. 2,254 avocet nest

records; Skorupa et al., unpubl. data; see Appendix of Unpublished Data), although basin-specific ratios can be highly variable from year to year. Likewise, it was estimated that approximately a 1:1 ratio of stilts and avocets was attracted to Westlake Farm's demonstration wetland near Kettleman City during the 1994 breeding season (i.e., estimates of 199 stilt vs. 180 avocet nesting attempts; Medlin 1994).

(HP-3) Weighting the stilt and avocet data equally, estimates of $2p - p^2$ for exposure categories of 0-5 ppm, 5.1-20 ppm, 21-40 ppm, 41-70 ppm, and $\geq$71 ppm egg selenium are: 0.0, 0.1889, 0.2551, 0.5083, and 0.9261 respectively.

The above henwise risk function is based on 354 stilt clutches and 229 avocet clutches that survived to full-term incubation and that also had a randomly selected sample egg analyzed for selenium (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). The data were collected during 1983-1994 at Kesterson Reservoir, Volta Wildlife Management Area, Grasslands Resource Conservation District, and at evaporation basins and reference sites within the Tulare Lake Basin. Clutches were classified as impaired or normal based on whether or not they contained any fail-to-hatch eggs. Based on 141 recurvirostrid clutches with a sample egg containing 0-5 ppm selenium, the background value for p (the proportion of impaired clutches) was estimated as 0.08. By comparison, Holmes (1972) estimated that the normal proportion of impaired clutches among western sandpipers (Calidris mauri) nesting on the Yukon-Kuskokwim Delta of Alaska was 0.09. Like recurvirostrids, western sandpipers are shorebirds that normally produce four-egg clutches. Due to its remoteness, presumably, the Yukon-Kuskokwim Delta is a relatively uncontaminated environment. Thus, background p = 0.08 (and background 1-p = 0.92) was taken to represent normal reproductive performance (i.e., zero contaminant-induced reproductive depression), and all measures of reproductive depression for other egg selenium (exposure) categories were calibrated accordingly (i.e., {(calibrated p) = 1 - [(1-raw p)/(0.92)]}).

COMPENSATION COEFFICIENTS: HENWISE BASIS

Based on general premises GP-1 to GP-8, and the henwise risk function premises HP-1 to HP-3, compensation coefficients for each evaporation basin can be calculated using the following equation:

$$CC = HU \times [(F1 \times L1) + (F2 \times L2) + (F3 \times L3) + (F4 \times L4) + (F5 \times L5)]$$

where,

CC = compensation coefficient = the multiple of an evaporation basin's acreage that, on average, would be required in predominantly shallow wetland acreage to replace lost production,

F1 = the proportion of randomly sampled eggs containing 0 to 5 ppm selenium,

F2 = the proportion of randomly sampled eggs containing 5.1 to 20 ppm selenium,

F3 = the proportion of randomly sampled eggs containing 21 to 40 ppm selenium,

F4 = the proportion of randomly sampled eggs containing 41 to 70 ppm selenium,

F5 = the proportion of randomly sampled eggs containing 71 or more ppm selenium,

L1 = proportion of production lost when egg contamination is from 0 to 5 ppm selenium (L1 = 0.0 from premise HP-3),

L2 = proportion of production lost when egg contamination is from 5.1 to 20 ppm selenium (L2 = 0.1889 from premise HP-3),

L3 = proportion of production lost when egg contamination is from 21 to 40 ppm selenium (L3 = 0.2551 from premise HP-3),

L4 = proportion of production lost when egg contamination is from 41 to 70 ppm selenium (L4 = 0.5083 from premise HP-3),

L5 = proportion of production lost when egg contamination is 71 or more ppm selenium (L5 = 0.9261 from premise HP-3),

HU = the relative habitat utility for evaporation basins (HU = 0.59; from premises GP-7 and GP-8).

Tulare Basin Compensation Coefficients: Henwise Basis

Based on randomly sampled recurvirostrid eggs collected in 1986-1993 the following compensation coefficients have been calculated for evaporation basins in the Tulare Basin:

EVAPORATION BASIN	SAMPLE SIZE	F1	F2	F3	F4	F5	COMPENSATION COEFFICIENT
Souza	--	----	----	----	----	----	----
Lindemann	--	----	----	----	----	----	----
Britz South Dos Palos	--	----	----	----	----	----	----
Sumner Peck	38	----	0.21	0.16	0.34	0.29	0.3079
Britz Davenport 5-Pts.	5	----	0.80	0.20	----	----	0.1192
Stone Land Company	18	0.94	0.06	----	----	----	0.0007
Lemoore Naval Air Station	8	0.88	0.12	----	----	----	0.0134
Westlake Farms North	51	0.86	0.12	0.02	----	----	0.0164
Fabry Farms	9	0.11	0.33	0.33	0.22	----	0.1524
Meyers Ranch	--	----	----	----	----	----	----
Barbizon Farms	--	----	----	----	----	----	----
TLDD North	49	0.86	0.14	----	----	----	0.0156
Westlake Farms South	22	0.55	0.45	----	----	----	0.0502
Liberty Farms	18	0.17	0.83	----	----	----	0.0925
Pryse Farms	71	0.38	0.61	0.01	----	----	0.0695
Bowman Farms	15	0.07	0.53	0.40	----	----	0.1193
Morris Farms	29	0.03	0.55	0.28	0.14	----	0.1454
Martin Farms	10	----	0.80	0.20	----	----	0.1192
Smith Farms	--	----	----	----	----	----	----
Four-J Corporation	15	0.13	0.87	----	----	----	0.0969
Nickell	--	----	----	----	----	----	----
TLDD Hacienda	34	0.09	0.85	0.06	----	----	0.1038
TLDD South	62	0.03	0.89	0.06	0.02	----	0.1142
Westfarmers	286	0.01	0.23	0.38	0.33	0.05	0.2091
Carmel Ranch	10	0.90	0.10	----	----	----	0.0112
Lost Hills Ranch	13	1.00	----	----	----	----	0.0000
Rainbow Ranch	68	0.03	0.72	0.18	0.03	0.03	0.1328
Chevron Land Company	--	----	----	----	----	----	----

Tulare Basin Compensation Acreage: Henwise Basis

From the compensation coefficients listed above, the following acreages of shallow compensation wetlands would be required to balance the loss of avian production on evaporation basins:

EVAPORATION BASIN	EVAPORATION BASIN ACREAGE	COMPENSATION COEFFICIENT	COMPENSATION ACREAGE
Sousa	10	No Data	No Data
Lindemann	100	No Data	No Data
Britz South Dos Palos	50	No Data	No Data
Sumner Peck	100	0.3079	31
Britz-Davenport 5-Pts	25	0.1192	3
Stone Land Company	210	0.0007	0
Lemoore Naval Air Station	80	0.0134	1
Westlake Farms North	260	0.0164	4
Fabry Farms	7	0.1524	1
Meyers Ranch	59	Insufficient Data	Insufficient Data
Barbizon Farms	95	No Data	No Data
TLDD North	301	0.0156	5
Westlake Farms South	740	0.0502	37
Liberty Farms	(160)	0.0925	15
Pryse Farms	(40)	0.0695	3
Bowman Farms	15	0.1193	2
Morris Farms	35	0.1454	5
Martin Farms	13	0.1192	2
Smith Farms	7	No Data	No Data
Four-J Corporation	25	0.0969	2
Nickell	20	No Data	No Data
TLDD Hacienda	1026	0.1038	106
TLDD South	1832	0.1142	209
Westfarmers	542	0.2091	113
Carmel Ranch	180	0.0112	2
Lost Hills Ranch	90	0.00	0
Rainbow Ranch	100	0.1328	13
Chevron Land Co.	65	No Data	No Data
TOTALS	**6107** (5760 sampled)	---	**554**

NOTES: Evaporation basin acreages in parentheses are for sites that routinely had less than the full system capacity flooded up during most of the study period. Other acreages are from an October, 1994, Regional Water Quality Control Board statistical compilation.

CONCLUDING DISCUSSION

Based on best available information and empirically testable premises, it is estimated that about 550 acres of shallow nondrainwater wetlands would be needed to compensate for breeding season avian losses on about 5,760 acres of Tulare Basin evaporation basins. Overall, that's a ratio of approximately 0.10 acres compensation for every acre of evaporation pond. For the ten basins (ca. 5,000 acres) that were listed as active by the Regional Water Quality Control Board as of October, 1994, it is estimated that about 490 acres of compensation wetlands would be needed. The cumulative compensation acreage is nearly identical for eggwise versus henwise calculations, however, obligations for individual basins often differ under the two sets of calculations. The henwise risk functions are more responsive to the nonlinear increase in risk associated with increasing exposure to selenium. Consequently, the main difference between eggwise and henwise calculations is that highly contaminated evaporation basins bear a higher proportion of the total obligation for compensation under the henwise protocol. The Service, as well as most reviewers of the draft Compensation Habitat Protocol, prefer the henwise calculations because they are based on more detailed and qualitatively superior (i.e., nonlinear) response functions.

It was envisioned that the task of setting compensation obligations would be a continuous cyclic process whereby there would be an initial iteration of compensation obligations that would be in effect for a 3-year period, then any new data collected or research findings reported during the compensation cycle would be incorporated into an updated iteration of compensation obligations, which in turn would be in effect for another 3-year compensation cycle and so on. The only way to realistically implement such a process is to base the compensation protocol on data that can be measured with reasonable certainty and at low cost. Thus, this protocol relies principally on measures of egg selenium, exposure-response functions, and long-term average comparative habitat utility (which is based on nest densities and therefore is responsive to changes in absolute abundances of breeding birds) for evaporation ponds versus compensation wetlands.

Egg selenium can be measured with greater certainty and precision than any other biological variable potentially relevant to assessing compensation obligations, and therefore provides the single most appropriate and equitable foundation upon which to build a compensation protocol. The structure of the protocol built upon that foundation will change as the state of knowledge regarding exposure-response functions and comparative habitat utility change. Accordingly, research and monitoring resources can be efficiently focused on those topics.

The Service prefers the concept of long-term relative habitat utility (HU) to site-specific absolute counts of birds or nests because site-specific absolute counts vary unpredictably from year-to-year under even under relatively constant basin management and are of dubious certainty due to the myriad of potential biases in effect (for several reviews of such biases see the papers in Ralph and Scott 1981). For example, at TLDD South in June, 1990, within the same week, a standard park'n'drive count of birds conducted by two experienced observers (Todd Sloat & William Erickson, UCD Dept. Wildlife and

Fisheries Biology hazing research team) was followed by an intensive on-foot simultaneous count of snowy plovers by 19 observers deployed to achieve rapid complete coverage of the basin. The standard count yielded an estimate of 45 snowy plovers inhabiting the basin, whereas the complete coverage simultaneous count yielded an estimate of 95 snowy plovers inhabiting the basin...more than a 100% difference (Skorupa 1990). Despite the large uncertainty in the accuracy of standard park'n'drive absolute counts, the relative utility of habitats can be measured with good certainty if the biases affecting absolute counts are relatively uniform between habitats. If as envisioned by the Service, compensation habitat is concentrated at one or two regional compensation sites of well-documented and relatively constant habitat utility, then changes in HU due to changing nest densities monitored at evaporation basins will directly track absolute numbers of breeding birds.

Additionally, it is important to remember that the compensation protocols presented here do not explicitly address many potential impacts of evaporation basins on avian populations, including:

(1) Historic contaminant-induced losses not previously compensated.

Some basins were operational in the 1970's, and all basins were operational by 1985 (Westcot et al. 1988). The earliest studies (1984-1986) of environmental contamination and avian exposure to contaminants at evaporation basins revealed "potentially harmful levels" of exposure to selenium and impaired avian reproduction (Barnum and Gilmer 1988; Fujii 1988; Schroeder et al. 1988). From those earliest studies in the mid 1980's until the early 1990's avian exposure to selenium has been fairly constant (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). The first compensation wetland, however, was not established until 1994. Consequently, markedly elevated avian exposure to selenium at evaporation basins has gone completely uncompensated for a decade or more.

(2) Contaminant-induced losses not detected among birds nesting outside the normal search radius of biologists conducting nest monitoring.

Agricultural fields and other "cover" habitat within several miles of an evaporation basin could harbor nesting ducks that are foraging at evaporation basins. See discussion of this topic under premise GP-1 above for an example. Biologists monitoring avian nests at evaporation basins rarely search for nests outside the perimeter levees of the basin system. Thus, adverse effects (if any) suffered by nesting ducks or any other species of waterbirds "commuting" to an evaporation basin would not be detected or compensated.

(3) Losses due to hazing during the breeding season.

Losses due to off-road vehicle activity associated with hazing efforts have been documented at one evaporation basin for western snowy plovers (*Charadrius alexandrinus*) and for recurvirostrids (Skorupa 1991b). These losses were discovered incidentally, and adverse impacts of hazing could easily have gone undetected at other evaporation basins.

(4) Losses due to levee grading, vegetation removal and managed water level fluctuations during the breeding season.

Several incidents of levee grading during the breeding season have been documented at three evaporation basins with the resultant loss of hundreds of recurvirostrid eggs (Skorupa 1991b; Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Vegetation removal at two pond systems during the breeding season has been documented to have caused substantive (but not fully monitored) losses of waterbird eggs (Skorupa et al., pers. comm.). Managed water level fluctuations during the breeding season have also been documented to have caused losses of waterbird eggs (particularly eared grebes and black-necked stilts) at several evaporation basins (Skorupa et al., unpubl. data; see Appendix of Unpublished Data).

(5) Losses due to the use of automobile tires for levee stabilization.

The occurrence of losses of recurvirostrid chicks trapped inside automobile tires used to stabilize basin levees was documented at one evaporation basin (Skorupa et al., unpubl. photographs).

(6) Losses due to other physical barriers such as wave-induced foam, open pit blinds, and experimental shoreline netting.

Most ponds produce a ring of wave-induced foam along downwind shorelines. Foam encrustation of the down or feathers of recurvirostrid chicks has been documented to cause juvenile mortality (Marn and Anthony 1995). Several ponds retain concrete pit blinds, presumably originally intended for duck hunting, that are generally left uncovered. A variety of dead and dying wildlife and other animals have been found trapped in these blinds ranging from recurvirostrid chicks, to long-tailed weasels (*Mustela frenata*), to domestic sheep (*Ovis* spp.)(Skorupa et al., pers. obs.). Experimental shoreline netting at one evaporation basin has been documented to cause mortality of juvenile and adult shorebirds (Skorupa et al., unpubl. photographs; Barnum et al., in prep.).

(7) Losses due to contaminants other than selenium.

Although concentrations of trace elements other than selenium *in avian eggs* at evaporation basins do not exceed concentrations demonstrated to cause embryotoxicity (Ohlendorf et al. 1993), concentrations of arsenic and boron *in the food chain* at some evaporation basins are high enough to cause post-hatch adverse effects (e.g., Camardese et al. 1990; Hoffman et al. 1990). In addition, the spatial distribution of eared grebe colonies experiencing complete failure of eggs (directly bathed in drainwater) is not explained by the selenium content of the water (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Finally, in addition to a possible role in the grebe reproductive failures, the high salinity of drainwater has been documented to cause adverse effects (severe feather damage) for ruddy ducks (Euliss et al. 1989).

(8) Secondary hazards to predators of birds and their eggs.

Peregrine falcons (Falco peregrinus), northern harriers (Circus cyaneus), and burrowing owls (Athene cunicularia) have been observed preying on shorebirds at evaporation basins (Skorupa et al., pers. obs.). Gopher snakes (Pituophis catenifer), and mammalian predators have been observed preying on avian eggs at evaporation basins (Skorupa et al., pers. obs.). No studies of secondary hazards have quantified the risk that such predators are exposed to at evaporation basins. A peregrine falcon that was too weak to fly was recovered from a wheat field near an evaporation basin in 1992. A blood sample from the peregrine revealed a markedly elevated concentration of selenium as did feather samples. The peregrine quickly recovered when placed on a clean diet (consistent with selenium poisoning, but not conclusively diagnostic). A fresh cinnamon teal (Anas cyanoptera) carcass that a peregrine falcon was observed feeding from was recovered at the same evaporation basin and found to exhibit markedly elevated selenium concentrations (Detwiler 1991; White 1993; Skorupa et al., unpubl. data; see Appendix of Unpublished Data).

(9) Nonlethal impacts during the breeding season.

Lower mean body weights have been documented for breeding black-necked stilt hens collected from a medium-selenium and a high-selenium evaporation basin as compared to hens collected from a low-selenium evaporation basin (White 1993). The implications, if any, of this generally reduced body condition with regard to average adult longevity or other "fitness" parameters is unknown. Barnum (1992) notes, however, that poor body condition has been linked to lowered fitness (i.e. survival and future reproductive success) in several species of waterfowl.

(10) Lethal and nonlethal impacts occurring outside the breeding season.

There is a general lack of information on this topic. Barnum (1992) summarized available information on trends in body condition of birds wintering at evaporation ponds. He concluded that in general waterbirds wintering on evaporation ponds appeared to exhibit lower overall body condition, significantly enlarged salt glands, and elevated concentrations of breast and/or liver selenium. He further noted a general trend suggesting that increasing selenium exposure results in decreasing body condition; a trend that was statistically significant only for ruddy ducks (Oxyura jamaicensis). Based on a large program of experimental research conducted on behalf of the San Joaquin Valley Drainage Program, it was estimated that survival of wintering birds would be protected by not permitting food items to become contaminated with more than 10 ppm selenium on a dry weight basis (Heinz 1989; Patuxent Wildlife Research Center 1990). The widespread occurrence of food items with greater than 10 ppm selenium at evaporation basins (Moore et al. 1989) establishes the plausibility of substantive biological impacts outside the breeding season. As mentioned earlier, to the extent that such impacts may occur, they may also be partially or wholly alleviated by the provision of year-round alternative habitat as part of hazing and mitigation requirements.

Finally, there is a very important caveat associated with this protocol that was brought to our attention via the review comments of Ms. Carolyn Marn, a Ph.D. candidate at Oregon State University who conducted her Ph.D. research at Tulare Basin evaporation basins (for details see Ms. Marn's letter in the collection of comment letters, USFWS exhibit #10). Ms. Marn outlines mathematically several permutations of regional demographic conditions for avian populations under which our proposed Compensation Habitat Protocol would provide inadequate compensation. Since those conditions require the regional population of birds to behave as a demographically closed population, which the Service currently views as unlikely (especially for species that are not year-round territory holders), the outcomes modelled by Ms. Marn are probably not applicable (but, that has not been factually established). Nonetheless, Ms. Marn's line of reasoning does bring up the issue that if our protocol works regionally because of a demographic subsidy from outside the region, then strictly speaking there may be extra-regional demographic impacts that would constitute yet another class of impacts that this compensation protocol does not explicitly address.

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