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HISTORIC CHANGES IN MID-WINTER USE OF LAGUNA CUYUTLÁN, COLIMA, MEXICO, BY WATERFOWL

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Resumen. – Cambios históricos en el uso de Laguna Cuyutlán, Colima, México, por aves acuáticas a mediados del invierno. – Para entender los cambios en la abundancia de aves acuáticas a mediados de invierno en Laguna Cuyutlán, analizamos los datos de los Conteos de Invierno del Departamento de Pesca y Vida Silvestre de Estados Unidos. Los datos muestran una caída drástica en la abundancia de aves acuáticas en esta laguna en 1955, misma que no tuvo equivalente en otros sistemas estuarinos del sur de México. Las especies involucradas tampoco exhibieron disminuciones generales en toda su distribución. Esta disminución fue causada, con toda probabilidad, por la derivación de la mayoría del agua dulce de la cuenca hidrológica Ayuquila-Armería hacía usos humanos, principalmente agricultura, lo que causó la pérdida o deterioro de procesos ecológicos en la laguna. El papel del agua dulce en Laguna Cuyutlán se ha menospreciado tanto por investigadores como por manejadores, al tiempo que se ha apoyado la apertura de conexiones artificiales entre la laguna y el mar. Los efectos del ingreso de agua dulce, al igual que los beneficios supuestos de las conexiones con el mar, se deben de examinar mucho más detalladamente, para derivar acciones de manejo más adecuadas para la conservación o restauración de las características ecológicas de la laguna.

Abstract. – To understand changes in winter waterfowl abundance at Laguna Cuyutlán, we analyzed data from the U.S. Fish and Wildlife Service Midwinter Waterfowl Surveys. Data exhibited the plummeting of waterfowl abundance in this lagoon in 1955, which had no equivalence in other estuarine systems in southern Mexico. The species involved did not exhibit range-wide population reductions either. Most likely, this reduction was caused by man deriving the greatest part of fresh water from the Ayuquila-Armería watershed for human use, mostly agriculture, causing the loss or deterioration of ecological processes in the lagoon. The role of freshwater supply to Laguna Cuyutlán has been neglected by researchers and managers alike, while, conversely, they supported the opening of the lagoon to the sea. The effects of freshwater flow into Laguna Cuyutlán, as well as the supposed benefit of artificial connections with the sea, should be examined much more thoroughly, to provide sounder management actions for the conservation or restoration of the lagoon's ecological characteristics. *Accepted 30 January 2009*.

Keywords: Tropical Mexico, coastal lagoon, freshwater flow, waterfowl, development.

INTRODUCTION

The southern part of Mexico's Pacific coast supports less than 5% of the waterfowl wintering along the western coast of the country (Kramer & Migoya 1989). Concerning all data, no coastal lagoon in this region appears to be of importance as wintering place for waterbirds (Pérez-Arteaga *et al.* 2002). Although being modest in this context, Laguna Cuyutlán has been historically considered the most important waterfowl site along the southern Pacific Mexican coast, and was the only site mentioned among the important waterfowl sites of the mainland west coast of Mexico in appendix C of the Mexican edition of Leopold (1977) (the original, English version, published in 1959, did not include these appendices). This lagoon is the only large wetland in a span of 1150 km along the Pacific coast of Mexico. While some information on its inventory of waterbirds has been published recently (Mellink & de la Riva 2005, Mellink & Riojas-López 2005, 2006, 2008, 2009; Mellink *et al.* 2007, Palacios & Mellink 2007), local ecology as well as the hydrological dynamics of the lagoon are not well known. This lack of knowledge includes waterfowl, although some information was recently provided by Saunders & Saunders (1981).

In a 1947 winter aerial census, 177,435 ducks were counted, including 46,200 Lesser Scaups (*Aythya affinis*), 41,900 Gadwalls (*Anas strepera*), and several thousand Black-bellied Whistling Ducks (*Dendrocygna autumnalis*), and the following year (1948) there were 109,450 ducks, of which 39,500 were Scaups (*Aythya* sp., possibly Lesser Scaup), 14,750 Ruddy Ducks (*Oxyura jamaicensis*), and several thousand Black-bellied Whistling Ducks (Saunders & Saunders 1981). However, the number of ducks dropped to 14,790 ducks in 1951 and 5840 in 1955, but subsequently increased to 17,370 in 1960 and 26,850 in 1965, the later including 12,700 Lesser Scaups and 8600 Pintails (*Anas acuta*, Saunders & Saunders 1981). In January 1970, in spite of only 5500 individuals counted, Laguna Cuyutlán had the largest concentration of Lesser Scaup along the western coast of Mexico (Leopold 1977).

In contrast, between September 1996 and March 1997, Mellink & de la Riva (2005), counted almost 9000 Ruddy Ducks (*Oxyura jamaicensis*), over 4000 Blue-winged Teal (*Anas discors*), but only 122 Lesser Scaups, during eight counts in Laguna Cuyutlán and nearby wetlands. However, during January 1997, they counted only 1706 ducks in total in the region, and most of them occurred in Laguna de las Garzas, which is not part of the lagoon. These observations were shore-bound, and some waterfowl favoring deep water in the central parts of the lagoon could have been missed. Therefore, on 20–22 January 2008 we surveyed the entire lagoon to document the waterfowl present. We found only 62 Northern Shoveler (*Anas clypeata*), 6 Green-winged Teal (*Anas crecca*), and less than 20 Cinnamon Teal (*Anas cyanoptera*).

At the time of our 2008 visit, water level was very low. Rainfall in the region during 2007 had been slightly above average (1048 mm at Manzanillo), and low water level was a consequence of an artificial connection to the sea being choked and perhaps, based on observations of local inhabitants, too much water being pumped to cool the turbines of the local thermoelectric facility.

The objective of this essay has been to review and explore the causes of the variation in waterfowl numbers at Laguna Cuyutlán. Therefore we analyzed the data available both for waterfowl and the physical and biological characteristics of the lagoon, as well as the limited bibliography. We are aware that the paucity of these data produces some uncertainty in our conclusions, but at the same time feel obliged to this analysis in view of current strong pressures for the development of the lagoon.

METHODS

The most appropriate data for assessing the overall changes of Laguna Cuyutlán's waterfowl were generated by the Mid-winter Aerial Waterfowl Survey, an airborne count carried out in January, from 1947–2006, by the U.S. Fish and Wildlife Service (USFWS), with assistance of the Mexican wildlife authority. Data are available from the USFWS Division of Migratory Bird Managements web site. We used this data set as the basis for our analysis, but we removed the 1947 data as an outlier, as the counts for all the sites considered were several times larger than in all later years.

Several factors, especially differences in visibility, may cause the data obtained during these surveys to contain important, but unmeasured, amounts of error, which makes them inappropriate for the detection of small variations in abundance (Eggeman & Johnson 1989, Seber 1992, Sauer *et al.* 1994, Link & Sauer 1998). To correct for visibility errors, a number of procedures have been proposed (Pollock & Kendall 1987, Seber 1992). However, they rely on additional data having been collected at the time of the survey, data that were never gathered for coastal lagoons in southern Mexico.

Mid-winter aerial surveys are, however, useful to interpret population dynamics when they exhibit significant changes and long-term trends (Eggeman & Johnson 1989), as used in the analysis presented here. After examining the overall waterfowl abundance, we performed a regression analysis of the total waterfowl counts at Cuyutlán, Marismas Nacionales Huizache Caimanero in Nayarit and southern Sinaloa, and the wetlands of the Isthmus of Tehuantepec between 1948 and 1956, using years as independent variables.

We obtained data on rainfall and river flow from the Comisión Nacional del Agua, in Colima. Despite extensive bibliographic searches (Mellink & Riojas-López 2007, 2009; this article), we failed to find any solid long-term data on water levels and estuarine conditions, including salinity, productivity, and changes in the flora and fauna in Laguna Cuyutlán.

RESULTS

At Laguna Cuyutlán, waterfowl abundances plummeted to almost zero in 1955 (Fig. 1). Total waterfowl numbers reduced progressively, with a highly significant trend, between 1948 and 1956 (F = 17.05, P = 0.004, r^2 = 0.71). Other wetland conglomerates in southern Mexico, Marismas Nacionales-Huizache Caimanero in Nayarit and southern Sinaloa, and the wetlands of the Isthmus of Tehuantepec, although exhibiting important fluctuations in waterfowl numbers through time, did not experience such a drop (Fig. 1) and did not exhibit a significant trend in waterfowl numbers between 1948 and 1956 (F = 0.008, P = 0.15, and F = 2.57, P = 0.15, respectively). The most abundant ducks in Cuyutlán before the decline, American Green-winged Teal, Whistling-ducks (*Dendrocygna* spp.), Northern Pintail, Blue-winged/Cinnamon Teal, Northern Shoveler, American Wigeon (*Anas americana*), Gadwall, Ruddy Duck, and Lesser Scaup did not exhibit overall regional population declines along the western coast of Mexico (Fig. 2).

Rainfall patterns in the Cuyutlán region have not significantly changed during the past decades (Fig. 3). Likewise, although there have been important fluctuations in the water flow at gauge stations on the Ayuquila-Armería watershed, there is no long-term reduction or increase in this factor (Fig. 4).

DISCUSSION

There are strong variations in the data, but much of it is probably due to differences in survey effort, as derived from the number of areas reported on and suggested by the coincidental decrease in all species abundances. Reduced numbers of waterfowl in 1958–1960 and 1968–1976 are possibly a result of low survey effort rather than they reflect a real quantitative reduction. The high 1947 counts,

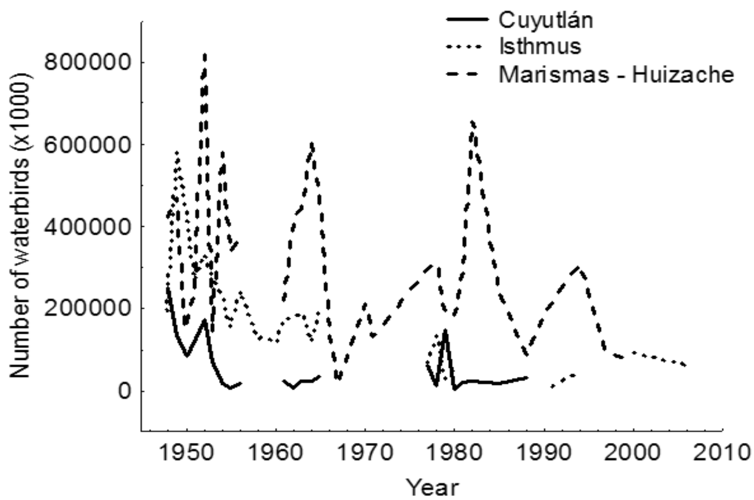

FIG. 1. Waterfowl counted during mid-winter aerial surveys at Laguna Cuyutlán (solid line), Marismas Nacionales and Huizache-Caimanero, Nayarit and Colima (dotted line), and the coastal Lagoons of the Isthmus of Tehuantepec, Oaxaca, and Chiapas (dashed line) (source: U.S. Fish and Wildlife Service Mid-winter Waterfowl Surveys).

which we did not include, could have derived from methodological problems, as it was the first survey along western Mexico, but no information exists to analyze or correct any bias.

Number and specific composition of waterfowl assemblages in Cuyutlán have been said to vary from year to year, possibly in response to water level and circulation inside the lagoon (Saunders & Saunders 1981), both of which have been severely modified by human-made structures (Mellink & Riojas-López 2007). Indeed, local fishermen indicated in 1950 that the supply of fresh water through the Río Armería influenced fish and shrimp abundance in the lagoon (Saunders & Saunders 1981).

Freshwater inflow has strong and complex ecological influences on estuarine systems (Drinkwater 1986, Day *et al.* 1989, Therriault & Levasseur 1986). In general, though, it appears to promote productivity of at least the primary members of the food chain (Kimmerer 2002, and references therein; Montagna *et al.* 2002a), with the potential for cascading effects on consumers. It has been argued that freshwater flows to the Sofala Bank, Mozambique, favor shrimp production (da Silva 1986). Also, fronts resulting from freshwater outflows into the sea can cause aggregations of food and fish larvae (Côté *et al.* 1986). River discharge has been positively associated with fishery production in the southern Gulf of Mexico (Yáñez-Arancibia *et al.* 1985), Texas (Chapman 1966), and the Upper Gulf of California (Galindo Bect *et al.* 2000).

As only Cuyutlán, but not the other coastal ecosystems in southern Mexico, experienced a waterfowl reduction, local causes are the most likely explanation. Rainfall patterns in the Cuyutlán region have not exhibited significant variation (Fig. 3); hence, diminishing rainfall can be discarded as the cause of the waterfowl reduction. The only regional-scale abiotic factor that may have changed since the 1940s is the inflow of freshwater into the lagoon. Although not

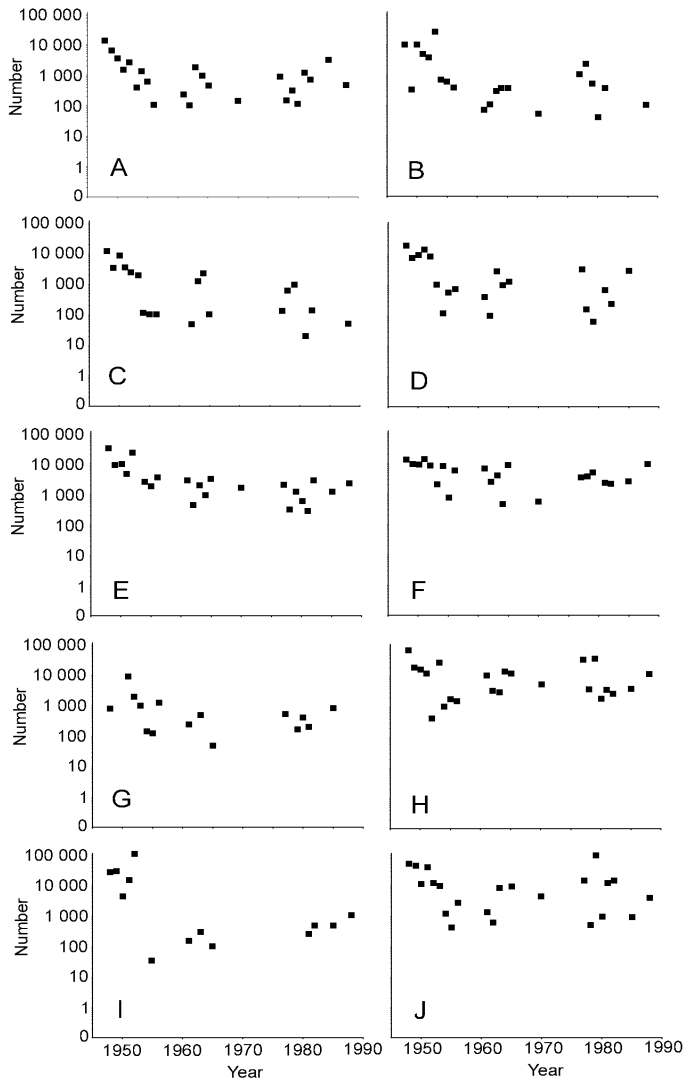

FIG. 2. Changes in the total abundance of ten selected waterfowl species along the west coast of Mexico, during mid-winter aerial surveys (source: U.S. Fish and Wildlife Service Mid-winter Waterfowl Surveys). Some variation, for example 1958-1960, is due to low survey effort; data for 1947 are not included. Y axis is scaled logarithmically (Log10). (A) Whistling-ducks; (B) Gadwall; (C) American Wigeon; (D) Blue-winged/Cinnamon Teal; (E) Northern Shoveler; (F) Northern Pintail; (G) American Green-winged Teal; (H) Lesser Scaup; (I) Ruddy Duck; and (J) American Coot.

clear at all, it seems that water from the Ayuquila-Armería watershed entered the lagoon through the Estero de Palo Verde (Mellink & Riojas-López 2009).

Water from this river system began to be diverted heavily in the late 1940s to the Valle de Tecomán, Colimas prime agricultural area. Cash crop production was introduced at that

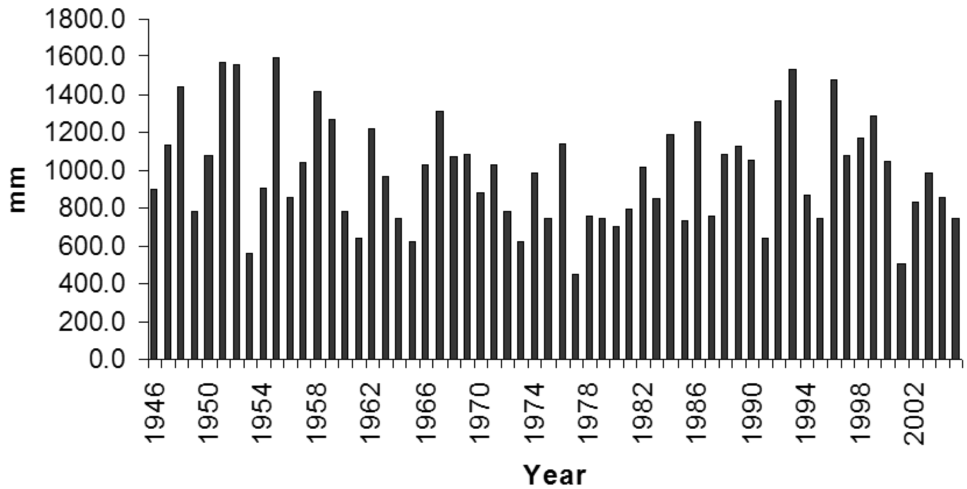

FIG. 3. Precipitation at Manzanillo, Colima, from 1946 to 2005 (source: Comisión Nacional del Agua, Colima, México).

time, and by 1950 it had received substantial funds to develop irrigation under a recently established federal program (Serrano-Álvarez 1999). One of the three most important dams on the watershed, and the first of the large storage dams on the watershed, Presa Tacotán, was built in 1951–1958. A large diverting dam, Presa Derivadora Peñitas, was finished in 1963. More building of infrastructure followed, and the system currently harbors 58 storage dams and many diverting dams (Castro-Caro 2008).

The temporal coincidence between the building of the first large dam and the demise of waterfowl cannot be overlooked. Regrettably, there is no water gauge beyond the last dam that would give an indication of the amount of water not being saved for anthropocentric uses. However, little water reaches the lower parts of the Armería river, as can be seen during any visit to the area (EM, MRL unpubl. obs.).

In other parts of the world, dams have caused severe reductions of fish by restricting freshwater flow into coastal systems (Day *et al.* 1989, George 1972). We have found no reports on the effects of inflow restrictions on waterfowl, and this issue seems scarcely addressed (e.g., the publications produced for the special session Freshwater inflow: Science, policy and management, at the 2001 biennial conference of the Estuarine Research Federation, did not mention waterfowl; Montagna *et al.* 2002b). Nevertheless, the possibility of a cascade effect makes sense, especially given the diet of most waterfowl. Saunders & Saunders (1981) guessed that most waterfowl in Laguna Cuyutlán fed on insect larvae, small mollusks, and crustaceans, and indicated also that aquatic vegetation varied as a function of fresh water flow into the system.

This connection between Laguna Cuyutlán productivity and freshwater inflow has been neglected by fishery researchers and managers (Mellink & Riojas-López 2009). Conversely, a lack of connections between the lagoon and the sea has been blamed for low fisheries production inside the lagoon (e.g., Ascencio-Borodón *et al.* 1987, Mena-Herrera 1979). Consequently, an artificial connection was built in 2000. Previous artificial connections consisted of a tunnel under the city of

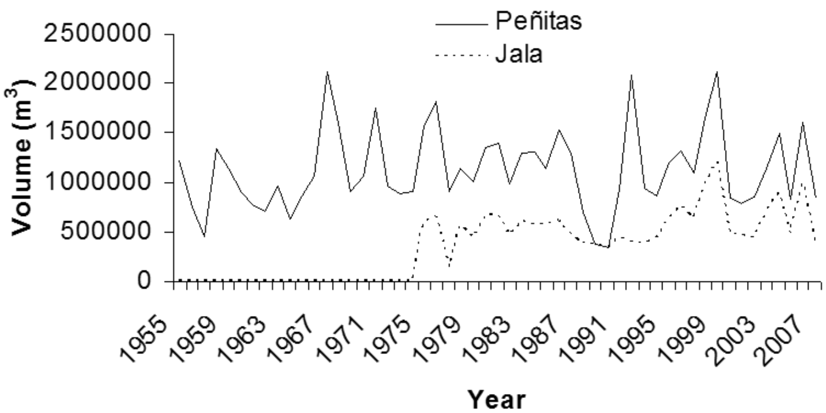

FIG. 4. Water discharge at two gauge stations along the Ayuquila-Armería system (source: Comisión Nacional del Agua, Colima, México).

Manzanillo, built in 1932, and Canal Ventanas, built in 1978, to furnish water for the cooling of the turbines of the just-built thermoelectric facility (Mellink & Riojas-López 2007).

The ecological effects of the 1932 tunnel and of Canal Ventanas are completely unknown. A few months after the opening of Canal Ventanas, in 1979, there was a small waterfowl peak in Cuyutlán, mostly of American Coot (*Fulica americana*), but the two events cannot be linked. Not only are the effects of Canal Ventanas local, given its tie to the thermoelectric plant, but American Coots are a fresh-water species, and the canal increased saltwater flow. With respect to rain, 1978 was a normal year, and both rainfall at Manzanillo (Fig. 3) and river flow at gauge stations on the Ayuquila-Armería watershed were about average (Fig. 4). However, at higher elevations rainfall could have been higher than normal, as suggested by the weather stations at Madrid and Camotlán, in an adjacent watershed, and provided some fresh water to Cuyutlán (E. Castro pers. com.).

After Canal Tepalcates was opened in 2000, fish diversity values in the immediate vicinity of the channel increased (Cabral-Solis *et al.* 2006), but nothing has been reported on the channels more lasting effects. Fishermen, however, said that the fishery did not increase (J. Aguilar-Torres pers. com.), and that a thin-shelled clam (possibly fresh-water *Anodonta* sp.) disappeared afterwards. Canal Tepalcates was built after the last mid-winter survey for which we have data. However, it seems clear that waterfowl did not experience large increases after its construction (Mellink & de la Riva 2005; our data).

In conclusion, the only satisfactory explanation behind the drastic reduction in waterfowl winter use of Laguna Cuyutlán is the reduction in freshwater flow due to its derivation from the Ayuquila-Armería watershed for human uses. This reduction indicates also the loss or deterioration of a number of ecological processes. This issue has not been addressed properly before (Mellink & Riojas-López 2009), and, without adequate study, researchers and managers have supported the construction of artificial connections that allow seawater to enter the lagoon. Such interventions could alter the environmental conditions that affect fisheries inside the lagoon and reduce the habitat quality for waterfowl and other waterbird species.

Clearly, the effects of freshwater flow into

Laguna Cuyutlán, as well as the supposed benefit of artificial connections with the sea, should be examined much more thoroughly. Although only limited information is available on this matter, the agencies involved in their collection and storage can provide useful empirical knowledge. Their participation is urgently needed in view of planned or already starting large-scale infrastructural developments (Mellink & Riojas-López 2009). Timely analysis of the impacts of freshwater might allow appropriate conservation planning in order to reduce further risks for this fragile ecosystem.

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