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Artificial Incubation of Resplendent Quetzal *(Pharomachrus mocinno)* Eggs: Egg Weight Loss, Hatch Rate, and Fledging Success

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Abstract

The scientific literature lacks information about incubation conditions, hatching and fledging success for the Resplendent Quetzal (Pharomachrus mocinno mocinno). Dr. Jesús Estudillo López, founder of "El Nido" aviary, was the first to succeed with Quetzal reproduction in captivity. The aim of this study was to develop an artificial incubation procedure for the Quetzal, which has rarely reproduced in captivity. Data regarding Quetzal eggs, artificial incubation, and diet were recorded for three years. Eggs were incubated 17-18 days at 37.2°C - 37.6°C with a relative humidity of 20% - 40%. Fisher's exact test (two-tailed, α = 0.05) was used for statistical analyses. A total of 27 Quetzal eggs (Mean weight (g)=17.3, St. Dev.=1.2) were incubated, of which 10 (~37%) hatched, with 3 (30%) fledging. Six eggs (~22%) suffered embryonic mortality during incubation, while 11 eggs were infertile (~41%). During Year (Yr)1 and Yr2, two eggs hatched annually compared to six eggs in Yr3, a noteworthy albeit non-significant difference (Yr1 vs Yr2, P=1; Yr1 vs Yr3, P=0.188; Yr2 vs Yr3, P=0.170). Egg embryonic death was also not significantly different (Yr1 vs Yr2, P=1; Yr1 vs Yr3, P=0.314; Yr2 vs Yr3, P=0.303). However, the number of infertile eggs was significantly different between Yr1 vs Yr3 (P=0.007) and Yr2 vs Yr3 (P=0.003), but not Yr1 vs Yr2 (P=1). Notably, 63% of the eggs did not produce chicks, which may be due to the level of consanguinity. The results of this study provide a foundation for incubating Quetzal eggs which could benefit conservation efforts.

Keywords: *Egg Weight Loss, Fledging, Hatch, Incubation, Resplendent Quetzal (Pharomachrus mocinno mocinno)*

1. INTRODUCTION

The Resplendent Quetzal (*Pharomachrus mocinno mocinno*) belongs to the family Trogonidae. The members of this family of birds have a pantropical distribution, and as such are found in tropical and subtropical forests of the African, Asian and American continents. All of the members of this family are derived from a single ancestral line that originated in the Miocene in the areas of Africa, Europe, Asia and the Americas, the latter being the second site of species diversification (Espinosa de los Monteros, 1998) and for this reason it is considered that this family is a monophyletic group (Sibley and Monroe,1990).

There are 39 species of Trogons and Quetzals of which 9 are found distributed in Mexican territory. However, for diverse reasons such as the commercial and illegal trafficking of the species, and the destruction of natural zones, five species are placed under protection of the law NOM-059-ECOL-1994 (Espinosa de los Monteros, 1998).

The Resplendent Quetzal is a bird that presents sexual dimorphic markings based on the coloration of its feathers. Both sexes have a green coloration with a characterisitic irridescence and delicate feet of a

grayish color, with a beak having a brilliant yellow color. A notable aspect is that the male has dorsal feathers of the tail or supracaudals that can measure from 40 to more than 100 cm in length, feathers of the chest are of an intense red color, as is the base of the tail. The females have a brown-grayish coloration on the head and the ventral part of the body, the beak is of grayish-black color and the tail is short, the ventral part having dark transverse bars over a clear base.

It has been established that two subespecies of Quetzal exist. *Pharomachrus mocinno mocinno* also known as the Northern Quetzal or Mesoamerican Quetzal has a distribution from the southeast of Mexico to Nicaragua (Sibley and Monroe, 1990), this subspecies being the largest and most striking of the two. *Pharomachrus mocinno costaricensis* also known as the southern Quetzal, with its distribution in Costa Rica and Panama (Sibley and Monroe, 1990); is smaller and less striking than the other sub-species.

The reproductive habitat of the Quetzal is found in the tropical seasonal and cloud forests that are found at an altitude of 1600 to 3400 meters above sea level. The quetzal is a monogamous species, with reproduction occuring during the months of January and Februrary. Once a Quetzal pair forms, the reproductive behavior begins with mountings or copulations. Afterwards, they nest and usually incubate a couple of eggs which are of sky blue color. The incubation period takes place during the months of February, March, April and occasionally extending into May. The nests are built inside of hollows previously made by other birds or in odd forms in the trees. Afterwards, the raising of the chicks takes place during the months of March to June, with both parents participating.

After reproduction has finished, the Quetzals begin the migration toward the lower altitude ecosystems, between 1100 and 1400 meters above sea level. The migration phenomenon occurs towards the temperate forests of pine, oak, redgum, riparian vegetation, among others (Solórzano *et al.*, 2000).

An important factor in egg incubation and embryo development is egg weight loss. Determining the average weight loss for eggs with developing embryos over the incubation period can be useful for improving subsequent incubation outcomes for a particular species. Olsen and Olsen (1987) reported that weight loss for freshly laid eggs until pipping is linear if the temperature and humidity are kept constant. Egg weight loss during incubation occurs when water vapor escapes from the egg by diffusing across the eggshell (Rahn and Ar, 1974; Ar and Rahn, 1980), which depends upon the number of pores, pore structure and shell thickness (Ar *et al.*, 1974; Rahn *et al.*, 1976). If an egg begins losing weight faster than it should, or not fast enough, the humidity level of an incubator can be adjusted to slow or increase, respectively, egg water vapor conductance. To our knowledge, the egg weight loss data for the Resplendent Quetzal does not exist in the scientific literature.

The Quetzal is known for its difficulty to maintain and to reproduce in captivity. In the 1980`s studies were carried out in the Chiapas, Mexico mountains to understand the biology and behaviour of the quetzal in the wild. Given that the Resplendent Quetzal is difficult to manage in captivity, a team of researchers at the Miguel Alvarez del Toro regional zoo (Zoomat) in Chiapas, Mexico started by working with similar species belonging to the trogon family. To date, very few reports exist in the scientific literature concerning successful captive breeding efforts of *Pharomachrus mocinno mocinno*, although the Zoomat team has successfully bred a chick in captivity (Orellana, 2004). However, the scientific literature has been lacking information regarding the incubation conditions, hatching, and fledging success of the Resplendent Quetza. Dr. Jesús Estudillo López, founder of “El Nido” aviary was the first to succeed with Quetzal reproduction in captivity. The aim of this study was to develop an artificial incubation procedure for the Quetzal, a species that does not typically reproduce in captivity, and as such methods to increase its fecundity through artificial incubation are desired.

2. METHODS

Over a three-year period (Yr1, Yr2, Yr3), data about Quetzal eggs, artificial incubation, and diet were recorded. Eggs were manually collected from artificial nests and egg substitution was utilized. The nests were made with a palm trunk, split lengthwise in half and hollowed inside. An internal grating surface is made, so that the animal can climb easily. The trunk rejoins and filled with sawdust, a sign that the couple have reproductive activity is a part of the sawdust withdrew from the nest (Figure 1a) and included a videocamera (Boscom Tech®, Shenzhen, China) monitoring system.

Quetzals can continue laying eggs up to 8 times when eggs are removed for incubation, if the removed egg is replaced with a false one that is an infertile egg having had the contents removed and replaced

with water, and having a similar weight as the real one (egg substitution). After being laid, eggs were weighed on a digital scale (range=0.010g-200g) (Figure 1b) and placed into an 80 watt, 580 mm (width) x 340 mm (depth) x 265 mm (height) incubator (INCA 200®, Israel) with an automatic egg turner. The eggs were incubated 17-18 days at 37.2°C - 37.6°C with a relative humidity of 20% to 40%. Thereafter, weighing of the eggs was performed every two days between 7:00 am and 8:00 am, by removing the egg from the incubator and weighing it on the digital scale while not taking more than 20 seconds for the process to avoid excess cooling of the egg. Some of the data collected included egg weight, number of incubation days, percent weight loss of eggs during incubation, the birth weight of chicks and the weight gain of chicks, among other characterstics.

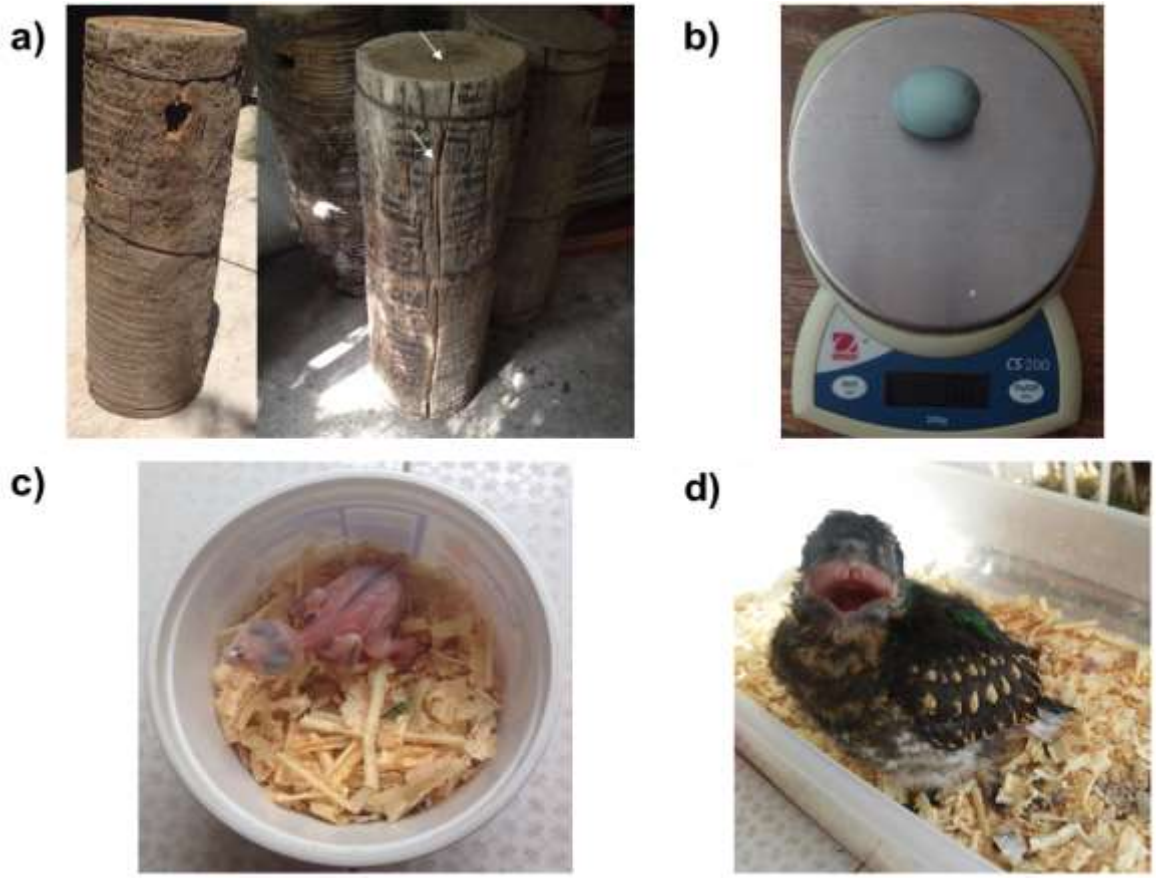

Figure 1. a) Artificial Resplendent Quetzal nest at El Nido (white arrows show where palm log was split), b) Resplendent Quetzal (*Pharomachrus mocinno mocinno*) egg on scale, c) recently hatched Resplendent Quetzal chick, and d) Resplendent Quetzal chick at 1 month old

The diet of the Quetzals consisted of fruit (aguacatillo, banana and papaya) and a mouse pup once a week. In Yr3 the diet was modified to include blueberry and a commercial food for Tucans (Mazuri®).

2.1. Statistical Analysis

Fisher's exact test (two-tailed) was used for statistical analyses comparing the numbers of eggs hatched, infertile eggs, and eggs experiencing embryonic death for the study period. Statistical differences were considered to exist at $\alpha = 0.05$.

3. RESULTS

A total of 27 Quetzal eggs ranging from a mínimum of 15.4 g to a maximum of 20.24 g (Mean weight (g)=17.3, St. Dev.=1.2) were incubated over three years, of which 10 (~37%), were fertile and hatched (Figure 1c, 1d). However, only 3 (30%) of the chicks fledged and survived to adulthood. Six of the eggs (~22%) suffered embryonic mortality during incubation, while 11 eggs were infertile (~41%). In Yr1, 8 eggs were collected from 2 Quetzal pairs (from June to September) of which 2 eggs hatched, 5 were infertile and 1 suffered embryonic death toward the end of incubation. In Yr2, 9 eggs were obtained from 2 Quetzal pairs (same pairs) (from April to August) of which 2 eggs hatched, 6 were infertile, and 1 suffered embryonic death in the third stage of embryonic development. Both of the chicks produced in Yr2 were female and survived to adulthood. In Yr3, 10 eggs were obtained from 3 Quetzal pairs (new

pair added) (from April to August) of which 6 hatched and 4 suffered embryonic death, of which 1 died in the second stage of development and 3 died in the fourth stage of embryonic development. Although the hatch rate was higher than in Yr1 and Yr2, only 1 male chick survived to adult in Yr3.

During Yr1 and Yr2 two eggs hatched each year, and compared to the six eggs that hatched in Yr3, a noteworthy but not signficant difference can be observed (Yr1 vs Yr2, P=1; Yr1 vs Yr3, P=0.188; Yr2 vs Yr3, P=0.170). Embryonic death of the eggs was also not significantly different between the years (Yr1 vs Yr2, P=1; Yr1 vs Yr3, P=0.314; Yr2 vs Yr3, P=0.303). However, the number of infertile eggs was significantly different between Yr1 vs Yr3 (P=0.007) and Yr2 vs Yr3 (P=0.003), but not Yr1 vs Yr2 (P=1). Of the eggs that survived to hatch, egg weight loss ranged from a minimum of 6.6% to a maximum of 16.2% (Mean = 11.28%, St. Dev.= 2.77%).

Notably, during Yr1 there was a delay of almost two months in egg laying. Regarding the 2 eggs that developed, number 1 and 2, both had an egg weight loss of 9.35% and 7.62%, respectively, after 16 days of incubation (Table 1, Figure 2). During Yr2, the same as in Yr1; the laying of eggs was delayed a couple of weeks. The two eggs that developed satisfactorally, number 3 and 4, had an egg wieght loss of 8.77% and 16.23%, respectively, after 16 days of incubation (Table 1). In Yr3 the egg laying time span was prolonged in comparison with that of the past two years. The six eggs that hatched, numbers 5, 6, 7, 8, 9, and 10, had a weight loss at day 16 of 8.82%, 13.71%, 9.94%, 12.66%, 13.41% and 12.22% respectively (Table 1).

Table 1. *Results of Resplendent Quetzal (Pharomachrus mocinno mocinno) egg weight loss during incubation.*

Egg Number (Year)	Incubation Start Date - Julian Day Calendar	Hatching Date - Julian Day Calendar	Incubation Days	Initial Egg Weight (grams)	Day 16 Egg Weight (grams)	Weight Loss (%)
1 (Yr1)	173	191	18	17.1	15.5	9.36
2 (Yr1)	197	215	18	15.47	14.29	7.63
3 (Yr2)	114	132	18	17.1	15.6	8.77
4 (Yr2)	150	168	18	15.4	12.9	16.23
5 (Yr3)	94	112	18	17	15.5	8.82
6 (Yr3)	98	116	18	17.5	15.1	13.71
7 (Yr3)	119	137	18	16.1	14.5	9.94
8 (Yr3)	123	141	18	15.8	13.8	12.66
9 (Yr3)	145	163	18	16.4	14.2	13.41
10 (Yr3)	182	200	18	18	15.8	12.22

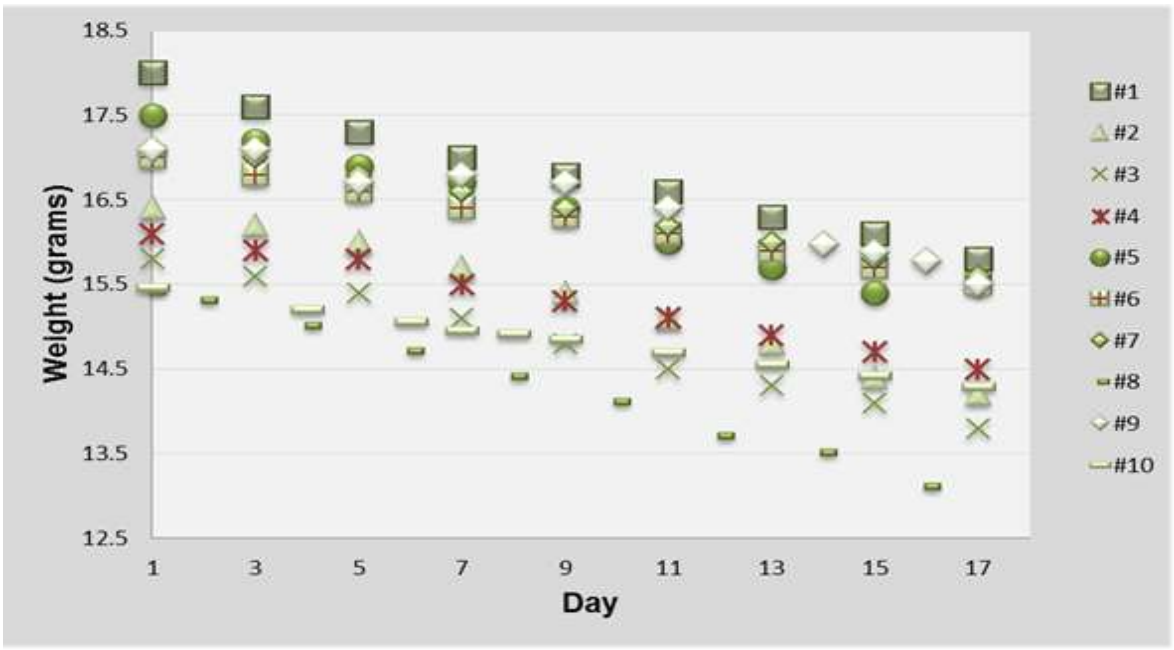

Figure 2. Egg weight loss during incubation for Resplendent Quetzals (*Pharomachrus mocinno mocinno*) (n=10) that hatched

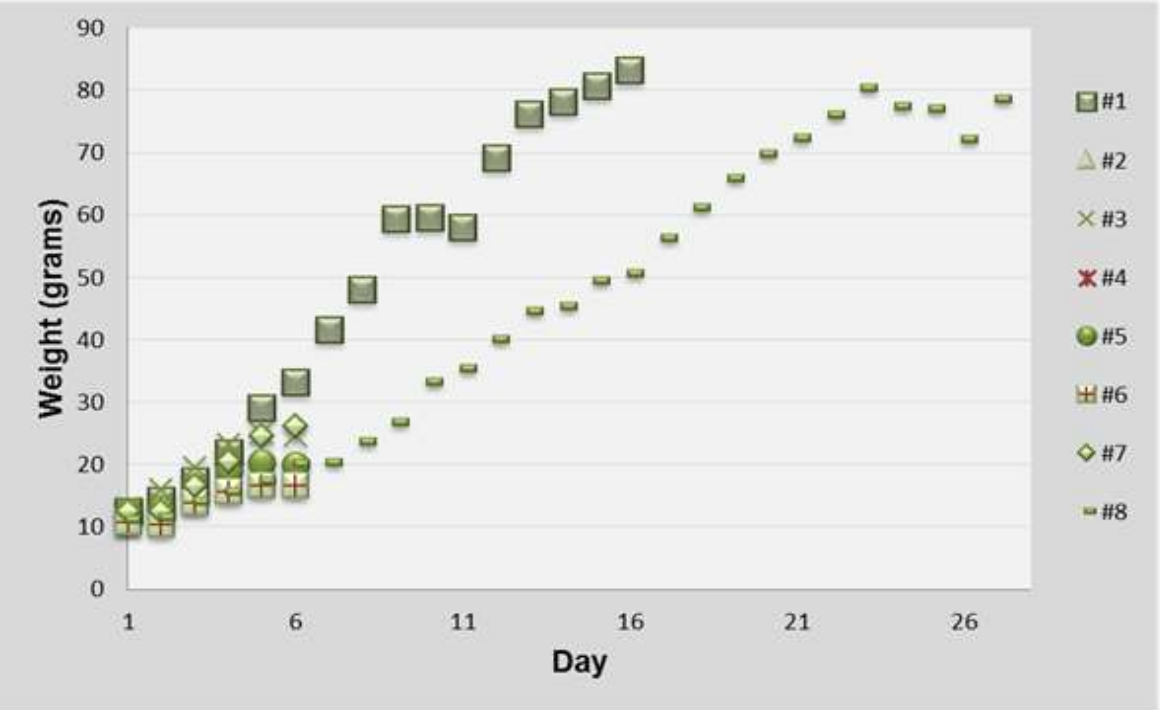

Figure 3. Resplendent Quetzal (*Pharomachrus mocinno mocinno*) chick weights over time

In the reproductive period of the Quetzal at El Nido during the three-year period, a total of 27 eggs of which 10 (37%), were fertile and incubated in an adequate manner. Six of the eggs (22%), suffered embryonic mortality during incubation, while 11 eggs were infertile (41%). The birth weight of chicks and the weight gain of chicks can be observed in Figure 3.

4. Discussion And Conclusions

During the incubation process of *Pharomachrus mocinno mocinno* eggs, it was discovered that the eggs lost between 7.63% and 16.23% of their weight, with an average of 11.28%. In comparison, Cutler and Abbott (1986) reported that cockatiel eggs lost 9.6 % of initial egg weight at lay over the first 15 days of incubation, hatching at 18 days. Stoodley (1983, 1984) reported that optimum hatching resulted after a 16% egg weight loss for amazon and pionus parrots.

According to Solórzano *et al.* (2000), the period of *Pharomachrus mocinno mocinno* egg laying in the wild includes the months of February, March, April and May. Although, at El Nido during Yr1 there was a long delay in the laying of eggs compared to Yr2 and Yr3. Such an egg laying delay could be caused by a defficiency in the diet of the reproductive pairs or the number of hours of light that they received during this time.

During Yr1 and Yr2 two eggs hatched each year, if this is compared to the six eggs that hatched in Yr3, a sizeable difference can be observed. Various hypotheses have been established that could have caused this large difference. One of the explanations is that the diet of the reproductive pairs was changed. During Yr1 and Yr2 the diet consisted of fruit (aguacatillo, banana and papaya) and a mouse pup once a week. In Yr3 the diet was modified to include blueberry and a commercial food for Tucans (Mazuri®). Another important factor in the rise of the number of offspring that were born in Yr3 was the addition of new reproductive pairs, using the same pairs and some young from previous years to form new pairs. Besides the two factors already mentioned, changes to the reproductive pairs' habitat were also made such as the hanging of new nests and disinfection of the enclosure.

Based on the data collected during the three years, approximately 41% of the eggs were infertile and 22% experienced embryonic death. This is a total of 63% that were lost of those collected. One reason for these results may be due to the level of consanguinity with this population of Quetzals at El Nido. Another factor that may be attributed to this could be the constant management of the eggs for weight loss assessment, opening the incubator and weighing may have provoked just enough variation in temperature to influence embryo survival, as the room temperature was not the same as the incubator temperature.

The results of the present study provide a foundation for incubating Quetzal eggs which could benefit conservation efforts. Improvements in captive Quetzal reproduction could provide for the release or "re-wilding" of individuals either into extant populations or re-establishment of extirpated populations. A similar study by Estrada (2014) describes a successful scarlet macaw (*Ara macao cyanoptera*) reintroduction in the tropical rainforests of Palenque, Mexico. However, it will take more than increasing Quetzal fecundity and re-introduction efforts to boost population numbers, given ongoing habitat fragmentation and consumption of Quetzals by local inhabitants in their current range in Mexico.

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REFERENCES

[1] Ar, A., Paganelli, C.V., Reeves, R.B., Greene, D.G. and Rahn, H. (1974) The avian egg: water vapor conductance, shell thickness, and functional pore area. Condor 76, 153-158.

[2] Ar, A. and Rahn, H. (1980) Water in the avian egg: overall budget of incubation. Amer. Zool. 20, 373-384.

[3] Ávila, M. and Hernández, V.H. (1990) Contribución a la biología y distribución del quetzal Pharomachrus mocinno mocinno (TROGONIDAE, AVES) en la reserva "El Triunfo", Chiapas. México. Tesis de Licenciatura. Facultad de Ciencias, UNAM, México D.F. México

[4] Ávila, M.L., Obregón, V.H. and Velarde, E. (1996) The diet of Resplendent Quetzal Pharomachrus mocinno (Trogonidae) in a Mexican cloud forest. Biotropica 28, 720-727.

[5] Bird, D.M. and Laque, P.C. (1980) Fertility, egg weight loss, hatchability, and fledgling success in replacement clutches of captive American Kestrels. Can. J. Zool. 60, 80-88.

[6] Cutler, B.A. and Abbott, U.K. (1986) Effects of temperature on the hatchability of artificially incubated cockatiel eggs (Nymphicus hollandicus). In: 35th Western Poultry Disease Conference pp. 32-35.

[7] Espinosa de los Monteros, A. (1997) Molecular phylogeny of Trogoniformes. Ph.D. Dissertation. The City University of New York. New York, New York, USA.

[8] Espinosa de los Monteros, A. (2000) Higher-level phylogeny of Trogoniformes. Mol. Phylogenet. Evol. 14, 20-34.

[9] Estrada, A. (2014) Reintroduction of the scarlet macaw (Ara macao cyanoptera) in the tropical rainforests of Palenque, Mexico: project design and first year progress. Trop. Conserv. Sci. 7(3), 342-364.

[10] Guía de Observación del Quetzal en Guatemala. (2009) Instituto Guatemalteco de Turismo-INGUAT- División de Desarrollo del Producto. Sección de Patrimonio Natural.

[11] Navarro, A.G. and Peterson, A.T. (2007) Pharomachrus moccino (quetzal masoamericano) residencia permanente. Distribución potencial Extraído del proyecto CE015: "Mapas de las aves de México basados en WWW". Museo de Zoología, Facultad de Ciencias, UNAM & Univerdity of Kansas, Museum of Natural History. Financiado por la Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México.

[12] Olsen, P.D. and Olsen, J. (1987) Egg weight loss during incubation in captive Australian Kestrels Falco cenhroides and Brown Goshawks Accipiter fasciatus. Emu 87, 196-199.

[13] Orellana, C. (2004) Quetzals Bred in Captivity in Chiapas. Front. Ecol. Environ. 2(7), 345.

[14] Rahn, H. and Ar, A. (1974) The avian egg: incubation time and water loss. Condor 76, 147-152.

[15] Rahn, H., Paganelli, C.V., Nisbet, I.C.T. and Whittow, G.C. (1976) Regulation of incubation water loss in eggs of seven species of terns. Physiol. Zool. 49, 245-259.

[16] Sibley, C. and Monroe, Jr. B.L. (1990) Distribution and taxonomy of birds of the world. Yale University Press, New Haven.

[17] Solórzano Lujano, S. (1995) Fenología de 22 especies arbóreas y su relación con la migración altitudinal del quetzal (Pharomachrus mocinno mocinno De la Llave, 1832) en la Reserva de la Biosfera El Triunfo, Chiapas, México. Facultad de Ciencias (Biología), UNAM, México.

[18] Solórzano, S. and Oyama, K. (2002) El quetzal, una especie en peligro de extinción. Biodiversitas 45, 1-6.

[19] Solórzano, S., Castillo, S., Valverde, T. and Ávila, M.L. (2000) Quetzal abundance in relation to fruit availability in a cloud forest in Southeastern Mexico. Biotropica 32, 523-532.

[20] Stoodley, J. and Stoodley, P. (1983) Parrot production incorporating incubation. Bezels Pub. Portsmouth, England.

[21] Stoodley, J. and Stoodley, P. (1984) Pionus Parrots. Bezels Pub. Portsmouth, England.

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