Organochlorine Contaminants in Ashy Storm-Petrel Eggs from Santa Cruz Island, California, in 1992-2008: preliminary findings

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Progress Report
13 November 2008

Suggested Citation: Carter, H.R., J.L. Yee, D. Welsh, and D.W. Anderson. 2008. Organochlorine contaminants in Ashy Storm-Petrel eggs from Santa Cruz Island, California, in 1992-2008: preliminary findings. Unpubl. report, Carter Biological Consulting, Victoria, British Columbia; and U.S. Geological Survey, Western Ecological Research Center, Sacramento, California. 10 p.

Introduction

With funding from the U.S. Fish and Wildlife Service and the Montrose Trustee Council, organochlorine contaminant levels and eggshell thinning are being examined in eggs of Ashy Storm-Petrels (*Oceanodroma homochroa*) collected from breeding colonies at Santa Cruz Island, California, between 1992 and 2008. In 1992, Ashy Storm-Petrels had the highest levels of organochlorine contaminants and eggshell thinning of any seabird examined in the Channel Islands off southern California (Fry 1994, Kiff 1994). Reproductive success at Santa Cruz Island was moderate in 1995-98, with relatively low hatching success and many broken eggs during incubation, consistent with effects from organochlorine contaminants (Carter et al. 1999; McIver 2002; Carter et al. 2008a; McIver et al., in prep.). In 2005-07, hatching success at Santa Cruz Island had improved and few broken eggs occurred during incubation, consistent with little or no impacts from organochlorine contaminants (Carter et al. 2007; McIver et al. 2008, in prep.).

Chief goals of this study are: a) to determine 2008 levels and trends in levels of organochlorine contaminants (i.e., DDT, DDE, and PCB) from 1992 to 2008; b) to determine 2008 levels and trends in levels of eggshell thinning from 1992 to 2008; and c) to interpret changes in reproductive success between 1992 and 2008 that may be related to organochlorine contaminants. This information is needed for assessing past, present, and future impacts from organochlorine contaminants on Ashy Storm-Petrels in southern California where over half of the global population breeds (Carter et al. 1992, 2008a, unpubl. data; Ainley 1995; Sydeman et al. 1998). Continuing impacts from organochlorine contaminants also are being assessed as part of on-going restoration of Ashy Storm-Petrels at Santa Cruz Island (MSRP 2005; Carter et al. 2008a; McIver et al. 2008).

By fall 2008, all organochlorine contaminant data and reproductive success data from 1992-2008 were available for analyses but 2008 eggshell thinning data were not yet available for analyses. In this brief report, preliminary findings of organochlorine contaminant analyses of Ashy Storm-Petrel eggs collected at Santa Cruz Island in 1992-2008 are summarized. A final report will be completed in 2009 that includes final analyses of contaminant and eggshell thinning data.

Methods

Similar protocols and chain-of-custody procedures were followed for egg collections, egg processing, tissue storage, and USFWS-approved laboratory analyses (Kiff 1992; McIver and Carter 1996; Carter et al. 2008b). In 1992, 15 eggs were collected randomly at Orizaba Rock and Cave of the Birds Eggs; during this analysis, 2 abandoned eggs collected in August were excluded from the random sample and added to salvaged eggs. In 1995-97, 20 eggs were collected randomly and 20 eggs were salvaged at Bat Cave; during this analysis, 2 abandoned eggs collected in August 1997 were excluded from the random sample and added to salvaged eggs. In 2008, 10 eggs were collected randomly and 2 eggs were salvaged at Dry Sandy Beach Cave. Wet weight (ww) concentrations (ug/g [ppm]) of various organochlorine contaminants (DDE, DDT and PCB) and their p,p and o,p congeners were determined for all 67 eggs. All 2008 non-detected values were

replaced with half of the Measurement Detection Limit (MDL); however, previously summarized data for 1992 and 1995-97 were used and how non-detected values were treated is still being examined. In addition to examining the dominant DDT congener (i.e., p,p-DDE), both p,p and o,p congeners were added together to determine total concentrations for DDD, DDE, and DDT. All DDD, DDE and DDT values were added to obtain "Total DDTs" values. All PCB congeners were added to obtain "Total PCBs" values.

For best estimation of contaminant concentrations, wet weights were adjusted to obtain fresh weights (fw ppm) after Fry (1994) as follows:

$$\text{fw} = \frac{\text{egg weight}}{\text{egg volume}} \times \text{ww}$$

where egg weight is measured in g and egg volume is measured in ml. Fresh weight adjustments avoided potential biases in contaminant concentrations associated with potential variable water loss among eggs (e.g., Stickel et al. 1973). However, only a subset of 36 randomly collected eggs had adequate egg weight or egg volume data for fresh weight adjustments, including 13, 10, 3, and 10 eggs in 1992, 1996, 1997, and 2008, respectively. For 33 of these 36 eggs, displacement volume had been determined prior to egg processing. For 3 other eggs, egg volume was calculated using the equation $c \times \text{length} \times \text{breadth}^2$ where the constant c was estimated by linear regression using 33 eggs with length, breadth, and displacement volume data. The regression yielded $c = 0.512$ (SE = 0.007) and a high predictive accuracy (r^2=0.993), consistent with the recommendation by Hoyt (1979) to use $c = 0.51$. Volumes for these 3 eggs were estimated as follows:

$$\text{volume} = 0.51 \times \text{length} \times \left(\text{breadth}^2\right)$$

Fresh weight contaminant data were summarized by: a) constructing box-and-whisker plots where the box showed the median and interquartile range (i.e., 25 and 75 percentiles), whiskers extended to minimum and maximum data values excluding outliers (i.e., values within 1.5 interquartile ranges), and outlier points showed any data beyond 1.5 interquartile ranges; and b) calculating mean, median, and geometric mean concentrations of each contaminant separately by year. Due to the small sample size of fresh weights in 1997 (n = 3), 1996 and 1997 samples were combined into a 1996-97 period (n = 13) for certain analyses.

Percent changes in contaminant levels from earlier to later years (i.e., 1992 to 1996-97, and 1996-97 to 2008) were calculated, as follows:

$$\%\,\text{change} = \frac{\left(\text{fw}_{\text{later}} - \text{fw}_{\text{earlier}}\right)}{\text{fw}_{\text{earlier}}} \times 100\%$$

Percent change was converted into percent per annum change based on *k*, the number of years lapsed (*k* = 4.5 years from 1992 to 1996-97 and *k* = 11.5 years from 1996-97 to 2008), as follows:

$$\%\ \text{per annum change} = \left[(1 + \%\ \text{change})^{1/k} - 1\right] \times 100\%$$

Linear mixed regression was used to model trends in p,p-DDE and total PCBs concentrations across years. Year was treated as both a continuous variable and a categorical random effect, in order to model the general trend across years and to account for year-to-year variation not attributable to trend. The log+1 transformation ($Y = \log_e(fw+1)$) was used to satisfy normality assumptions.

Results

Concentrations of p,p-DDE, DDE, Total DDT, and Total PCBs are summarized in Figure 1. Concentrations of DDT and DDD plus ratios of DDT/DDE and DDT+DDD/DDE are summarized in Figure 2. For this report, p,p-DDE and Total PCBS were focused on for outlining preliminary findings because: a) p,p-DDE comprises a highly dominant portion of DDE and Total DDTs; b) except for p,p-DDE, individual congener breakdowns for 1992 data were not yet available; c) p,p-DDE concentrations have been linked with eggshell thinning and lower hatching success; and d) PCBS have been linked to premature embryo death and lower hatching success (e.g., Anderson et al. 1969; Gress 1995).

For p,p-DDE (fw ppm), mean, median, and geometric mean values were determined as follows: a) 1992 – 12.752, 11.625, and 11.539; b) 1996-97 – 8.584, 8.369, and 8.433; and c) 2008 – 2.815, 2.035, and 1.647. A larger range of values and larger box occurred in 1992 than in 1996, 1997 and 2008. Although box values overlapped between 1992, 1996, and 1997, these box values did not overlap with 2008; however, the low end of the range in 1992 did overlap with the high end of the range in 2008. A high outlier was noted only in 2008.

For Total PCBs (fw ppm), mean, median, and geometric mean values were determined as follows: a) 1992 – 5.849, 5.630, and 5.474; b) 1996-97 – 3.364, 3.009, and 3.270; and c) 2008 – 1.135, 0.792, and 0.610. A larger range of values occurred in 1992 than in 1996, 1997 and 2008 but the low end of the range in 1992 did not overlap the high end of the range in 2008. High and low outliers were noted in 1992 and a high outlier was noted in 2008.

Significant declines were found in both p,p-DDE (slope = -0.08506, SE = 0.01093, t_{32} = -7.78, $p<0.0001$) and Total PCBs (slope = -0.07359, SE = 0.01527, t_{32} = -4.82, $p<0.0001$). Mean, median and geometric mean values of percent per annum change ranged from -8.8 to -11.3% for p,p-DDE and ranged from -8.4 to -13.5% for Total PCBs.

Ratios of DDT/DDE and DDT+DDD/DDE in 1996-2008 (Figure 2) showed little variation between years, consistent with the primary local source of DDT in the Palos Verde Shelf region off Los Angeles.

Discussion

These preliminary findings indicate that p,p-DDE and Total PCBs have reduced to much lower levels between 1992 and 2008. In 1992-97, relatively high contaminant levels and associated eggshell thinning and premature embryo deaths likely were a significant contributing factor to relatively low hatching success recorded during this period, although other factors also were involved (Fry 1994; Kiff 1994; Carter et al. 1999; McIver 2002; McIver et al., in prep.). In the 1960s to 1980s, higher organochlorine contaminant concentrations likely occurred in Ashy Storm-Petrels, as found in other breeding seabirds (i.e., Brown Pelicans *Pelecanus occidentalis* and Double-crested Cormorants *Phalacrocorax auritus*) in southern California during this period (Risebrough et al. 1971, Gress et al. 1973, Anderson et al. 1975, Gress 1995). These higher concentrations probably contributed to lower hatching success and lower population size of Ashy Storm-Petrels in southern California during the 1960s to 1980s than observed in the 1990s. However, no data on contaminant levels or hatching success and little data on population sizes of Ashy Storm-Petrels were obtained in the Channel Islands off southern California during the 1960s to 1980s (Hunt et al. 1979). While larger populations and a wider breeding distribution found in the 1990s may reflect partial recovery from impacts of organochlorine contaminants, some or all of the larger estimated 1990's population of Ashy Storm-Petrels may reflect greater research effort (Carter et al. 1992, unpubl. data). While no contaminants data for Ashy Storm-Petrels were available in southern California prior to 1992, limited data obtained at the South Farallon Islands off the coast of central California suggested a reduction in organochlorine contaminant levels between 1969 and 1992 (Coulter and Risebrough 1973, Fry 1994).

By 2008, mean, median, and geometric mean values for p,p-DDE and Total PCBs were at low levels that may no longer affect reproductive success of Ashy Storm-Petrels on a population level. However, outlier values for both p,p-DDE and Total PCBs provided evidence that certain individuals are still carrying high levels of these contaminants and may still experience significant eggshell thinning or premature embryo deaths. Salvaged eggs also may show higher levels of contaminants and eggshell thinning than randomly collected eggs. Additional work is needed to further analyze organochlorine contaminant data and examine changes in eggshell thinning in randomly collected and salvaged eggs.

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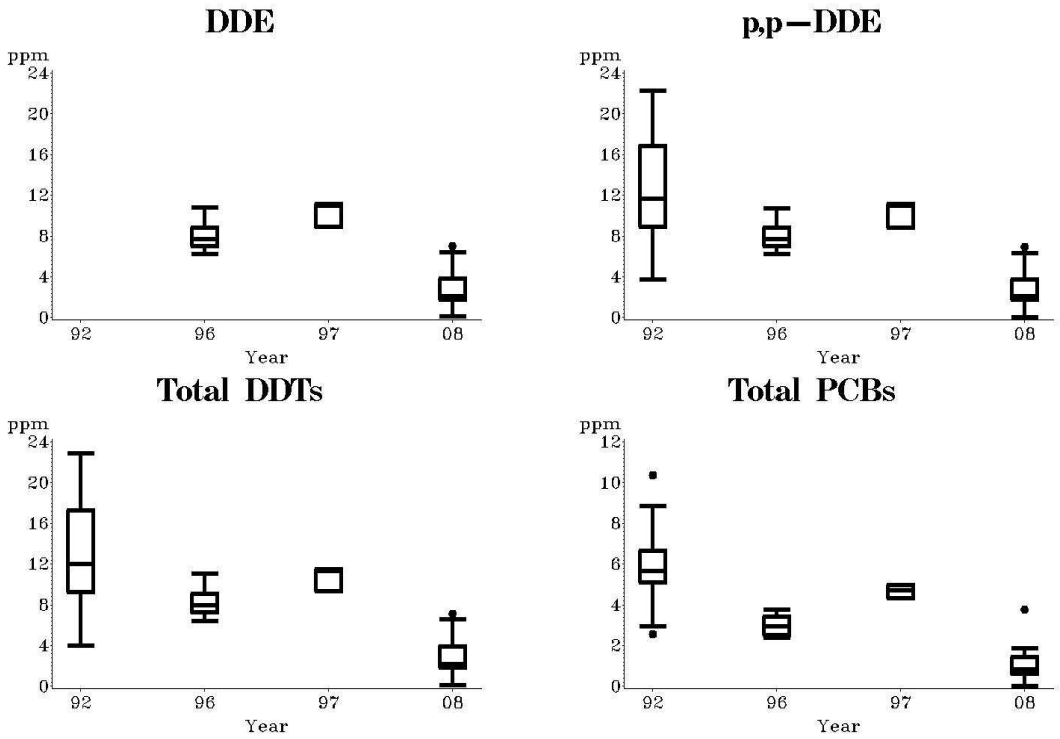

Figure 1. DDE, p,p-DDE, Total DDT, and Total PCBs concentrations (fresh weight ug/g [ppm]) in Ashy Storm-Petrel eggs collected at Santa Cruz Island, California, in 1992-2008. See methods for details of box and whiskers plots. Except for p,p-DDE, individual congener data were not available for 1992.

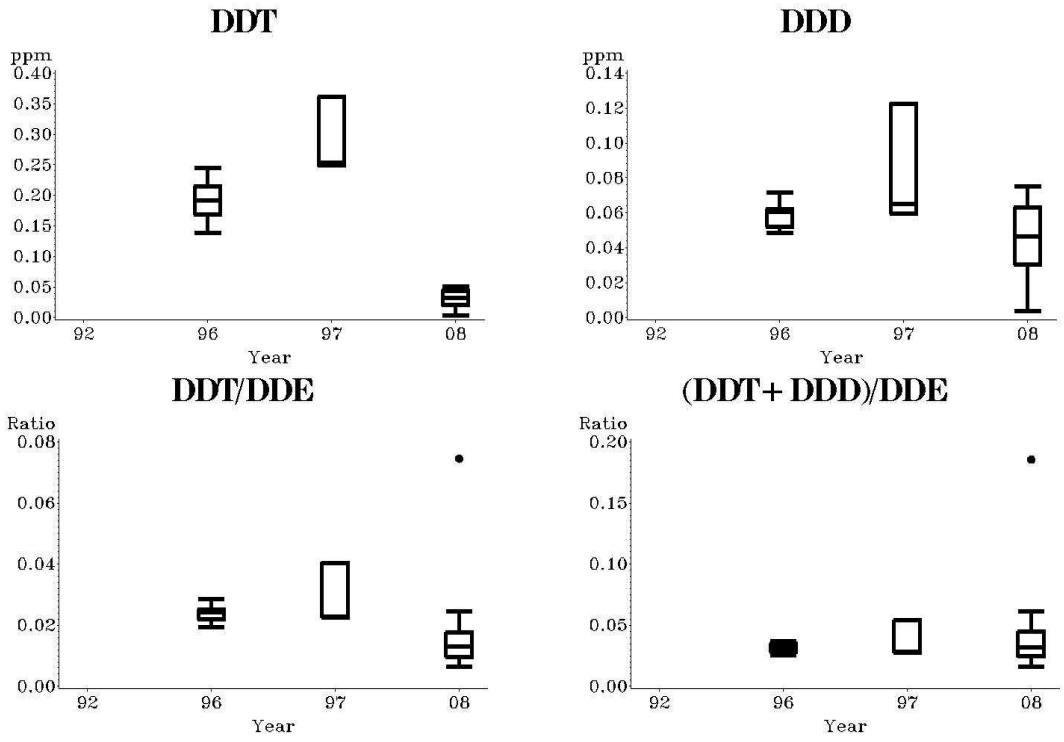

Figure 2. DDT and DDD concentrations (fresh weight ug/g [ppm]) and DDT/DDE and DDT+DDD/DDE ratios in Ashy Storm-Petrel eggs collected at Santa Cruz Island, California, in 1992-2008. See methods for details of box and whiskers plots. Except for p,p-DDE, individual congener data were not available for 1992.