

San Francisco Bay Triennial Bird Egg Monitoring Program for Contaminants, California—2018



Data Series 1114

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph: Forster's tern standing over nest and eggs. Photograph by Abe Borker, University of California, Santa Cruz, graduate student collaborating with U.S. Geological Survey at time of photo, July 9, 2010.

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By Joshua T. Ackerman, C. Alex Hartman, Mark P. Herzog, and Matthew Toney

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
Length		
millimeter (mm)	0.03937	inch (in.)
Area		
square meter (m ²)	0.0002471	acre
hectare (ha)	2.471	acre
square hectometer (hm ²)	2.471	acre
square kilometer (km ²)	247.1	acre
square centimeter (cm ²)	0.001076	square foot (ft ²)
square meter (m ²)	10.76	square foot (ft ²)
square centimeter (cm ²)	0.1550	square inch (in ²)
square hectometer (hm ²)	0.003861	section (640 acres or 1 square mile)
hectare (ha)	0.003861	square mile (mi ²)
square kilometer (km ²)	0.3861	square mile (mi ²)
Volume		
milliliter (mL)	0.033814	ounce, fluid (fl. oz)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as
 $^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$.

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Concentrations of total mercury (THg) in eggs are given in micrograms per gram ($\mu\text{g/g}$).

Abbreviations

fww fresh wet weight

RMP Regional Monitoring Program for Water Quality in San Francisco Bay

SFEI San Francisco Estuary Institute

THg total mercury

USGS U.S. Geological Survey

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Introduction

The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), administered by the San Francisco Estuary Institute, is a large-scale effort to monitor contaminant trends in water, sediment, fish, and birds throughout San Francisco Bay (San Francisco Estuary Institute, 2016). As part of the RMP and the U.S. Geological Survey (USGS) long-term Wildlife Contaminants Program, the USGS samples double-crested cormorant (*Phalacrocorax auritus*) and Forster's tern (*Sterna forsteri*) eggs throughout the San Francisco Bay approximately every 3 years to assess temporal trends in contaminant concentrations. This sampling has previously been carried out by USGS in 2009, 2012, and 2016. This document summarizes egg collections for 2018, as well as mercury concentrations in Forster's tern eggs on an individual egg basis. These data are available in a USGS data release (Ackerman and others, 2019).

Egg Collection and Processing

Double-Crested Cormorants

Double-crested cormorant eggs were sampled between May 10 and 16, 2018, from three locations: (1) Wheeler Island, (2) Richmond–San Rafael Bridge, and (3) Pond A5/A7 levee in the eastern Alviso salt pond complex (region not shown on fig. 1) of south San Francisco Bay (fig. 1). The Pond A5/A7 cormorant egg sampling location replaced the nearby A9/A10 collection site used for RMP in 2006, 2012, and 2016 because cormorants did not nest at A9/A10 in 2018. A total of 21 eggs were collected from 21 separate nests from each of the Richmond–San Rafael Bridge and Pond A5/A7 levee locations (total of 42 eggs). At the Wheeler Island location, double-crested cormorants nest in dying Eucalyptus trees (*Eucalyptus globulus*) on private land. Because of difficulties with site access owing to a private levee road inhibiting use of a boom truck until a later date in the nesting season and difficult climbing conditions of the dying Eucalyptus trees (for the tree climbers externally hired by San Francisco Estuary Institute;

SFEI), we collected six eggs from three nests (four eggs from one nest, one egg from each of two nests) at the Wheeler Island location. We measured egg mass, egg length, and egg width for each double-crested cormorant egg (appendix 1; Ackerman and others, 2019), and then the double-crested cormorant eggs were shipped unopened in a highly padded package to SGS AXYS (Sidney, British Columbia, Canada) on July 9, 2018, for dissection, processing, contaminant analyses, and further reporting. AXYS confirmed receiving all 48 eggs on July 13, 2018, and AXYS reported that 11 of the 48 eggs were cracked during shipment with some contents released into the surrounding Whirl-Pak bag. The remaining 37 eggs were all intact.

Forster's Terns

Forster's tern eggs were sampled between May 17 and July 17, 2018, from four different colonies: (1) Pond A3W, (2) Pond N1, (3) New Chicago Marsh, and (4) Pond SF2 at the Don Edwards San Francisco Bay National Wildlife Refuge (fig. 2; refuge not shown in fig. 2). Ponds A3W, N1, and SF2 replaced sampling locations used in previous years (for example, Ponds A1, A2W, A7, AB1, and AB2; ponds not shown in fig. 2) because Forster's terns either did not nest at these sites in 2018 or did not nest in sufficient numbers to allow for egg collections. At another location used in previous years, Hayward Shoreline Regional Park (area not shown in fig. 2), site managers did not allow egg collections in 2018.

A total of 21 Forster's tern eggs were collected from 21 separate nests at each of the 4 locations (total of 84 eggs). Eggs were collected randomly from monitored nests at early incubation stages determined via egg flotation (Ackerman and Eagles-Smith, 2010). Eggs were placed in egg cartons and stored on wet ice until transport back to the laboratory, where they were stored in a refrigerator until dissection. During egg dissection, refrigerated eggs were allowed to warm to room temperature before egg length and width were measured to the nearest 0.01 millimeter (mm) using digital calipers (Fowler High Precision), and total egg weight (including eggshell) was weighed to the nearest 0.01 gram (g) on a digital balance (Ohaus Adventurer Pro, model AV212C;

Ohaus). Using clean, stainless steel instruments, we cut a hole approximately 15 mm in diameter in the wide end of each egg and removed the entire contents into a chemically-cleaned and certified 60-milliliter (mL) jar (Thermo Scientific™ Wide-Mouth Short-Profile Amber Glass Jars, with PTFE-lined polypropylene lid). Egg content (without eggshell) was then weighed with a digital balance to the nearest 0.01 g, and egg contents were stored at -20°C until processing and mercury determination. During processing, eggs were thawed at room temperature, and then the entire egg contents were dried at 50°C for >96 hours until completely dried. To determine moisture content, we reweighed dried egg contents with a digital balance to the nearest 0.0001 g (Ohaus Adventurer Balance, model AR064; Ohaus). Dried egg contents were then homogenized to a powder using a spice grinder with stainless steel blades, followed by further grinding by hand in a mortar and pestle. Processed egg samples were stored in a desiccator until mercury determination.

Each Forster's tern egg was analyzed for total mercury (THg) concentrations at the USGS Dixon Field Station Environmental Mercury Laboratory on a Nippon MA-3000 Direct Mercury Analyzer (Nippon Instruments North America, College Station, Texas, U.S.A.), following Environmental Protection Agency Method 7473 (U.S. Environmental Protection Agency, 2000), using an integrated sequence of drying, thermal decomposition, catalytic conversion, and then amalgamation, followed by atomic absorption spectroscopy. Prior research has demonstrated that an average of 96 percent of the mercury in eggs is in the methylmercury form and that total mercury concentrations in eggs are highly correlated with methylmercury concentrations in eggs (Ackerman and others, 2013b). We converted the dry weight THg concentrations for Forster's tern egg contents to a fresh wet weight (fww) THg concentration for each individual egg's contents, following the methods of Ackerman and others (2013b) and accounting

for the thickness of the eggshell following Herzog and others (2016).

Quality assurance measures included analysis of a certified reference material (dogfish muscle tissue [DORM] and lobster hepatopancreas [TORT] certified by the National Research Council of Canada, Ottawa, Canada), system blank, method blank, continuing calibration verification, and duplicate with each set of approximately 10 samples and 2 spiked duplicates with each set of approximately 20 samples. In total, quality assurance measures for the 84 Forster's tern eggs included 10 system blanks, 10 method blanks, 10 continuing calibration verification, 13 certified reference material, 10 duplicates, 10 matrix spikes, and 5 matrix spike duplicates. Recoveries (mean \pm standard deviation) were 101.3 ± 2.7 percent ($n = 13$) for certified reference materials, 100.3 ± 1.9 percent ($n = 10$) for continuing calibration verifications, and 100.0 ± 1.8 percent ($n = 10$) for matrix spikes. Relative percent difference averaged 2.0 ± 1.6 percent ($n = 10$) for duplicates and 1.6 ± 1.3 percent ($n = 5$) for matrix spike duplicates (appendix 2; Ackerman and others, 2019).

After homogenizing the eggs, equal masses (dried) from each of seven randomly chosen eggs per colony were combined to make three separate composite samples of seven eggs each per Forster's tern colony (appendix 2; Ackerman and others, 2019). Each composite sample was then re-homogenized, and aliquots were put into jars provided by each external lab. Forster's tern egg composite samples were shipped at room temperature to the California Department of Fish and Wildlife Moss Landing Marine Lab (Moss Landing, California) on December 10, 2018, for selenium determination and further reporting and shipped at room temperature to AXYS Analytical laboratories on February 19, 2019, for polybrominated diphenyl ethers (PBDE) analyses and further reporting.

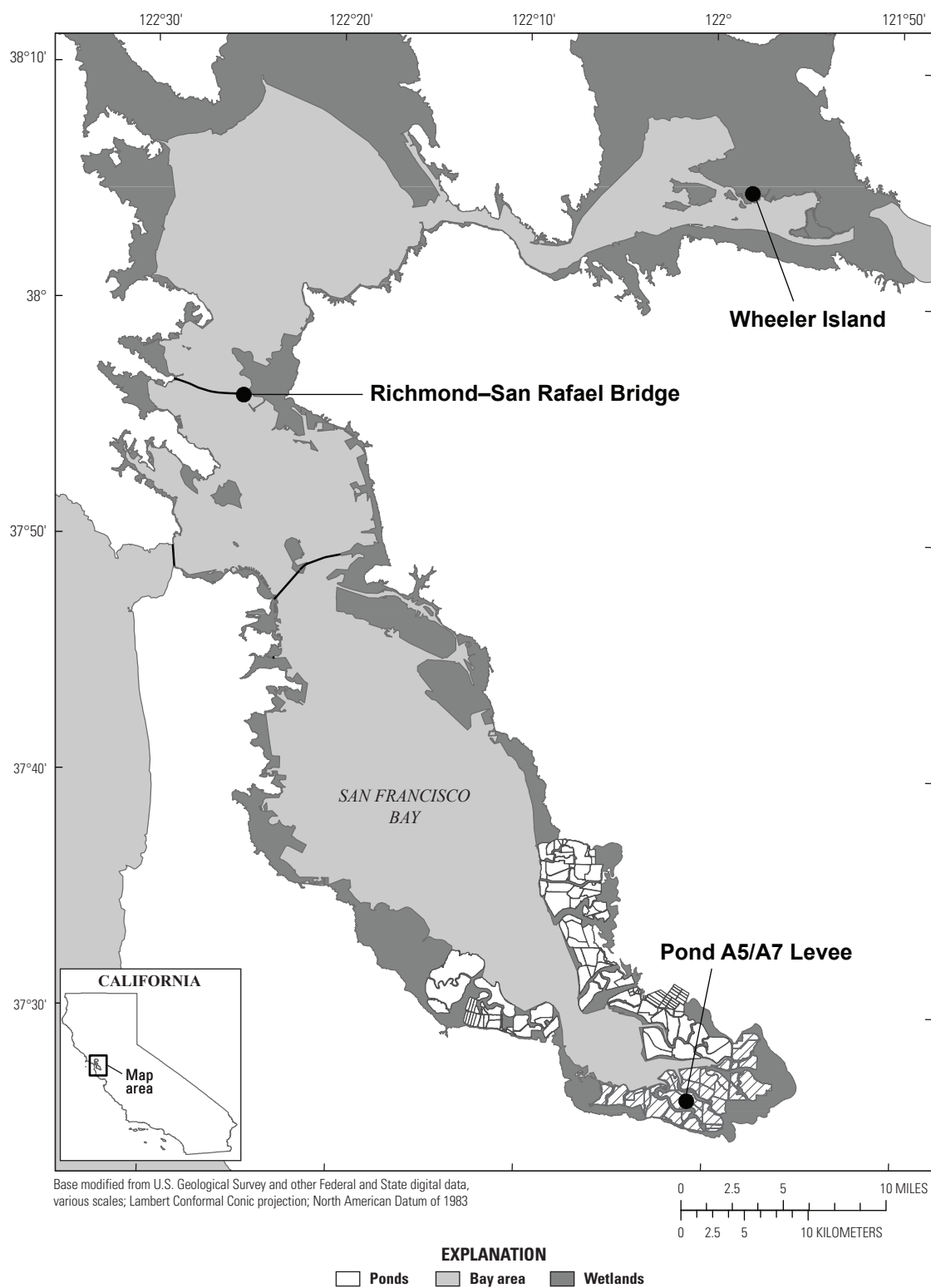


Figure 1. Double-crested cormorant colony locations that were sampled by U.S. Geological Survey for the Regional Monitoring Program for Water Quality in San Francisco Bay, California, in 2018.

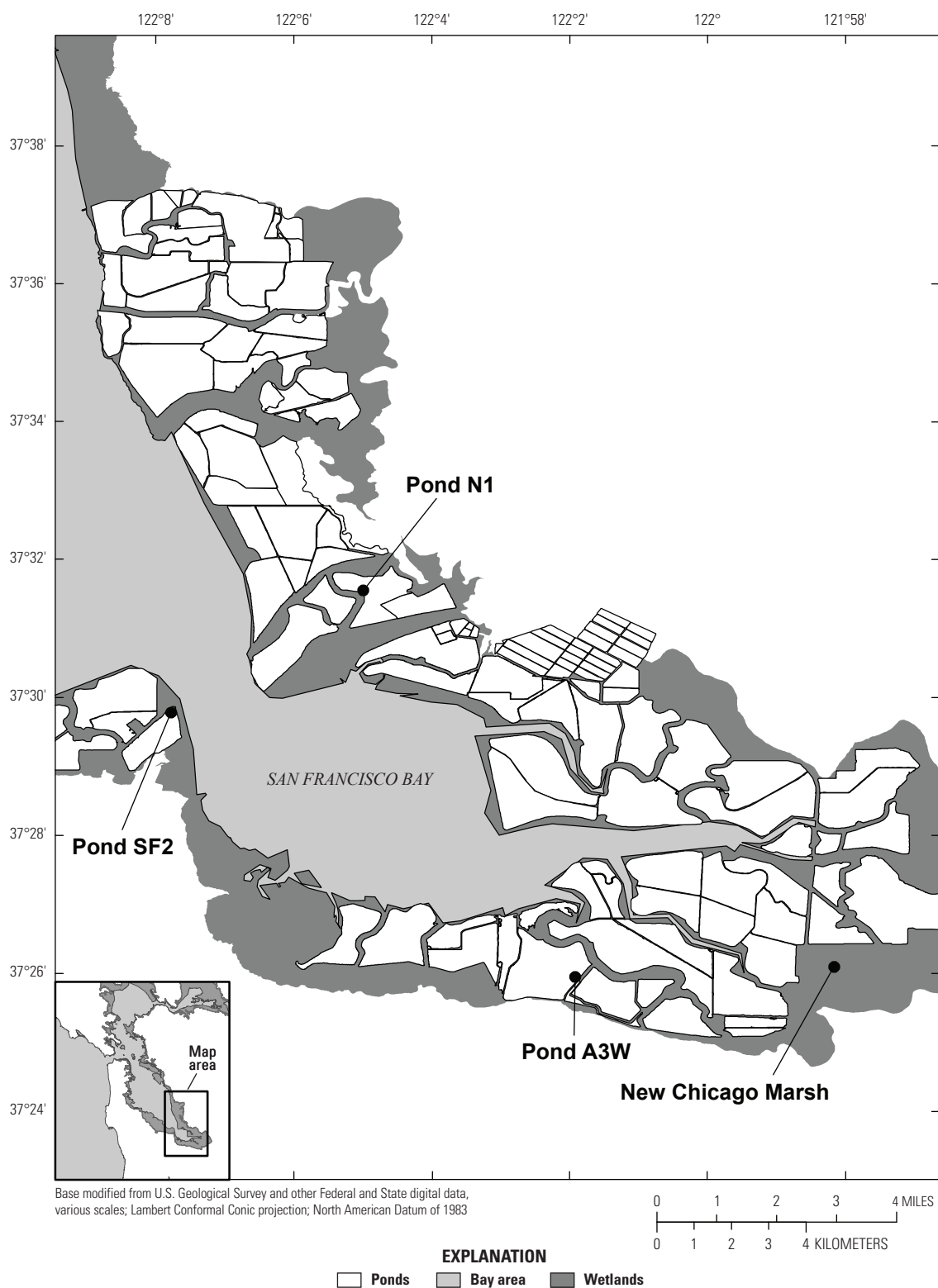


Figure 2. Forster's tern colony locations that were sampled by U.S. Geological Survey for the Regional Monitoring Program for Water Quality in San Francisco Bay, California, in 2018.

Forster's Tern Egg Total Mercury Concentrations

Across all sites, the geometric mean (\pm standard error) THg concentrations in Forster's tern eggs was 1.3 ± 0.07 micrograms per gram ($\mu\text{g/g}$) fww, and concentrations in individual eggs ranged from $0.30 \mu\text{g/g}$ to $3.60 \mu\text{g/g}$ fww (appendix 3; Ackerman and others, 2019). Mercury concentrations in Forster's tern eggs varied slightly among colonies (ANOVA: $F_{3,80} = 2.52$, $P=0.06$; fig. 3). Egg mercury concentrations varied greatly among individuals within the same colony (fig. 3), indicating that using composite samples would not adequately characterize risk of mercury to Forster's terns in San Francisco Bay.

We evaluated risk to Forster's tern breeding productivity by assessing individual egg mercury concentrations in

relation to a benchmark value of $0.75 \mu\text{g/g}$ fww, which is associated with Forster's terns beginning the process of methylmercury demethylation in the liver (Eagles-Smith and others, 2009; Ackerman and others, 2016a). Overall, 85 percent of eggs sampled (71 of 84) exceeded this $0.75 \mu\text{g/g}$ fww benchmark. On a site-specific basis, 100 percent of eggs at the Pond A3W colony, 76 percent of eggs at the New Chicago Marsh colony, 86 percent of eggs at the Pond SF2 colony, and 76 percent of eggs at the Pond N1 colony exceeded $0.75 \mu\text{g/g}$ fww. Geometric mean mercury concentrations in Forster's tern eggs were, on average, higher in 2018 ($1.30 \pm 0.07 \mu\text{g/g}$ fww) compared to 2016 ($1.07 \pm 0.07 \mu\text{g/g}$ fww), 2012 ($1.09 \pm 0.04 \mu\text{g/g}$ fww), and 2009 ($0.97 \pm 0.05 \mu\text{g/g}$ fww) (fig. 4). The samples document egg mercury concentrations that continue to be above benchmarks for high risk of impaired reproduction to Forster's terns in San Francisco Bay.

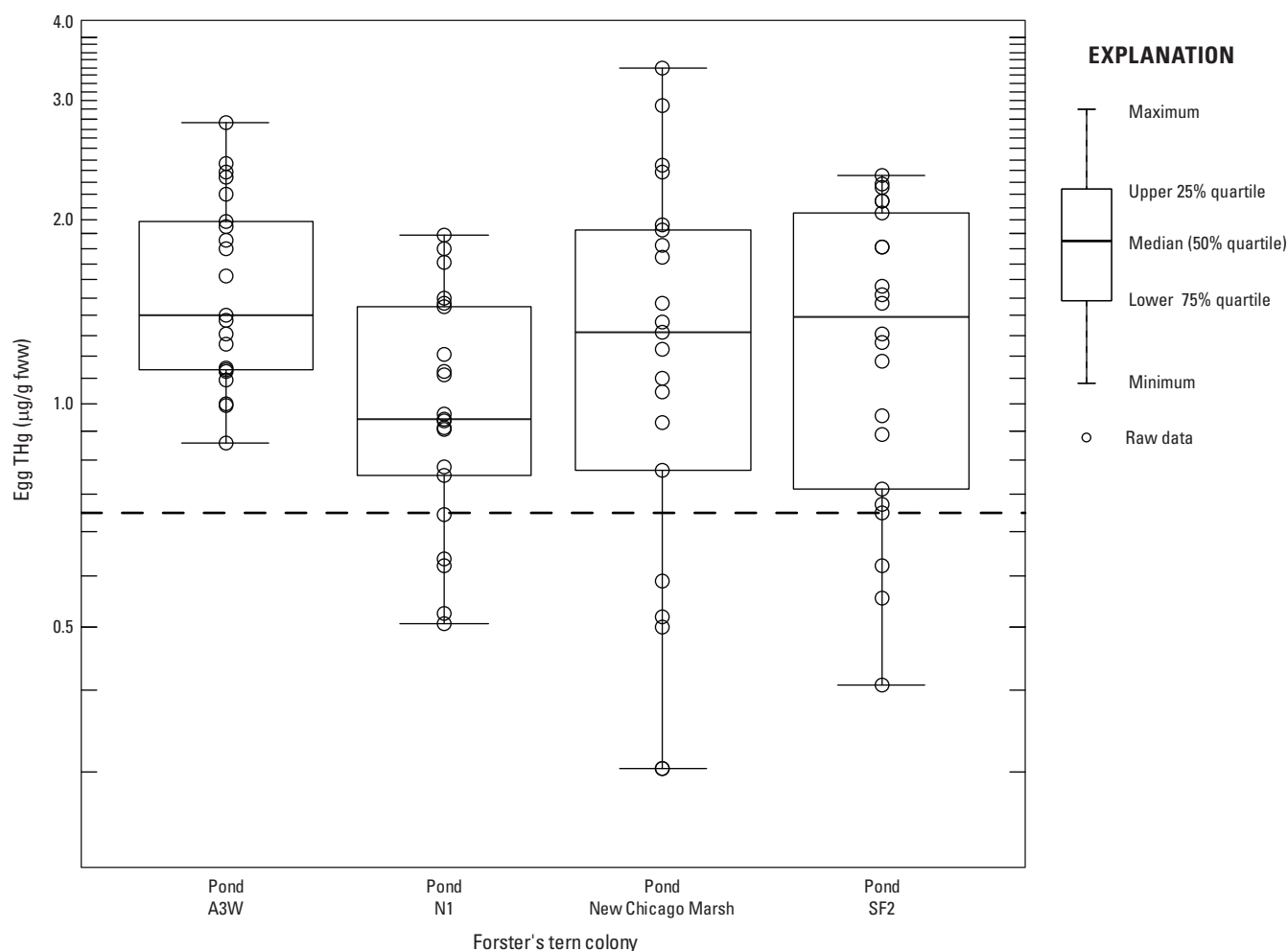


Figure 3. Total mercury (THg) concentrations (micrograms per gram [$\mu\text{g/g}$] fresh wet weight [fww]) in Forster's tern eggs sampled from four colonies in San Francisco Bay during the 2018 breeding season. The stippled line indicates a benchmark value of $0.75 \mu\text{g/g}$ fww where Forster's tern health may be impaired (Eagles-Smith and others, 2009; Ackerman and others, 2016a).

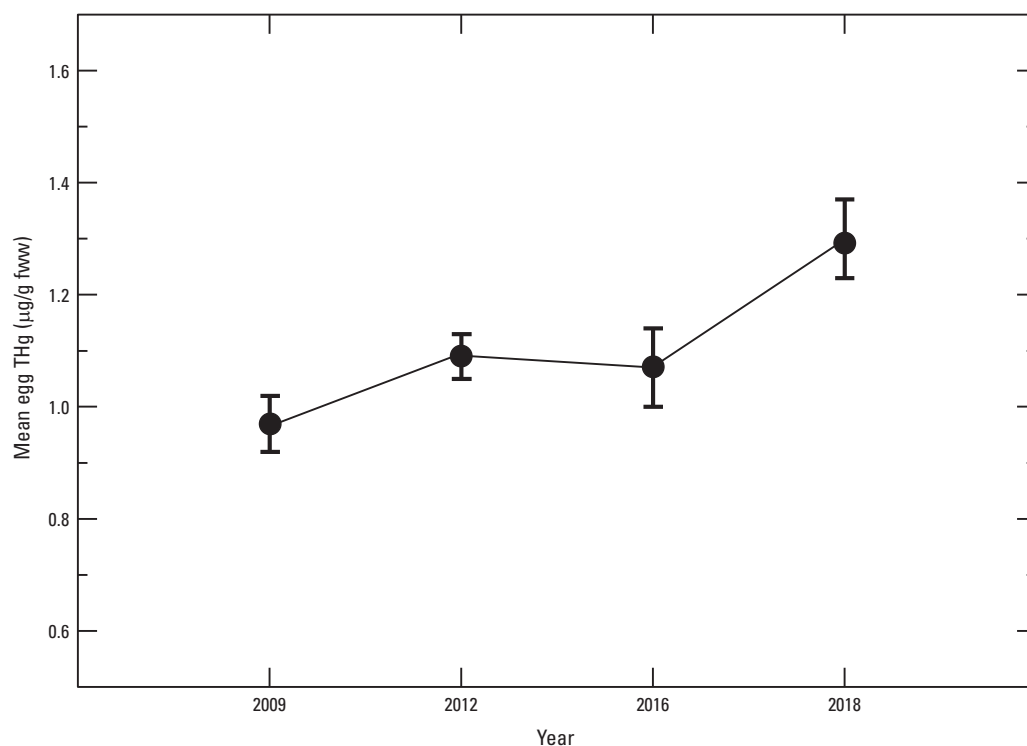


Figure 4. Mean \pm standard error total mercury (THg) concentrations (micrograms per gram [$\mu\text{g/g}$] fresh wet weight [fww]) in Forster's tern eggs in 2009 (Eagles-Smith and Ackerman, 2009), 2012 (Ackerman and others, 2013a), 2016 (Ackerman and others, 2016b), and 2018 (this report).

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Appendix 1. Double-Crested Cormorant Egg Collection and Measurement Data for Eggs Collected by U.S. Geological Survey (USGS) From San Francisco Bay, California, in 2018

[g, gram; ID, identification; mm, millimeter; mm/dd/yyyy, month/day/year; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator coordinate system; USGS, U.S. Geological Survey]

USGS egg ID	Species	Collection date (mm/dd/yyyy)	Year	Location	Station code	UTM-easting (NAD 83)	UTM-northing (NAD 83)	USGS egg measuring date (mm/dd/yyyy)	USGS whole egg mass (g)	USGS whole egg length (mm)	USGS whole egg width (mm)
RB-1	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	43.90	59.15	38.87
RB-2	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	41.31	62.25	37.49
RB-3	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	48.51	57.97	40.93
RB-4	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	42.98	64.19	36.54
RB-5	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	50.01	60.67	41.37
RB-6	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	42.67	55.09	39.07
RB-7	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	50.41	65.26	39.95
RB-8	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	41.81	56.83	38.37
RB-9	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	45.93	57.67	39.67
RB-10	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	39.69	55.81	38.79
RB-11	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	49.79	60.97	40.21
RB-12	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	42.83	59.75	38.65
RB-13	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	42.69	59.87	37.91
RB-14	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	40.75	61.73	36.13
RB-15	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	46.46	58.98	39.31
RB-16	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	47.02	63.77	38.74
RB-17	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	51.12	65.14	39.18
RB-18	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	45.86	57.69	39.98
RB-19	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	43.19	59.43	38.29
RB-20	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	57.91	61.52	42.82
RB-21	Double-crested cormorant	05/16/2018	2018	Richmond Bridge	2EEPSRB	549605	4198701	06/07/2018	56.19	66.09	40.85
SB-1	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EEPSSB-A5A7	587481	4144081	06/07/2018	51.71	60.81	39.71
SB-2	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EEPSSB-A5A7	587477	4144086	06/07/2018	55.98	66.80	40.51
SB-3	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EEPSSB-A5A7	587470	4144093	06/07/2018	54.57	60.43	40.75
SB-4	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EEPSSB-A5A7	587471	4144092	06/07/2018	49.71	61.59	39.89

USGS egg ID	Species	Collection date (mm/dd/yyyy)	Year	Location	Station code	UTM-easting (NAD 83)	UTM-northing (NAD 83)	USGS egg measuring date (mm/dd/yyyy)	USGS whole egg mass (g)	USGS whole egg length (mm)	USGS whole egg width (mm)
SB-5	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587472	4144096	06/07/2018	49.42	61.07	40.87
SB-6	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587476	4144087	06/07/2018	49.16	61.78	39.67
SB-7	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587428	4144123	06/08/2018	42.21	60.94	37.24
SB-8	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587432	4144121	06/08/2018	44.74	61.60	37.01
SB-9	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587435	4144118	06/08/2018	51.32	67.55	38.94
SB-10	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587432	4144122	06/08/2018	51.64	58.75	40.86
SB-11	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587431	4144123	06/08/2018	55.05	62.18	40.41
SB-12	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587423	4144122	06/08/2018	44.40	62.99	37.16
SB-13	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587472	4144094	06/08/2018	48.11	62.20	39.20
SB-14	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587465	4144093	06/08/2018	37.78	55.73	36.66
SB-15	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587473	4144093	06/08/2018	51.04	61.13	41.81
SB-16	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587464	4144096	06/08/2018	45.42	60.54	38.74
SB-17	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587466	4144097	06/08/2018	47.72	59.91	39.46
SB-18	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587475	4144092	06/08/2018	43.33	61.24	37.72
SB-19	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587431	4144120	06/08/2018	45.78	60.90	37.22
SB-20	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587428	4144123	06/08/2018	51.85	63.47	40.47
SB-21	Double-crested cormorant	05/15/2018	2018	South Bay (A5/A7 levee)	2EPPSSB-A5A7	587430	4144121	06/08/2018	43.61	61.56	37.36
WI-1-N4	Double-crested cormorant	05/10/2018	2018	Wheeler Island	2EPPSWI	590750	4215217	06/08/2018	42.59	62.49	37.03
WI-2-N4	Double-crested cormorant	05/10/2018	2018	Wheeler Island	2EPPSWI	590750	4215217	06/08/2018	44.74	65.21	36.66
WI-3-N4	Double-crested cormorant	05/10/2018	2018	Wheeler Island	2EPPSWI	590750	4215217	06/08/2018	46.93	67.68	36.93

Appendix 2. Quality Assurance and Quality Control Results for Total Mercury (THg) Analyses of Forster's Tern Eggs Collected by U.S. Geological Survey (USGS) from San Francisco Bay, California, in 2018

Table 2-1. Quality assurance and quality control: Certified reference materials.

[CRM, certified reference materials; mm/dd/yyyy, month/day/year; µg/g dw, micrograms per gram dry weight; DORM-4, fish protein certified reference material for trace metals; THg, total mercury; TORT-3, lobster hepatopancreas reference material for trace metals]

Analysis date (mm/dd/yyyy)	CRM	Certified value THg (µg/g dw)	Measured THg (µg/g dw)	Percent recovery ¹
09/18/2018	DORM-4	0.41	0.40	97.0
09/18/2018	DORM-4	0.41	0.41	100.3
09/19/2018	DORM-4	0.41	0.40	97.8
09/19/2018	DORM-4	0.41	0.41	100.1
09/19/2018	DORM-4	0.41	0.42	102.7
09/20/2018	DORM-4	0.41	0.40	98.7
09/20/2018	DORM-4	0.41	0.43	105.2
09/20/2018	DORM-4	0.41	0.42	101.9
09/21/2018	DORM-4	0.41	0.44	106.5
09/19/2018	TORT-3	0.29	0.30	102.0
09/19/2018	TORT-3	0.29	0.29	100.6
09/20/2018	TORT-3	0.29	0.30	101.6
09/21/2018	TORT-3	0.29	0.30	102.6

¹Percent recovery values are based on non-rounded data and therefore would differ slightly from the values obtained if they were calculated directly from the rounded data reported in these tables.

Table 2-2. Quality assurance and quality control: Continuing calibration verifications.

[CCV, continuing calibration verification; g, gram; mm/dd/yyyy, month/day/year; ng, nanogram; THg, total mercury; µg/g ww, microgram per gram wet weight]

Analysis date (mm/dd/yyyy)	CCV (ng)	CCV certified value THg (µg/g ww)	Weight of CCV sample (g)	Expected THg (ng)	Measured THg (ng)	Measured THg (µg/g ww)	Percent recovery ¹
09/19/2018	200	1.0170	0.19642	199.76	198.72200	1.01	99.5
09/20/2018	200	1.0170	0.19671	200.05	197.26100	1.00	98.6
09/21/2018	200	1.0170	0.19563	198.96	197.87900	1.01	99.5
09/19/2018	50	1.0170	0.04850	49.32	49.34600	1.02	100.0
09/20/2018	50	1.0170	0.04972	50.57	50.24000	1.01	99.4
09/21/2018	50	1.0170	0.04933	50.17	50.41000	1.02	100.5
09/18/2018	8.5	0.1060	0.08020	8.50	8.30400	0.10	97.7
09/19/2018	8.5	0.1060	0.08059	8.54	8.77600	0.11	102.7
09/19/2018	8.5	0.1060	0.08017	8.50	8.64100	0.11	101.7
09/20/2018	8.5	0.1060	0.08079	8.56	8.89000	0.11	103.8

¹Percent recovery values are based on non-rounded data and therefore would differ slightly from the values obtained if they were calculated directly from the rounded data reported in these tables.

Table 2-3. Quality assurance and quality control: Sample duplicates.

[ID, identification; mm/dd/yyyy, month/day/year; THg, total mercury; µg/g fww, microgram per gram fresh wet weight]

Analysis date (mm/dd/yyyy)	Sample ID	THg (µg/g fww) replicate 1	THg (µg/g fww) replicate 2	Relative percent difference ¹
09/18/2018	18FE177	1.48	1.49	0.6
09/19/2018	18FE119	1.34	1.34	0.6
09/19/2018	18FE175	1.96	2.00	2.5
09/19/2018	18FE183	2.44	2.39	1.8
09/20/2018	18FE172	1.90	1.97	3.4
09/20/2018	18FE23	0.81	0.80	1.2
09/20/2018	18FE33	0.62	0.64	2.4
09/21/2018	18FE21	2.15	2.28	5.7
09/21/2018	18FE217	1.66	1.67	0.4
09/21/2018	18FE3	0.62	0.63	1.8

¹Relative percent difference values are based on non-rounded data and therefore would differ slightly from the values obtained if they were calculated directly from the rounded data reported in these tables.

Table 2-4. Quality assurance and quality control: System and method blanks.

[ID, identification; mm/dd/yyyy, month/day/year; THg, total mercury; ng, nanogram]

Analysis date (mm/dd/yyyy)	Sample ID	THg (ng)
09/18/2018	System blank	0.084
09/18/2018	Method blank	0.085
09/18/2018	System blank	0.229
09/18/2018	Method blank	0.228
09/18/2018	System blank	0.248
09/18/2018	Method blank	0.252
09/19/2018	System blank	0.211
09/19/2018	Method blank	0.188
09/19/2018	System blank	0.204
09/19/2018	Method blank	0.195
09/19/2018	System blank	0.22
09/19/2018	Method blank	0.22
09/20/2018	System blank	0.195
09/20/2018	Method blank	0.203
09/20/2018	System blank	0.219
09/20/2018	Method blank	0.193
09/20/2018	System blank	0.238
09/20/2018	Method blank	0.232
09/21/2018	System blank	0.263
09/21/2018	Method blank	0.266

Table 2-5. Quality assurance and quality control: Matrix spikes and matrix spike duplicates.

[g, gram; ID, identification; mm/dd/yyyy, month/day/year; ng, nanogram; THg, total mercury; µg/g dw, microgram per gram dry weight]

Analysis date (mm/dd/yyyy)	Sample ID	Weight of egg sample (g)	Mean THg (µg/g dw) of duplicate samples prior to spiking	Expected THg (ng) from egg sample	THg (ng) spike amount	Total expected THg (ng) of egg sample + spike	Measured THg (ng) egg sample + spike	Percent recovered	Relative percent difference in duplicate spike samples ¹
09/18/2018	18FE177	0.02910	7.02	204.27	197.46	401.73	408.64	101.8	3.4
09/18/2018	18FE177	0.03120	7.02	219.01	193.58	412.59	412.71	98.4	3.4
09/19/2018	18FE119	0.03230	6.02	194.54	197.53	392.07	396.00	100.3	1.7
09/19/2018	18FE119	0.03281	6.02	197.61	192.88	390.49	397.67	102.0	1.7
09/20/2018	18FE172	0.02747	8.68	238.41	198.65	437.06	437.89	98.7	0.7
09/20/2018	18FE172	0.02792	8.68	242.31	199.40	441.71	441.20	98.1	0.7
09/20/2018	18FE23	0.02978	3.96	118.04	196.99	315.03	313.09	97.4	2.4
09/20/2018	18FE23	0.02978	3.96	118.04	196.44	314.48	317.34	99.8	2.4
09/21/2018	18FE3	0.03305	2.98	98.54	198.53	297.07	303.76	101.6	0.0
09/21/2018	18FE3	0.03145	2.98	93.76	195.74	289.51	296.20	101.7	0.0

¹Relative percent difference values are based on non-rounded data and therefore would differ slightly from the values obtained if they were calculated directly from the rounded data reported in these tables.

Appendix 3. Forster's Tern Egg Collection Data and Total Mercury (THg) Concentrations for Eggs Collected by USGS From San Francisco Bay, California, in 2018

[dw, dry weight; fww, fresh wet weight; g, gram; ID, identification; mm, millimeter; mm/dd/yyyy, month/day/year; NAD 83, North American Datum of 1983; µg/g, microgram per gram; ww, wet weight]

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Station code	Egg collection date (mm/dd/yyyy)	Whole egg mass (g)	Egg length (mm)	Egg width (mm)	UTM-Easting (NAD 83)	UTM-Northing (NAD 83)	Egg content mass (g ww)	Egg content mass (g dw)	Percent moisture
18FE171	A3W-1	9.26	2.05	2018	A3W	2EEPSSB-A3W	05/23/2018	18.12	42.77	28.91	4143822	585791	16.53	3.92	76.3
18FE175	A3W-1	8.91	1.96	2018	A3W	2EEPSSB-A3W	05/23/2018	18.28	47.03	30.02	4143832	585788	16.61	4.62	72.2
18FE182	A3W-1	7.00	1.50	2018	A3W	2EEPSSB-A3W	05/23/2018	21.30	47.24	30.36	4143833	585790	19.57	4.65	76.3
18FE87	A3W-1	5.18	1.10	2018	A3W	2EEPSSB-A3W	05/23/2018	19.93	44.80	31.20	4143830	585789	18.14	4.60	74.6
18FE88	A3W-1	8.05	1.73	2018	A3W	2EEPSSB-A3W	05/23/2018	18.16	43.04	30.76	4143277	585586	16.62	4.37	73.7
18FE89	A3W-1	11.55	2.49	2018	A3W	2EEPSSB-A3W	05/23/2018	18.26	41.89	29.40	4143277	585583	16.83	3.89	76.9
18FE98	A3W-1	4.38	0.96	2018	A3W	2EEPSSB-A3W	05/23/2018	18.86	42.18	30.11	4143279	585584	17.26	4.15	75.9
18FE178	A3W-2	5.29	1.19	2018	A3W	2EEPSSB-A3W	05/23/2018	18.98	43.50	29.80	4143828	585790	17.45	4.34	75.1
18FE181	A3W-2	10.03	2.10	2018	A3W	2EEPSSB-A3W	05/23/2018	20.08	46.10	30.22	4143833	585790	18.41	4.39	76.2
18FE184	A3W-2	6.86	1.41	2018	A3W	2EEPSSB-A3W	05/23/2018	18.28	43.74	30.70	4143832	585790	16.70	4.22	74.7
18FE29	A3W-2	8.99	1.90	2018	A3W	2EEPSSB-A3W	05/23/2018	18.86	43.11	30.89	4143277	585586	17.27	4.34	74.9
18FE90	A3W-2	6.66	1.35	2018	A3W	2EEPSSB-A3W	05/23/2018	18.41	44.57	30.32	4143831	585790	16.79	4.14	75.3
18FE92	A3W-2	14.33	2.97	2018	A3W	2EEPSSB-A3W	05/23/2018	18.89	43.60	31.16	4143830	585780	17.42	4.40	74.8
18FE95	A3W-2	5.12	1.23	2018	A3W	2EEPSSB-A3W	05/23/2018	18.24	38.18	30.42	4143527	585712	16.47	4.20	74.5
18FE177	A3W-3	7.00	1.48	2018	A3W	2EEPSSB-A3W	05/23/2018	20.54	45.41	30.76	4143276	585583	18.92	4.53	76.0
18FE183	A3W-3	11.47	2.44	2018	A3W	2EEPSSB-A3W	05/23/2018	17.90	43.85	29.05	4143525	585714	16.43	3.92	76.2
18FE226	A3W-3	5.49	1.24	2018	A3W	2EEPSSB-A3W	06/01/2018	17.83	43.28	29.76	4143276	585583	16.21	4.31	73.4
18FE31	A3W-3	10.37	2.30	2018	A3W	2EEPSSB-A3W	05/23/2018	19.40	42.80	30.48	4143276	585583	17.85	4.39	75.4
18FE5	A3W-3	4.87	1.10	2018	A3W	2EEPSSB-A3W	05/23/2018	21.67	47.58	30.24	4143831	585791	19.99	4.87	75.6
18FE86	A3W-3	5.80	1.25	2018	A3W	2EEPSSB-A3W	05/23/2018	18.13	42.76	30.32	4143831	585893	16.49	4.20	74.5
18FE91	A3W-3	11.90	2.56	2018	A3W	2EEPSSB-A3W	05/23/2018	18.76	45.33	29.70	4143524	585714	17.06	4.27	75.0
18FE100	N1-1	2.30	0.53	2018	N1	2EEPSSB-N1	05/25/2018	17.59	40.55	29.90	4153620	581043	16.08	4.13	74.3
18FE172	N1-1	8.53	1.90	2018	N1	2EEPSSB-N1	05/25/2018	17.76	43.65	30.67	4153660	581064	16.18	4.57	71.7
18FE187	N1-1	7.32	1.59	2018	N1	2EEPSSB-N1	06/13/2018	18.63	45.24	29.25	4153552	581413	17.17	4.20	75.5
18FE3	N1-1	2.95	0.62	2018	N1	2EEPSSB-N1	05/18/2018	19.81	42.97	30.38	4153623	581045	18.20	4.15	77.2
18FE32	N1-1	4.03	0.88	2018	N1	2EEPSSB-N1	05/18/2018	20.89	44.66	31.22	4153623	581045	19.19	4.76	75.2
18FE94	N1-1	4.87	1.04	2018	N1	2EEPSSB-N1	05/25/2018	18.72	44.17	30.61	4153620	581053	17.26	4.43	74.3
18FE97	N1-1	7.27	1.57	2018	N1	2EEPSSB-N1	05/25/2018	19.44	44.11	31.29	4153620	581043	17.75	4.65	73.8

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Station code	Egg collection date (mm/dd/yyyy)	Whole egg mass (g)	Egg length (mm)	Egg width (mm)	UTM-Easting (NAD 83)	UTM-Northing (NAD 83)	Egg content mass (g ww)	Egg content mass (g dw)	Percent moisture
18FE174	N1-2	4.62	1.01	2018	N1	2EEPSSB-N1	05/25/2018	19.78	43.59	30.82	4153623	581045	18.21	4.52	75.2
18FE176	N1-2	5.34	1.03	2018	N1	2EEPSSB-N1	05/25/2018	20.99	46.62	30.81	4153623	581046	19.36	4.28	77.9
18FE198	N1-2	3.92	0.86	2018	N1	2EEPSSB-N1	06/13/2018	17.97	41.20	29.78	4153549	581412	16.47	3.97	75.9
18FE2	N1-2	3.01	0.64	2018	N1	2EEPSSB-N1	05/18/2018	18.43	43.36	30.75	4153622	581045	16.76	4.33	74.2
18FE220	N1-2	10.64	1.99	2018	N1	2EEPSSB-N1	06/13/2018	18.76	43.34	31.32	4153550	581412	17.16	3.95	77.0
18FE93	N1-2	8.63	1.81	2018	N1	2EEPSSB-N1	06/13/2018	17.91	42.50	29.64	4158540	581411	16.31	3.88	76.2
18FE96	N1-2	7.31	1.55	2018	N1	2EEPSSB-N1	05/25/2018	19.94	43.34	31.48	4153620	581044	18.43	4.57	75.2
18FE136	N1-3	4.95	1.06	2018	N1	2EEPSSB-N1	07/17/2018	16.63	41.97	28.95	4153624	581045	15.06	3.73	75.2
18FE179	N1-3	4.56	1.00	2018	N1	2EEPSSB-N1	05/25/2018	18.09	44.31	29.91	4153621	581045	16.62	4.35	73.8
18FE185	N1-3	6.18	1.31	2018	N1	2EEPSSB-N1	05/25/2018	16.89	42.15	29.19	4153621	583048	15.47	3.80	75.4
18FE209	N1-3	5.80	1.23	2018	N1	2EEPSSB-N1	06/13/2018	21.10	44.05	31.51	4153541	581412	19.46	4.65	76.1
18FE22	N1-3	3.51	0.74	2018	N1	2EEPSSB-N1	05/30/2018	20.15	45.64	30.56	4153622	581044	18.44	4.49	75.7
18FE35	N1-3	2.25	0.51	2018	N1	2EEPSSB-N1	06/13/2018	17.92	40.75	30.05	4153538	581409	16.49	4.13	75.0
18FE37	N1-3	5.22	1.22	2018	N1	2EEPSSB-N1	06/13/2018	19.00	40.85	30.59	4153538	581411	17.47	4.46	74.5
18FE1	NCM-1	6.88	1.46	2018	NCM	2EEPSSB-NCM	05/22/2018	18.72	42.03	30.31	4143803	591486	17.21	4.10	76.2
18FE10	NCM-1	1.23	0.30	2018	NCM	2EEPSSB-NCM	05/17/2018	17.64	42.05	30.32	4143756	591505	15.80	4.71	70.2
18FE26	NCM-1	8.11	1.84	2018	NCM	2EEPSSB-NCM	05/22/2018	18.83	45.71	29.76	4143792	591503	17.40	4.61	73.5
18FE27	NCM-1	1.99	0.50	2018	NCM	2EEPSSB-NCM	05/22/2018	18.12	44.85	29.60	4144081	590918	16.39	4.89	70.2
18FE30	NCM-1	11.76	2.48	2018	NCM	2EEPSSB-NCM	05/22/2018	19.09	41.12	30.79	4144110	590919	17.51	4.11	76.6
18FE6	NCM-1	5.33	1.15	2018	NCM	2EEPSSB-NCM	05/17/2018	20.72	45.59	30.66	4143801	591495	19.20	4.62	75.9
18FE9	NCM-1	2.40	0.52	2018	NCM	2EEPSSB-NCM	05/17/2018	20.05	43.31	30.72	4143800	591522	18.36	4.39	76.1
18FE11	NCM-2	6.76	1.57	2018	NCM	2EEPSSB-NCM	05/17/2018	21.76	43.01	31.94	4143778	591502	20.18	5.08	74.8
18FE13	NCM-2	9.55	2.06	2018	NCM	2EEPSSB-NCM	05/17/2018	18.92	42.92	30.41	4143805	591536	17.38	4.28	75.4
18FE18	NCM-2	5.34	1.03	2018	NCM	2EEPSSB-NCM	05/17/2018	19.79	43.39	31.04	4143808	591508	18.01	4.01	77.7
18FE208	NCM-2	5.37	1.20	2018	NCM	2EEPSSB-NCM	06/07/2018	19.32	43.48	30.59	4144105	590976	17.46	4.51	74.2
18FE25	NCM-2	11.94	2.55	2018	NCM	2EEPSSB-NCM	05/22/2018	17.30	42.82	29.87	4143806	591519	15.87	4.08	74.3
18FE40	NCM-2	9.53	2.03	2018	NCM	2EEPSSB-NCM	05/22/2018	18.61	44.20	30.85	4143814	591530	17.13	4.48	73.8
18FE7	NCM-2	2.62	0.59	2018	NCM	2EEPSSB-NCM	05/17/2018	18.80	42.21	30.61	4143792	591536	17.04	4.40	74.2
18FE119	NCM-3	6.00	1.34	2018	NCM	2EEPSSB-NCM	07/10/2018	17.95	43.04	29.89	4144100	590975	16.31	4.25	74.0
18FE12	NCM-3	6.30	1.42	2018	NCM	2EEPSSB-NCM	05/17/2018	19.86	43.72	30.55	4144121	590981	18.18	4.57	74.9
18FE145	NCM-3	1.26	0.30	2018	NCM	2EEPSSB-NCM	07/10/2018	18.95	44.44	31.05	4144102	590977	17.19	5.16	70.0
18FE16	NCM-3	16.91	3.60	2018	NCM	2EEPSSB-NCM	05/22/2018	17.67	43.99	29.78	4144109	590978	15.97	4.12	74.2

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Station code	Egg collection date (mm/dd/yyyy)	Whole egg mass (g)	Egg length (mm)	Egg width (mm)	UTM-Easting (NAD 83)	UTM-Northing (NAD 83)	Egg content mass (g ww)	Egg content mass (g dw)	Percent moisture
18FE28	NCM-3	14.37	3.14	2018	NCM	2EEPSSB-NCM	05/22/2018	16.48	41.77	29.11	4143799	591530	15.05	3.86	74.4
18FE39	NCM-3	3.95	0.87	2018	NCM	2EEPSSB-NCM	05/22/2018	20.31	45.24	30.92	4143822	591514	18.72	4.76	74.6
18FE8	NCM-3	9.20	1.92	2018	NCM	2EEPSSB-NCM	05/17/2018	18.59	44.45	30.43	4143787	591532	16.93	4.28	74.7
18FE173	SF2-1	1.90	0.41	2018	SF2	2EEPSSB-SF2	05/31/2018	19.18	42.57	30.27	4150336	576952	17.56	4.18	76.2
18FE188	SF2-1	10.56	2.25	2018	SF2	2EEPSSB-SF2	06/12/2018	18.94	44.10	29.87	4150249	576855	17.30	4.17	75.9
18FE201	SF2-1	11.31	2.47	2018	SF2	2EEPSSB-SF2	06/12/2018	20.31	44.95	30.80	4150339	576954	18.64	4.63	75.1
18FE211	SF2-1	8.64	1.92	2018	SF2	2EEPSSB-SF2	06/05/2018	17.45	41.68	29.11	4150337	576950	15.99	3.90	75.6
18FE23	SF2-1	3.99	0.81	2018	SF2	2EEPSSB-SF2	05/31/2018	18.09	42.67	30.06	4150252	576856	16.30	3.88	76.2
18FE235	SF2-1	10.01	2.25	2018	SF2	2EEPSSB-SF2	05/31/2018	20.98	44.53	30.71	4149782	576938	19.28	4.69	75.7
18FE99	SF2-1	2.52	0.55	2018	SF2	2EEPSSB-SF2	06/12/2018	18.49	43.25	29.77	4150346	576988	17.11	4.21	75.4
18FE186	SF2-2	6.17	1.41	2018	SF2	2EEPSSB-SF2	06/12/2018	16.79	42.83	28.49	4150350	576942	15.41	3.95	74.4
18FE202	SF2-2	11.47	2.39	2018	SF2	2EEPSSB-SF2	06/05/2018	19.42	42.33	31.33	4150073	576930	17.78	4.33	75.7
18FE222	SF2-2	8.40	1.91	2018	SF2	2EEPSSB-SF2	06/05/2018	21.20	43.44	30.91	4150206	576957	19.37	4.67	75.9
18FE225	SF2-2	7.26	1.57	2018	SF2	2EEPSSB-SF2	06/05/2018	16.54	42.18	29.01	4150252	576856	15.09	3.82	74.7
18FE231	SF2-2	4.54	0.99	2018	SF2	2EEPSSB-SF2	05/31/2018	18.13	42.89	29.22	4149777	576938	16.67	3.97	76.2
18FE24	SF2-2	5.26	1.06	2018	SF2	2EEPSSB-SF2	06/12/2018	20.19	43.94	31.17	4150249	576857	18.38	4.26	76.8
18FE33	SF2-2	3.02	0.62	2018	SF2	2EEPSSB-SF2	06/12/2018	20.48	46.60	30.30	4150342	576995	19.02	4.41	76.8
18FE197	SF2-3	10.96	2.36	2018	SF2	2EEPSSB-SF2	06/12/2018	19.44	42.82	30.78	4150340	576954	17.73	4.35	75.5
18FE203	SF2-3	3.70	0.77	2018	SF2	2EEPSSB-SF2	06/05/2018	19.61	44.19	29.94	4150130	576965	18.10	4.12	77.2
18FE206	SF2-3	7.54	1.61	2018	SF2	2EEPSSB-SF2	06/12/2018	17.99	41.53	29.90	4150248	576856	16.43	3.95	76.0
18FE21	SF2-3	9.79	2.15	2018	SF2	2EEPSSB-SF2	05/24/2018	15.63	39.24	28.53	4150250	576857	14.28	3.49	75.5
18FE228	SF2-3	3.63	0.75	2018	SF2	2EEPSSB-SF2	06/05/2018	18.77	43.28	30.38	4150246	576856	17.28	4.11	76.2
18FE229	SF2-3	6.35	1.36	2018	SF2	2EEPSSB-SF2	06/05/2018	20.21	42.94	30.76	4150252	576856	18.53	4.34	76.6
18FE230	SF2-3	5.92	1.28	2018	SF2	2EEPSSB-SF2	06/05/2018	21.00	43.25	31.72	4150252	576856	19.42	4.70	75.8

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