RMP
REGIONAL MONITORING
PROGRAM FOR WATER QUALITY
IN SAN FRANCISCO BAY

sfei.org/rmp

RMP Field Sampling Report 2016

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TABLE OF CONTENTS

1. INTRODUCTION

PROGRAM STRUCTURE AND OBJECTIVES

The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) is the primary source for long-term contaminant monitoring information for the Bay. The RMP is an innovative and collaborative effort among the scientific community, the San Francisco Bay Regional Water Quality Control Board (Water Board), and the regulated discharger community. The Program was initiated by the Water Board as a pilot study in 1989 and has been collecting water, sediment, and bivalve tissue data since its official inception in 1993. Regular monitoring of sport fish tissue and bird eggs for toxic contaminants was incorporated into the Program in 1997 and 2006, respectively.

The Program monitors the different matrices included in "status and trends" monitoring on varying schedules. In 2016, the RMP conducted monitoring for contaminants in bivalves and bird eggs. Bird egg monitoring was originally scheduled to occur in 2015 but was delayed a year.

The purpose of this report is to document how RMP Status and Trends samples were collected in 2016. The report is organized into chapters on bivalves and bird eggs. Each chapter contains information on:

- The locations where these samples were collected,
- The field sampling methods,
- The target analytes, laboratories, and analytical methods for each matrix,
- The number and type of samples archived for short- and long-term storage, and
- Any problems encountered or non-conformances to planned procedures.

This report does not include any of the laboratory results for the samples or other data analysis.

The appendix to this report contains details of RMP contractors, coordinates of sampling locations in 2016, and any additions to the running list of changes to the RMP sampling and analysis methods.

Additional information about field methods, analytical methods, and quality assurance/quality control are in the RMP's Program QAPP (SFEI, 2016).

2. BIVALVE MONITORING

BACKGROUND

The RMP has been analyzing bivalve tissue samples for trace contaminants since 1993. The RMP is continuing the long-term monitoring of the State Mussel Watch Program, which monitored sites throughout the Estuary beginning in 1976. Bivalve monitoring was conducted annually from 1993-2006. Biennial monitoring began after 2006, and is planned to continue for at least the next 10 years.

SAMPLING SITES

The bivalve sample types fall into four categories.

Bivalve Transplant Samples (n=7). Mussels (*Mytilus californianus*) are collected from Bodega Head, an uncontaminated "background" site of known chemistry, and transplanted to 7 targeted sites within the Bay. Three transplant sites are within the Lower South Bay-South Bay, two transplant sites are in Central Bay and two transplant sites are in San Pablo Bay. Three of the 7 transplant sites serve as back-ups in case something goes wrong with the transplants at one of the primary sites.

Resident Bivalve Samples (n=2). Resident clams (*Corbicula fluminea*) are collected from 2 sites: BG20 on the Sacramento River and BG30 on the San Joaquin River.

"Time Zero" (T-0) Bivalve Sample (n=1): A subset of the mussels from Bodega Head are sacrificed and frozen at the time of bivalve deployment in the Bay, and then analyzed after the 100-day deployment period along with the transplanted samples. This sample is used as a baseline for the "pre-deployment" tissue condition. Size measurements on T-0 samples are also compared with size measurements on transplanted and T-1 samples to measure growth in the transplanted and T-1 sample mussels during the deployment period.

"Time One" (T-1) Bivalve Sample (n=1): A new batch of mussels from Bodega Head is collected after 100 days to use as a control for mussel growth during the 100-day deployment.

Station names, codes, location, and sampling dates for the 2016 monitoring effort are listed in Appendix 2 and shown in Figure 2.1.

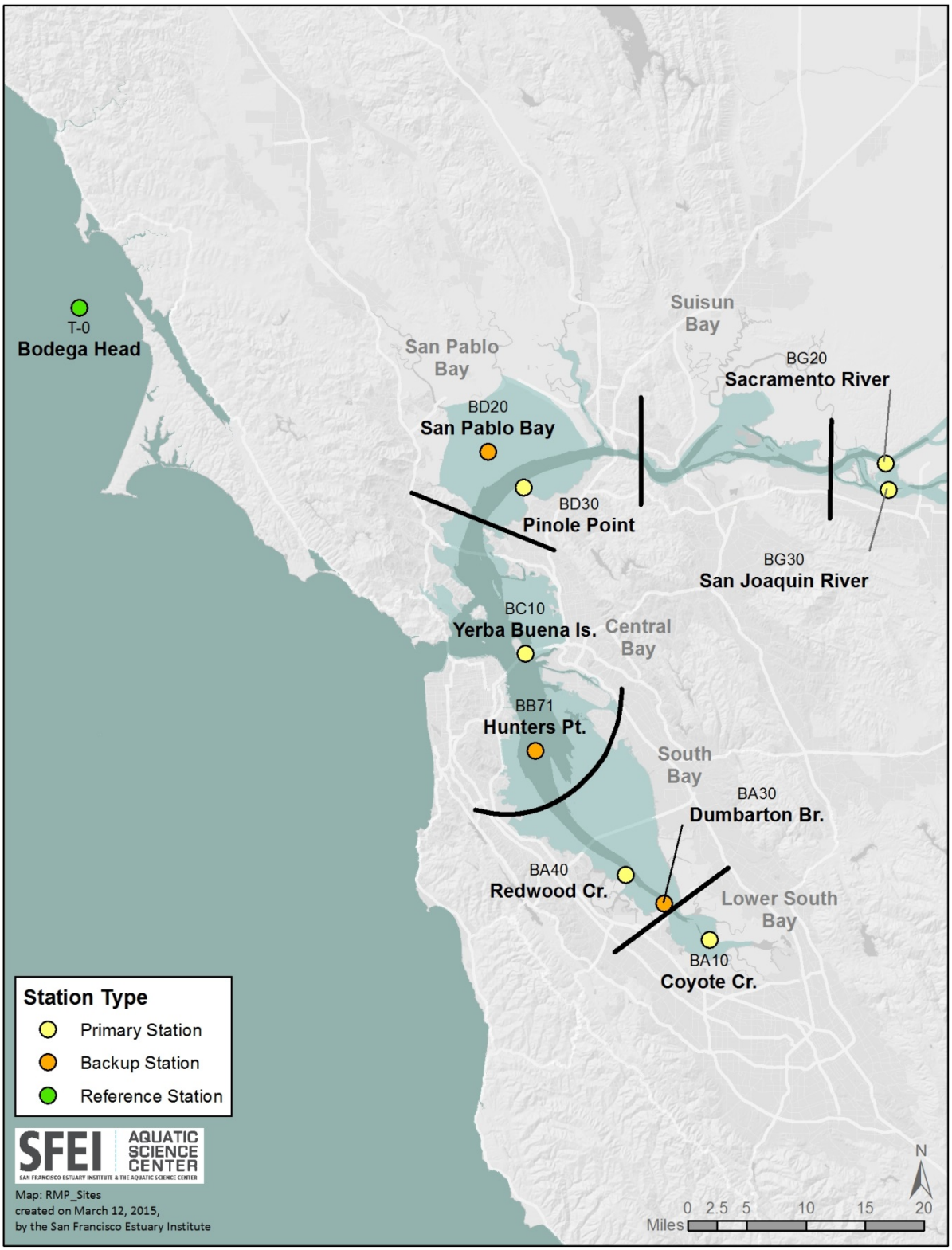

Figure 2.1 Map of 2016 Bivalve Monitoring Stations. T-1 samples were also collected from the Bodega Head reference station. In 2016, samples from backup stations were not analyzed or archived as explained in the text.

FIELD METHODS

The RMP sampling plan for bivalve sampling is to transplant the samples during the dry season, usually in June, and retrieve the samples after approximately 100 days. In 2016, *M. californianus* samples were collected from Bodega Head on June 6, transplanted to the seven Bay locations on June 28 - July 1 and retrieved on October 4-7. Additional *M. californianus* samples were collected from Bodega Head on September 30 (T-1 sample) for growth analysis. Samples of the resident *C. fluminea* were collected from the river sites on October 13.

Bivalve Sample Collection Methods

Bivalve Collection – Reference Site

Bivalves were collected from intertidal areas within the Bodega Marine Reserve in June. Mussels were placed in rigid oyster bags and depurated in filtered seawater tanks operated by the Bodega Marine Lab Aquatic Resource Group, and cleaned of fouling organisms prior to deployment in the Bay. A subsample of these bivalves (T-0 sample) was retained at the time of bivalve deployment to provide a baseline on "pre-deployment" tissue condition.

A second sample of mussels were collected from the Bodega Marine Reserve at the end of the deployment period (T-1 sample) for a control measurement of growth.

Bivalve Deployment and Retrieval – Bay Sites

At each transplant site, 240 mussels were randomly allocated and placed into predator resistant cages for deployment. Mussels of approximately the same shell length were used (49-81 mm). The same number was also used for the reference (T-0) sample.

The cages were constructed out of rigid plastic mesh and PVC pipe. The mesh overlapped around itself to keep predators from slipping through any gaps between the edges. After the cages were built, they were soaked in water for at least a day to remove potential contamination associated with the adhesives used for the construction.

At each site, a line ran from the bottom of the fixed structure out to the bivalve mooring, which consisted of a large screw (earth anchor) that was threaded into the bottom and was associated with pilings or other permanent structures. A large subsurface buoy was attached to the earth anchor by a one to two meter line. The bivalve cages were attached to the buoy line, which kept the bivalves off the bottom to prevent smothering. Since the beginning of the program, loss of a mooring has occurred on only two occasions, probably due to being ripped out by a vessel anchor. Mooring installation, bivalve deployment, and retrieval were all accomplished by SCUBA divers.

Upon retrieval, the bivalve cages were cut off the buoy line and taken to the surface. On the vessel, the number of dead organisms was recorded. Bivalves allocated for trace organic, selenium, microcystin, and emerging contaminants analyses were not rinsed, wrapped in two layers of aluminum foil, placed in 2-gallon zip-top bags and placed on dry ice. Bivalves allocated for growth analysis were rinsed in the field to remove overlying mud, placed in 2-gallon zip-top bags and placed on dry ice.

Resident clams at sites BG20 and BG30 were collected using a clam dredge approximately two feet wide by three feet long and 50 pounds in weight. The dredge was deployed from a boat and was dragged along the bottom.

When brought to the surface, the clams were placed into a clean plastic container and packaged for organics analysis.

Based on findings by Stephenson (1992) during the RMP Pilot Program, bivalve guts were not depurated before homogenization for tissue analyses. However, sediment in bivalve guts may contribute to the total tissue concentration for trace organic contaminants.

Difficulties Encountered

Over the course of deployment, the bivalve cages at site Coyote Creek (BA10) were covered by sediment, causing high levels of mortality. Sedimentation at the Dumbarton Bridge backup site (BA30) caused full mortality, so backup samples were not available to replace the small volume of sample collected at BA10. At BG20, not enough clams were encountered to provide sample mass for all planned analyses and archives. At both BA10 and BG20, enough samples was available to support all planned analyses, but only two sample vials were able to be saved for long-term sample archive.

Samples collected at the backup sites at Alameda (BB71) and San Pablo Bay (BD20) were not needed and were discarded. Archive samples were not retained from these sites due to a communication error. For future bivalve cruises, archive samples should be retained from the backup sites.

Bivalve Deployment Transition

In 2018, the equipment used for bivalve deployments will change from moored deployment stations to acoustic-release deployment systems. Therefore, moored deployment equipment at each bivalve station was retrieved during the bivalve retrieval cruise in October 2016. Buoy lines were removed and earth anchors left in the sediment to degrade. The acoustic-release system will be purchased and monitoring design reviewed by the Technical Review Committee before bivalve monitoring is next scheduled to occur in 2018.

Shipboard Measurements

CTD profiles were collected at each bivalve site during both deployment and retrieval cruises to help determine how ambient environmental factors affect the transplanted bivalves. Salinity, dissolved oxygen, temperature, and total suspended solids impact bivalve health and could affect contaminant bioaccumulation rates.

LABORATORY METHODS

Whole bivalve samples were sent to AXYS Analytical, Inc., where bivalves were shucked and homogenized into a single composite sample for each site. Samples were shipped frozen on dry ice on October 31. Each composite was subsequently subsampled for each analysis and archive.

The laboratories and analytical methods that were used to measure target analytes are presented in Table 2.1 below. Additional target analytes for special studies or *pro bono* research by collaborators are listed below the table. SFEI maintains copies of the detailed protocols for all laboratory analyses.

Table 2.1 2016 bivalve target analytes, analytical laboratories, reporting units, and method codes

Analyte	Analytical Lab	Reporting Unit	Method #
Growth	AMS	G	AMS-CA Growth SOP
PAHs	AXYS	ng/g (ppb)	EPA 8270M
PBDEs	AXYS	ng/g (ppb)	EPA 1614M
Selenium	BRL	ug/g (ppm)	EPA 1638M

QA/QC sample analyses included a minimum of one lab blank, one lab duplicate, one matrix spike, and one certified reference material analysis per sample batch.

Archives and Add-on Analytes

When mass was available, additional tissue from each site composite was archived at both -18 °C (short-term archive) and -150 °C (long-term archive) for potential future analyses, such as for organic parameters and perfluorinated chemicals. These samples are presented below in Table 2.2. Archive samples were prepared for composites at all of the primary sites except BA10 and BG20, for which enough sample mass was available only to partially fill two 22 mL Teflon vials per site (long-term archive).

Table 2.2 2016 bivalve archive samples and storage locations.

Storage Location	Container Type	Sample Mass per Archive (g)	Number of Archives per site	Archive Location
Long Term	10 mL polypropylene cryovials	16	2	NIST
Long Term	22 mL standard Teflon vial, round interior	45	3	NIST
Short Term	30 mL polypropylene jar	30	2	Oakland
Short Term	60 mL clear short glass jar	45	3	Oakland

Requests were made by researchers outside of the RMP to collect samples to support their research during the 2016 cruise. These requests were accommodated alongside regular S&T sampling with minimal disruption to regularly planned sampling activities. Samples collected for these studies are listed below.

- Emerging alternative flame retardants, halogenated carbazoles, and emerging plastic additives by the Chen Laboratory, Southern Illinois University for a RMP Emerging Contaminants Special Study
- Microcystin in bivalves by the Kudela Laboratory, UC Santa Cruz for a Nutrient Management Strategy study

Bivalve Growth and Survival

Applied Marine Sciences (AMS) calculated the growth mean of transplanted bivalves as a measure of bivalve health measure. The growth mean is a measure of growth of the composite of bivalves at a particular site in comparison to the T-0 bivalves. The growth mean was determined by taking the dry weight of each individual and subtracting the mean dry weight of the T-0 samples. This calculation was done for each individual bivalve. The mean of the difference of all the individuals at a particular site was then calculated to give the growth mean.

REFERENCES FOR ADDITIONAL DETAILS

2016 Bivalve Deployment Cruise Report - http://www.sfei.org/documents/2016-rmp-bivalve-deployment-cruise-report

2016 Bivalve Retrieval Cruise Report - http://www.sfei.org/documents/2016-rmp-bivalve-retrieval-cruise-report

3. BIRD EGG MONITORING

BACKGROUND

Double-crested Cormorant and Forster's Tern bird egg monitoring was incorporated into the RMP's Status and Trends Program in 2009. Substantial monitoring of eggs (cormorant in 2002, 2004, and 2006, and tern in 2002 and 2004) were previously conducted through RMP Exposure and Effects Pilot Studies. In addition to the initial 2009 sampling, sampling also occurred in 2012, and was scheduled for 2015, but was delayed until 2016.

SAMPLING SITES

In 2016, bird eggs were collected from seven unique locations.

Double-crested cormorant (*Phalacrocorax auritus*) eggs were collected between April 11th and June 2nd, 2016 at three locations: Wheeler Island, Richmond Bridge, and South Bay (Pond A9/A10 levee). The Pond A9/A10 site replaced the South Bay PG&E tower sampling location from 2009. A total of 24 cormorant eggs were collected at each site.

Forster's Tern (*Sterna forsteri*) eggs were collected between May 12th and June 22nd, 2016 at four locations: Pond AB1, Pond AB2, New Chicago Marsh at the Don Edwards San Francisco Bay National Wildlife Refuge, and Pond 2 at the Hayward Shoreline Regional Park. A total of 21 tern eggs were collected at each of the four sample sites. The number of locations was reduced from six to four due to sampling and analysis costs. The previously sampled Eden Landing Ecological Reserve and the Napa-Sonoma Marsh Wildlife Area sites were not sampled in 2016. Terns are known to be nomadic, and change colony sites in response to local conditions, sometimes requiring certain sample sites to be replaced. Previous sampling locations Pond A1 and A7 could not be sampled in 2016 as terns did not nest at these locations, while nesting did not occur at a high enough density at Pond A2W to allow for sampling. Station names, codes, location, and sampling dates for the 2016 monitoring effort are listed in Appendix 2 and shown in Figure 3.1.

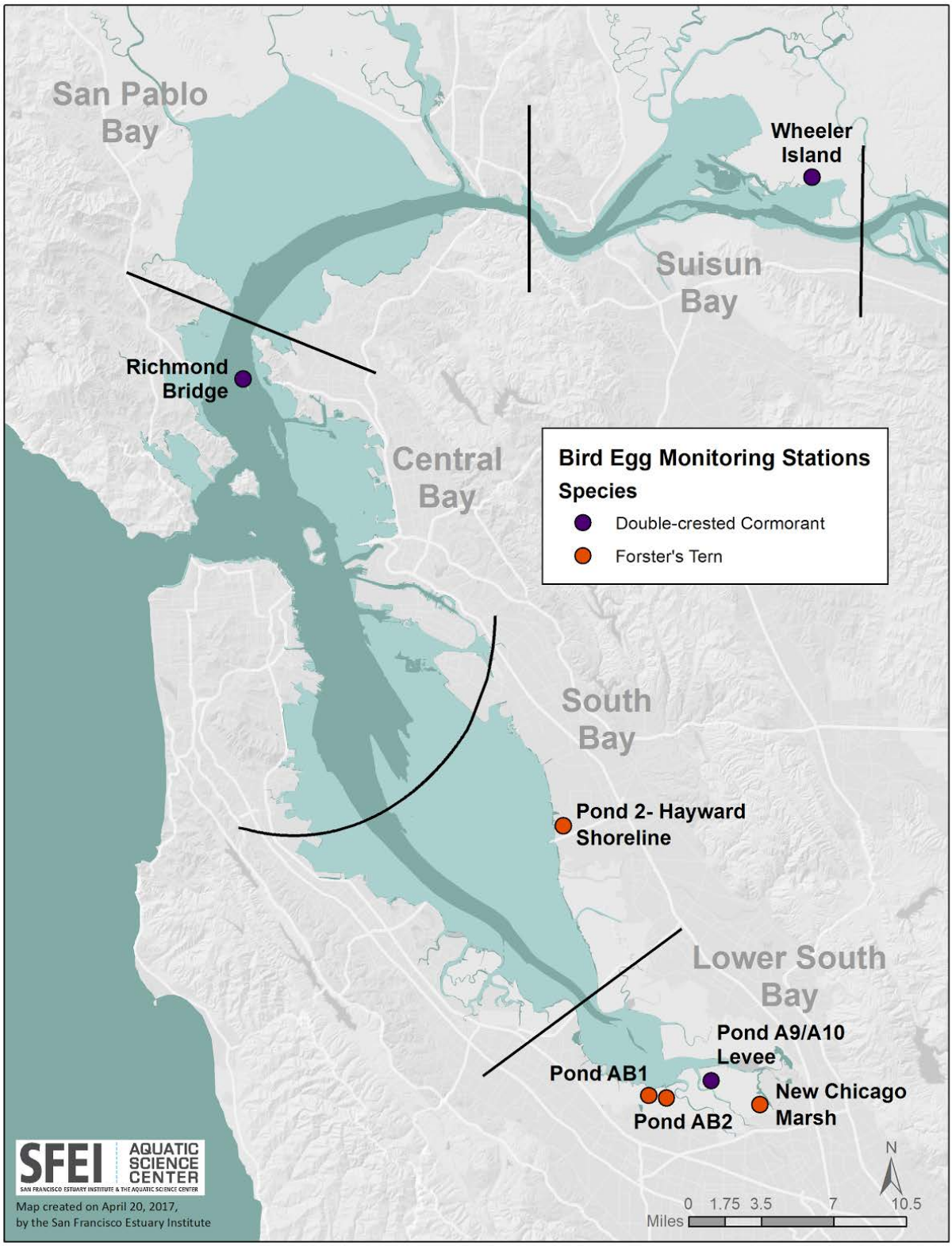

Figure 3.1 Map of 2016 Bird Egg Monitoring Stations. Double-crested Cormorant eggs were collected at three locations, and Forster's Tern eggs were collected at four locations.

FIELD METHODS

Sampling was conducted by staff from the USGS Western Ecological Research Center (USGS-WERC) using approved USGS field collection and handling protocols (SFEI, 2016; Ackerman et al., 2013). For the cormorant eggs, 24 eggs were collected from 24 separate nests at each of the three locations, for a total of 72 eggs. This includes three additional eggs per site in case of breakage during whole egg shipment. For the tern eggs, 21 eggs were collected from 21 separate nests at each of the four locations, for a total of 84 eggs. No additional tern eggs were collected, as these eggs are not shipped.

Coordinates of actual sample sites were recorded with a hand-held GPS. Each egg was given a unique sample ID in the field, following a prescribed labeling scheme. Cormorant eggs were labeled with site code and number (e.g. RB-8), while Tern eggs were labeled with year, project code, egg number (e.g. 16-FE-23). Eggs were then transported on ice back to the USGS-WERC laboratory, where they were refrigerated until processing.

The USGS-WERC laboratory stored the collected eggs in the refrigerator until sample processing. Staff allowed the refrigerated stored eggs to reach room temperature, and then measured each egg's length, width, and total weight (at time of processing). Cormorant eggs were then sent to AXYS Analytical, Inc. on June 28th, 2016 for dissection and processing, while Forster's Tern eggs were dissected and processed at USGS-WERC.

Difficulties Encountered

The bird egg collection occurred as planned, with the exception of not being able to sample Ponds A1 or A7 because terns were not nesting, or Pond A2W because of low density of nesting.

LABORATORY METHODS

Cormorant Eggs

Twenty-four cormorant eggs from each of the three sample locations, for a total of 72 eggs, were shipped to AXYS. Upon arrival, the cormorant eggs were inspected for breakage. AXYS reported that four eggs, all from Wheeler Island, had broken during shipment. The remaining unbroken eggs were individually weighed, and the 21 largest eggs from each location were then selected for analysis. For each location, three composites of equal mass from seven eggs were prepared. Each composite was then subsampled, with prescribed mass placed into sample containers for each analyte and for archive. Storing each sample at -20C, AXYS sent the frozen samples to the appropriate laboratory for analysis. Composites for halogenated carbazoles was the lowest priority, and only were created after all other analyses and archives had been completed.

The laboratories and analytical methods that were used to measure target analytes are presented in Table 3.1 below. For each analyte using a composite sample type, the three composites from each field site will serve as the field duplicate samples. Additional target analytes for special studies or *pro bono* research by collaborators are listed below the table. SFEI maintains copies of the detailed protocols for all laboratory analyses.

Table 3.1 2016 cormorant eggs target analytes, analytical laboratories, reporting units, and method codes

Analyte	Analytical Lab	Sample Type	Reporting Unit	Method #
Total Mercury	MLML-MPSL	individual	ug/g (ppm) wet weight	EPA 7473M
Selenium	MLML-MPSL	composite	ug/g (ppm) dry weight	EPA 200.8
PCBs	DFW-WPCL	composite	ng/g (ppb) wet weight	EPA 8082
PBDEs	DFW-WPCL	composite	ng/g (ppb) wet weight	EPA 8081BM
PFCs	AXYS	composite	ng/g (ppb) wet weight	AXYS MLA-043

Archives and Add-on Analytes

When mass was available, additional tissue from each site composite was archived at both -18 °C (short-term archive) and -150 °C (long-term archive) for potential future analyses, such as for organic parameters and perfluorinated chemicals. In addition, individual egg archives were collected for future selenium analyses (n=62, short term storage). The archive samples are presented below in Table 3.2. Archive samples were prepared for composites at all sites .

Table 3.2 2016 cormorant egg archive samples and storage locations.

Storage Location	Container Type	Sample Mass per Archive (g ww)	Number of Archives per site	Archive Location
Long term	22 mL Teflon vials	15	3	NIST
Long term	10 mL Polypropylene cryovials	8	2	NIST
Short term	60 mL Glass jars	15	3	Oakland
Short term	30 mL Polypropylene jars	15	2	Oakland
Short term	Polypropylene jars for selenium	39	21	Oakland

A request was made by Southern Illinois University for the RMP to collect samples to support their research. This request was accommodated alongside regular S&T sampling, with no disruption to regularly planned sampling activities. The samples collected are listed below.

- Halogenated carbazoles

When cormorant egg mass was available, and only after mass was allocated to all other analytes, additional tissue from each site composite was subsampled and sent to Southern Illinois University for analysis.

Forster's Tern Eggs

The 84 individual Forster's Tern eggs were processed at USGS-WERC. Egg material was removed from the shell and weighed (without the shell), and stored at -20C until processing. For processing, the egg material was thawed, then dried, and weighed again to determine moisture content of each individual egg. Moisture content was measured so that concentrations can be expressed on a fresh weight basis. Then the dried egg contents were homogenized into a powder, and prepared for sub-sampling. First, a 2 g dry weight aliquot was removed for individual egg total mercury analysis by the USGS laboratory. Next, equal amounts of material from each egg were composited for the remaining analyses. Three composites for each site were completed, with each composite made up of equal

masses (dried) from seven individual eggs. For the four sample sites, a total of twelve tern egg composites were created. Each composite was re-homogenized, then aliquots for selenium and PBDEs (if enough mass remained) were placed in appropriate sample containers. On November 16th, 2016 USGS-WERC shipped (at room temperature) selenium samples to Moss Landing Marine Labs for analysis, and shipped PBDE samples to AMS for archive and potential future analysis.

The laboratories and analytical methods that were used to measure target analytes are presented in Table 3.3 below. Tern egg samples were analyzed for mercury and selenium. PBDE analysis in tern eggs was discontinued to stay within budget. Samples were archived to allow for PBDE analyses in the future if desired. Additional target analytes for special studies or *pro bono* research by collaborators are listed below the table. SFEI maintains copies of the detailed protocols for all laboratory analyses.

Table 3.3 2016 tern egg target analytes, analytical laboratories, reporting units, and method codes

Analyte	Analytical Lab	Sample Type	Reporting Unit	Method #
Total Mercury	USGS-WERC	individual	ug/g (ppm) wet weight	EPA 7473
Selenium	MLML-MPSL	composite	ug/g (ppm) dry weight	EPA 200.8

Archives and Add-on Analytes

When mass was available, additional tissue from each site composite was archived at -18 °C (short-term archive) for potential future analyses for PBDEs. The archive samples are presented below in Table 3.4. Archive samples were prepared for composites at all sites .

Table 3.4 2016 tern egg archive samples and storage locations.

Storage Location	Container Type	Sample Mass per Archive (g dw)	Number of Archives per site	Archive Location
Short term – for PBDEs	20 mL glass jar	7	3	Oakland

REFERENCES FOR ADDITIONAL DETAILS

Ackerman, J.T., Herzog, M.P., and Schwarzbach, S.E. 2013. Methylmercury is the predominant form of mercury in bird eggs: a synthesis. Environmental Science and Technology 47:2052-2060.

Ackerman, J., Hartman, A., Herzog, M., and Toney, M., 2016. San Francisco Bay Triennial Bird Egg Monitoring Program for Contaminants- 2016 Data Summary. U.S. Geological Survey, Western Ecological Research Center,

Dixon, CA. 19 pp. http://www.sfei.org/documents/san-francisco-bay-triennial-bird-egg-monitoring-program-contaminants-2016-data-summary.

SFEI, 2016. Sampling and Analysis Plan for 2016 RMP Status and Trends Bird Egg Monitoring. San Francisco Estuary Institute, Richmond, CA. 31 pp. http://www.sfei.org/documents/sampling-and-analysis-plan-2016-rmp-status-and-trends-bird-egg-monitoring.

4. DATA ACCESS AND REPORTS

ANNUAL MONITORING ONLINE GRAPHICS AND DATA ACCESS TOOLS

The RMP Status and Trends data are available online using a dynamic mapping and graphing tool. The online Contaminant Data Display and Download (CD3, http://cd3.sfei.org) can be used to view, summarize, or download all water, sediment, and tissue monitoring results that have met specific data quality objectives and have passed a rigorous QA/QC evaluation as outlined in the RMP's Quality Assurance Project Plan. Additional information about data available through CD3 can be found on the RMP webpage (http://www.sfei.org/rmp/data).

Results from the 2016 samples have been reported by the laboratories and have been quality assured. The final results can be accessed through CD3 using the following steps:

- RMP 2016 Bivalve Data is available in CD3. Go to cd3.sfei.org. Click on "Direct Download Tool" and select the project called "2016 RMP Status and Trends".
- RMP 2016 Bird Egg Data is available in CD3. Go to cd3.sfei.org. Click on "Direct Download Tool" and select the project called "2016 RMP EEPS Pilot Study".

Values reported below the method detection limit (MDL) are estimated to be ½ of the MDL for trace elements and 0 for organic compounds in all calculations and graphics produced by the RMP. Some organic compounds are summed based on the target list of RMP congeners for that specific compound group (e.g., PBDEs, PAHs, and PCBs). When laboratory or field replicate data are available, the average of all the replicate concentrations is provided.

Several software programs were used to develop the online graphics in CD3. The R statistical analysis software package *spsurvey*, which is designed specifically by EPA for GRTS sample designs was used to calculate estimates of the regional and Estuary-wide contaminant mean, variance, standard deviation, standard error, and CDFs. The R program is an implementation of the S language developed at AT&T Bell Laboratories and can be downloaded for free from the Comprehensive R Archive Network (CRAN). The spsurvey library for the analysis of probability surveys is available from USEPA's Aquatic Resources Monitoring - Monitoring Design and Analysis.

5. REFERENCES

SFEI. 2016. Quality Assurance Program Plan for the Regional Monitoring Program for Water Quality in San Francisco Bay. San Francisco Estuary Institute, Richmond, CA. http://www.sfei.org/documents/2016-quality-assurance-program-plan-regional-monitoring-program-water-quality-san

Stephenson, M. 1992. A report on bioaccumulation of trace metals and organics in bivalves in the San Francisco Bay submitted to California Regional Water Quality Control Board San Francisco Region. California Department of Fish and Game.

6. APPENDIX TABLES

APPENDIX 1 – RMP CONTRACTORS AND PRINCIPAL INVESTIGATORS IN 2016

Acronym	Laboratory/Contractor	Role	Contact
Field Contractors			
AMS	Applied Marine Sciences Livermore, CA	Bivalve Collections	Mr. Paul Salop salop@amarine.com
USGS	U.S. Geological Survey Western Ecological Research Center Dixon Field Station Dixon, CA	Bird Egg Collections	Josh Ackerman jackerman@usgs.gov
Analytical Laboratories			
AXYS	AXYS Analytical Services Ltd. (AXYS), Sidney, BC	PCBs and PBDEs in bivalves, sample processing	Mr. Kalai Pillay kpillay@axys.com
BRL	Brooks-Rand Laboratory Seattle, WA	Se in bivalves	Ms. Tiffany Stilwater tiffany@brooksrand.com
DFG-WPCL	Department of Fish and Game – Water Pollution Control Laboratory	PCBs and PBDEs in cormorant eggs	Mary Curry mary.curry@wildlife.ca.gov
MLML	Marine Pollution Studies Lab Moss Landing, CA	Se and Hg in cormorant eggs, Se in tern eggs	Autumn Bonnema bonnema@mlml.calstate.edu
USGS	U.S. Geological Survey Western Ecological Research Center Dixon Field Station Dixon, CA	Hg in cormorant eggs	Josh Ackerman jackerman@usgs.gov
Analytical Laboratories – *pro bono*			
SIU	Southern Illinois University Carbondale, IL	Carbazoles in bivalves and cormorant eggs	Da Chen dachen@siu.edu
UCSC	University of California, Santa Cruz Santa Cruz, CA	Algal toxins in bivalves	Raphe Kudela kudela@ucsc.edu

APPENDIX 2 – SUMMARY OF 2016 RMP SAMPLING STATIONS

Cruise Type	Region	Site Code	Site Name	Sample Date	Species	Latitude	Longitude	Station Water Depth (m)	Sample Comment
Bivalve	San Pablo Bay	BD30	Pinole Point	10/4/2016	*Mytilus californianus*	38.01667	-122.3675	3	
Bivalve	Lower South Bay	BA10	Coyote Creek	10/5/2016	*Mytilus californianus*	37.46983	-122.06383	6	Burial – insufficient survival for growth or archive
Bivalve	South Bay	BA40	Redwood Creek	10/5/2016	*Mytilus californianus*	37.547	-122.195	3	Only two cages recovered, the third fell from buoy upon retrieval
Bivalve	Central Bay	BC10	Yerba Buena Island	10/6/2016	*Mytilus californianus*	37.81392	-122.35873	3	25 mussels compromised at deployment by failure of cage resulting in smaller recovery
Bivalve	Rivers	BG20	Sacramento River	10/13/2016	*Corbicula fluminea*	38.0557	-121.80593	11	Residents only, insufficient mass to support all analyses (short term archives not collected)
Bivalve	Rivers	BG30	San Joaquin River	10/13/2016	*Corbicula fluminea*	38.02362	-121.80048	11	Residents only, insufficient mass to support all analyses (short term archives not collected)
Bivalve	South Bay	BA30	Dumbarton Bridge	10/5/2016	*Mytilus californianus*	37.51333	-122.13467	5	Full Mortality

Cruise Type	Region	Site Code	Site Name	Sample Date	Species	Latitude	Longitude	Station Water Depth (m)	Sample Comment
Bivalve	Central Bay	BB71	Alameda	10/6/2016	*Mytilus californianus*	37.6955	-122.33967	9	Back up site. Samples not shipped for analysis.
Bivalve	San Pablo Bay	BD20	San Pablo Bay	10/4/2016	*Mytilus californianus*	38.059	-122.42367	2	Back up site. Samples not shipped for analysis.
Bivalve	Reference	T-1Bodega	Bodega Head	9/30/2016	*Mytilus californianus*	38.30482	-123.06534	0	Growth control. Samples not shipped for chemical analysis.
Bivalve	Reference	T-0Bodega	Bodega Head	6/29/2016	*Mytilus californianus*	38.30482	-123.06534	0	
Bird Egg	Suisun Bay	2EEPSWI	Wheeler Island	4/11/2016	*Phalacrocorax auritus*	38.08445	-121.93654	n/a	
Bird Egg	Central Bay	2EEPSRB	Richmond Bridge	5/3/2016 and 6/2/2016	*Phalacrocorax auritus*	37.93452	-122.43555	n/a	
Bird Egg	Lower South Bay	2EEPSDEP9/10C	Pond A9/A10 Levee	4/26/2016	*Phalacrocorax auritus*	37.45304	-122.00886	n/a	Replaced South Bay PG&E tower 2009 location
Bird Egg	Lower South Bay	2EEPSDEP_AB1	Pond AB1	6/1, 6/8, and 6/15/2016	*Sterna forsteri*	37.44181	-122.06349	n/a	
Bird Egg	Lower South Bay	AB2	Pond AB2	5/26, 6/1, 6/8, and 6/22/2016	*Sterna forsteri*	37.44060	-122.04778	n/a	
Bird Egg	South Bay	2EEPSNCM	New Chicago Marsh	5/12, 5/20, 5/24, and 5/27/2016	*Sterna forsteri*	37.43723	-121.96575	n/a	
Bird Egg	South Bay	2EEPSHRS	Pond 2-Hayward Shoreline	6/10/2016	*Sterna forsteri*	37.62864	-122.14388	n/a	

APPENDIX 3 – ANAYTES REPORTED IN BIVALVE SAMPLES (1997-2016)

Shaded areas indicate that parameters that were analyzed for RMP Status and Trends Sampling.

Parameter Type Codes: ANC = Ancillary Parameters, EC=Emerging Contaminants, ORGS = Organic Parameters, PESTs = Pesticide Parameters, SedTOX = Toxicity Parameters, SYN = Synthetic Parameters, TE = Trace Metal parameters

* Data available upon request

Reportable BivalveTissue Parameter	Parameter Type	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007[1]	2008	2009	2010	2011	2012	2013	2014[2]	2015	2016
% Moisture	ANC		■	■	■	■	■	■	■	■	■	■	■		■		■		■		■		■		■
% Solids	ANC	■	■	■	■	■	■	■	■	■	■	■	■				■						■		■
% Survival per Species	ANC	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■		■		■		■		■
Condition Index Mean	ANC	■	■	■	■	■	■	■	■								■								
CTD*	ANC							■	■	■	■	■	■		■		■		■		■		■		■
Dry Weight	ANC	■	■	■	■	■	■	■	■	■	■	■	■		■		■		■		■		■		■
Gonad Index CI Mean	ANC							■	■	■															
Growth Mean	ANC							■	■	■	■	■	■		■		■		■		■		■		■
209 PCBs	ORGS																		■		■		■		
40 PCBs	ORGS	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
Alkanes (C10-C34)	ORGS	■	■	■																					
Musk	ORGS										■	■	■												
PAHs	ORGS	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		■
PAHs Alkylated	ORGS	■	■	■	■	■	■	■	■	■	■	■			■		■		■		■		■		■
PBDEs	ORGS										■	■		■	■		■		■		■		■		■
Phthalates	ORGS										■	■	■												
Chlordanes	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
Cyclopentadienes	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
DDTs	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
HCHs	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
Hexachlorobenzene	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
Mirex	PESTs	■	■	■	■	■	■	■	■	■	■	■		■	■		■		■		■		■		
p-Nonylphenol	SYN										■	■	■												
Triphenylphosphate	SYN										■	■	■												
Aluminum	TE		■	■		■	■	■	■	■							■								
Arsenic	TE	■	■	■	■	■	■	■																	
Cadmium	TE	■	■	■	■	■	■	■	■	■							■								
Copper	TE	■	■	■	■	■	■	■	■	■							■								

Reportable BivalveTissue Parameter	Parameter Type	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007[1]	2008	2009	2010	2011	2012	2013	2014[2]	2015	2016
Chromium	TE																								
DBT (Dibutyltin)	TE																								
Iron	TE																								
Lead	TE																								
Manganese	TE																								
MBT (Monobutyltin)	TE																								
Mercury	TE																								
Methyl Mercury	TE																								
Nickel	TE																								
Selenium	TE																								
Silver	TE																								
TBT (Tributyltin)	TE																								
TTBT (Tetrabutyltin)	TE																								
Zinc	TE																								

[1]Beginning in 2007, bivalve monitoring began to occur biennially for trace organics and every 6 years for trace metal parameters.

[2] In 2014, the sampling design was reduced to PCBs, PBDEs, PAHs, and selenium. Pesticides and all other trace metals were removed from the sampling design to reduce costs. All four analyses were conducted in 2014. Subsequently, PCBs will be analyzed every 8 years, and PAHs, PBDEs and selenium analyzed every 2 years.

APPENDIX 4 – ANALYTES REPORTED IN BIRD EGG SAMPLES (2002-2016)

Shaded areas indicate that parameters that were analyzed for RMP Status and Trends Sampling.
Parameter Type Codes: ANC = Ancillary Parameters, EC=Emerging Contaminants, ORGS = Organic Parameters, PESTs = Pesticide Parameters, SedTOX = Toxicity Parameters, SYN = Synthetic Parameters, TE = Trace Metal parameters, PCDD/F = Dioxins and furans, PFC = Perfluoronate

Double-crested Cormorants																	
Parameter	Parameter Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
PCBs	ORGS	■		■		■			■			■				■
Hg	TE	■		■		■			■			■				■
Se	TE	■		■					■			■				■
OC Pests	PESTs	■		■		■			■			■				
PBDEs	ORGS	■		■		■			■			■				■
Dioxins	PCDD/F	■		■		■						■				
Phthalates	ORGS	■		■												
Musks	ORGS	■		■												
Nonylphenol	SYN	■		■												
Triphenylphosphate	SYN	■		■												
PFCs	PFC											■				■
PFOS	PFC					■			■							
Short chain chlorinated paraffins	ORGS					■										
Chlorinated naphthalenes	ORGS								■							
Alternative BFRs	ORGS							■								
Carbazoles	ORGS															■

Forster's Terns																
Parameter	Parameter Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Hg	TE															
Se	TE															
PBDEs	ORGS															

APPENDIX 5 – CHANGES TO THE RMP PROGRAM 2016

Action Codes: A= Analyte added or removed from sampling design; D= Data rejected or not available/data comparability issues; L= Change in laboratory conducting analysis or in laboratory methods; P= Change in program/sampling design; S= Station added or removed; T= Trends analysis performed.

Action Code	Year	Action	Detail/Rationale
A	2016	PBDEs removed from Tern Egg Analysis	PBDEs were dropped from the target analyte list for terns because of budget constraints. Archived samples could be analyzed for PBDEs is this analysis is desired.