DOI: 10.7589/2017-07-179

Journal of Wildlife Diseases, 54(3), 2018, pp. 569–574

Investigation of a Largescale Common Murre (*Uria aalge*) Mortality Event in California, USA, in 2015

Corinne Gibble,[1,8] Rebecca Duerr,[2] Barbara Bodenstein,[3] Kirsten Lindquist,[4] Jackie Lindsey,[5] Jessie Beck,[6] Laird Henkel,[1] Jan Roletto,[4] Jim Harvey,[5] and Raphael Kudela[7] [1]California Department of Fish and Wildlife, Marine Wildlife Veterinary Care and Research Center, 151 McAllister Way, Santa Cruz, California 95060, USA; [2]International Bird Rescue, 4369 Cordelia Road, Fairfield, California 94534, USA; [3]US Geological Survey, National Wildlife Health Center, 6006 Schroeder Road, Madison, Wisconsin 53711, USA; [4]Greater Farallones National Marine Sanctuary Association, 991 Marine Drive, San Francisco, California 94129, USA; [5]Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, California 95039, USA; [6]Oikonos Ecosystem Knowledge, 180 Benito Avenue, Santa Cruz, California 95062, USA; [7]University of California, Santa Cruz, 1156 High Street, Santa Cruz, California 95064, USA; [8]Corresponding author (email: corinne.gibble@wildlife.ca.gov)

ABSTRACT: From August through December 2015, beachcast bird survey programs reported increased deposition of Common Murres (*Uria aalge*) on central and northern California beaches, but not on southern California beaches. Coastal wildlife rehabilitation centers received more than 1,000 live, stranded, and debilitated murres from Sonoma County to San Luis Obispo County during August–October. Approximately two-thirds of admitted birds were after-hatch-year birds in emaciated body condition and in various stages of molt, with extremely worn plumage. Necropsies were done on a sample (n=35) of birds to determine the probable cause of death of beachcast carcasses. Most birds examined during necropsy were emaciated, with starvation the most likely cause of death. Birds were also tested for underlying infectious diseases at the US Geological Survey National Wildlife Health Center and harmful algal bloom toxins at the University of California at Santa Cruz and the National Oceanographic and Atmospheric Administration's Northwest Fisheries Science Center. Twenty-four out of 29 tested birds had detectable levels of domoic acid, and no indication of infectious disease was found. Emaciation is thought to be the cause of death for these birds, with a large warm water anomaly and harmful algal bloom playing a secondary detrimental role.

Key words: Common Murre, domoic acid, molt, *Pseudonitzschia*, starvation, warm water anomaly.

Because of the large population of Common Murres (*Uria aalge*; COMU) that inhabit the California coast, US (Briggs et al. 1987) it is not uncommon to find them beachcast throughout the year, with peaks in encounter rates during August and September (Roletto et al. 2003). However, beginning in August 2015, an unusually large number of COMU were reported dead on central and northern California beaches (Fig. 1). Beachcast bird survey programs, Beach Watch (Mendocino through San Mateo counties), and BeachCOMBERS (Santa Cruz through Ventura counties), conduct standardized beach surveys on a monthly basis for dead birds, and provide depositional data that can be used to investigate mortality events. Both programs recorded greater than average deposition of COMU from August through December, 2015. Beach Watch surveys in the north central coast recorded more than ninefold the long-term (22 yr), average rate (birds/km) for this season (Fig. 1). BeachCOMBERS central coast surveys recorded fivefold the long-term (18 yr) average rate for this season (Fig. 1). BeachCOMBERS south coast surveys reported 2.5-fold the long-term average rate for this season (Fig. 1).

Age data were available for beachcast birds surveyed by Beach Watch; beachcast birds recorded during monthly surveys were aged 77% hatch year and 16% adult in August, 75% hatch year and 12% adult in September, and 50% hatch year and 26% adult in October. Both survey programs collected birds (n=35) for postmortem examination between July 2015 and November 2015. The US Geological Survey National Wildlife Health Center (NWHC; Madison, Wisconsin) received seven specimens (four males, two females, one unknown) for diagnostic necropsy. The Marine Wildlife Veterinary Care and Research Center (MWVCRC; Santa Cruz, California) received an additional 28 birds (15 male, 10 female, three unknown). Carcasses were examined thoroughly, including an assessment of age,

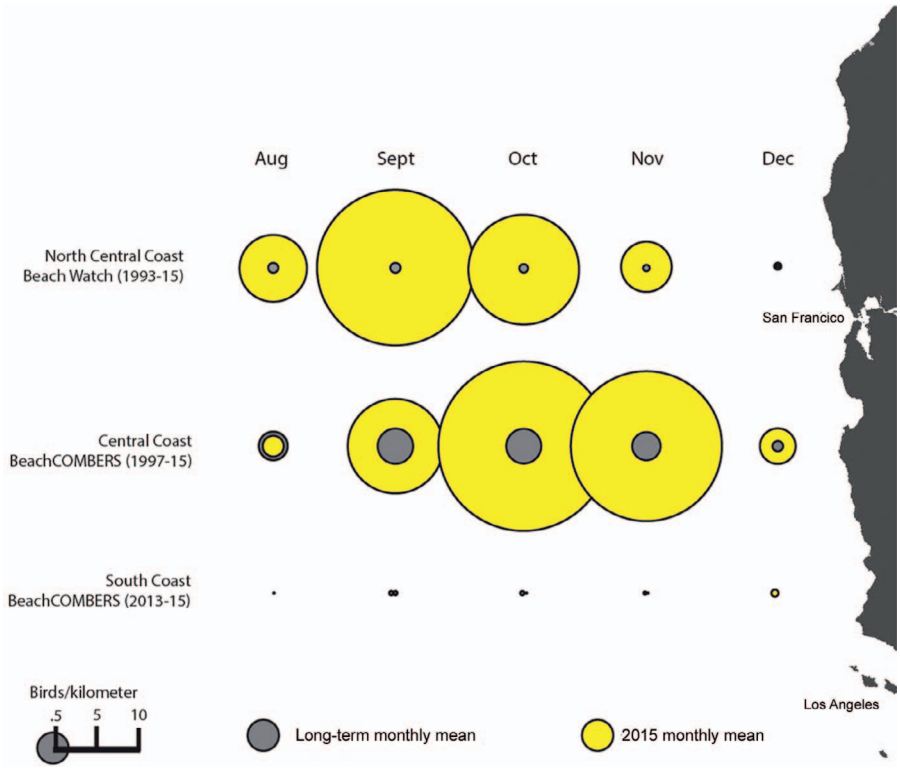

FIGURE 1. Map of effort-based beached bird survey program data. Circles (murres/kilometer) represent dead beachcast Common Murres (*Uria aalge*) along the central coast of California, USA; light gray circles represent the long-term monthly average of Common Murre carcass deposition; and dark gray circles represent the 2015 monthly average of Common Murre carcass deposition.

sex, body mass, body condition, and molt. Five of seven (71%) birds examined at NWHC were determined to be immature based on plumage, gonad development, and presence or absence of the bursa of Fabricius. Similarly, 20 of 28 (72%) COMU examined at MWVCRC were fledgling or immature hatch-year birds based on plumage, supraorbital ridge, the presence or absence of the bursa of Fabricius, and culmen length (Nevins and Carter 2003). Of the remaining eight adult birds examined at MWVCRC, five were undergoing molt (63%) and three had not yet molted (38%). All necropsied birds were emaciated, as indicated by severe atrophy of visceral fat, organs, and skeletal muscle, and by the presence of melena in the gastrointestinal tract (Gerdin et al. 2016). Fluid in the lungs and trachea suggested that many birds had drowned (Modell 1993). Histopathology and diagnostic testing was conducted at NWHC (n=7). Of the six birds sent to NWHC with adequate postmortem freshness, all tests for avian influenza, plumbism, botulism, and West Nile disease were either insignificant or negative. Histology results included no significant findings, lymphoid depletion, renal urate accumulation, lung aspiration, and depletion of bursa and spleen.

There was a large concurrent bloom of the toxigenic diatom *Pseudonitzschia*, which produces the neurotoxin, domoic acid (DA), during the initiation of the 2015 COMU die-off. Domoic acid poisoning is known to cause neurological problems, gastroenteritis, and in some cases, death in seabirds, although specific lethal limits for seabirds are still unknown (Work et al. 1993; Shumway et al. 2003). The bloom started during spring upwelling in March 2015, and DA toxin levels and cell counts in the ocean remained high from April through June in California. Additionally, DA remained in the marine ecosys-

tem in California and in prey items until spring 2016, resulting in massive fisheries and shellfisheries closures (McCabe et al. 2016; Ryan et al. 2017). The northern anchovy (*Engraulis mordax*) is a major prey item for COMU year-round (Ainley et al. 1996). In 2015, DA levels in anchovy viscera reached a maximum of 1,671 ppm DA in California, and the anchovy fishery was subsequently closed in June (McCabe et al. 2016). Due to this ongoing harmful algal bloom between August and December of 2015, samples from birds examined at NWHC were analyzed for DA (n=2) at the National Oceanographic and Atmospheric Administration, Northwest Fisheries Science Center, Seattle, Washington, US using enzyme-linked immunosorbent assay (NWHC 26742-3, NWHC 26742-4; Lefebvre et al. 2010); and samples (liver, kidney, stomach contents, cloacal contents) from birds examined at MWVCRC were analyzed for DA using liquid chromatography-mass spectrometry (n=27) at the University of California at Santa Cruz (15-0458-16-0702; Lane et al. 2010). Twenty-four out of 29 (83%) tested birds had detectable levels of DA (Table 1).

Synchronous with the large deposition of beachcast birds occurring in central California, wildlife rehabilitation centers collectively received 1,066 live-stranded, debilitated COMU from Sonoma County to Los Angeles County between August and December, with the greatest intake numbers occurring between Sonoma and Monterey counties. The International Bird Rescue San Francisco Bay Center (Fairfield, California) received 509 COMU, 59.5% of which were considered to be after-hatch-year (AHY) adults. Age was assessed through plumage, morphometrics, plumage wear, and supraorbital ridge development (Nevins and Carter 2003). These AHY COMU entered care underweight (n=274; mean±SD admission body weight=685±83.7 g) at 59–75% of wild mean mass (1,022±111 g; Newman 1998). After-hatch-year COMU are considered to be depleted of fat stores below 675 g (Duerr and Klasing 2015). Many AHY COMU entering rehabilitation were euthanized due to extreme emaciation and feather condition so poor (e.g., stripped flight feathers and bleached, worn, broken contour feathers) that it precluded reattainment of waterproof plumage. Hatch-year birds largely presented as older chicks in poor nutritional condition. Birds that survived initial assessment responded well to supplemental food and did not exhibit neurologic symptoms. Renourished murres gained body mass quickly but took up to 3 mo to complete molt before release.

Although starvation was likely the ultimate cause of death for many of these birds, oceanographic conditions and harmful algae also appeared to have contributed to this event. A warm water anomaly began in 2014 and extended into the California Current, warming the Pacific and expanding from Alaska through central Mexico (Bond et al. 2015; Kintisch 2015). This anomaly continued in the California Current through 2015 (Peterson et al. 2016), causing major food-web upheavals and normally productive ocean areas to be unproductive (Kintisch 2015; McCabe et al. 2016). Additionally, an unparalleled harmful algal bloom was present along the west coast of North America (McCabe et al. 2016; Ryan et al. 2017). Warm conditions were halted by spring upwelling in the California Current in 2015, which provided ideal conditions for *Pseudonitzschia australis*. This toxic bloom affected a large number of marine species from shellfish and planktivorous fish to marine mammals (McCabe et al. 2016; Ryan et al. 2017) and was considered the largest, most prolonged, and, in some areas, the most toxic and harmful algal bloom event ever recorded (McCabe et al. 2016; Ryan et al. 2017). Perhaps most importantly, this bloom directly impacted important COMU prey species such as anchovies. Anchovy viscera tested well above the regulatory limit of 20 ppm DA during this time period, with a maximum of 1,671 ppm DA in May 2015 in California (McCabe et al. 2016). Although the majority of birds tested had detectable levels of DA, COMU at rehabilitation facilities did not present with clinical neurological signs of DA intoxication. Thus, it is unclear to what extent DA intoxication might have affected these birds.

Murre mortality in 2015 appeared to peak in the north central coast of California during

TABLE 1. Domoic acid concentrations (ng/g) in samples from dead beachcast Common Murres (*Uria aalge*) collected during a die-off in July–November 2015 along the central coast of California, USA. Samples were analyzed for domoic acid at University of California at Santa Cruz via liquid chromatography-mass spectrometry (LCMS), except for two samples (26742-3 and 26742-4) that were analyzed via enzyme-linked immunosorbent assay (ELISA) at the National Oceanographic and Atmospheric Administration, Northwest Fisheries Science Center (Seattle, Washington, USA). The method detection limits for domoic acid for each assay were ELISA: 1.0 ng/g and LCMS: 0.30 ng/g. BDL = below detectable limit.

Necropsy no.	Collection date (2015)	Sample type	Domoic acid concentration	County
15-0458	2 September	Cloacal contents	63.15	Santa Cruz
		Liver	BDL	
		Stomach contents	5.36	
15-0459	2 September	Cloacal contents	11.77	Santa Cruz
		Liver	4.00	
		Stomach contents	10.77	
15-0589	2 November	Cloacal contents	BDL	Santa Cruz
		Kidney	BDL	
		Liver	BDL	
15-0590	1 September	Cloacal contents	4.98	San Luis Obispo
		Kidney	10.69	
		Liver	BDL	
15-0591	7 October	Cloacal contents	trace	Monterey
		Kidney	BDL	
		Liver	3.71	
15-0592	7 October	Cloacal contents	103.52	Monterey
		Kidney	82.91	
		Liver	17.07	
15-0593	5 September	Cloacal contents	46.44	Santa Cruz
		Kidney	BDL	
		Liver	BDL	
15-0594	27 August	Cloacal contents	18.42	Santa Cruz
		Kidney	BDL	
		Liver	BDL	
15-0595	2 October	Cloacal contents	22.83	Monterey
		Kidney	BDL	
		Liver	BDL	
15-0596	2 October	Cloacal contents	BDL	Monterey
		Kidney	5.16	
		Liver	BDL	
15-0597	5 September	Cloacal contents	19.97	Monterey
		Kidney	BDL	
		Liver	BDL	
15-0598	5 September	Cloacal contents	64.14	Monterey
		Kidney	BDL	
		Liver	BDL	
15-0599	5 September	Cloacal contents	BDL	Monterey
		Kidney	BDL	
		Liver	BDL	
15-0600	5 September	Kidney	BDL	Monterey
		Liver	BDL	
15-0601	5 September	Cloacal contents	21.97	Monterey
		Kidney	BDL	
		Liver	BDL	

TABLE 1. Continued.

Necropsy no.	Collection date (2015)	Sample type	Domoic acid concentration	County
15-0602	5 September	Kidney	31.51	Monterey
		Liver	9.54	
16-0687	Unknown	Liver	21.55	San Luis Obispo
16-0688	1 September	Cloacal contents	13.06	San Luis Obispo
		Liver	BDL	
16-0690	15 July	Cloacal contents	654.12	San Luis Obispo
		Liver	332.96	
16-0691	30 August	Cloacal contents	65.70	San Luis Obispo
		Liver	78.86	
16-0692	15 August	Liver	174.88	San Luis Obispo
16-0693	16 July	Cloacal contents	110.93	San Luis Obispo
16-0694	18 July	Cloacal contents	59.02	San Luis Obispo
		Liver	915.84	
16-0697	13 August	Liver	BDL	San Luis Obispo
16-0699	26 August	Liver	66.88	San Luis Obispo
16-0700	13 August	Liver	361.99	San Luis Obispo
16-0702	29 August	Cloacal contents	10.61	San Luis Obispo
		Liver	50.78	
26742-3	5 November	Cloaca contents	BDL	Marin
26742-4	5 November	Cloaca contents	6.50	Marin

September, the central coast in October, and in the south central coast region in November. More than 7,122 birds in California were affected based on rehabilitation intake numbers and beachcast bird survey numbers. We hypothesized that limited prey availability potentially caused by the oceanographic anomaly was likely the primary driver of this mortality event, with harmful algal blooms secondary in effect. A similar die-off of Cassin's Auklet (*Ptychoramphus aleuticus*) in September 2014–January 2015 preceded the COMU deaths. Starvation was attributed to prey shortages caused by the warm-water anomaly, but tissues were not tested for DA. It is not clear why other species of piscivorous birds did not appear to be similarly affected by the anomaly based on beachcast depositional data in 2015. It is possible that the coincidence of limited prey with a simultaneous wing-feather molt reduced the ability of COMU to move quickly to new prey patches. Subadult and adult COMU experience a period of annual flightlessness in late summer and fall, when both wings undergo simultaneous molt of flight feathers (Birkhead and Taylor 1977). Chicks leave the nest accompanied by the male parent without full juvenile plumage in July–August (Scott 1990; Thompson et al. 1998). At the time of molt, birds are unable to fly, and foraging is limited to prey accessible by swimming and diving. The ongoing oceanographic condition, coupled with the inability to fly to better feeding areas might have left COMU (especially at young life stages) vulnerable to starvation. In addition, simultaneous wing molt in COMU increases energetic demands, further stressing birds in poor nutritional condition (Bridge 2004). The amalgamation of natural history, abnormal oceanographic conditions, and DA in the area might have affected this species disproportionally in relation to other near-shore feeding seabirds. Spatially consistent with intensity of both the warm water anomaly and extent of *Pseudonitzschia*, a deposition rate of beachcast murres above the baseline threshold (the monthly mean+2 SD; Fig. 1) was not reported for southern California beaches. However, according to widespread media reporting, there was a large concurrent die-off of COMU in Alaska, Oregon, and Washington.

We greatly appreciate the efforts of the many field biologists and organizations who submitted carcasses for this study. We also thank BeachCOMBERS and Beach Watch beach survey volunteers and past BeachCOMBERS program managers: Scott Benson, Hannah Nevins, Erica Donnelly-Greenan; Marine Wildlife Veterinary Care and Research Center necropsy volunteers, especially Erica Donnelly-Greenan, Katherine Greenwald, and Angelina Reed; and the US Geological Survey, NWHC pathologists, specifically Julia Lankton, David Green, and Marcos Isidoro Ayza, who conducted diagnostic necropsies and provided review of this manuscript. We would also like to thank the staff and volunteers of International Bird Rescue and other California wildlife centers for sharing information and providing care for live birds affected by this event. Funding for toxin analysis (University of California at Santa Cruz) was provided by National Oceanic and Atmospheric Administration grant NA11NOS4780030, ECOHAB Publication ECO898. The use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the US Government. The US Geological Survey NWHC data associated with the manuscript can be found at https://doi.org/10.5066/F79W0DQR.

LITERATURE CITED

Ainley DG, Spear LB, Allen SG, Ribic CA. 1996. Temporal and spatial patterns in the diet of the common murre in California waters. *Condor* 98:691–705.

Birkhead TR, Taylor AM. 1977. Moult of the Guillemot *Uria aalge*. *Ibis* 119:80–85.

Bond NA, Cronin MF, Freeland H, Mantua N. 2015. Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophys Res Lett* 42:3414–3920.

Bridge ES. 2004. The effects of intense wing molt on diving in alcids and potential influences on the evolution of molt patterns. *J Exp Biol* 207:3003–3014.

Briggs KT, Tyler WB, Lewis DB, Carlson DR. 1987. *Bird communities at sea off California 1975 to 1993*. In: *Studies in avian biology no. 11*. Cooper Ornithological Society, Allen Press, Inc., Lawrence, Kansas, 74 pp.

Duerr RS, Klasing KC. 2015. Tissue component and organ mass changes associated with declines in body mass in three seabird species received for rehabilitation in California. *Mar Ornithol* 43:11–18.

Gerdin JA, McDonough SP, Reisman R, Scarlett J. 2016. Circumstances, descriptive characteristics, and pathologic findings in dogs suspected of starving. *Vet Pathol* 53:1087–1094.

Kintisch E. 2015. 'The Blob' invades Pacific, flummoxing climate experts. *Science* 348:17–18.

Lane JQ, Roddam CM, Langlois GW, Kudela RM. 2010. Application of solid phase adsorption toxin tracking (SPATT) for field detection of hydrophilic phycotoxins domoic acid and saxitoxin in coastal California. *Limnol Oceanogr Methods* 8:645–660.

Lefebvre KA, Robertson A, Frame ER, Colegrove KM, Nance S, Baugh KA, Wiedenhoft H, Gulland FMD. 2010. Clinical signs and histopathology associated with domoic acid poisoning in northern fur seals (*Callorhinus ursinus*) and comparison of toxin detection methods. *Harmful Algae* 9:374–383.

McCabe RM, Hickey BM, Kudela RM, Lefebvre KA, Adams NG, Bill BD, Gulland F, Thomson RE, Cochlan WP, Trainer VL. 2016. An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophys Res Lett* 43:10366–10376.

Modell JH. 1993. Drowning. *N Engl J Med* 328:253–256.

Nevins H, Carter HR. 2003. Age and sex of common murres *Uria aalge* recovered during the 1997–98 Point Reyes Tarball Incidents in Central California. *Mar Ornithol* 31:51–58.

Newman SH. 1998. *The toxicological and pathological effects of petroleum exposure and rehabilitation on the health of marine birds*. PhD Dissertation, University of California, Davis, California, 140 pp.

Peterson W, Bond N, Robert M. 2016. The Blob (Part three): Going, going, gone? *PICES Press* 24:46.

Roletto J, Mortenson J, Harrald IN, Hall JA, Grella LE. 2003. Beached bird surveys and chronic oil pollution in central California. *Mar Ornithol* 31:21–28.

Ryan JP, Kudela RM, Birch JM, Blum M, Bowers HA, Chavez FP, Doucette GJ, Hayashi K, Marin R, Mikulski CM, et al. 2017. Causality of an extreme harmful algal bloom in Monterey Bay, California during the 2014–2016 northeast Pacific warm anomaly. *Geophys Res Lett* 44:5571–5579.

Scott JM. 1990. Offshore distributional patterns, feeding habits, and adult-chick interactions of the common murre in Oregon. *Stud Avian Biol* 14:103–108.

Shumway SE, Allen SM, Boersma PD. 2003. Marine birds and harmful algal blooms: Sporadic victims or underreported events? *Harmful Algae* 2:1–7.

Thompson CW, Wilson ML, Melvin EF, Pierce DJ. 1998. An unusual sequence of flight-feather molt in common murres and its evolutionary implications. *Auk* 115:653–669.

Work TM, Barr B, Beale AM, Fritz L, Quilliam MA, Wright JL. 1993. Epidemiology of domoic acid poisoning in brown pelicans (*Pelecanus occidentalis*) and Brandt's cormorants (*Phalacrocorax penicillatus*) in California. *J Zoo Wildl Med* 24:54–62.

Submitted for publication 27 July 2017.
Accepted 12 October 2017.