

Limited Outbreak of Highly Pathogenic Influenza A(H5N1) in Herring Gull Colony, Canada, 2022

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In summer 2022, highly pathogenic influenza A(H5N1) virus reached the herring gull (*Larus argentatus* subspecies *smithsonianus*) breeding colony on Kent Island, New Brunswick, Canada. Real-time monitoring revealed a self-limiting outbreak with low mortality. Proactive seabird surveillance is crucial for monitoring such limited outbreaks, protecting seabirds, and tracing zoonotic transmission routes.

Highly pathogenic avian influenza (HPAI) viruses pose a near-term threat to commercial poultry and a long-term risk for human pandemics (1,2). Recent outbreaks of HPAI A(H5N1) virus have also caused mass mortality events in vulnerable seabird populations (3). Because outbreaks are difficult to predict, knowledge of HPAI in wild birds is often limited to cross-sectional surveillance or post hoc records of mass mortality events (4–6).

Beginning in December 2021, an HPAI H5N1 virus strain spread from Eurasia into Canada, subsequently infecting wild, commercial, and backyard bird populations across North America (4) (<https://www.usgs.gov/centers/nwhc/science/distribution-highly-pathogenic-avian-influenza-north-america-20212022>). During summer 2022, we studied the life history of American herring gulls (*Larus argentatus* subspecies *smithsonianus*) at the Kent Island breeding colony in New Brunswick, Canada (Figure 1). Thus, we had an unusual opportunity to monitor emerging

disease symptoms and deaths in a wild population. We report timelines, clinical details, and epidemiologic observations from a laboratory-confirmed HPAI outbreak that caused a relatively low death rate within a seabird colony.

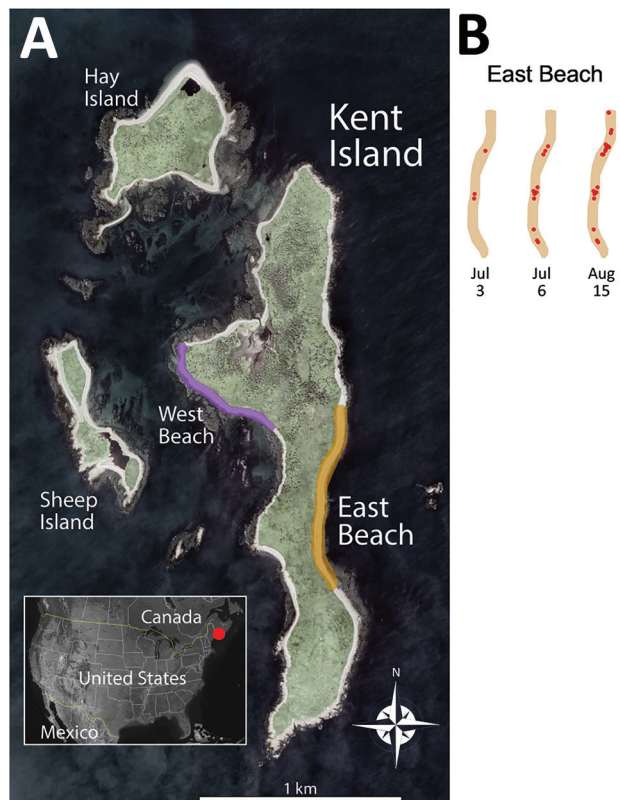


Figure 1. Location of gull breeding colony on Kent Island, New Brunswick, Canada, in study of limited outbreak of highly pathogenic influenza A(H5N1) in herring gull colony, 2022. A) Inset shows location of Kent Island in Canada. The main study site was on East Beach (yellow strip), and a secondary site was on West Beach (purple strip). Intermittent monitoring occurred across Kent, Hay, and Sheep Islands. Satellite image from Google Earth (<https://earth.google.com>). B) Accumulating carcass locations (red points) for 3 timepoints on East Beach.

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Table 1. Summary of influenza-related herring gull deaths on Kent Island and neighboring islands in study of limited outbreak of highly pathogenic influenza A(H5N1), Canada, 2022*

Area	Census count† (+SD)	No. censuses conducted	No. deaths	Death rate, ‡ %	Survey schedule
Kent Island, East Beach	526 (169)	110	22	4.2	1–3×/d, Jun 1–Aug 15, Sep 2
Kent Island, West Beach	221 (60)	88	15	6.8	1–2×/d, Jun 1–Jul 7, Jul 22–Aug 14, Sep 2
Kent Island, total§	3,077 (937)	10	66–87	2.1–2.8	1×/wk, Jun 1–Jul 7, Jul 15 (partial), Jul 22– Aug 14, Sep 2 (partial)
Sheep Island	900	1	25	2.8	Jul 5 (boat count), Jul 14 (partial), Aug 29
Hay Island	617 (267)	2	41	6.7	Jun 21, Aug 7

*Mean counts are of adult herring gulls >10 months of age. Partial surveys covered only part of the survey area.

†Census counts varied with time, tide, and seasonal fluctuations for both breeding and nonbreeding populations.

‡Calculated according to mean census count. Our assumption that all intact adult gull carcasses were influenza-related might have raised death rate estimates, whereas intermittent surveys and imperfect carcass detection might have lowered death rate estimates.

§Ranges for number of deaths and death rate are provided because of possible double counting of untagged carcasses by 2 observers outside of the main study sites.

The Study

We monitored herring gulls on Kent Island (latitude 44.5828°N, longitude 66.7568°W; Figure 1). Gulls nest across the ≈100-ha island and on adjacent Hay and Sheep Islands (Figure 1). Herring gulls on Kent Island generally migrate north from eastern North America in early May, lay eggs in mid-May, hatch chicks in mid-June, and fledged chicks in August (7,8).

During June 1–August 15, 2022, we surveyed the main study area on East Beach (Figure 1) 1–3 times/day, conducting full census counts, monitoring disease symptoms, and individually marking carcasses. Other areas of Kent Island were surveyed on an intermittent schedule (Table 1). We assumed that all generally intact adult carcasses were virus-induced deaths because sudden deaths of adult birds are rare in breeding colonies. Because injuries and deaths are common among chicks, we were unable to assess virus-induced deaths in chicks except for suspected cases C1–C3 (Appendix, <https://wwwnc.cdc.gov/EID/article/29/10/23-0536-App1.pdf>).

We did not observe illness in the colony during a preliminary visit to Kent Island (May 24–27). On the

morning of June 27, we spotted a lethargic adult herring gull on East Beach that died that afternoon (Table 2; Figure 2). Disease symptoms and deaths spiked at 9 deaths during July 4–8 (Figure 2). We observed 9 more deaths that accumulated more slowly through August 15; a final check on September 2 revealed only 1 new carcass. The total number of East Beach cases was 25, resulting in 22 confirmed deaths (4.2% site mortality; Tables 1, 2). Daily checks of West Beach for part of the summer showed a similar timeline and effect as that observed on East Beach (Tables 1, 2). Total carcass counts across Kent, Sheep, and Hay Islands indicated a <10% mortality rate (Table 2).

During the summer 2022 breeding season, colony populations declined beginning in July (Figure 2). We assume that gulls exited the breeding colony because of normal seasonal phenology (8) rather than off-site deaths. Boat surveys of the surrounding Grand Manan archipelago (mid-June, mid-July) noted only 3 dead adult herring gulls in the water, and no mass mortality was reported on nearby beaches (1 dead HPAI virus-positive herring gull was found on Grand Manan on July 4; <https://cfia-ncr.maps.arcgis.com/>

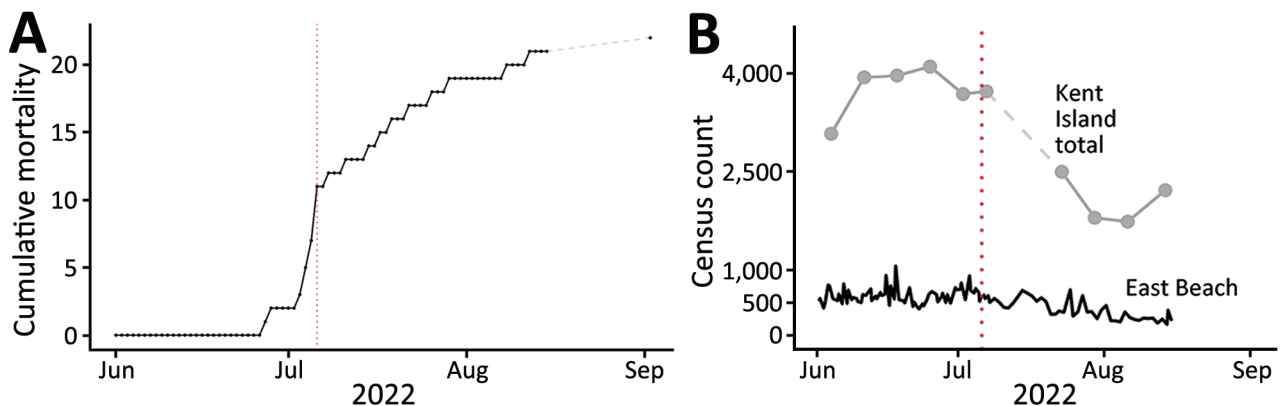


Figure 2. Adult herring gull deaths (cumulative, end-of-day) on East Beach, Kent Island, New Brunswick, Canada, in study of limited outbreak of highly pathogenic influenza A(H5N1) in herring gull colony, 2022. A) Cumulative mortality of herring gulls on East Beach during summer 2022. B) Census counts (number of breeding and nonbreeding adult herring gulls) from 1–3 surveys/day on East Beach and weekly total counts from surveys of the entire island. Red dotted lines mark July 6, the date of maximum gull deaths on East Beach.

apps/dashboards/89c779e98cdf492c899df23e1c38fdb). Censuses in June 2023 confirmed that the Kent Island herring gull population had returned for another breeding season (mean 4,290 herring gulls).

We collected case descriptions, images, and videos of herring gull adults and chicks from Kent Island (Appendix). Putative HPAI clinical signs in herring gulls matched those observed after experimental inoculations of HPAI H5N1 in related species (9,10). Neurologic symptoms progressed from lethargy and drooped wings to incoordination, head tremors, torticollis, and immobility over the course of hours or days. During the peak of the outbreak, dozens of additional birds displayed putative minor symptoms (e.g., slumped postures, hesitancy to fly) that were difficult to track and could not be linked to subsequent

death. One bird manifesting severe neurologic distress apparently recovered within hours (case 27).

We collected 3 carcasses of adult symptomatic birds (case 8, case 20, and 1 euthanized bird in southwest Kent Island on July 15) along with 3 chicks (cases C1–C3). Carcasses were collected under Canadian Wildlife Service permit no. SS2506 (to R.A.R.). All 3 adults and 1 chick (case C2) tested positive for a Eurasian strain of HPAI H5N1 virus (Appendix).

All sick or dead adult gulls throughout June and July were ≥ 4 years old according to plumage, matching the usual minimum breeding age for the species (Table 2) (8). Plumage-based censuses suggested 3%–6% of colony birds were 1–3 years of age (data not shown). Those younger birds were not breeding, and only 2 were found dead on East Beach later in the

Table 2. Putative highly pathogenic influenza A(H5N1) virus cases in herring gulls on East Beach and West Beach study areas in study of limited outbreak on Kent Island, Canada, 2022*

Case no.	Location	Age, † y	First seen sick		Last seen alive		Found dead	
			Date	Time	Date	Time	Date	Time
1	East Beach	≥ 4	Jun 27	≈09:30	Jun 27	≈09:30	Jun 27	≈16:30
2	East Beach	≥ 4	NA	NA	NA	NA	Jun 28	≈17:00
6	East Beach	≥ 4	Jul 2	12:11	Jul 2	12:11	Jul 3	09:38
8	East Beach	≥ 4	Jul 3	09:49	Jul 5	13:22	Jul 5	17:52
11	East Beach	≥ 4	Jul 3	20:30	Jul 3	20:30	Jul 4	08:57
12	East Beach	≥ 4	Jul 4	09:14	Jul 4	14:10	Jul 5	08:46
15	East Beach	≥ 4	Jul 4	13:51	Jul 4	17:09	Missing	NA
16	East Beach	≥ 4	Jul 4	14:21	Jul 5	13:22	Jul 6	12:01
18	East Beach	4	NA	NA	NA	NA	Jul 4	17:13
20	East Beach	≥ 4	Jul 5	08:51	Jul 6	16:46	Jul 6	19:39
24	East Beach	≥ 4	Jul 5	17:45	Jul 5	18:18	Jul 6	11:34
26	East Beach	≥ 4	Jul 5	17:10	Jul 6	11:36	Missing	NA
27	East Beach	4	Jul 6	11:54	Jul 6	19:53	Recovered?	NA
28	East Beach	≥ 4	NA	NA	NA	NA	Jul 6	11:58
31	East Beach	≥ 4	Jul 8	16:23	Jul 8	16:23	Jul 8	19:50
32	East Beach	≥ 4	Jul 10	16:30	Jul 10	19:45	Jul 11	16:42
33	East Beach	≥ 4	NA	NA	NA	NA	Jul 15	16:06
34	East Beach	≥ 4	NA	NA	NA	NA	Jul 17	16:25
35	East Beach	≥ 4	NA	NA	NA	NA	Jul 19	16:30
36	East Beach	≥ 4	Jul 21	07:39	Jul 21	16:26	Jul 22	09:46
37	East Beach	≥ 4	Jul 25	13:45	Jul 25	13:45	Jul 26	10:28
38†	East Beach	≥ 4	Jul 26	10:25	Jul 26	10:25	Jul 29	08:36
39	East Beach	1	NA	NA	NA	NA	Aug 8	10:13
40	East Beach	1	NA	NA	NA	NA	Aug 12	08:13
NA	East Beach	NA	NA	NA	NA	NA	Sep 2	NA
4	West Beach	4	NA	NA	NA	NA	Jul 1	11:45
5	West Beach	≥ 4	Jul 1	16:18	Jul 1	16:18	Jul 1	17:20
9	West Beach	≥ 4	Jul 3	16:41	Jul 3	16:41	Jul 4	10:20
10	West Beach	≥ 4	Jul 3	16:43	Jul 3	16:43	Jul 4	10:25
13	West Beach	≥ 4	Jul 4	10:04	Jul 4	10:04	Jul 4	14:49
14	West Beach	≥ 4	NA	NA	NA	NA	Jul 4	10:11
19	West Beach	≥ 4	NA	NA	NA	NA	Jul 5	09:46
22	West Beach	≥ 4	NA	NA	NA	NA	Jul 5	17:15
25	West Beach	≥ 4	NA	NA	NA	NA	Jul 5	16:20
NA	West Beach	≥ 4	NA	NA	NA	NA	Jul 7	NA
NA	West Beach	≥ 4	NA	NA	NA	NA	Jul 7	NA
NA	West Beach	≥ 4	NA	NA	NA	NA	Jul 23	NA
NA	West Beach	NA	NA	NA	NA	NA	Sep 2	NA
NA	West Beach	NA	NA	NA	NA	NA	Sep 2	NA
NA	West Beach	NA	NA	NA	NA	NA	Sep 2	NA

*Case details are provided in the Appendix (<https://wwwnc.cdc.gov/EID/article/29/10/23-0536-App1.pdf>). Some carcasses were not numbered. NA, not applicable.

†Estimated according to plumage (8) when noted.

summer (Table 2). From 16 fully-tracked cases (Table 2) and surveys conducted 1–3 times/day, we showed the mean time (\pm SD) from first seen sick to last seen alive was 7.8 \pm 15.0 hours; the mean time from first seen sick to found dead was 20.9 \pm 14.9 hours.

We calculated the basic reproduction number (R_0) by using daily East Beach incidence data (June 1–August 15), gamma-distributed generation times from poultry data (4.8 \pm 0.58 days) (11), and the exponential growth rate method from the R package R0 (12). Overall R_0 was 1.02 (95% CI 0.95–1.11). R_0 was 8.23 (95% CI 3.97–21.11) if estimated from the rising incidence period (June 1–July 6) but fell to 0.84 (95% CI 0.64–1.07) if estimated from the falling incidence period (July 7–August 15).

H5N1 was suspected or confirmed in 4 other species breeding on Kent Island (Appendix): great black-backed gulls (*Larus marinus*), Canada geese (*Branta canadensis*), common eiders (*Somateria mollissima*), and American crows (*Corvus brachyrhynchos*). Unlike the mostly intact gull carcasses on Kent Island (Appendix Table 1), many carcasses on Hay Island were partially consumed. Likely predators or scavengers were great black-backed gulls and bald eagles (*Haliaeetus leucocephalus*). Beginning in July, we noted gray seals (*Halichoerus grypus*) loitering offshore at East Beach. Seals rarely interacted with adult seabirds but harassed herring gull chicks paddling from shore.

Conclusions

A Eurasian lineage of H5N1 virus swept through the Kent Island herring gull colony starting in late June 2022. The outbreak appeared to slow within weeks (Figure 2) and resulted in <10% apparent colony mortality rate (Table 1). Low carcass disturbance (Appendix Table 1) and disease resistance or recovery (case 27) might have limited H5N1 virus infections in the gulls. Furthermore, our islandwide censuses suggest 2022 population sizes were <25% of historical size across the same island area (Table 1) (13). Low densities might have reduced intraspecific transmission by limiting social interactions with infected conspecifics. However, we observed possible interspecific exposure routes through cohabitation (e.g., common eiders), predation/scavenging (e.g., bald eagles), and interactions between chicks and marine mammals (e.g., gray seals). Those pathways are consistent with global H5N1 virus transmission between populations, including recent spillover events in mammals (14,15).

The current understanding of H5N1 virus transmission in wild birds involves circulation in migratory waterfowl or roving gulls (6) and mass mortality

events within seabird colonies (3,5). Our study suggests that limited outbreaks in seabird colonies could play an important role in H5N1 transmission chains. Post hoc surveillance of mass mortality is insufficient if seabird colonies can circulate H5N1 without mass mortality. Therefore, we propose that more proactive monitoring of seabirds for H5N1 virus infections will be critical for guarding commercial poultry (1), averting potentially catastrophic zoonotic transmission (2), and protecting vulnerable seabirds, including gulls.

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Confirmatory laboratory test results were obtained from Canada's interagency surveillance program for avian influenza viruses in wild birds, a partnership that includes Environment and Climate Change Canada, the Canadian Food Inspection Agency, Canadian Wildlife Health Cooperative, and other federal, provincial, territorial, indigenous, and academic partners involved in wildlife, domestic animal, and human health (see website for full list of partners: <https://cfia-ncr.maps.arcgis.com/apps/dashboards/89c779e98cdf492c899df23e1c38fdbcb>).

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Mr. Taylor is a PhD candidate in the Department of Ecology and Evolutionary Biology at Yale University. He studies how social development influences, and is influenced by, the life history evolution of birds, with a focus on delayed reproduction and delayed plumage maturation in lekking manakins and colony-breeding gulls.

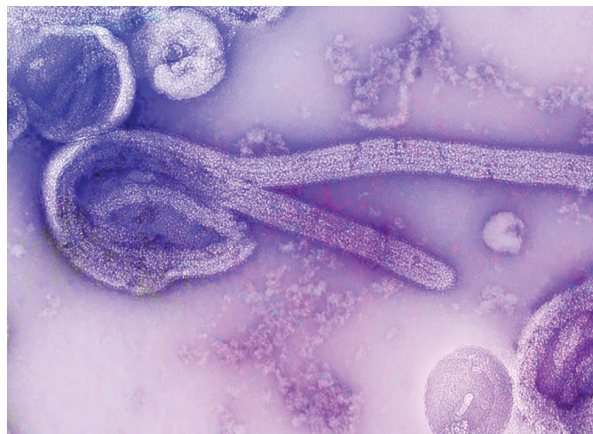
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Appendix

Additional Methods

Case details are shown for the highly pathogenic avian influenza (HPAI) outbreak in American herring gulls (*Larus argentatus* subsp. *smithsonianus*) on Kent Island, New Brunswick, Canada, summer 2022 (Appendix Table 1). Images and videos of carcasses and live, symptomatic cases are available from a Dryad open-access repository (<https://doi.org/10.5061/dryad.z08kprjz>).

Laboratory Testing

Six herring gull carcasses from Kent Island were collected for laboratory genetic testing for avian influenza virus, comprising 3 adults (cases 8, 20, and an additional euthanized adult) and 3 chicks (cases C1–C3). Initial sampling was performed by the Canadian Wildlife Health Cooperative, Atlantic Region. For each carcass, oropharyngeal and cloacal swab samples were collected and combined in viral transport media (Multitrans Transport System; Starplex Scientific, <https://starplexscientific.com>). PCR testing on those samples was performed at the Regional Diagnostic Virology Laboratory, Atlantic Veterinary College, University of Prince Edward Island, Canada. Samples were tested according to the Canadian Animal Health Surveillance Network protocol (Detection of Type A Influenza Viruses and Avian H5 and H7 Hemagglutinin Subtypes by Real-Time Reverse Transcription PCR [RT-PCR]). This protocol involves an initial avian influenza A matrix gene RT-PCR, then strain-specific RT-PCR to determine H5 or H7 subtypes.

Samples from 4 carcasses were positive for influenza A matrix and H5 subtype (adult cases 8, 20, and the euthanized bird along with chick case C2). All samples were negative for H7 influenza virus. Influenza A virus was not detected in chick cases C1 and C3. Positive samples (cases 8, 20, C2, and the euthanized bird) were sent to the National Centre for Foreign Animal Diseases, Canadian Food Inspection Agency (CFIA) for confirmatory testing (PCR, virus isolation, and genetic sequencing); testing identified a fully Eurasian lineage of influenza A(H5N1) in all 4 cases.

CFIA test results are accessible from the general public dashboard (<https://cfia-ncr.maps.arcgis.com/apps/dashboards/89c779e98cdf492c899df23e1c38fdb>). To navigate to the case results for this study, in the dashboard address bar, search for: Kent Island, NB, CAN. Test results for herring gulls from Kent Island were listed by CFIA under collection dates that were different from true field collection dates and are not provided in a recognizable order (Appendix Table 2); however, those 4 cases correspond to the only 4 herring gull specimens submitted to CFIA from Kent Island (our 4 positive cases: 8, 20, C2, and the euthanized bird).

Adult Herring Gull Case Details

Case 1. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [latitude 44.578253, longitude -66.755109]; (2022-06-27, $\approx 09:30$) first seen lethargic with drooped wings; (2022-06-27, $\approx 16:30$) found dead following heavy rain, carcass with abdominal wound; carcass in mid-beach region, above tideline and below nesting area; (2022-07-04, 09:22; photo) noted undisturbed carcass; (2022-07-05, $\approx 09:00$) noted undisturbed carcass.

Case 2. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.578507, -66.755071]; (2022-06-28, $\approx 17:00$) first seen dead, carcass bent and spot of blood on stomach feathers but otherwise intact; carcass in mid-beach region, above tideline and below nesting area; 1 wing collected 36 hours after death; (2022-07-04, 09:18; photo) noted undisturbed carcass with abdominal wound, decomposing; (2022-07-06, 11:49; photo) noted undisturbed carcass.

Case 3. Number was used for a great black-backed gull.

Case 4. Definitive plumage with minor predefinitive plumage elements (\approx 4 years old), American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.585663, -66.763724]; (2022-07-01, 11:45) first seen dead, carcass huddled stomach down; carcass in low beach region, below tideline; (2022-07-04, 10:20) carcass missing (washed away?).

Case 5. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.583981, -66.762365]; (2022-07-01, 16:18) first seen lethargic with drooped wings; (2022-07-01, 17:20) found dead slightly higher up on beach from original position, stomach down; carcass in mid-beach region, above tideline and below nesting area; (2022-07-04, 10:15; photo) noted undisturbed carcass; (2022-07-05, 9:35; photo) noted undisturbed carcass; (2022-07-06, 12:34; photo) noted undisturbed carcass. Field notes record how carcass was ignored by nearby herring gulls, 2 of which walked near carcass (<2 m) when flushed during a census.

Case 6. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.5809163, -66.7542265]; (2022-07-02, 12:11) first seen lethargic with drooped wings; (2022-07-03 09:38) found dead near original location; carcass in mid-beach region, above tideline and below nesting area; (2022-07-04, 09:06; photo) noted undisturbed carcass; (2022-07-05, \approx 09:00) noted undisturbed carcass; (2022-07-06, 11:31; photo) noted undisturbed carcass.

Case 7. Offsite. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); northwest Kent Island, New Brunswick, Canada [44.584545, -66.754029]; (2022-07-02, 14:48) first seen dead.

Case 8. Confirmed avian influenza virus. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.575913, -66.75488]; (2022-07-03, 09:49; video) first seen stationary and unresponsive with continuous head ticking; (2022-07-03, 16:42) alive in same spot, head ticking continues. Field notes record another slightly smaller herring gull in good health performing courtship or pair-bond behaviors and standing within inches of focal bird, alarmed at observer but back turned comfortably toward focal bird; head-nod toward focal bird (i.e., possible courtship display or food-begging); (2022-07-04, 09:30; video) alive in same spot, with head sagging down but still

softly ticking in identical repetitive movement; (2022-07-04, 14:18; photo) alive in same spot, eyes nearly closed, body hunched, and head barely but continuously ticking; (2022-07-05, 09:01) alive in same spot, fully collapsed with bill stuck in sand, immobile but breathing evident; (2022-07-05, 13:22) alive near same spot, now on back with eyes wide and tracking movement, feet kicking up in air; (2022-07-05, 17:52; video) found dead and carcass collected immediately for laboratory testing; carcass in mid-beach region, above tideline and below nesting area. Laboratory test results were confirmed positive for fully Eurasian avian influenza A(H5N1) virus.

Case 9. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.584552, -66.76353]; (2022-07-03, 16:41) first seen with severe loss of coordination, stumbling and flying toward water, then collapsing among intertidal boulders; attacked by nearby gulls while flailing in intertidal boulders; (2022-07-04, 10:20) found dead in same spot among rocks; carcass below the tideline.

Case 10. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.585997, -66.763762]; (2022-07-03, 16:43) same as adjacent case 9, first seen with severe loss of coordination, stumbling and flying toward water; attacked by nearby gulls while flailing and attempting to land in intertidal area; (2022-07-04, 10:25; photo) found dead, washed above tideline near previous flailing location; carcass chest cavity exposed (chest cavity eaten or rapidly decomposed during time in water?); (2022-07-05, 09:51; photo) noted undisturbed carcass; (2022-07-06, 12:36; photo) noted undisturbed carcass.

Case 11. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.581168, -66.754012]; (2022-07-03, 20:30) first seen collapsed, wings partially spread; (2022-07-04 08:57) found dead in same spot, carcass undisturbed; carcass in mid-beach region, above tideline and below nesting area; (2022-07-04, 13:28; photo) noted undisturbed carcass; (2022-07-06, 11:30; photo) noted undisturbed carcass.

Case 12. Because of tracking difficulties, possible interchanges with case 18. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.5788778, -66.7548414]; (2022-07-04, 09:13; video) first seen

lethargic with drooped wings, responsive to disturbance and nearby birds but slow and stumbling movement; (2022-07-04, 14:10) alive nearby, having moved from the mid-beach area to the tideline, head active but body wobbling and stiff; (2022-07-05, 08:46; photo) found dead near previous location, carcass just below tideline; (2022-07-06, 11:41; photo) noted undisturbed carcass.

Case 13. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.583007, -66.760653]; (2022-07-04, 10:04; video) first seen immobile, face down in sand with wings partially spread, open and responsive eyes; (2022-07-04, 14:49; photo) found dead in same spot, carcass near nesting area; (2022-07-06, 12:32; photo) noted undisturbed carcass.

Case 14. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.583888, -66.762139]; (2022-07-04, 10:11; photo) first seen dead with fully intact carcass, carcass near nesting area; (2022-07-04, 14:54) noted undisturbed carcass with blue-black flies swarming eyes; (2022-07-05, 09:35; photo) noted undisturbed carcass. (2022-07-06, 12:34; photo) noted undisturbed carcass.

Case 15. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [\approx 44.579046, -66.754931]; (2022-07-04, 13:51) first seen floating in water with spread wings, ruffled body but active head gazing toward a nearby, unresponsive flock of female common eiders (*Somateria mollissima*); (2022-07-04, 17:09) putative same individual seen alive at tideline, straight in from original floating location, lethargic and rocking back-and-forth with partially spread wings and narrow eyes; missing afterwards.

Case 16. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.575815, -66.75478982]; (2022-07-04, 14:21) first seen lethargic, head alert but no body coordination while stuck among rocks at edge of intertidal area; (2022-07-04, 17:23) seen alive but even less steady with bent neck among intertidal rocks; (2022-07-05, 09:05) seen alive in same spot; (2022-07-05, 17:54; video) seen alive, lethargic and wet with wings held close to body; (2022-07-06, 12:01) found dead near original location, carcass below the tideline.

Case 17. Offsite. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); South Basin, Kent Island, New Brunswick, Canada [44.5897, -66.75967]; (2022-07-04, 15:14; video) first seen flailing wings among group of ≈ 8 herring gulls. Flailing induced the other birds to panic and fly circles around flailing bird that was not coordinated enough to raise wings. As observer approached, focal bird found a way to take off, half flying and half carried by strong wings until it regained some composure higher in the air. Not seen again (impossible to confirm individual).

Case 18. Because of tracking difficulties, possible interchanges with case 12. Definitive plumage with minor predefinitive plumage elements (≈ 4 years old), American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.578673, -66.755152]; (2022-07-04, 17:13; photo) first seen dead with wings folded and head down, carcass near nesting area; (2022-07-05, $\approx 09:00$) noted undisturbed carcass; (2022-07-06, 11:42; photo) noted undisturbed carcass.

Case 19. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.584494, -66.763426]; (2022-07-05, 09:46; photo) first seen dead with upper body intact but lower body ripped apart, carcass below tideline.

CASE 20. Confirmed avian influenza virus. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.578598, -66.754922]; (2022-07-05, 08:51) first seen with mobile head but uncoordinated body, stumbling, and unable to raise wings. Flailing from focal bird caused several dozen nearby herring gulls to flush with wild alarm, circling and screaming within 20 m; (2022-07-05, 13:15) seen alive near dense nesting area, wings spread and barely mobile; (2022-07-06, 11:37; video) seen alive having moved partially closer to tideline, eyes open and responsive but otherwise completely immobile; (2022-07-06, 16:46) seen alive in the same location, immobile with eyes wide open and still tracking movement; (2022-07-06, 19:39; photo) found dead and carcass collected immediately for pathology; carcass in mid-beach region, above tideline and below nesting area. Laboratory test results were confirmed positive for fully Eurasian avian influenza A(H5N1) virus.

Case 21. Number was skipped during field organization.

Case 22. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.583586, -66.7617]; (2022-07-05, 17:15; photo) found dead, soaking wet with stained but otherwise undisturbed carcass. Carcass was at tideline.

Case 23. Number was skipped during field organization.

Case 24. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.580714, -66.754379]; (2022-07-05, 17:45; video) first seen flailing in high-tide water causing alarm among nearby gulls; (2022-07-05, 18:18; video) after crawling on shore, flipped sideways with wing stuck in the air, quivering legs and active eye; (2022-07-06, 11:34; photo) found dead in same spot, carcass below tideline.

Case 25. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); West Beach, Kent Island, New Brunswick, Canada [44.584865, -66.764062]; (2022-07-05, 16:20) found dead, carcass floating in water off beach. Confirmation of other monitored carcasses nearby supports new case.

Case 26. Missing. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.580752, -66.75464]; (2022-07-05, 17:10) first seen lethargic and wet high up in berm among dense nesting area; (2022-07-06, 11:35; video) seen again in same territory, lethargic, slumped in shrub, eyes nearly closed, wet head and body after rains; (2022-07-06, 16:49) noted absent with 3 dead chicks found within 4 m of each other on the same territory where focal bird was previously loafing (1 chick collected [case C2], which tested positive for HPAI A virus).

Case 27. Recovered? Definitive-plumage with minor predefinitive plumage elements (≈ 4 years old), American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.5776, -66.75518]; (2022-07-06, 11:54; video) first seen fully flailing and unable to lift wings, prompting many nearby gulls to rise in alarm; (2022-07-6, 16:42; video) seen ≈ 20 m from original spot but now coordinated enough to hold wings and walk; (2022-07-06, 19:53) seen in same spot as previous observation, now fully mobile and, after a few steps, able to fly down the beach; subsequently lost from monitoring. Although it is not

obvious in all recorded media, we were able to identify this bird more confidently across sightings via a distinct predefinitive plumage element (black primary coverts).

Case 28. Definitive-plumage with minor predefinitive plumage elements (\approx 4 years old), American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.576526, -66.75514]; (2022-07-06, 11:58; photo) first seen dead face down in sand and undisturbed; carcass in mid-beach region, above tideline and below nesting area.

Case 29. Offsite. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); South Basin, Kent Island, New Brunswick, Canada [44.58616, -66.76336]; (2022-07-07, 11:03; photo) first seen dead, carcass clearly disturbed with chest wound and scattered feathers among intertidal rocks.

Case 30. Offsite. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); South Basin, Kent Island, New Brunswick, Canada [44.587328, -66.759744]; (2022-07-7, 11:10; photo) first seen dead, carcass wet but undisturbed among intertidal rocks.

Case 31. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.580715, -66.754472]; (2022-07-08, 16:23; video) first seen lethargic and hunched in intertidal area; (2022-07-08, 19:50; photo) found dead near original location, carcass below tideline; (2022-07-09, 16:41; photo) noted undisturbed carcass.

Case 32. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.581122, -66.753938]; (2022-07-10, 16:30; video) first seen uncoordinated and trembling close to water; (2022-07-10, 19:45; video) seen again immobile, floating at edge of water; (2022-07-11, 16:42; photo) found dead, carcass below tideline.

Case 33. Definitive-plumaged (\geq 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.581909, -66.7538]; (2022-07-15, 16:06; photo) found dead; carcass in mid-beach region above tideline and below nesting area.

Case 34. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.581141, -66.754134]; (2022-07-17, 16:25; photo) first seen dead having washed up on beach, carcass at tideline.

Case 35. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.583043, -66.753943]; (2022-07-19, 16:30; photo) found dead, carcass near nesting area.

Case 36. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.583052, -66.753972]; (2022-07-21, 7:39; video) first seen lethargic and uncoordinated in nesting area; (2022-07-21, 16:26; video) seen alive in same spot, head mobile but otherwise collapsed; (2022-07-22, 9:46) found dead in same location among nesting territories; (2022-07-26, 10:22; photo) noted undisturbed carcass.

Case 37. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.580984, -66.75419]; (2022-07-25, 13:45) first seen minorly lethargic, wings drooped and ruffled feathers but mobile and coordinated wing movements; (2022-07-26, 10:28; photo) found dead, carcass below tideline; (2022-07-27, 10:09) carcass noted missing, possibly swept away by tide.

Case 38. Definitive-plumaged (≥ 4 years old) American herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.580984, -66.75419]; (2022-07-26, 10:25; video) first seen with uncoordinated movement. Not seen for multiple days; (2022-07-29, 8:56) found dead after thorough search a few meters from original live location, carcass intact but drenched from heavy rains. Carcass was in nesting area.

Case 39. First-cycle plumage (≈ 1 year old), America herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.581149, -66.75398]; (2022-08-08, 10:13; photo) first seen dead face down in sand, carcass wet but otherwise intact. Carcass was at tideline.

Case 40. First-cycle plumage (≈ 1 year old), America herring gull (*L. a. smithsonianus*); East Beach, Kent Island, New Brunswick, Canada [44.582075, -66.753745]; (2022-08-12,

8:13) first seen dead with heavily decomposed carcass suggesting earlier death. Carcass was at tideline.

Chick Herring Gull Case Details

Case C1. Negative for HPAI A virus. Recently hatched (\approx 1 month old) American herring gull chick (*L. a. smithsonianus*); in field nesting territory on South Field, Kent Island, New Brunswick, Canada [44.581384, -66.755459]; some difficulties tracking individual chick across multiple sightings; first accurately noted (2022-07-06, \approx 13:30), seen dry and upright, but slow moving and not fleeing from observer, 1 definitive-plumaged parent was closely attending; (2022-07-06, 16:07) seen dry and upright but more stationary; (2022-07-06, 17:28; video) dry and walking with stumbling and uncoordinated movements; (2022-07-07, 12:16) found dead with healthy parent in close attendance (<2 m from chick, alarmed at and defensive with observer). Carcass was collected for testing. Laboratory testing was negative for HPAI virus.

Case C2. Confirmed HPAI A virus. Recently hatched (\approx 1 month old) American herring gull chick (*L. a. smithsonianus*), putative offspring of case 26, found in nesting territory where that adult bird was seen ill; East Beach, Kent Island, New Brunswick, Canada [44.580752, -66.75464]; (2022-07-06, 16:49; photo) first seen dead with 2 other chicks (<4 m apart), all carcasses unattended but fully intact. Carcass was collected for testing; laboratory testing was confirmed positive for fully Eurasian avian influenza A(H5N1) virus.

Case C3. Negative for HPAI A virus. Recently hatched (\approx 1 month old) American herring gull chick (*L. a. smithsonianus*); in field nesting territory on South Field, Kent Island, New Brunswick, Canada [44.580765, -66.755776]; (2022-07-07, 12:52) first seen dead, carcass fully intact and parent closely attending. Carcass was collected immediately for testing; laboratory testing returned negative for HPAI virus.

Putative HPAI in Other Kent Island Species

Great Black-Backed Gull (*Larus marinus*)

One closely-monitored putative HPAI case in great black-backed gull (*L. marinus*); definitive-plumaged adult (≥ 4 years old) on East Beach, Kent Island, New Brunswick, Canada [44.575719, -66.754705]; (2022-06-29, 16:20; photo) first seen severely uncoordinated in intertidal area, where flailing caused mob of other gulls to rise up nearby; observed multiple

times over subsequent hours, recording how flailing diminished to complete immobility despite open and active eyes; (2022–06–30, 9:22) found dead with wet carcass (drowned overnight?); (2022–07–04, 9:37; photo) noted undisturbed carcass; (2022–07–04, 17:20; photo) noted carcass disturbance with body in new position, feathers strewn about, and body cavity peeled open. (2022–07–05, ≈9:00) noted undisturbed carcass. Additional *L. marinus* deaths found across Kent Island (2 carcasses, definitive plumage, ≥ 4 years old), Sheep Island (7 carcasses, definitive plumage, ≥ 4 years old), and Hay Island (1 carcass, first-cycle plumage, ≈ 1 year old).

Canada Goose (*Branta canadensis*)

At least 3 adult *B. canadensis* carcasses found across Kent Island. Carcasses were generally decomposed but otherwise intact.

Common Eider (*Somateria mollissima*)

One adult female *S. mollissima* was reported lethargic and curled up on West Beach, Kent Island, later found dead with intact carcass. Another intact female carcass was found on Hay Island. Regional monitoring confirmed fully Eurasian avian influenza A(H5N1) virus in 2 carcasses from nearby Grand Manan, New Brunswick, Canada (1 collected on 2022–06–18; 1 collected on 2022–07–03) (<https://cfia-ncr.maps.arcgis.com/apps/dashboards/89c779e98cdf492c899df23e1c38fdbbc>).

American Crow (*Corvus brachyrhynchos*)

A living adult crow was seen uncoordinated and flailing in intertidal area just south of East Beach, Kent Island. As with flailing herring gulls, the flailing crow drew aggressive mobbing behaviors from nearby gulls (video). At least 3 additional intact carcasses were reported across Kent Island (photo). Laboratory testing confirmed fully Eurasian avian influenza A(H5N1) virus infection in 1 American crow carcass from Kent Island (2022–07–10; <https://cfia-ncr.maps.arcgis.com/apps/dashboards/89c779e98cdf492c899df23e1c38fdbbc>).

Other

H5N1 cases from those above and other avian species (e.g., Arctic terns, *Sterna paradisaea*) were reported in the Bay of Fundy and Atlantic Canada (<https://cfia-ncr.maps.arcgis.com/apps/dashboards/89c779e98cdf492c899df23e1c38fdbbc>). Although black

guillemots (*Cepphus grylle*) and Leach's storm petrels (*Hydrobates leucorhous*) also breed among herring gulls on Kent Island, we saw no evidence of HPAI in those species.

Appendix Table 1. Summary of herring gull locations and carcass status for putative highly pathogenic avian influenza cases on the East and West beach study areas of American herring gull colony on Kent Island, New Brunswick, Canada*

Case	Beach	Latitude	Longitude	Area†	Media	Carcass status	Carcass disturbance‡
1	East	44.578253	-66.755109	Mid	Dead	Abdominal wound	Undisturbed ≥7.7 d
2	East	44.578507	-66.755071	Mid	Dead	Abdominal wound	Undisturbed ≥7.9 d
6	East	44.5809163	-66.7542265	Mid	Dead	Intact	Undisturbed ≥3.1 d
8	East	44.575913	-66.75488	Mid	Live, Dead	Intact	Collected immediately
11	East	44.581168	-66.754012	Mid	Dead	Intact	Undisturbed ≥2.1 d
12	East	44.5788778	-66.7548414	Low	Live, Dead	Intact	Undisturbed ≥1.9 d
15	East	44.579046	-66.754931	Low	NA	Missing	NA
16	East	44.575815	-66.75478982	Low	Live, Dead	Intact	NA
18	East	44.578673	-66.755152	Nest	Dead	Intact	Undisturbed ≥1.8 d
20	East	44.578598	-66.754922	Mid	Live, Dead	Intact	Collected immediately
24	East	44.580714	-66.754379	Low	Live, Dead	Intact	NA
26	East	44.580752	-66.75464	Nest	Live	Missing	NA
27	East	44.5776	-66.75518	Mid	Live	Recovered?	NA
28	East	44.576526	-66.75514	Mid	Dead	Intact	NA
31	East	44.580715	-66.754472	Low	Live, Dead	Intact	Undisturbed ≥0.9 d
32	East	44.581122	-66.753938	Low	Live, Dead	Intact	NA
33	East	44.581909	-66.7538	Mid	Dead	Intact	NA
34	East	44.581141	-66.754134	Low	Dead	Intact	NA
35	East	44.583043	-66.753943	Nest	Dead	Intact	NA
36	East	44.583052	-66.753972	Nest	Live, Dead	Intact	Undisturbed ≥5.1 d
37	East	44.580984	-66.75419	Low	Dead	Intact	Carcass missing after 1.0 d
38	East	44.581273	-66.754193	Nest	Live	Intact	NA
39	East	44.581149	-66.75398	Low	Dead	Intact	NA
40	East	44.582075	-66.753745	Low	NA	Decomposed	NA
4	West	44.585663	-66.763724	Low	NA	Intact	NA
5	West	44.583981	-66.762365	Mid	Dead	Intact	Undisturbed ≥4.8 d
9	West	44.584552	-66.76353	Low	NA	Not recorded	
10	West	44.585997	-66.763762	Mid	Dead	Lower body missing	Undisturbed ≥2.1 d
13	West	44.583007	-66.760653	Nest	Live, Dead	Intact	Undisturbed ≥1.9 d
14	West	44.583888	-66.762139	Nest	Dead	Intact	Undisturbed ≥2.1 d
19	West	44.584494	-66.763426	Low	Dead	Lower body destroyed	NA
22	West	44.583586	-66.7617	Low	Dead	Intact	NA
25	West	44.584865	-66.764062	Low	NA	Intact	NA

*Locations approximate given GPS reception. NA, not applicable.

†Section of beach where the carcass or living bird was found. The nest area near the berm included all nests and breeding territories, the low area was at or below the tideline, and the mid area was in-between.

‡Carcass disturbance records simply indicate when monitoring ended; no herring gull carcass was clearly damaged after being discovered (but see case details for great black-backed gulls). Only 7/33 carcasses (27%) with beach location data were found in the nesting area farther from shore. The remaining birds either wandered or were forced toward the water (presumably by aggression from other birds) before dying. Some carcasses on Kent Island appeared with initial injuries but otherwise remained undisturbed (monitored 0.9–7.9 d). Carcasses monitored for disturbance remained untagged.

Appendix Table 2. Canadian Food Inspection Agency confirmatory testing for avian influenza A(H5N1) virus in 4 herring gull specimens submitted from Kent Island, New Brunswick, Canada, 2022

CFIA collection date	Result authorized	Common name	Province	Status	Strain	Result	Lineage
7/18/2022	8/10/2022	Herring gull	New Brunswick	Dead	H5N1	Confirmed	Fully Eurasian
7/5/2022	8/10/2022	Herring gull	New Brunswick	Dead	H5N1	Confirmed	Fully Eurasian
7/4/2022	8/10/2022	Herring gull	New Brunswick	Dead	H5N1	Confirmed	Fully Eurasian
7/2/2022	8/10/2022	Herring gull	New Brunswick	Dead	H5N1	Confirmed	Fully Eurasian