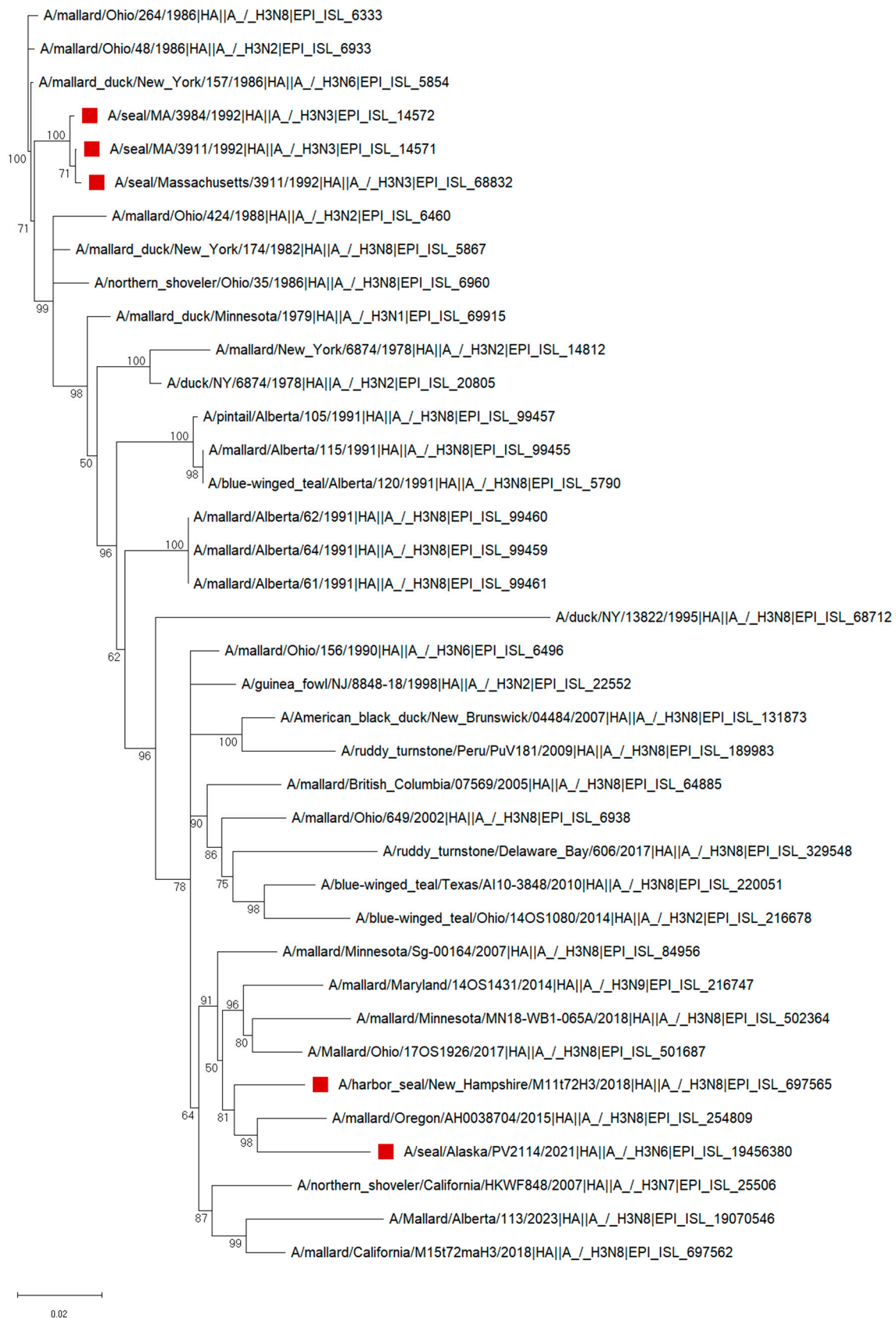
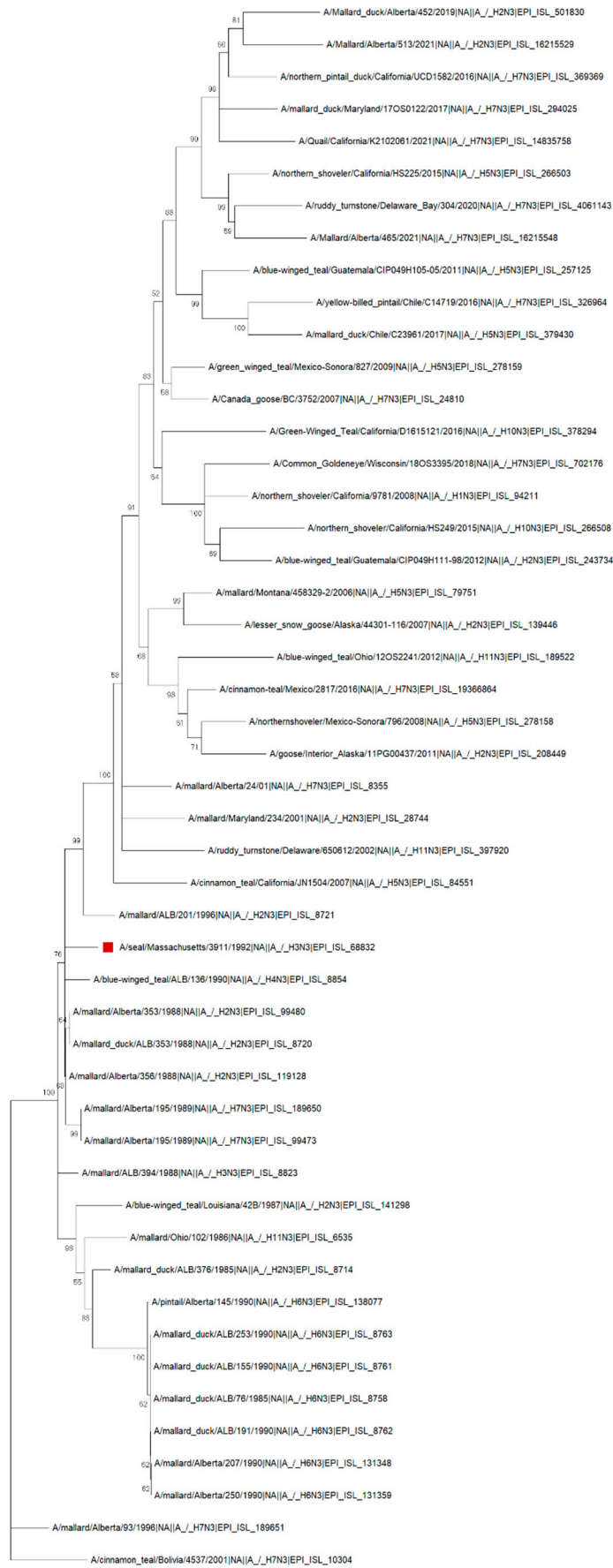


Supplementary figures



Suppl. **Figure S1**. Phylogenetic tree of HA segment of H3Nx avian influenza viruses obtained from seals (marked in red) and representative wild bird population. A full-length HA segment

of H3Nx seal and wild bird isolates available in the GISAID (n= 1840) were retrieved and representative sequences (n= 256) were selected based on sequence identity at 97% level using CD-HIT package. The wild bird isolates that clustered with a seal isolates (n=38) were selected to generate phylogenetic tree. The nucleotide sequences of complete HA segments were aligned using MUSCLE on MEGA 11.03.13. GTR nucleotide substitution model, with among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.



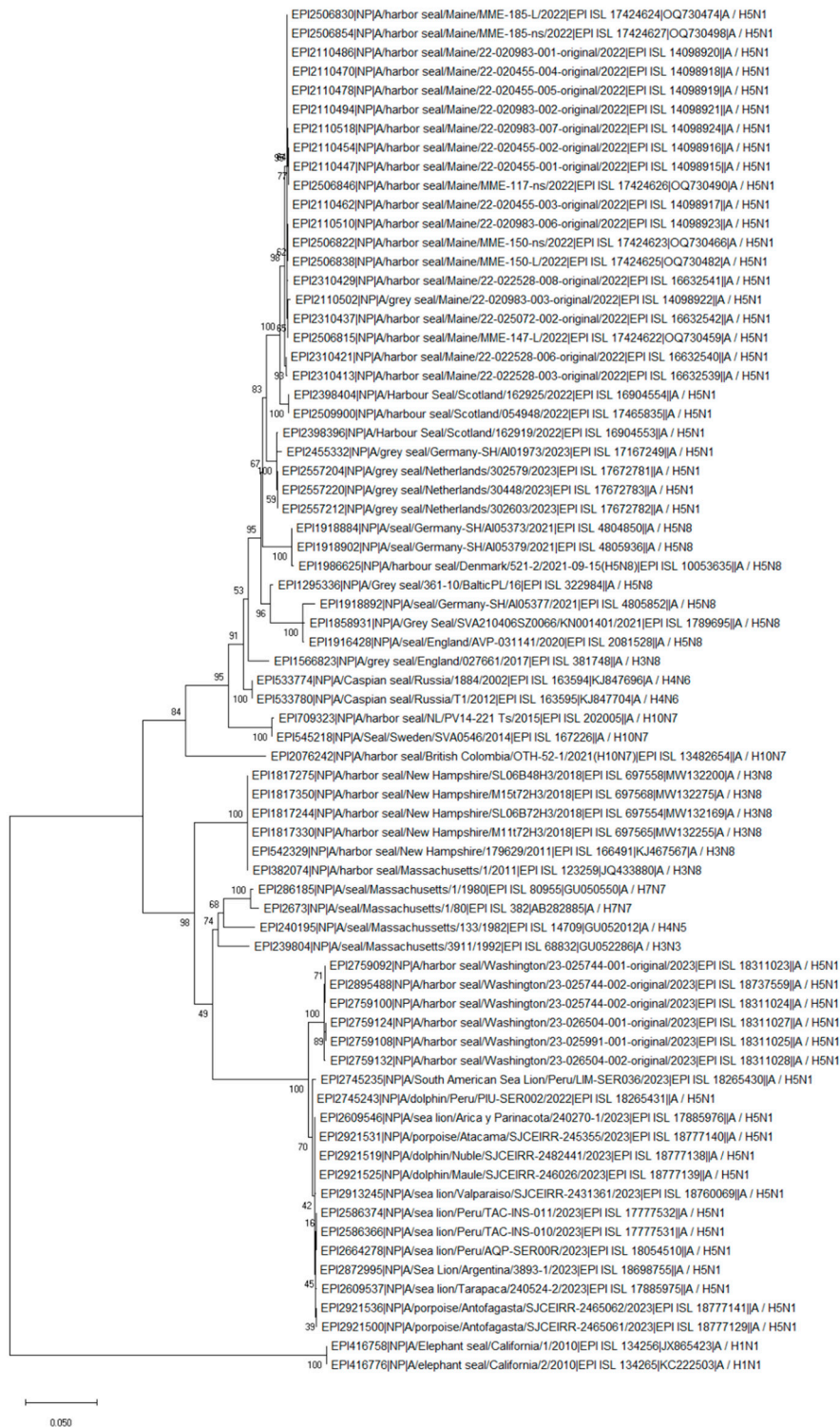
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Suppl. **Figure S2.** Phylogenetic tree of NA segment of HxN3 avian influenza viruses obtained from seal (red dot) and representative wild bird population. The representative sequences (n= 181) were selected based on sequence identity at 97% level using CD-HIT package out of all HxN3 isolates available in GISAID. The viral isolates that clustered with a H3N3 seal isolate (n=51) were selected to generate a phylogenetic tree. The nucleotide sequences of the NA segment were aligned using MUSCLE. GTR nucleotide substitution model, with an among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.

E627K D701N

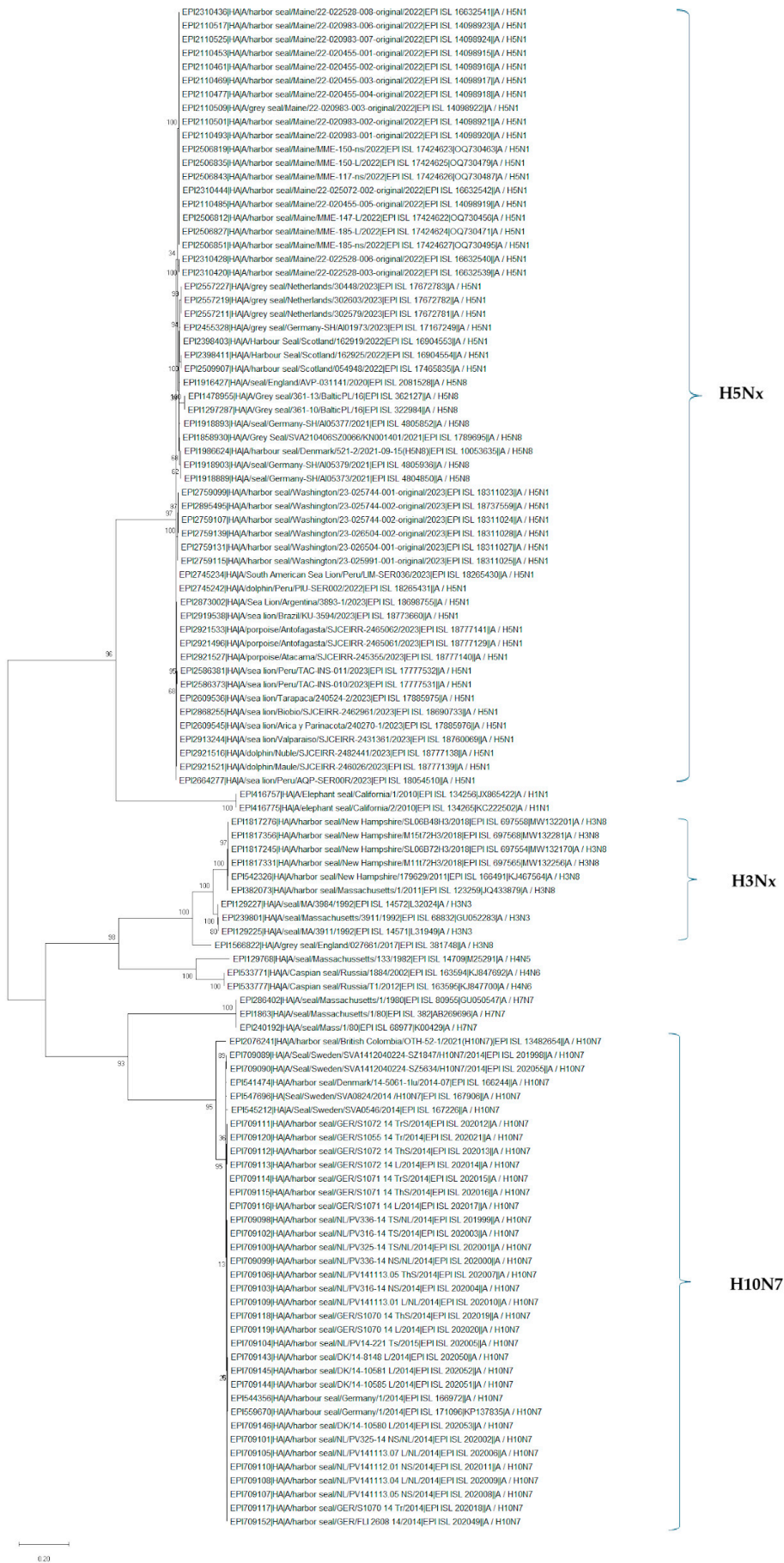
Name	Δ	P	E	Q	S	D	K
1. EPI285739 PB2 A/seal/Massachusetts/1/1980 EPI_ISL_80955 ACY79809 A/_H7N7	-	-	-	-	-	-	-
2. EPI2667 PB2 A/seal/Massachusetts/1/80 EPI_ISL_382 A/_H7N7	-	-	-	-	-	-	-
3. EPI533770 PB2 A/Caspian_seal/Russia/1884/2002 EPI_ISL_163594 AID48103 A/_H4N6	-	-	-	-	-	-	-
4. EPI533776 PB2 A/Caspian_seal/Russia/T1/2012 EPI_ISL_163595 AID48091 A/_H4N6	-	-	-	-	-	-	-
5. EPI130331 PB2 A/seal/Massachusetts/133/1982 EPI_ISL_14709 JM73522 A/_H4N5	-	-	-	-	-	-	-
6. EPI239807 PB2 A/seal/Massachusetts/391/1992 EPI_ISL_68832 ACZ45453 A/_H3N3	-	-	-	-	-	-	-
7. EPI1566819 PB2 A/grey_seal/England/027661/2017 EPI_ISL_381748 A/_H3N8	-	-	-	-	-	-	N
8. EPI542331 PB2 A/harbor_seal/New_Hampshire/179629/2011 EPI_ISL_166491 AHL58698 A/_H3N8	-	-	-	-	-	-	N
9. EPI1817242 PB2 A/harbor_seal/New_Hampshire/SLO6872H3/2018 EPI_ISL_697554 QOL23882 A/_H3N8	-	-	-	-	-	-	N
10. EPI1817278 PB2 A/harbor_seal/New_Hampshire/SLO6848H3/2018 EPI_ISL_697558 QOL23935 A/_H3N8	-	-	-	-	-	-	N
11. EPI1817332 PB2 A/harbor_seal/New_Hampshire/M11h72H3/2018 EPI_ISL_697565 QOL24003 A/_H3N8	-	-	-	-	-	-	N
12. EPI1817351 PB2 A/harbor_seal/New_Hampshire/M15h72H3/2018 EPI_ISL_697568 QOL24029 A/_H3N8	-	-	-	-	-	-	N
13. EPI382070 PB2 A/harbor_seal/Massachusetts/1/2011 EPI_ISL_123259 AFA51731 A/_H3N8	-	-	-	-	-	-	N
14. EPI709327 PB2 A/harbor_seal/NL/PV14-221_Ts/2015 EPI_ISL_202005 A/_H10N7	-	-	-	-	-	-	-
15. EPI545217 PB2 A/Seal/Sweden/SVA0546/2014 EPI_ISL_167226 A/_H10N7	-	-	-	-	-	-	-
16. EPI2076238 PB2 A/harbor_seal/British_Columbia/OTH-52-1/2021(H10N7) EPI_ISL_13482654 A/_H10N7	-	-	-	-	-	-	N
17. EPI416772 PB2 A/elephant_seal/California/2/2010 EPI_ISL_134265 AGA19347 A/_H1N1	-	-	-	-	-	-	-
18. EPI416754 PB2 A/elephant_seal/California/1/2010 EPI_ISL_134256 AFV31451 A/_H1N1	-	-	-	-	-	-	-
19. EPI1858927 PB2 A/Grey_Seal/SVA210406S20066/KN001401/2021 EPI_ISL_1789695 A/_H5N8	-	K	-	-	-	-	-
20. EPI1916418 PB2 A/seal/England/AVP-031141/2020 EPI_ISL_2081528 A/_H5N8	-	-	-	-	-	-	N
21. EPI1295330 PB2 A/Grey_seal/361-10/BalticPL/16 EPI_ISL_322984 A/_H5N8	-	-	-	-	-	-	-
22. EPI1918888 PB2 A/seal/Germany-SH/AI05373/2021 EPI_ISL_4804850 A/_H5N8	-	K	-	-	-	-	-
23. EPI1918896 PB2 A/seal/Germany-SH/AI05377/2021 EPI_ISL_4805852 A/_H5N8	-	K	-	-	-	-	-
24. EPI1918906 PB2 A/seal/Germany-SH/AI05379/2021 EPI_ISL_4805936 A/_H5N8	-	-	-	-	-	-	-
25. EPI1986621 PB2 A/harbour_seal/Denmark/521-2/2021-09-15(H5N8) EPI_ISL_10053635 A/_H5N8	-	K	-	-	-	-	-
26. EPI2110458 PB2 A/harbor_seal/Maine/22-020455-002-original/2022 EPI_ISL_14098916 A/_H5N1	-	-	-	-	-	-	-
27. EPI2110466 PB2 A/harbor_seal/Maine/22-020455-003-original/2022 EPI_ISL_14098917 A/_H5N1	-	-	-	-	-	-	-
28. EPI2110474 PB2 A/harbor_seal/Maine/22-020455-004-original/2022 EPI_ISL_14098918 A/_H5N1	-	-	-	-	-	-	-
29. EPI2110482 PB2 A/harbor_seal/Maine/22-020455-005-original/2022 EPI_ISL_14098919 A/_H5N1	-	-	-	-	-	-	N
30. EPI2110490 PB2 A/harbor_seal/Maine/22-020983-001-original/2022 EPI_ISL_14098920 A/_H5N1	-	-	-	-	-	-	-
31. EPI2110498 PB2 A/harbor_seal/Maine/22-020983-002-original/2022 EPI_ISL_14098921 A/_H5N1	-	K	-	-	-	-	-
32. EPI2110506 PB2 A/grey_seal/Maine/22-020983-003-original/2022 EPI_ISL_14098922 A/_H5N1	-	-	-	-	-	-	-
33. EPI2110514 PB2 A/harbor_seal/Maine/22-020983-006-original/2022 EPI_ISL_14098923 A/_H5N1	-	-	-	-	-	-	-
34. EPI2110522 PB2 A/harbor_seal/Maine/22-020983-007-original/2022 EPI_ISL_14098924 A/_H5N1	-	-	-	-	-	-	-
35. EPI2134832 PB2 A/harbor_seal/Maine/22-020455-001-original/2022 EPI_ISL_14098915 A/_H5N1	-	-	-	-	-	-	-
36. EPI2310471 PB2 A/harbor_seal/Maine/22-022528-003-original/2022 EPI_ISL_16632539 A/_H5N1	-	-	-	-	-	-	-
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38. EPI2310433 PB2 A/harbor_seal/Maine/22-022528-008-original/2022 EPI_ISL_16632541 A/_H5N1	-	-	-	-	-	-	-
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41. EPI2398408 PB2 A/Harbour_Seal/Scotland/162925/2022 EPI_ISL_16904554 A/_H5N1	-	K	-	-	-	-	-
42. EPI2455325 PB2 A/grey_seal/Germany-SH/AI01973/2023 EPI_ISL_17167249 A/_H5N1	-	-	-	-	-	-	-
43. EPI2506818 PB2 A/harbor_seal/Maine/MME-147-L/2022 EPI_ISL_17424622 WFD50780 A/_H5N1	-	-	-	-	-	-	-
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45. EPI2506834 PB2 A/harbor_seal/Maine/MME-185-L/2022 EPI_ISL_17424624 WFD50804 A/_H5N1	-	K	-	-	-	-	-
46. EPI2506842 PB2 A/harbor_seal/Maine/MME-150-L/2022 EPI_ISL_17424625 WFD50816 A/_H5N1	-	-	-	-	-	-	-
47. EPI2506850 PB2 A/harbor_seal/Maine/MME-117-ns/2022 EPI_ISL_17424626 WFD50828 A/_H5N1	-	-	-	-	-	-	-
48. EPI2506858 PB2 A/harbor_seal/Maine/MME-185-ns/2022 EPI_ISL_17424627 WFD50840 A/_H5N1	-	K	-	-	-	-	-
49. EPI2509904 PB2 A/harbour_seal/Scotland/054948/2022 EPI_ISL_17465835 A/_H5N1	-	K	-	-	-	-	-
50. EPI2557208 PB2 A/grey_seal/Netherlands/302579/2023 EPI_ISL_17672781 A/_H5N1	-	-	-	-	-	-	-
51. EPI2557216 PB2 A/grey_seal/Netherlands/302603/2023 EPI_ISL_17672782 A/_H5N1	-	-	-	-	-	-	-
52. EPI2557224 PB2 A/grey_seal/Netherlands/30448/2023 EPI_ISL_17672783 A/_H5N1	-	-	-	-	-	-	-
53. EPI2586370 PB2 A/sea_lion/Peru/TAC-INS-010/2023 EPI_ISL_17777531 A/_H5N1	-	-	-	-	-	-	N
54. EPI2586378 PB2 A/sea_lion/Peru/TAC-INS-011/2023 EPI_ISL_17777532 A/_H5N1	-	-	-	-	-	-	N
55. EPI2609542 PB2 A/sea_lion/Tarapaca/240524-2/2023 EPI_ISL_17885975 A/_H5N1	-	-	-	-	-	-	N
56. EPI2609549 PB2 A/sea_lion/Arica_y_Parinacota/240270-1/2023 EPI_ISL_17885976 A/_H5N1	-	-	-	-	-	-	N
57. EPI2664281 PB2 A/sea_lion/Peru/AQP-SER00R/2023 EPI_ISL_18054510 A/_H5N1	-	-	-	-	-	-	N
58. EPI2745231 PB2 A/South_American_Sea_Lion/Peru/LIM-SER036/2023 EPI_ISL_18265430 A/_H5N1	-	-	-	-	-	-	-
59. EPI2745239 PB2 A/dolphin/Peru/PIU-SER002/2022 EPI_ISL_18265431 A/_H5N1	-	-	-	-	-	-	-
60. EPI2759096 PB2 A/harbor_seal/Washington/23-025744-001-original/2023 EPI_ISL_18311023 A/_H5N1	-	-	-	-	-	-	-
61. EPI2759104 PB2 A/harbor_seal/Washington/23-025744-002-original/2023 EPI_ISL_18311024 A/_H5N1	-	-	-	-	-	-	-
62. EPI2759112 PB2 A/harbor_seal/Washington/23-025991-001-original/2023 EPI_ISL_18311025 A/_H5N1	-	-	-	-	-	-	-
63. EPI2759128 PB2 A/harbor_seal/Washington/23-026504-001-original/2023 EPI_ISL_18311027 A/_H5N1	-	-	-	-	-	-	-
64. EPI2759136 PB2 A/harbor_seal/Washington/23-026504-002-original/2023 EPI_ISL_18311028 A/_H5N1	-	-	-	-	-	-	-
65. EPI2872999 PB2 A/Sea_Lion/Argentina/3893-1/2023 EPI_ISL_18698755 A/_H5N1	-	-	-	-	-	-	N
66. EPI2895492 PB2 A/harbor_seal/Washington/23-025744-002-original/2023 EPI_ISL_18737559 A/_H5N1	-	-	-	-	-	-	-
67. EPI2913248 PB2 A/sea_lion/Valparaiso/SJCEIRR-2431361/2023 EPI_ISL_18760069 A/_H5N1	-	-	-	-	-	-	N
68. EPI2921498 PB2 A/porpoise/Antofagasta/SJCEIRR-2465061/2023 EPI_ISL_18777129 A/_H5N1	-	-	-	-	-	-	N
69. EPI2921518 PB2 A/dolphin/Nuble/SJCEIRR-2482441/2023 EPI_ISL_18777138 A/_H5N1	-	-	-	-	-	-	N
70. EPI2921523 PB2 A/dolphin/Maule/SJCEIRR-246026/2023 EPI_ISL_18777139 A/_H5N1	-	-	-	-	-	-	N
71. EPI2921529 PB2 A/porpoise/Atacama/SJCEIRR-245355/2023 EPI_ISL_18777140 A/_H5N1	-	-	-	-	-	-	N
72. EPI2921535 PB2 A/porpoise/Antofagasta/SJCEIRR-2465062/2023 EPI_ISL_18777141 A/_H5N1	-	-	-	-	-	-	N

Suppl. **Figure S3.** Avian influenza virus PB2 protein alignment of all available strains obtained from marine mammals in the last 45 years. The PB2 amino acid position at 627 and 701 is highlighted in yellow. The substitution E627K and D701N in PB2 segment is frequently observed in AIVs isolated from mammals.

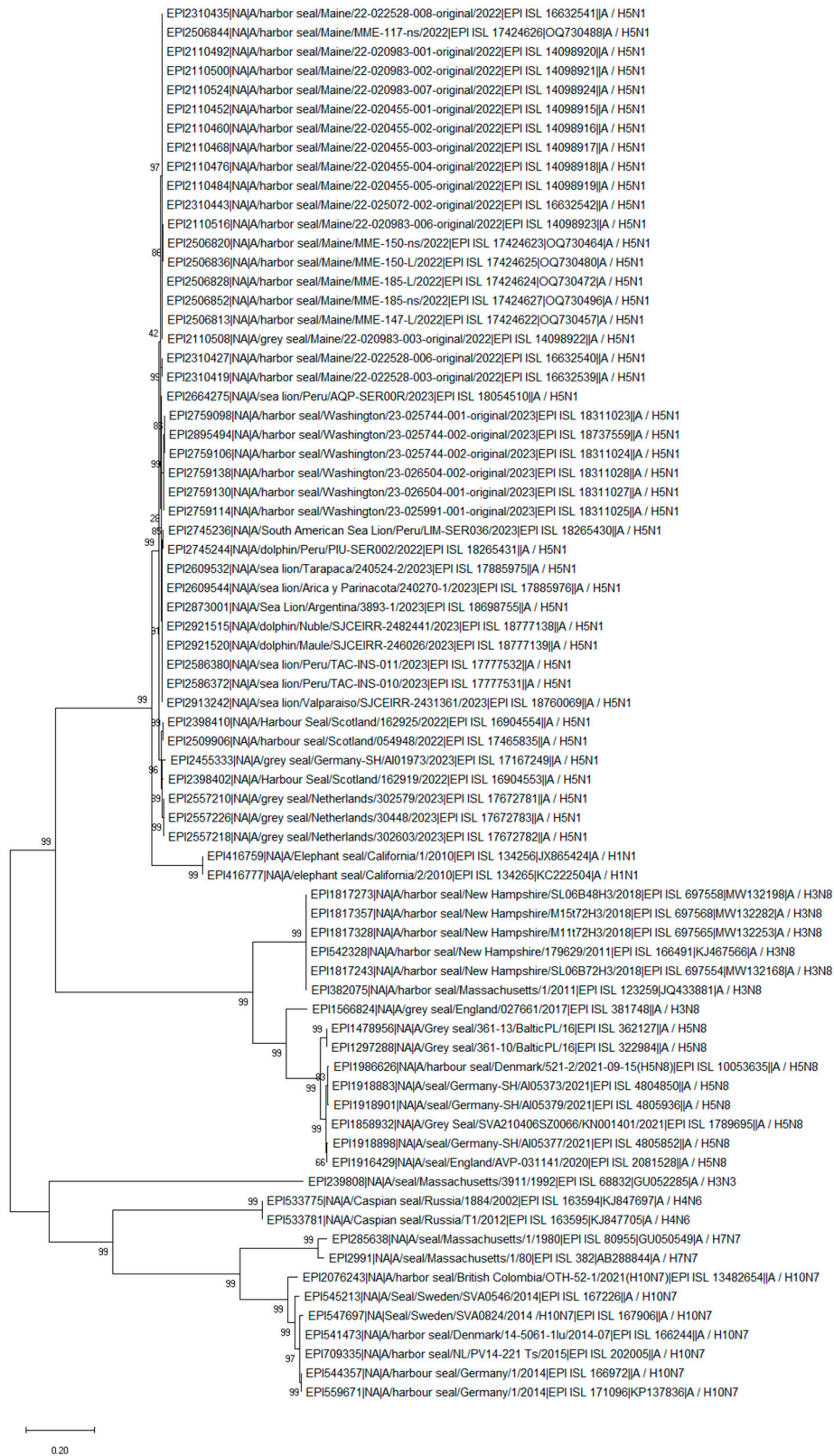


Suppl. **Figure S4**. Phylogenetic tree of NP segment of avian influenza viruses found in seal population over the last 45 years. The analysis includes seal isolates of different avian influenza subtypes isolated between 1980-2023 along with current H5N1 clade 2.3.4.4b viruses from 8 sea lions, 3 dolphins and 3 porpoises available in GSAID (as of March 2024). The nucleotide sequences of the NP segment were aligned using MUSCLE and MEGA 11.03.13.

The General Time Reversible (GTR) nucleotide substitution model, with among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.



Suppl. **Figure S5**. Phylogenetic tree of HA segment of avian influenza viruses found in seal population over the last 45 years. The analysis includes seal isolates of different avian influenza subtypes isolated between 1980-2023 along with current H5N1 clade 2.3.4.4b viruses from 8 sea lions, 3 dolphins and 3 porpoises available in GSAID (as of March 2024). The nucleotide sequences of the HA segment were aligned using MUSCLE software. The General Time Reversible (GTR) nucleotide substitution model, with among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.



Suppl. **Figure S6.** Phylogenetic tree of NA segment of avian influenza viruses found in seal population over the last 45 years. The analysis includes seal isolates of different avian influenza subtypes isolated between 1980-2023 along with current H5N1 clade 2.3.4.4b viruses

from 8 sea lions, 3 dolphins and 3 porpoises available in GSAID (as of March 2024). The nucleotide sequences of the NA segment were aligned using MUSCLE software and GTR nucleotide substitution model, with an among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.



Suppl. Figure S7. Phylogenetic tree of NS segment of avian influenza viruses found in seal population over the last 45 years. The analysis includes seal isolates of different avian influenza subtypes isolated between 1980-2023 along with current H5N1 clade 2.3.4.4b viruses

from 8 sea lions, 3 dolphins and 3 porpoises available in GSAID (as of March 2024). The nucleotide sequences of the NS segment were aligned using MUSCLE software and GTR nucleotide substitution model, with an among-site rate variation model using a discrete gamma distribution. Bootstrap support values were generated using 500 rapid bootstrap replicates.

Supplementary Tables

Suppl. **Table S1.** The percentage of identity (%) between the haemagglutinin (HA) of A/seal/Massachusetts/133/1982 H4N5 and representative H4Nx influenza viruses from wild birds. All full-length HA segments of H4Nx bird isolates available in the GISAID (n= 3023) were retrieved and representative sequences (n= 189) were selected based on sequence identity at 97% level using CD-HIT package. Next, the wild bird isolates (n=70) that clustered with H4N5 seal isolates were aligned with A/seal/Massachusetts/133/1982 H4N5 and the percentage of similarity calculated using Geneious Prime software.

	The percentage of identity (%)
Isolates	A/seal/Massachusetts/133/1982 (H4N5)
A/blue-winged_teal/ALB/580/1979 HA A/_H4N2 EPI_ISL_8838	91.887
A/mallard_duck/ALB/291/1977 HA A/_H4N1 EPI_ISL_8863	91.542
A/blue-winged_teal/ALB/243/1977 HA A/_H4N6 EPI_ISL_8831	91.254
A/mallard/Alberta/209/1977 HA A/_H4N8 EPI_ISL_143735	91.138
A/domestic_duck/Minnesota/1086/1980 HA A/_H4N8 EPI_ISL_5833	90.679
A/mallard_duck/New_York/194/1982 HA A/_H4N8 EPI_ISL_5863	90.679
A/king_eider/Alaska/44068-067/2006 HA A/_H4N7 EPI_ISL_139426	90.587
A/blue-winged_teal/ALB/136/1990 HA A/_H4N3 EPI_ISL_8854	90.391
A/blue-winged_teal/ALB/103/1990 HA A/_H4N5 EPI_ISL_8853_1	90.161
A/ruddy_turnstone/DE/512/1988 HA A/_H4N6 EPI_ISL_8848	90.104
A/king_eider/Alaska/44479-841/2009 HA A/_H4N7 EPI_ISL_139428	90.085
A/blue-winged_teal/ALB/293/1994 HA A/_H4N6 EPI_ISL_8855	89.931
A/mallard/ALB/49/1995 HA A/_H4N6 EPI_ISL_8856	89.816
A/green-winged_teal/Ohio/344/1986 HA A/_H4N2 EPI_ISL_6146	89.789

A/mallard/Alberta/18/1991 HA A/_H4N6 EPI_ISL_99465	89.726
A/mallard/Alberta/296/1996 HA A/_H4N6 EPI_ISL_99399	89.726
A/giant_petrel/Antarctica/E96/2011 HA A/_H4N7 EPI_ISL_290314	89.721
A/pintail/Alberta/269/2001 HA A/_H4N6 EPI_ISL_8861	89.586
A/blue-winged_teal/Alberta/293/2003 HA A/_H4N6 EPI_ISL_8862	89.356
A/mallard/ALB/47/1998 HA A/_H4N1 EPI_ISL_8858	89.356
A/mallard/Alberta/237/2003 HA A/_H4N6 EPI_ISL_99333	89.317
A/green-winged_teal/Minnesota/Sg-00820/2008 HA A/_H4N5 EPI_ISL_141128	89.2
A/American_wigeon/California/HKWF450/2007 HA A/_H4N7 EPI_ISL_63350	89.068
A/shorebird/Delaware_Bay/312/2008 HA A/_H4N6 EPI_ISL_131486	88.987
A/turkey/CA/358533/2005 HA A/_H4N8 EPI_ISL_22672	88.973
A/Swine/Ontario/01911-1/99 HA A/_H4N6 EPI_ISL_1767	88.927
A/mallard/Alaska/417/2014 HA A/_H4N1 EPI_ISL_215543	88.908
A/American_Green-Winged_Teal/Alaska/19TL00078/2019 HA A/_H4N6 EPI_ISL_4056417	88.838
A/mallard/Alberta/295/98 HA A/_H4N6 EPI_ISL_4063	88.809
A/Swine/Ontario/01911-2/99 HA A/_H4N6 EPI_ISL_1766	88.698
A/wild_bird/Korea/YJ117/2007 HA A/_H4N6 EPI_ISL_131210	88.685
A/American_green-winged_teal/Alaska/14258/2006 HA A/_H4N6 EPI_ISL_234703	88.675
A/mallard/Minnesota/UGAI14-2820/2014 HA A/_H4N8 EPI_ISL_258499	88.616
A/northern_pintail/Interior_Alaska/2/2007 HA A/_H4N8 EPI_ISL_29427	88.55
A/Anas_discors/New_Mexico/A00327683/2007 HA A/_H4N6 EPI_ISL_147772	88.55
A/northern_pintail/Alaska/85/2011 HA A/_H4N6 EPI_ISL_257217	88.5
A/mallard/Alberta/30/2001 HA A/_H4N8 EPI_ISL_8860	88.493
A/American_Green-winged_Teal/Ohio/17OS2020/2017 HA A/_H4N6 EPI_ISL_701646	88.435
A/mallard/Minnesota/Sg-00133/2007 HA A/_H4N6 EPI_ISL_31599	88.426
A/blue-winged_teal/Texas/UGAI15-6514/2015 HA A/_H4N8 EPI_ISL_258539	88.383
A/mallard/Alberta/455/2015 HA A/_H4N5 EPI_ISL_273593	88.378
A/environment/Maryland/09OS1310/2009 HA A/_H4N6 EPI_ISL_181002	88.325

A/Mallard/Alberta/508/2023 HA A/_H4N6 EPI_ISL_19070535	88.325
A/Mallard/California/D1610190/2016 HA A/_H4N6 EPI_ISL_378298	88.32
A/mallard/California/2532V/2011 HA A/_H4N6 EPI_ISL_135074	88.266
A/Mallard/Colorado/AH0026547I.4.A/2015 HA A/_H4N6 EPI_ISL_701000	88.262
A/duck/Alberta/36/2016 HA A/_H4N5 EPI_ISL_273549_2	88.053
A/mallard_duck/California/UCD738/2016 HA A/_H4N5 EPI_ISL_266520	88.032
A/Blue-winged_Teal/Texas/AH0040397I.4.A/2015 HA A/_H4N6 EPI_ISL_700992	87.975
A/mallard_duck/Ohio/16OS0818/2016 HA A/_H4N5 EPI_ISL_294008	87.916
A/mallard/Maine/23-033198-001-original/2023 HA A/_H4N2 EPI_ISL_19387820	87.906
A/yellow-billed_pintail/Chile/6/2013 HA A/_H4N6 EPI_ISL_224998	87.898
A/American_wigeon/California/LDC111/2014 HA A/_H4N8 EPI_ISL_230088	87.86
A/American_Black_Duck/Virginia/AH0041816I.4.A/2016 HA A/_H4N2 EPI_ISL_701049	87.854
A/yellow-billed_pintail/Chile/C9588/2016 HA A/_H4N2 EPI_ISL_326968	87.745
A/glaucous-winged_gull/Alaska/UGAI17-5355/2017 HA A/_H4N7 EPI_ISL_14767368	87.729
A/mallard/Alberta/199/2017 HA A/_H4N6 EPI_ISL_328321	87.687
A/long-tailed_duck/Wisconsin/18OS2983/2018 HA A/_H4N6 EPI_ISL_506168	87.552
A/Anas_carolinensis/Arizona/A00480494/2008 HA A/_H4 EPI_ISL_96867	87.514
A/black-necked_swan/Chile/C32668/2017 HA A/_H4N5 EPI_ISL_19167898	87.457
A/blue-winged_teal/Ohio/17OS1836/2017 HA A/_H4N9 EPI_ISL_376234	87.449
A/Northern_Pintail/Alberta/516/2022 HA A/_H4N6 EPI_ISL_16215976	87.332
A/duck/Pennsylvania/USDA-003364003/2020 HA A/_H4N2 EPI_ISL_18898318	87.257
A/Mallard/Alberta/445/2023 HA A/_H4N6 EPI_ISL_19070526	87.157
A/mallard/Interior_Alaska/9BM1968/2009 HA A/_H4N6 EPI_ISL_85232	87.156
A/blue-winged_teal/Minnesota/23-029707-011-original/2023 HA A/_H4N6 EPI_ISL_19325210	87.021
A/environment/Chile/C62071/2022 HA A/_H4N6 EPI_ISL_19167928	85.509
A/environment/Mexico/CPA-04740/2011 HA A/_H4N2 EPI_ISL_202117	84.58
A/quail/California/D113023808/2012 HA A/_H4N2 EPI_ISL_167891	82.568

A/mallard/Interior_Alaska/9BM2239/2009 HA A/_H4N6 EPI_ISL_85281	82.064
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Suppl. **Table S2.** Estimates of Evolutionary Divergence between the hemagglutinin (HA) of H3Nx seal and wild bird isolates. The number of base substitutions per site from between sequences are shown. Analyses were conducted using the Maximum Composite Likelihood model. This analysis involved 38 nucleotide sequences. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There were a total of 1889 positions in the final dataset. Evolutionary analyses were conducted in MEGA11.

	A/seal/MA/3984/1992 H3N3	A/seal/MA/3911/1992 H3N3	A/seal/Massachusetts/3911/1992 H3N3	A/harbor_seal/New_Hampshire/M11t72H3/2018 H3N8	A/seal/Alaska/PV2114/2021 H3N6
A/seal/MA/3984/1992 HA A/_H3N3 EPI_ISL_14572					
A/seal/MA/3911/1992 HA A/_H3N3 EPI_ISL_14571	0.0023				
A/seal/Massachusetts/3911/1992 HA A/_H3N3 EPI_ISL_68832	0.0035	0.0017			
A/harbor_seal/New_Hampshire/M11t72H3/2018 HA A/_H3N8 EPI_ISL_697565	0.0772	0.0772	0.0791		
A/seal/Alaska/PV2114/2021 HA A/_H3N6 EPI_ISL_19456380	0.0885	0.0898	0.0912	0.0506	
A/American_black_duck/New_Brunswick/04484/2007 HA A/_H3N8 EPI_ISL_131873	0.0709	0.0709	0.0716	0.0478	0.0613
A/mallard/Alberta/115/1991 HA A/_H3N8 EPI_ISL_99455	0.0517	0.0517	0.0524	0.0660	0.0845
A/mallard/Oregon/AH0038704/2015 HA A/_H3N8 EPI_ISL_254809	0.0789	0.0795	0.0814	0.0382	0.0437
A/blue-winged_teal/Texas/AI10-3848/2010 HA A/_H3N8 EPI_ISL_220051	0.0742	0.0742	0.0748	0.0569	0.0672

A/mallard/Minnesota/MN18-WB1-065A/2018 HA A/_H3N8 EPI_ISL_502364	0.0829	0.0829	0.0843	0.0474	0.0684
A/pintail/Alberta/105/1991 HA A/_H3N8 EPI_ISL_99457	0.0505	0.0505	0.0511	0.0647	0.0819
A/mallard/Ohio/156/1990 HA A/_H3N6 EPI_ISL_6496	0.0470	0.0470	0.0476	0.0383	0.0560
A/mallard/Maryland/14OS1431/2014 HA A/_H3N9 EPI_ISL_216747	0.0788	0.0788	0.0795	0.0450	0.0596
A/blue-winged_teal/Ohio/14OS1080/2014 HA A/_H3N2 EPI_ISL_216678	0.0841	0.0841	0.0848	0.0633	0.0757
A/northern_shoveler/California/HKWF848/2007 HA A/_H3N7 EPI_ISL_25506	0.0674	0.0674	0.0691	0.0444	0.0651
A/Mallard/Alberta/113/2023 HA A/_H3N8 EPI_ISL_19070546	0.0904	0.0904	0.0925	0.0701	0.0873
A/guinea_fowl/NJ/8848-18/1998 HA A/_H3N2 EPI_ISL_22552	0.0592	0.0592	0.0606	0.0395	0.0544
A/mallard_duck/New_York/157/1986 HA A/_H3N6 EPI_ISL_5854	0.0114	0.0114	0.0122	0.0668	0.0837
A/mallard/California/M15t72maH3/2018 HA A/_H3N8 EPI_ISL_697562	0.0706	0.0706	0.0723	0.0462	0.0669
A/mallard/Ohio/424/1988 HA A/_H3N2 EPI_ISL_6460	0.0297	0.0297	0.0309	0.0775	0.0944
A/mallard/Ohio/649/2002 HA A/_H3N8 EPI_ISL_6938	0.0716	0.0716	0.0722	0.0497	0.0620
A/Mallard/Ohio/17OS1926/2017 HA A/_H3N8 EPI_ISL_501687	0.0732	0.0732	0.0750	0.0364	0.0525

A/mallard_duck/Minnesota/1979 HA A_/_H3N1 EPI_ISL_69915	0.0323	0.0304	0.0313	0.0628	0.0788
A/mallard/Alberta/64/1991 HA A_/_H3N8 EPI_ISL_99459	0.0450	0.0450	0.0456	0.0609	0.0766
A/mallard/Alberta/61/1991 HA A_/_H3N8 EPI_ISL_99461	0.0450	0.0450	0.0456	0.0609	0.0766
A/ruddy_turnstone/Delaware_Bay/606/2017 HA A_/_H3N8 EPI_ISL_329548	0.0883	0.0883	0.0897	0.0707	0.0807
A/mallard/New_York/6874/1978 HA A_/_H3N2 EPI_ISL_14812	0.0569	0.0569	0.0584	0.0784	0.0923
A/duck/NY/13822/1995 HA A_/_H3N8 EPI_ISL_68712	0.1201	0.1201	0.1221	0.1332	0.1340
A/mallard/Minnesota/Sg-00164/2007 HA A_/_H3N8 EPI_ISL_84956	0.0727	0.0727	0.0732	0.0325	0.0549
A/ruddy_turnstone/Peru/PuV181/2009 HA A_/_H3N8 EPI_ISL_189983	0.0858	0.0858	0.0865	0.0595	0.0751
A/mallard/Ohio/264/1986 HA A_/_H3N8 EPI_ISL_6333	0.0129	0.0129	0.0134	0.0708	0.0869
A/mallard/Ohio/48/1986 HA A_/_H3N2 EPI_ISL_6933	0.0122	0.0122	0.0128	0.0698	0.0857
A/mallard/Alberta/62/1991 HA A_/_H3N8 EPI_ISL_99460	0.0450	0.0450	0.0456	0.0609	0.0766
A/mallard_duck/New_York/174/1982 HA A_/_H3N8 EPI_ISL_5867	0.0196	0.0196	0.0205	0.0674	0.0824
A/mallard/British_Columbia/07569/2005 HA A_/_H3N8 EPI_ISL_64885	0.0706	0.0706	0.0720	0.0469	0.0604

A/blue-winged_teal/Alberta/120/1991 HA A/_H3N8 EPI_ISL_5790	0.0510	0.0510	0.0524	0.0650	0.0832
A/northern_shoveler/Ohio/35/1986 HA A/_H3N8 EPI_ISL_6960	0.0237	0.0237	0.0243	0.0730	0.0877
A/duck/NY/6874/1978 HA A/_H3N2 EPI_ISL_20805	0.0411	0.0411	0.0417	0.0687	0.0830

Suppl. **Table S3.** Estimates of Evolutionary Divergence between the neuraminidase (NA) of A/seal/Massachusetts/3911/1992 H3N3 and HxN3 wild bird isolates. The number of base substitutions per site from between sequences are shown. Analyses were conducted using the Maximum Composite Likelihood model. This analysis involved 49 nucleotide sequences. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There were a total of 1507 positions in the final dataset. Evolutionary analyses were conducted in MEGA11.

A/seal/Massachusetts/3911/1992 H3N3	
AIV	Divergence
A/green_winged_teal/Mexico-Sonora/827/2009 NA A/_H5N3 EPI_ISL_278159	0.02847
A/northernshoveler/Mexico-Sonora/796/2008 NA A/_H5N3 EPI_ISL_278158	0.03720
A/blue-winged_teal/Ohio/12OS2241/2012 NA A/_H11N3 EPI_ISL_189522	0.04081
A/cinnamon-teal/Mexico/2817/2016 NA A/_H7N3 EPI_ISL_19366864	0.03278
A/goose/Interior_Alaska/11PG00437/2011 NA A/_H2N3 EPI_ISL_208449	0.03950
A/ruddy_turnstone/Delaware/650612/2002 NA A/_H11N3 EPI_ISL_397920	0.02902
A/mallard/Maryland/234/2001 NA A/_H2N3 EPI_ISL_28744	0.02675
A/mallard/Alberta/24/01 NA A/_H7N3 EPI_ISL_8355	0.02450
A/cinnamon_teal/California/JN1504/2007 NA A/_H5N3 EPI_ISL_84551	0.02680

A/cinnamon_teal/Bolivia/4537/2001 NA A/_H7N3 EPI_ISL_10304	0.02817
A/mallard/Alberta/93/1996 NA A/_H7N3 EPI_ISL_189651	0.02107
A/pintail/Alberta/145/1990 NA A/_H6N3 EPI_ISL_138077	0.02225
A/mallard/Alberta/207/1990 NA A/_H6N3 EPI_ISL_131348	0.02270
A/mallard/Alberta/250/1990 NA A/_H6N3 EPI_ISL_131359	0.02270
A/mallard_duck/ALB/191/1990 NA A/_H6N3 EPI_ISL_8762	0.02270
A/mallard_duck/ALB/76/1985 NA A/_H6N3 EPI_ISL_8758	0.02270
A/mallard_duck/ALB/155/1990 NA A/_H6N3 EPI_ISL_8761	0.02270
A/mallard_duck/ALB/253/1990 NA A/_H6N3 EPI_ISL_8763	0.02270
A/blue-winged_teal/Louisiana/42B/1987 NA A/_H2N3 EPI_ISL_141298	0.01908
A/mallard/Ohio/102/1986 NA A/_H11N3 EPI_ISL_6535	0.01930
A/mallard_duck/ALB/376/1985 NA A/_H2N3 EPI_ISL_8714	0.01686
A/mallard/ALB/201/1996 NA A/_H2N3 EPI_ISL_8721	0.01377
A/mallard/ALB/394/1988 NA A/_H3N3 EPI_ISL_8823	0.01113
A/blue-winged_teal/ALB/136/1990 NA A/_H4N3 EPI_ISL_8854	0.01072
A/mallard/Alberta/195/1989 NA A/_H7N3 EPI_ISL_189650	0.00854
A/mallard/Alberta/195/1989 NA A/_H7N3 EPI_ISL_99473	0.00854
A/mallard/Alberta/356/1988 NA A/_H2N3 EPI_ISL_119128	0.00595
A/mallard/Alberta/353/1988 NA A/_H2N3 EPI_ISL_99480	0.00638
A/mallard_duck/ALB/353/1988 NA A/_H2N3 EPI_ISL_8720	0.00638
A/Mallard/Alberta/465/2021 NA A/_H7N3 EPI_ISL_16215548	0.04760
A/ruddy_turnstone/Delaware_Bay/304/2020 NA A/_H7N3 EPI_ISL_4061143	0.04558
A/northern_shoveler/California/HS225/2015 NA A/_H5N3 EPI_ISL_266503	0.04172
A/Mallard/Alberta/513/2021 NA A/_H2N3 EPI_ISL_16215529	0.04862
A/Quail/California/K2102061/2021 NA A/_H7N3 EPI_ISL_14835758	0.04607
A/Mallard_duck/Alberta/452/2019 NA A/_H2N3 EPI_ISL_501830	0.04809
A/mallard_duck/Maryland/17OS0122/2017 NA A/_H7N3 EPI_ISL_294025	0.04372
A/northern_pintail_duck/California/UCD1582/2016 NA A/_H7N3 EPI_ISL_36936	0.04166

A/northern_shoveler/California/HS249/2015 NA A/_H10N3 EPI_ISL_266508	0.04669
A/Common_Goldeneye/Wisconsin/18OS3395/2018 NA A/_H7N3 EPI_ISL_702176	0.04097
A/blue-winged_teal/Guatemala/CIP049H111-98/2012 NA A/_H2N3 EPI_ISL_243734	0.04477
A/northern_shoveler/California/9781/2008 NA A/_H1N3 EPI_ISL_94211	0.03848
A/mallard/Montana/458329-2/2006 NA A/_H5N3 EPI_ISL_79751	0.03096
A/lesser_snow_goose/Alaska/44301-116/2007 NA A/_H2N3 EPI_ISL_139446	0.03302
A/yellow-billed_pintail/Chile/C14719/2016 NA A/_H7N3 EPI_ISL_326964	0.04519
A/mallard_duck/Chile/C23961/2017 NA A/_H5N3 EPI_ISL_379430	0.04432
A/Green-Winged_Teal/California/D1615121/2016 NA A/_H10N3 EPI_ISL_378294	0.04005
A/Canada_goose/BC/3752/2007 NA A/_H7N3 EPI_ISL_24810	0.03000
A/blue-winged_teal/Guatemala/CIP049H105-05/2011 NA A/_H5N3 EPI_ISL_257125	0.03654

Suppl. **Table S4.** Estimates of Evolutionary Divergence between the hemagglutinin (HA) of H10N7 seal and H10Nx wild bird isolates. The number of base substitutions per site from between sequences are shown. Analyses were conducted using the Maximum Composite Likelihood model. The primary analysis involved 124 representative nucleotide sequences, however to simplify the table, only sequences that showed less than 0.06 genetic distance (bold) to any of the seal isolates are shown here. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There were a total of 1807 positions in the final dataset. Evolutionary analyses were conducted in MEGA11.

Seal H10N7	H10Nx wild bird isolate of AIV																		
	A/little _curle w/Hebe i/QHD7 16/2013 H10N7	A/bar- tailed_ godwit/ Liaonin g/DD36 6/2019 H10N7	A/av ian/I srael /543/ 2008 H10 N7	A/malla rd_duc k/Nethe rlands/2 1/2010 H10N7	A/mall ard_d uck/G eorgia/ herland s/3/2007 1/2014 H10N7	A/Euras ian_wig eon/Net herland s/3/2007 H10N1	A/du ck/Ai chi/2 31110 /2012 H10 N8	A/Arenar ia_interpr es/Belgiu m/3125_0 002/2022 H10N4	A/Anas_pl atyrhyncho s/Belgium/ 11798_H18 9445/2016 H10N5	A/ma llard/ Swed en/4/ 2002 H10 N2	A/mal lard/S wede n/593 2/2005 H10N7	A/Du ck/It aly/2 6830 2/200 4 H10 N4	A/migr atory_d uck/Jia ngxi/68 47/2003 H10N5	A/du ck/Jia ngxi/ 33629 2039/ /2013 H10 N3	A/du ck/Jia ngxi/ 2005 /1034- 2_24V IR486 0- 21/202 4 H10N 4	A/com mon_ atyrhynch os/Belgium /1837_H10 1620/2018 H10N1	A/Anas_pl atyrhynch os/Belgium /1837_H10 1620/2018 H10N1	A/Pekin _duck/S outh_Af rica/AI1 642/2009 H10N7	A/mal lard/ Dages tan/00 4/2018 H10N5
A/harbor_seal/Br itish_Colombia/ OTH-52- 1/2021(H10N7)	0.049	0.052	0.071	0.086	0.073	0.087	0.082	0.087	0.092	0.099	0.099	0.101	0.103	0.069	0.102	0.095	0.076	0.091	0.097
A/harbour_seal/ Germany/1/2014	0.043	0.065	0.031	0.058	0.058	0.053	0.046	0.047	0.038	0.065	0.065	0.067	0.062	0.052	0.067	0.066	0.062	0.057	0.060

A/harbour_seal/ Germany/1/2014	0.043	0.065	0.031	0.058	0.058	0.053	0.046	0.047	0.038	0.065	0.065	0.067	0.062	0.052	0.067	0.066	0.062	0.057	0.060
A/harbour_seal/ Germany/1/2014	0.043	0.065	0.030	0.058	0.058	0.053	0.045	0.047	0.038	0.065	0.065	0.067	0.062	0.051	0.066	0.065	0.062	0.057	0.059
A/harbour_seal/ Germany/1/2014	0.043	0.065	0.030	0.058	0.058	0.053	0.045	0.047	0.038	0.065	0.065	0.067	0.062	0.051	0.066	0.065	0.062	0.057	0.059
A/harbor_seal/N L/PV141113.07_ L/NL/2014	0.045	0.067	0.031	0.061	0.061	0.054	0.047	0.049	0.041	0.068	0.068	0.069	0.065	0.054	0.071	0.067	0.062	0.061	0.061
A/harbor_seal/N L/PV141113.05_ NS/2014 HA A /_H10N7 EPI_I SL_202008	0.045	0.067	0.031	0.061	0.061	0.054	0.047	0.049	0.041	0.068	0.068	0.069	0.065	0.054	0.071	0.067	0.062	0.061	0.061
A/harbor_seal/N L/PV141113.04_ L/NL/2014 HA A/_H10N7 EP I_ISL_202009	0.045	0.067	0.031	0.061	0.061	0.054	0.047	0.049	0.041	0.068	0.068	0.069	0.065	0.054	0.071	0.067	0.062	0.061	0.061
A/harbor_seal/N L/PV325- 14_NS/NL/2014 HA A/_H10N 7 EPI_ISL_20200 2	0.045	0.067	0.031	0.061	0.061	0.054	0.047	0.049	0.041	0.068	0.068	0.069	0.065	0.054	0.071	0.067	0.062	0.061	0.061
A/harbor_seal/N L/PV14- 221_Ts/2015 HA A/_H10N7 E PI_ISL_202005	0.047	0.069	0.032	0.060	0.062	0.055	0.046	0.051	0.041	0.069	0.068	0.070	0.066	0.056	0.072	0.069	0.063	0.063	0.062
A/harbor_seal/D K/14- 10585_L/2014 H A A/_H10N7 EPI_ISL_202051	0.044	0.066	0.030	0.060	0.060	0.053	0.046	0.048	0.039	0.067	0.066	0.068	0.064	0.053	0.070	0.065	0.061	0.060	0.060

A/harbor_seal/D K/14- 10581_L/2014 H A A/_H10N7 EPI_ISL_202052	0.043	0.065	0.029	0.059	0.059	0.052	0.045	0.047	0.039	0.066	0.065	0.067	0.063	0.052	0.069	0.065	0.060	0.059	0.059
A/harbor_seal/D K/14- 10580_L/2014 H A A/_H10N7 EPI_ISL_202053	0.045	0.067	0.031	0.061	0.061	0.054	0.047	0.049	0.041	0.068	0.067	0.069	0.065	0.054	0.071	0.067	0.062	0.061	0.061
A/harbor_seal/D enmark/14-5061- 1lu/2014- 07 HA A/_H1 0N7 EPI_ISL_16 6244	0.042	0.064	0.030	0.058	0.057	0.052	0.045	0.046	0.037	0.064	0.064	0.066	0.061	0.051	0.066	0.065	0.059	0.058	0.060
Seal/Sweden/SV A0824/2014_/H1 0N7 HA A/_ H10N7 EPI_ISL _167906	0.056	0.076	0.035	0.062	0.061	0.057	0.046	0.050	0.040	0.066	0.066	0.069	0.063	0.052	0.068	0.067	0.063	0.060	0.062
A/Seal/Sweden/S VA0546/2014 H A A/_H10N7 EPI_ISL_167225	0.037	0.058	0.025	0.054	0.050	0.047	0.039	0.039	0.032	0.058	0.058	0.060	0.056	0.044	0.059	0.059	0.054	0.053	0.052
A/Seal/Sweden/S VA0546/2014 H A A/_H10N7 EPI_ISL_167226	0.037	0.058	0.025	0.054	0.050	0.047	0.039	0.039	0.032	0.058	0.058	0.060	0.056	0.044	0.059	0.059	0.054	0.053	0.052
A/Seal/Sweden/S VA1412040224- SZ5634/H10N7/2 014 HA A/_H 10N7 EPI_ISL_2 02055	0.042	0.064	0.029	0.058	0.058	0.051	0.045	0.046	0.039	0.065	0.065	0.066	0.063	0.051	0.067	0.064	0.060	0.058	0.059

A/Seal/Sweden/S VA1412040224- SZ1847/H10N7/2 014 HA A/_H 10N7 EPI_ISL_2 01998	0.040	0.062	0.027	0.056	0.056	0.049	0.043	0.044	0.037	0.063	0.062	0.064	0.060	0.050	0.066	0.062	0.057	0.056	0.057
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