

Can Mitogenomes of the Northern Wheatear (*Oenanthe oenanthe*) Reconstruct Its Phylogeography and Reveal the Origin of Migrant Birds?

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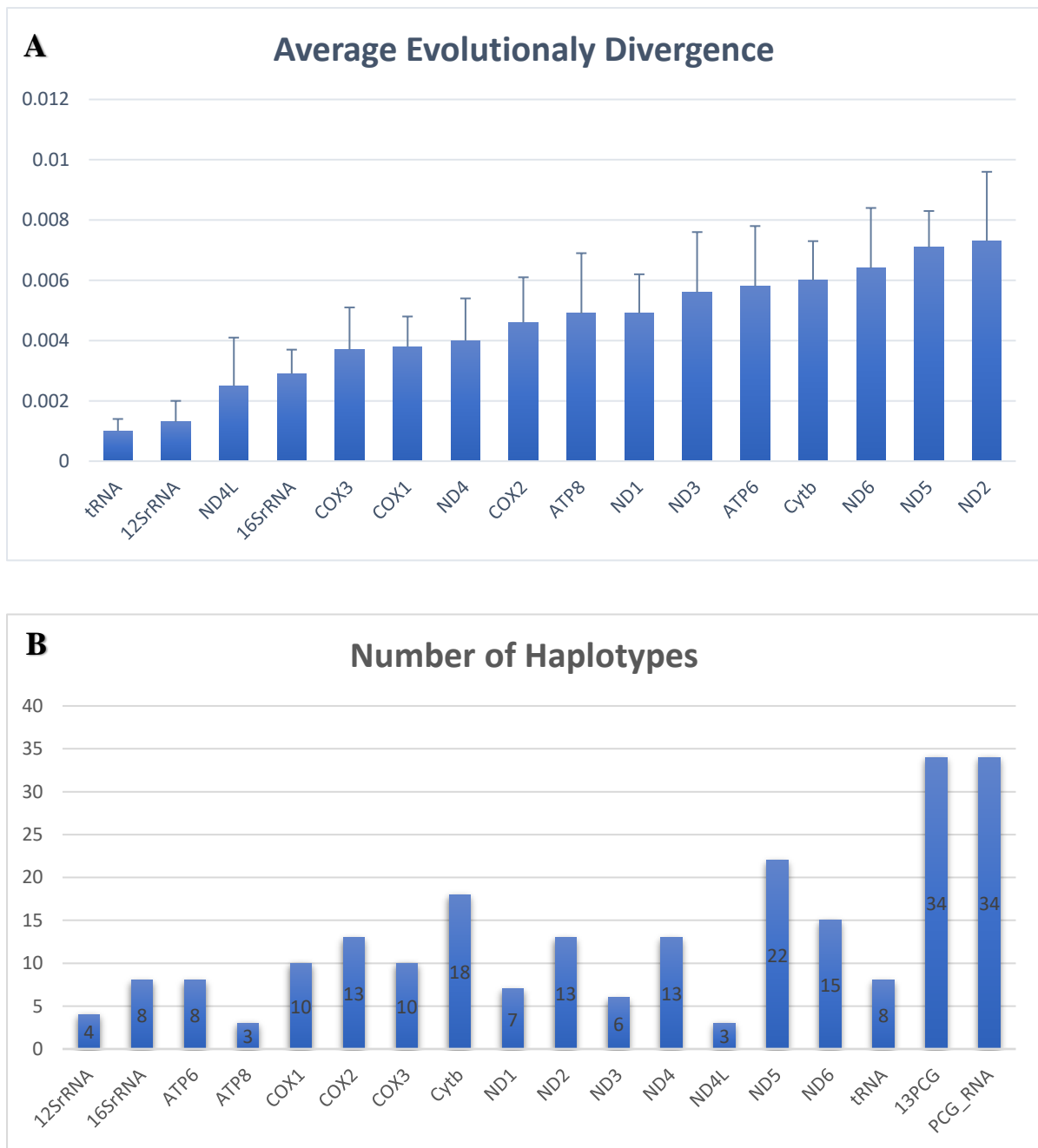


Figure S1 Characteristics of mtDNA markers. (A) Estimation of average evolutionary divergence over all sequence pairs for each marker. The calculations were generated the by the Maximum Composite Likelihood model in MEGA X. (B) Number of haplotypes for each marker for 38 breeding samples.

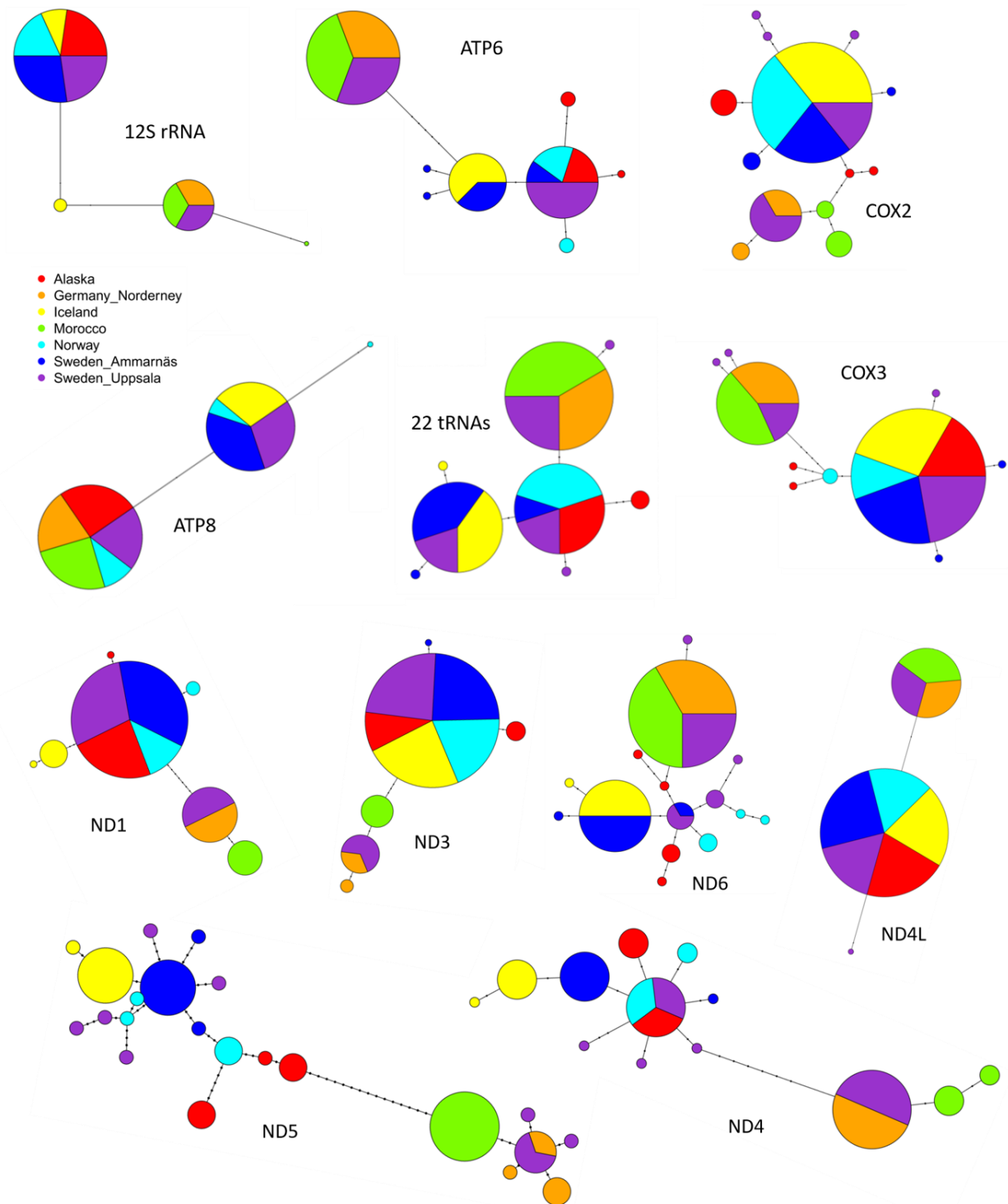
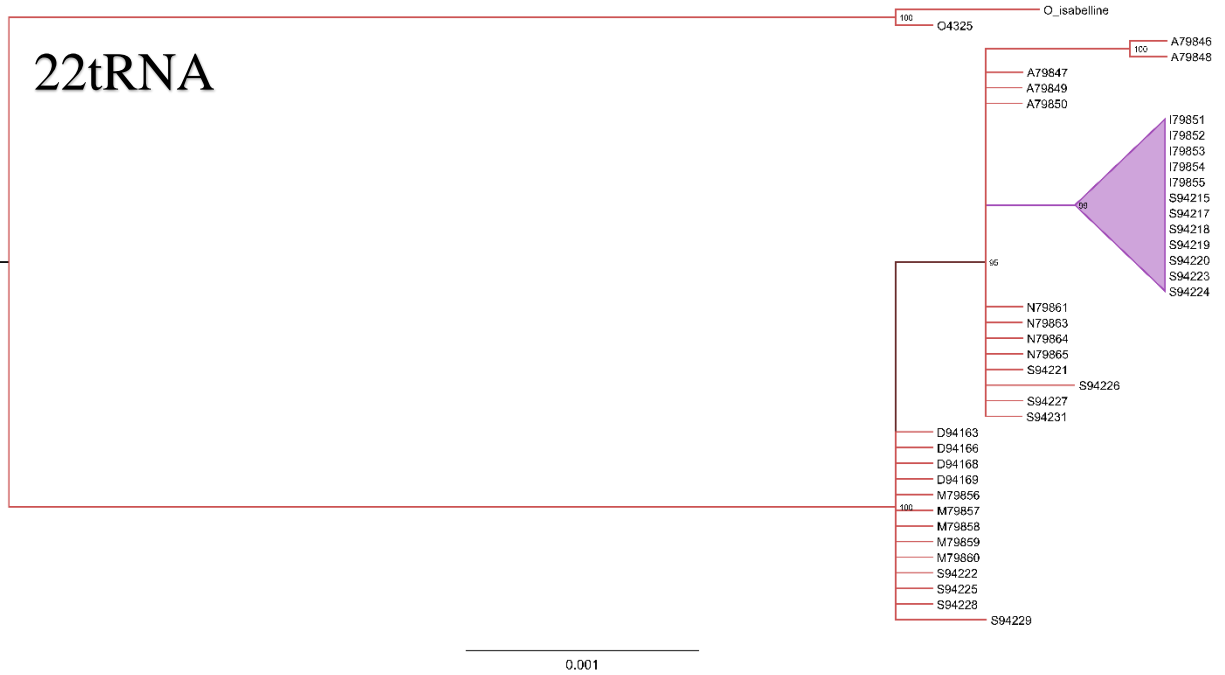
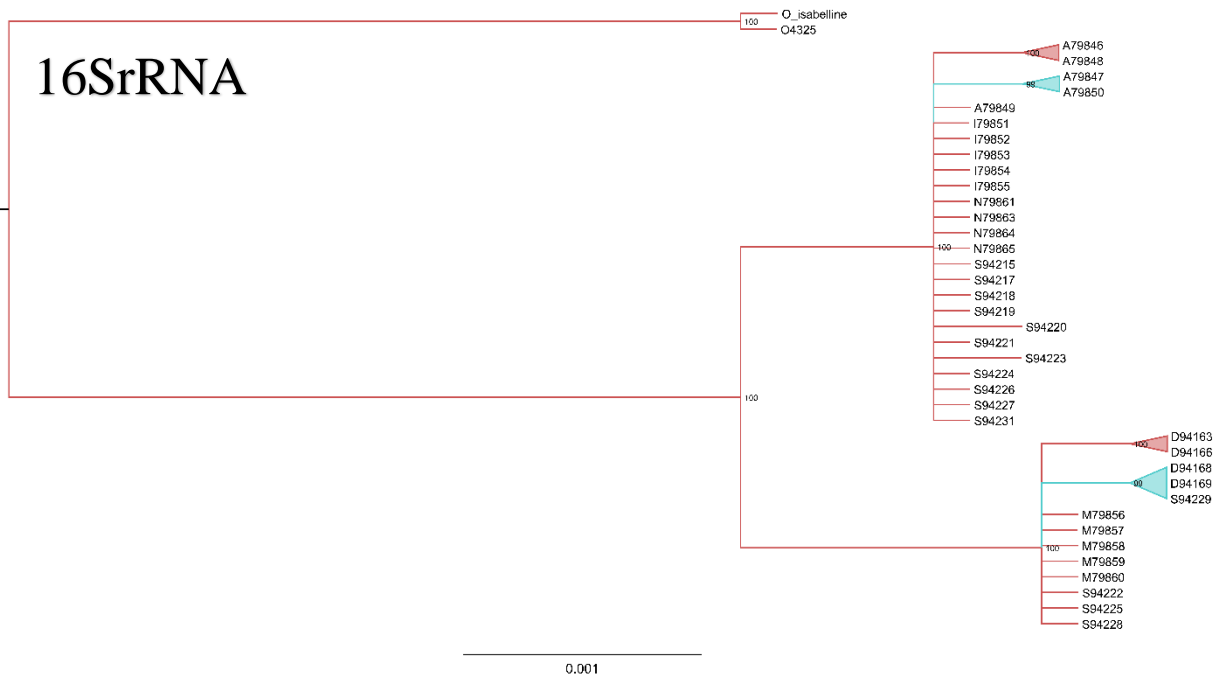


Figure S2 Haplotype network of single mitochondrial markers for 38 individuals of *Oenanthe*. Size of the circles represents the frequency of haplotypes. The breeding areas are coded by the colors. Each dot indicates one mutation step. Samples from Morocco are black throat wheatears (*O. seebohmi*); samples from Iceland are Greenland wheatears (*O. o. leucorhoa*); samples from Alaska, Germany, Norway and Sweden are nominate wheatears (*O. o. oenanthe*). The classification of (sub)species are identified by the morphological data.

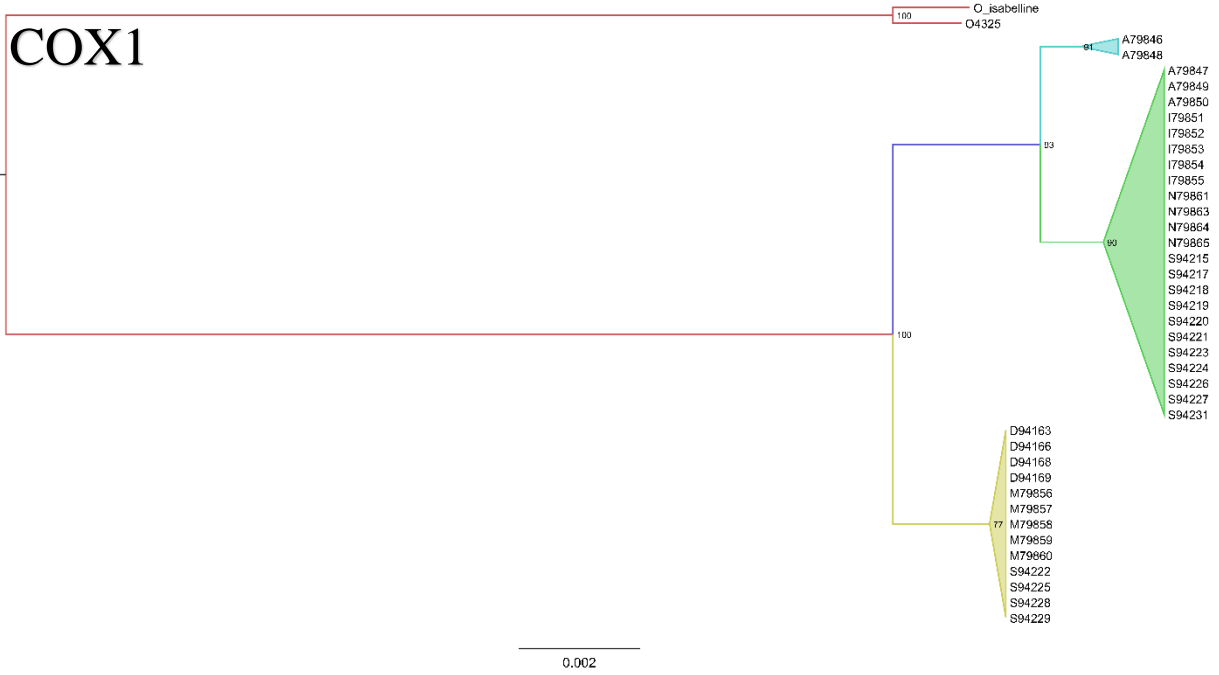
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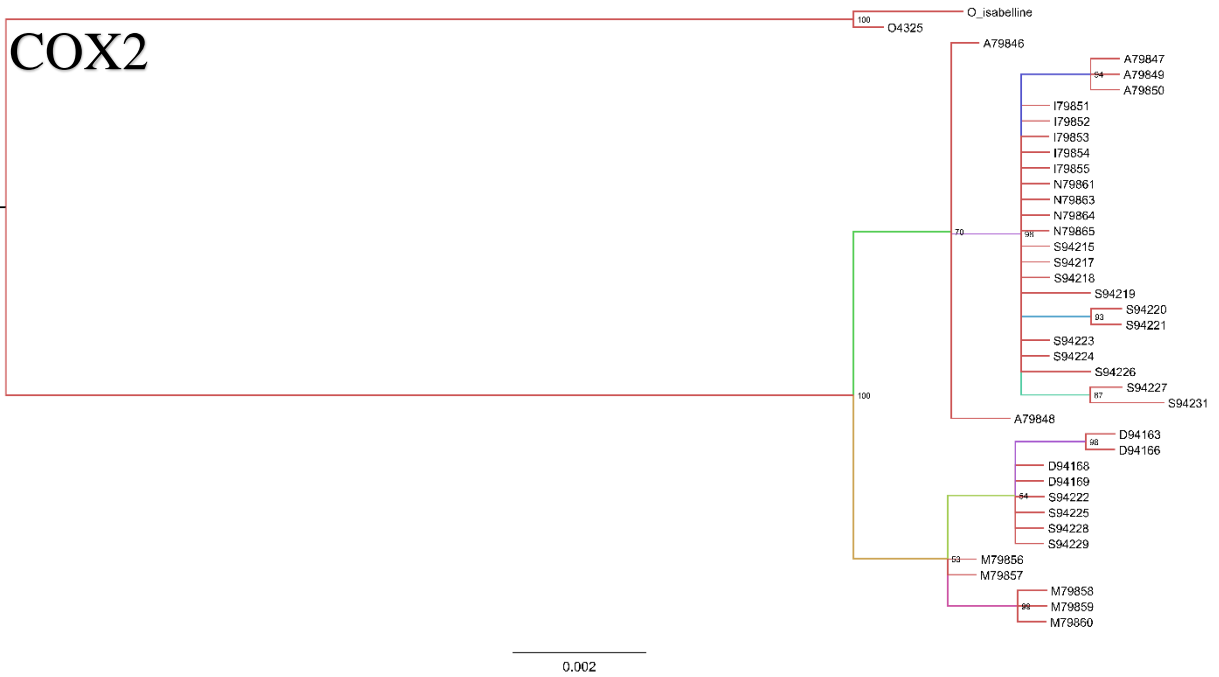
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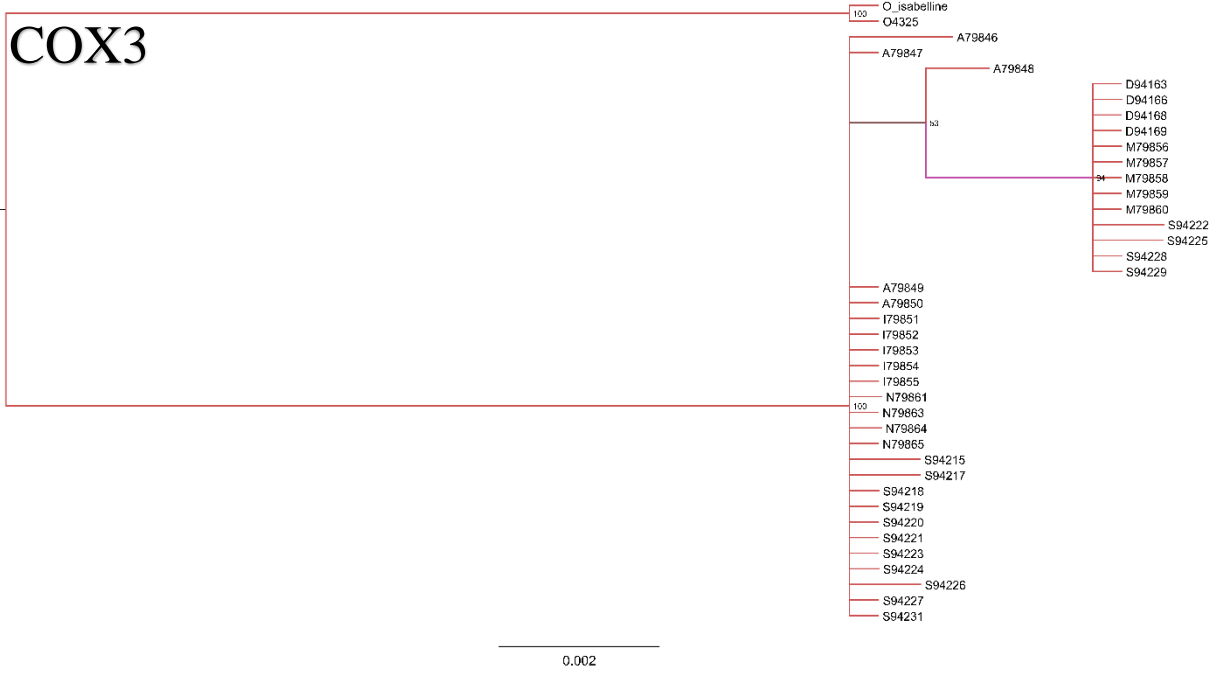
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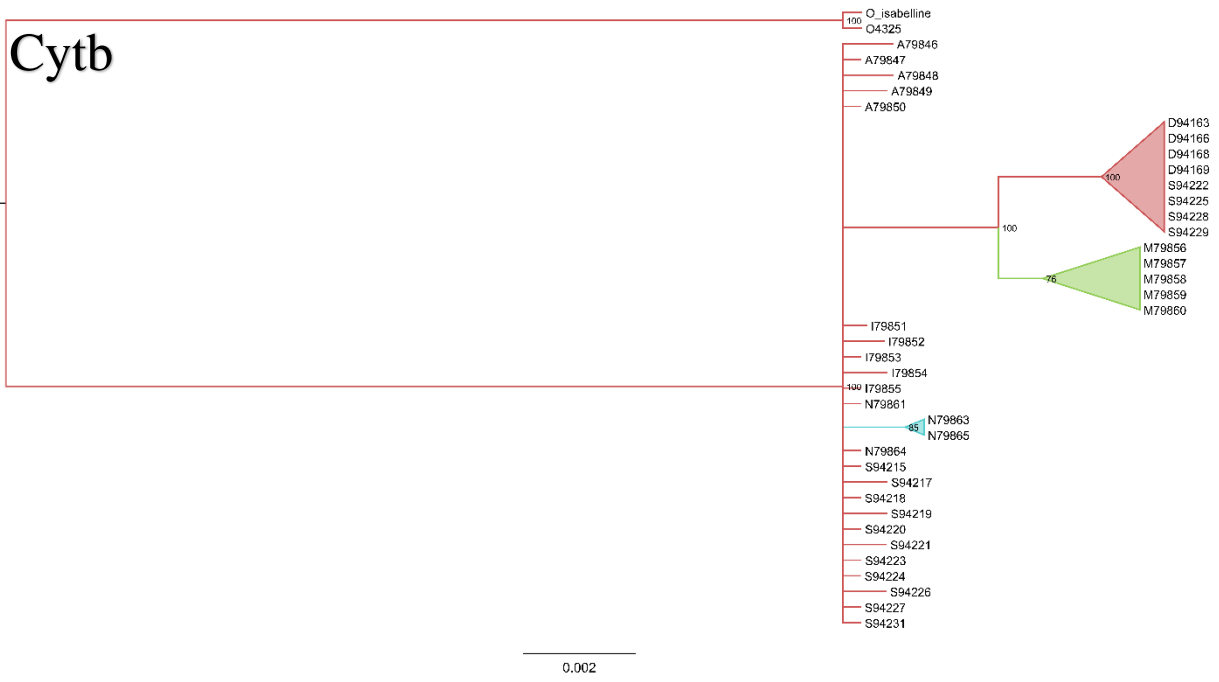
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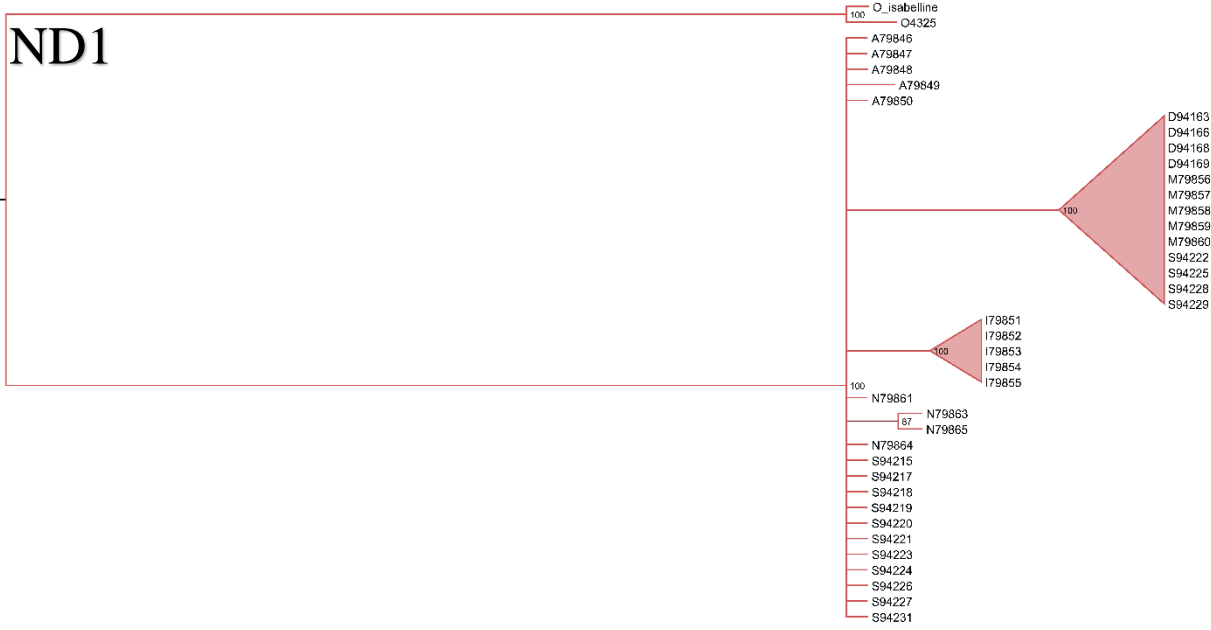
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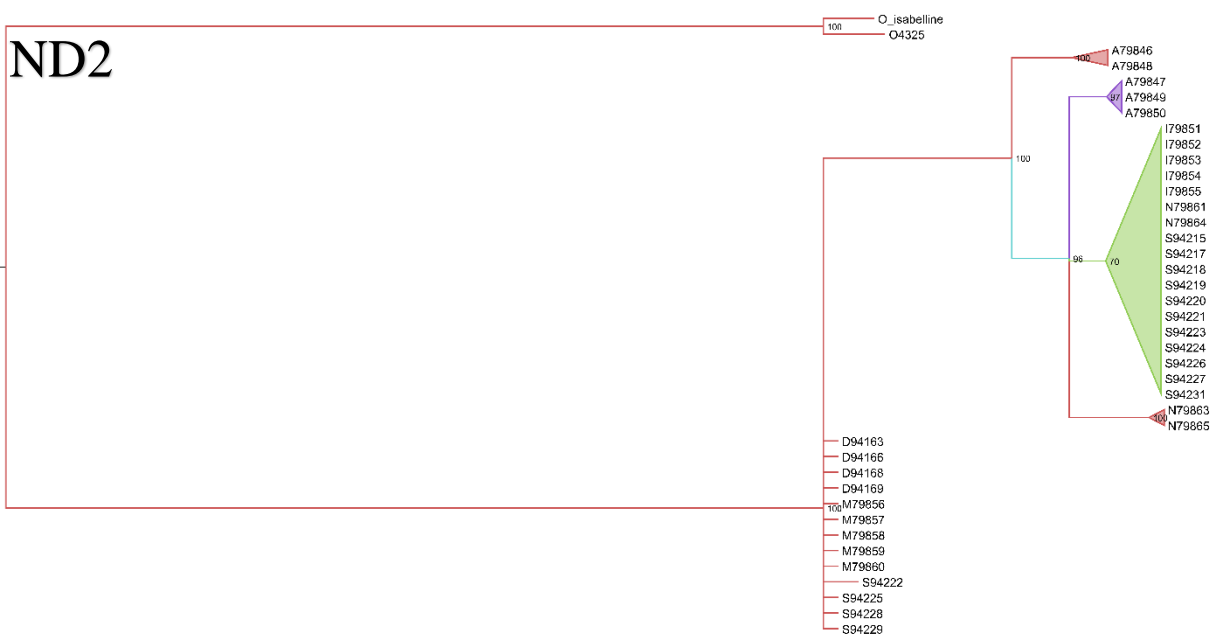
Cytb



ND1



ND2



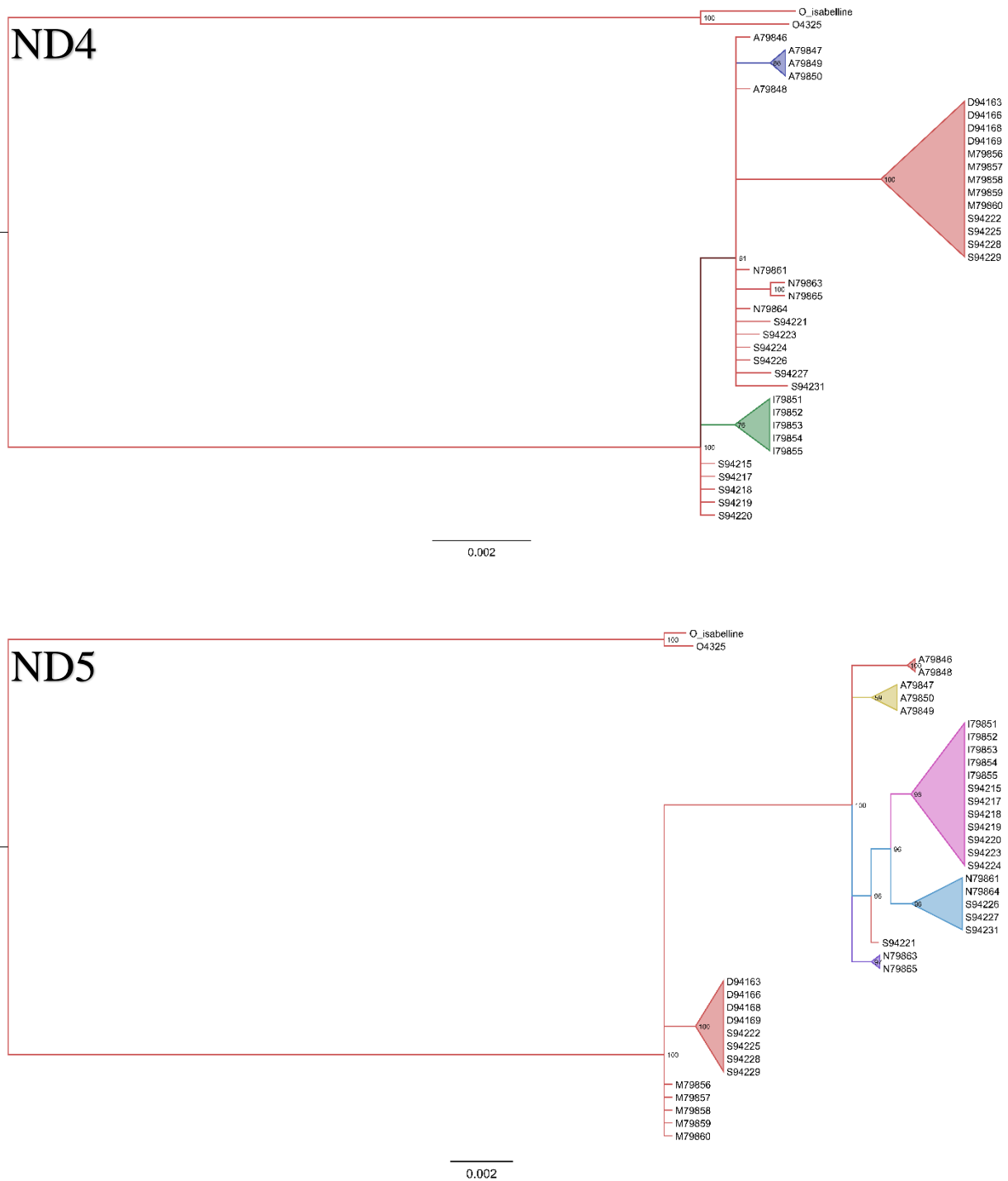
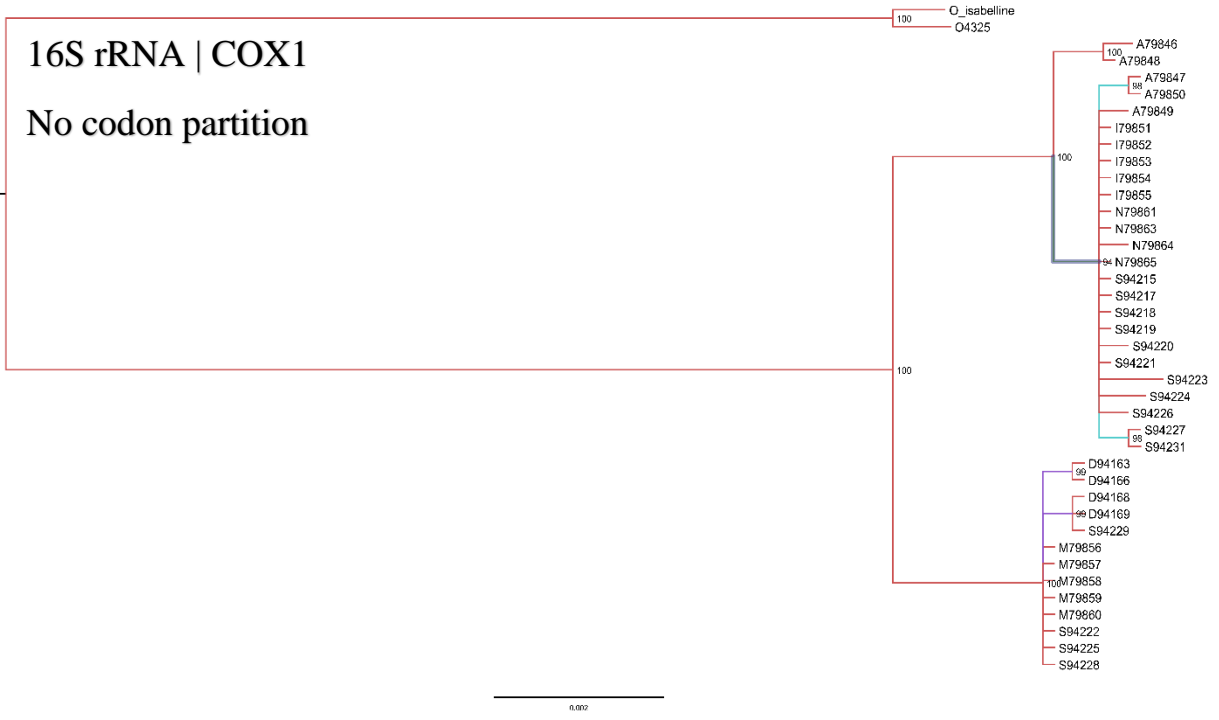
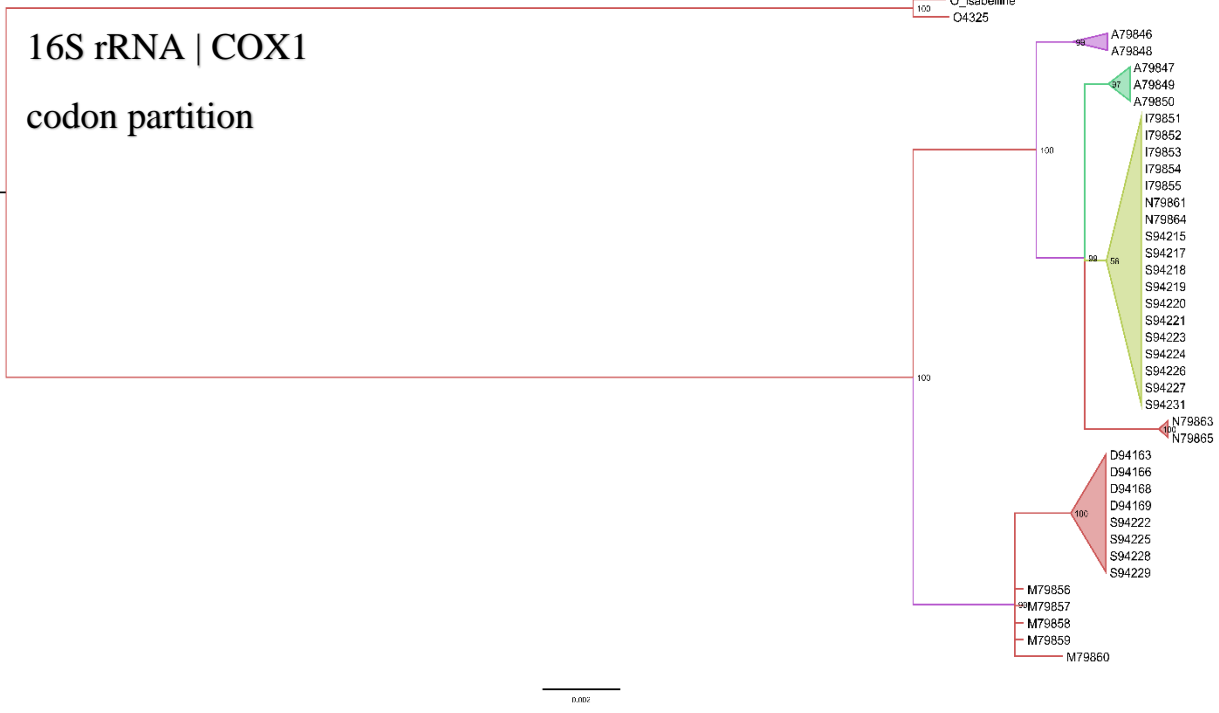


Figure S3. MrBayes reconstruction of the *Oenanthe oenanthe* and its outgroup *Oenanthe isabellina*. Numbers above nodes refer to the support values of Bayesian posterior probability. Sample names indicate the localities by the capital letter, ‘A’ refers to Alaska; ‘D’ refers to Germany; ‘I’ refers to Iceland; ‘M’ refers to Morocco; ‘N’ refers to Norway and ‘S’ refers to Sweden. Samples from Morocco are black throat wheatears (*O. seebohmi*); samples from Iceland are Greenland wheatears (*O. o. leucorhoa*); samples from Alaska, Germany, Norway and Sweden are nominate wheatears (*O. o. oenanthe*).



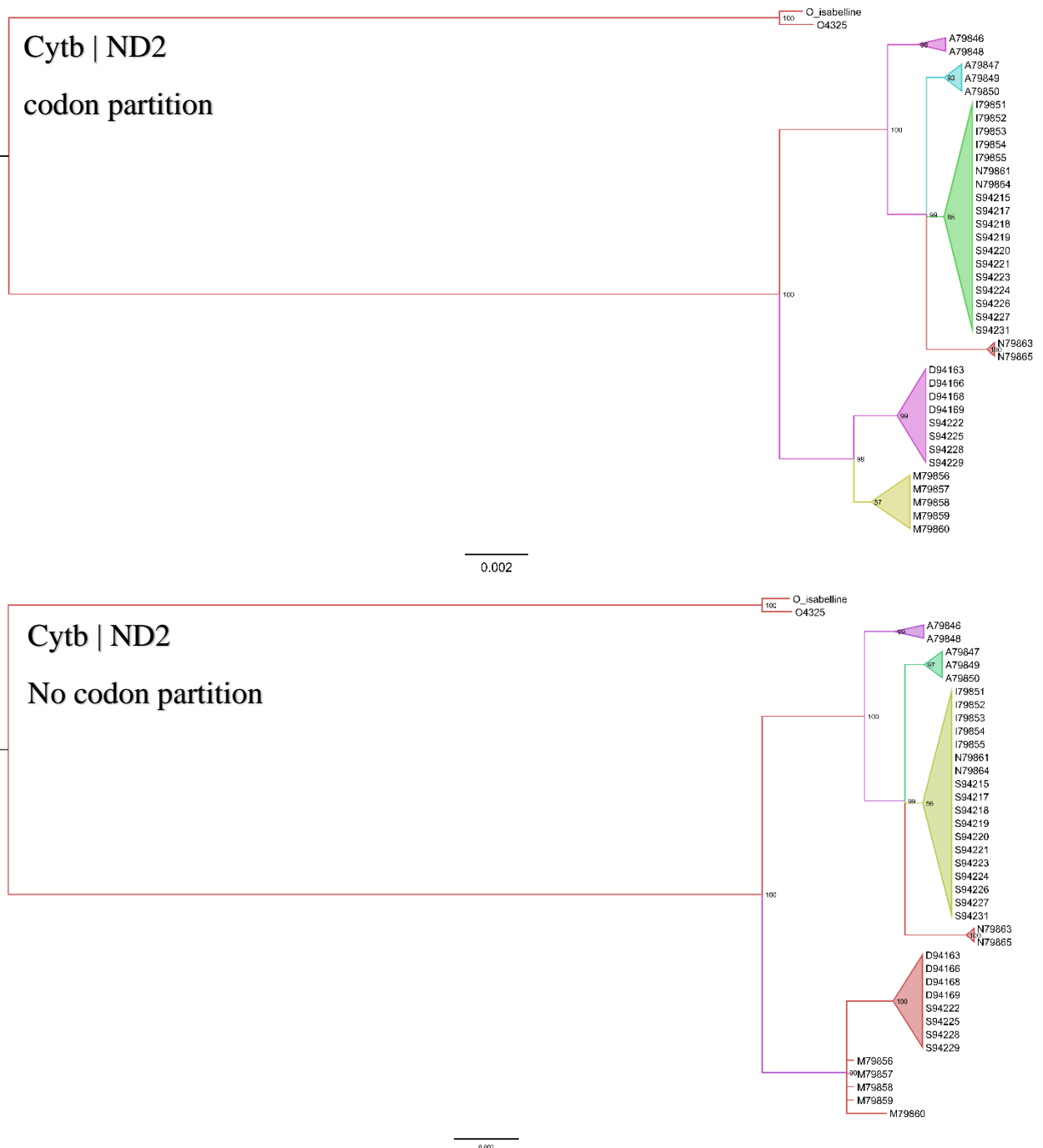


Figure S4. MrBayes reconstruction of the *Oenanthe oenanthe* and its outgroup *Oenanthe isabellina*. Numbers above nodes refer to the support values of Bayesian posterior probability. Sample names indicate the localities by the capital letter, ‘A’ refers to Alaska; ‘D’ refers to Germany; ‘I’ refers to Iceland; ‘M’ refers to Morocco; ‘N’ refers to Norway and ‘S’ refers to Sweden. Samples from Morocco are Seebohmi Wheatears (*O. seebohmi*); samples from Iceland are Greenland wheatears (*O. o. leucorhoa*); samples from Alaska, Germany, Norway and Sweden are nominate wheatears (*O. o. oenanthe*).

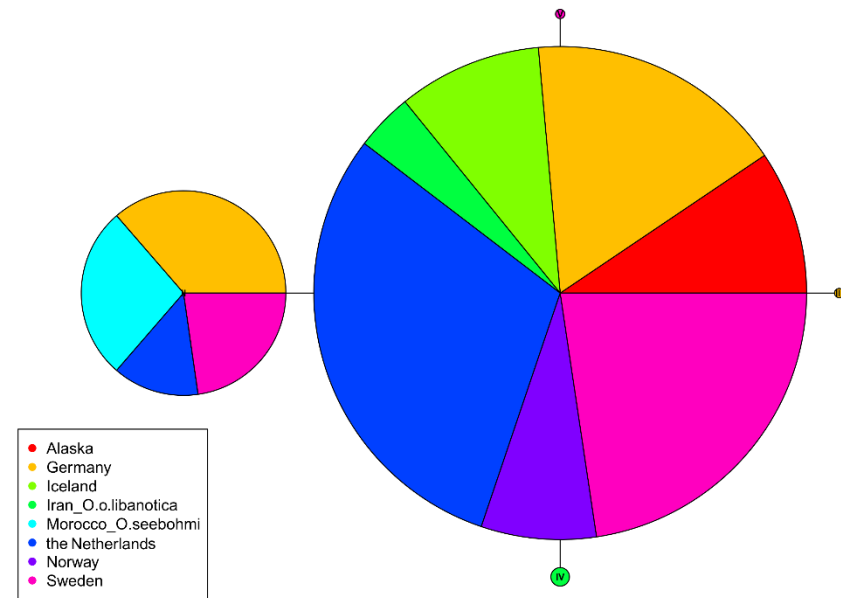
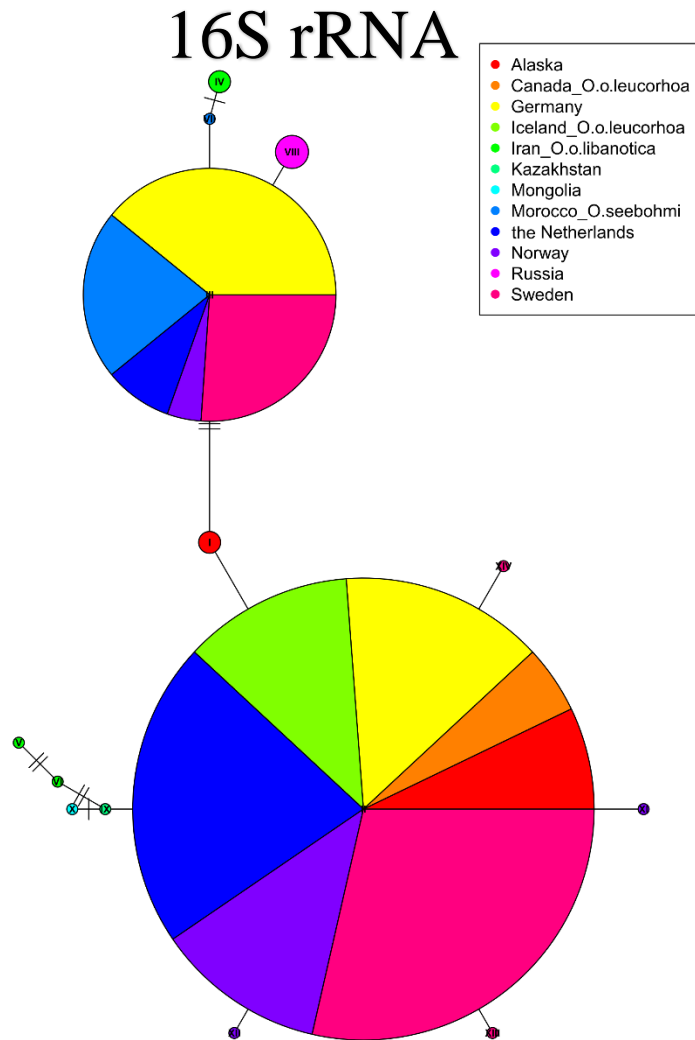


Figure S5. Haplotype network for *Oenanthe* including the samples from previous studies. Sample information are shown in the TableS1 and TableS2. Size of the circles represents the frequency of haplotypes. The sample localities are coded by the colors. Each dot indicates one mutation step. Samples from Morocco are Seebohmi Wheatears (*Oenanthe seebohmi*); samples from Iceland and Canada are Greenland Wheatears (*O. o. leucorhoa*); samples from Iran belong to *O. o. libanotica*. The rest of the samples are nominate wheatears (*O. o. oenanthe*). The classification of (sub)species are identified by the morphological data.

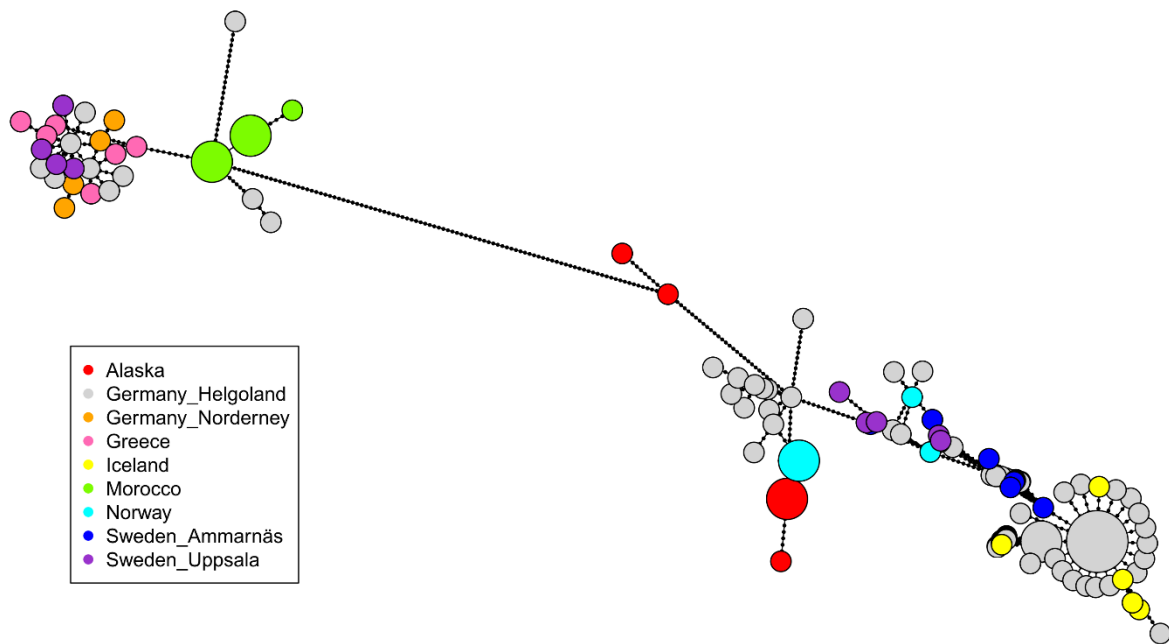


Figure S6. Haplotype network for 117 individuals of *Oenanthe* based on 13 PCGs, 14 tRNAs and 2 rRNAs. Size of the circles represents the frequency of haplotypes. The breeding areas are coded by the colors. Each dot indicates one mutation step. Samples from Morocco are Seebohmi Wheatears (*O. seebohmi*); samples from Iceland are Greenland wheatears (*O. o. leucorhoa*); samples from Alaska, Germany, Norway and Sweden are nominate wheatears (*O. o. oenanthe*); samples from Helgoland and Greece are migrating birds. The classification of (sub)species are identified by the morphological data.

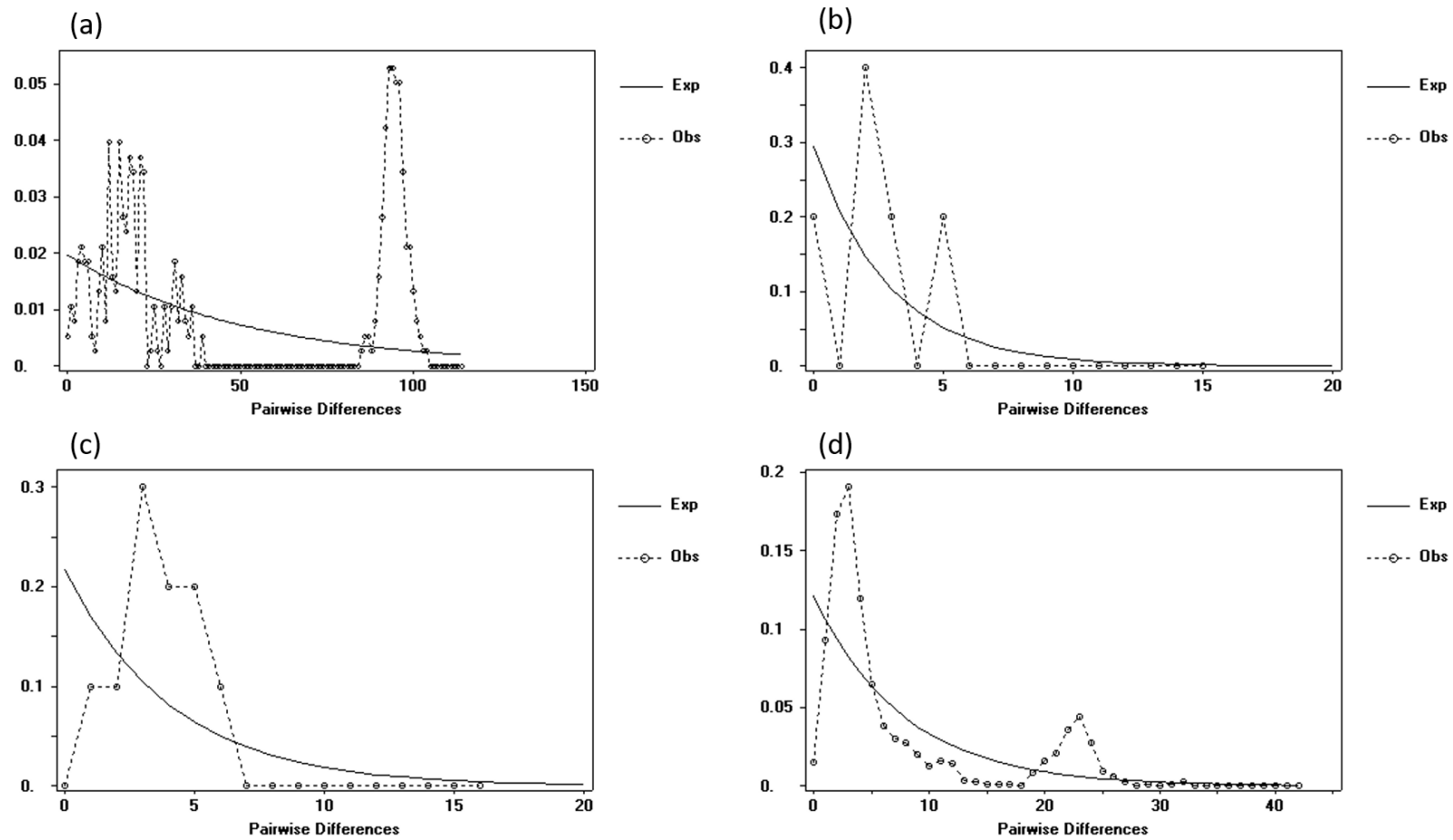


Figure S7. Mismatch distribution under the demographic expansion model. The graphs illustrate the frequency of pairwise difference among (a) breeding populations of *O. o. oenanthe*; (b) Morocco population of *O. seebohmi*; (c) Iceland population of *O. o. leucorhoa* and (d) migrating and breeding *O. o. leucorhoa*. based on 13 PCG. We included the migrating *O. o. leucorhoa* for the calculation, because of the limited sample size of breeding population.

Table S1 Mitochondrial molecular indices of 13 PCG

taxa	population	sample size	No. of polymorphic sites	haplotype diversity	nucleotide diversity	Tajima's D	P values	Fu's	P values
<i>O.o.oenanthe</i>	Alaska	5	39	0.9000 ± 0.1610	0.1010 ± 0.0631	0.7549	0.7560	2.8224	0.8650
<i>O.o.oenanthe</i>	Germany	4	6	1.0000 ± 0.1768	0.0180 ± 0.0137	1.1680	0.8350	-0.9463	0.1140
<i>O.o.oenanthe</i>	Norway	4	22	0.8333 ± 0.2224	0.0679 ± 0.0463	1.5698	0.9190	3.1779	0.8790
<i>O.o.oenanthe</i>	Ammarnäs	6	24	1.0000 ± 0.0962	0.0402 ± 0.0251	-1.3831	0.0560	-1.2713	0.1440
<i>O.o.oenanthe</i>	Uppsala	9	124	1.0000 ± 0.0524	0.2879 ± 0.1561	1.4859	0.9520	0.2284	0.3230
<i>O.o.leucorhoa</i>	Iceland	5	9	1.0000 ± 0.1265	0.0177 ± 0.0126	-1.1844	0.0310	-1.9011	0.0550
<i>O.seebohmi</i>	Morocco	5	5	0.8000 ± 0.1640	0.0118 ± 0.0090	0.0000	0.5780	0.9518	0.6350

Table S2 Sample List

Species	IPMB	Locality	Country	Institute of Collector	GenBank	Tissue	Status
<i>Oenanthe oenanthe</i>	A79846	Alaska	United States	Vogelwarte Helgoland, Wilhelmshaven	MT430990	blood	Breeding
<i>Oenanthe oenanthe</i>	A79847	Alaska	United States	Vogelwarte Helgoland, Wilhelmshaven	MT430991	blood	Breeding
<i>Oenanthe oenanthe</i>	79848	Alaska	United States	Vogelwarte Helgoland, Wilhelmshaven	MT430992	blood	Breeding
<i>Oenanthe oenanthe</i>	A79849	Alaska	United States	Vogelwarte Helgoland, Wilhelmshaven	MT430993	blood	Breeding
<i>Oenanthe oenanthe</i>	A79850	Alaska	United States	Vogelwarte Helgoland, Wilhelmshaven	MT430994	blood	Breeding
<i>Oenanthe oenanthe</i>	I79851		Iceland	Vogelwarte Helgoland, Wilhelmshaven	MT430995	blood	Breeding
<i>Oenanthe oenanthe</i>	I79852		Iceland	Vogelwarte Helgoland, Wilhelmshaven	MT430996	blood	Breeding
<i>Oenanthe oenanthe</i>	I79853		Iceland	Vogelwarte Helgoland, Wilhelmshaven	MT430997	blood	Breeding
<i>Oenanthe oenanthe</i>	I79854		Iceland	Vogelwarte Helgoland, Wilhelmshaven	MT430998	blood	Breeding
<i>Oenanthe oenanthe</i>	I79855		Iceland	Vogelwarte Helgoland, Wilhelmshaven	MT430999	blood	Breeding
<i>Oenanthe seebohmi</i>	M79856		Morocco	Vogelwarte Helgoland, Wilhelmshaven	MT431000	blood	Breeding
<i>Oenanthe seebohmi</i>	M79857		Morocco	Vogelwarte Helgoland, Wilhelmshaven	MT431001	blood	Breeding
<i>Oenanthe seebohmi</i>	M79858		Morocco	Vogelwarte Helgoland, Wilhelmshaven	MT431002	blood	Breeding
<i>Oenanthe seebohmi</i>	M79859		Morocco	Vogelwarte Helgoland, Wilhelmshaven	MT431003	blood	Breeding
<i>Oenanthe seebohmi</i>	M79860		Morocco	Vogelwarte Helgoland, Wilhelmshaven	MT431004	blood	Breeding
<i>Oenanthe oenanthe</i>	N79861		Norway	Vogelwarte Helgoland, Wilhelmshaven	MT431005	blood	Breeding
<i>Oenanthe oenanthe</i>	N79863		Norway	Vogelwarte Helgoland, Wilhelmshaven	MT431006	blood	Breeding

<i>Oenanthe oenanthe</i>	N79864		Norway	Vogelwarte Helgoland, Wilhelmshaven	MT431007	blood	Breeding
<i>Oenanthe oenanthe</i>	N79865		Norway	Vogelwarte Helgoland, Wilhelmshaven	MT431008	blood	Breeding
<i>Oenanthe oenanthe</i>	D94163	Norderney	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431009	blood	Breeding
<i>Oenanthe oenanthe</i>	D94166	Norderney	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431010	blood	Breeding
<i>Oenanthe oenanthe</i>	D94168	Norderney	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431011	blood	Breeding
<i>Oenanthe oenanthe</i>	D94169	Norderney	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431012	blood	Breeding
<i>Oenanthe oenanthe</i>	S94215	Ammarnäs	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431013	blood	Breeding
<i>Oenanthe oenanthe</i>	S94217	Ammarnäs	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431014	blood	Breeding
<i>Oenanthe oenanthe</i>	S94218	Ammarnäs	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431015	blood	Breeding
<i>Oenanthe oenanthe</i>	S94219	Ammarnäs	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431016	blood	Breeding
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<i>Oenanthe oenanthe</i>	S94221	Ammarnäs	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431018	blood	Breeding
<i>Oenanthe oenanthe</i>	S94222	Uppsala	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431019	blood	Breeding
<i>Oenanthe oenanthe</i>	S94223	Uppsala	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431020	blood	Breeding
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<i>Oenanthe oenanthe</i>	S94225	Uppsala	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431022	blood	Breeding
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<i>Oenanthe oenanthe</i>	S94231	Uppsala	Sweden	Department of Ecology, Swedish University of Agricultural Science	MT431027	blood	Breeding
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<i>Oenanthe oenanthe</i>	H93337	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431080	blood	Migrant
<i>Oenanthe oenanthe</i>	H93338	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431081	blood	Migrant
<i>Oenanthe oenanthe</i>	H93339	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431082	blood	Migrant

<i>Oenanthe oenanthe</i>	H93340	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431083	blood	Migrant
<i>Oenanthe oenanthe</i>	H93341	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431084	blood	Migrant
<i>Oenanthe oenanthe</i>	H93342	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431085	blood	Migrant
<i>Oenanthe oenanthe</i>	H93343	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431086	blood	Migrant
<i>Oenanthe oenanthe</i>	H93344	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431087	blood	Migrant
<i>Oenanthe oenanthe</i>	H93345	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431088	blood	Migrant
<i>Oenanthe oenanthe</i>	H93346	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431089	blood	Migrant
<i>Oenanthe oenanthe</i>	H93347	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431090	blood	Migrant
<i>Oenanthe oenanthe</i>	H93348	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431091	blood	Migrant
<i>Oenanthe oenanthe</i>	H93349	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431092	blood	Migrant
<i>Oenanthe oenanthe</i>	H93350	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431093	blood	Migrant
<i>Oenanthe oenanthe</i>	H93351	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431094	blood	Migrant
<i>Oenanthe oenanthe</i>	H93352	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431095	blood	Migrant
<i>Oenanthe oenanthe</i>	H93353	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431096	blood	Migrant
<i>Oenanthe oenanthe</i>	H93355	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431097	blood	Migrant
<i>Oenanthe oenanthe</i>	H93356	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431098	blood	Migrant
<i>Oenanthe oenanthe</i>	H93357	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431099	blood	Migrant
<i>Oenanthe oenanthe</i>	H93358	Helgoland	Germany	Vogelwarte Helgoland, Wilhelmshaven, Heiko Schmaljohann	MT431100	blood	Migrant
<i>Oenanthe oenanthe</i>	G2265	Crete	Greece	Ristow	MT431101	Tissue	Migrant

<i>Oenanthe oenanthe</i>	G2269	Crete	Greece	Ristow	MT431102	Tissue	Migrant
<i>Oenanthe oenanthe</i>	G8605	Kreta	Greece	Ristow	MT431103	Tissue	Migrant
<i>Oenanthe oenanthe</i>	G11501	Kreta	Greece	Ristow	MT431104	Tissue	Migrant
<i>Oenanthe oenanthe</i>	G19615	Crete	Greece	Ristow	MT431105	Tissue	Migrant
<i>Oenanthe oenanthe</i>	G19616	Crete	Greece	Ristow	MT431106	Tissue	Migrant
<i>Oenanthe isabellina</i>	O4325		Israel	Wittmann/Heidrich		Tissue	Unknown

Table S3 Information about the sequences in the study obtained from GenBank

Reference	Species	Sample no.	Location	GenBank accession 16S	GenBank accession COX1
Randler, 2012/Hebert,2004	<i>O. oenanthe</i>	1B-3210	Canada		AY666389
Randler, 2012/Kerr,2007	<i>O. oenanthe</i>	USNM 627617	Iceland		DQ433051.1
Aliabadian,2007	<i>O. o. libanotica</i>	BMNH A/2005.2.9	Iran	DQ683467	DQ683501
Aliabadian,2007	<i>O. o. libanotica</i>	BMNH A/2005.2.4	Iran	DQ683468	DQ683502
Aliabadian,2007	<i>O. o. libanotica</i>	MIUT2003-81	Iran	DQ683469	DQ683503
Aliabadian,2007	<i>O. o. libanotica</i>	BMNH A/2005.2.10	Iran	DQ683470	DQ683504
Aliabadian,2007	<i>O. seebohmi</i>	MIUT2003-83	Morocco	DQ683471	DQ683505
van Oosten,2016	<i>O. oenanthe</i>	WE13 005	Netherlands	KX352414.1	KX352390.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 007	Netherlands	KX352415.1	KX352391.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 015	Netherlands	KX352416.1	
van Oosten,2016	<i>O. oenanthe</i>	WE13 024	Netherlands	KX352417.1	KX352392.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 029	Netherlands	KX352418.1	KX352393.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 054	Netherlands	KX352419.1	KX352394.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 065	Netherlands	KX352420.1	
van Oosten,2016	<i>O. oenanthe</i>	WE13 075	Netherlands	KX352421.1	KX352395.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 080	Netherlands	KX352422.1	KX352396.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 088	Netherlands	KX352423.1	KX352397.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 104	Netherlands	KX352424.1	KX352398.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 111	Netherlands	KX352425.1	
van Oosten,2016	<i>O. oenanthe</i>	WE13 114	Netherlands	KX352426.1	
van Oosten,2016	<i>O. oenanthe</i>	WE13 123	Netherlands	KX352427.1	KX352399.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 133	Netherlands	KX352428.1	KX352400.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 143	Netherlands	KX352429.1	KX352401.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 149	Netherlands	KX352430.1	KX352402.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 155	Netherlands	KX352431.1	KX352403.1

van Oosten,2016	<i>O. oenanthe</i>	WE13 161	Netherlands	KX352432.1	KX352404.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 167	Germany	KX352433.1	KX352405.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 172	Germany	KX352434.1	
van Oosten,2016	<i>O. oenanthe</i>	WE13 176	Germany	KX352435.1	KX352406.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 177	Germany	KX352436.1	KX352407.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 181	Germany	KX352437.1	KX352408.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 184	Germany	KX352438.1	KX352409.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 193	Germany	KX352439.1	KX352410.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 201	Germany	KX352440.1	KX352411.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 204	Germany	KX352441.1	KX352412.1
van Oosten,2016	<i>O. oenanthe</i>	WE13 212	Germany	KX352442.1	KX352413.1
Johnsen,2010	<i>O. oenanthe</i>		Sweden_Uppsala		GU571994.1
Johnsen,2010	<i>O. oenanthe</i>		Sweden_Orebro		GU571993.1
Johnsen,2010	<i>O. oenanthe</i>		Norway_Telemark		GU571512.1
Johnsen,2010	<i>O. oenanthe</i>		Norway_Oppland		GU571511.1
Johnsen,2010	<i>O. oenanthe</i>		Norway_Rogaland		GU571510.1
Johnsen,2010	<i>O. oenanthe</i>		Norway_Vest-Agder		GU571509.1
Kerr, 2009	<i>O. oenanthe</i>		Mongolia_Dzavhan		GQ482270.1
Kerr, 2009	<i>O. oenanthe</i>		Russia_Rossiia		GQ482266.1
Kerr, 2009	<i>O. oenanthe</i>		Russia_Rossiia		GQ482269.1
Kerr, 2009	<i>O. oenanthe</i>		Kazakhstan		GQ482268.1
Kerr, 2009	<i>O. oenanthe</i>		Russia_Magadanskaya		GQ482267.1
Li, 2016	<i>O. isabellina</i>		China_Qinghai	Complete mitochondria genome NC_040290.1	