

Status, genetic diversity and possible breeding origin of wintering Great Northern Divers *Gavia immer* in Galicia, northwest Spain

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Background

- Scarce winter visitors to Iberia. Spanish population estimate of 270-240 wintering birds, mostly in Galicia, NW Spain (Sandoval & De Souza 2005)
- Included in the Red Book of Birds of Spain as Vulnerable (Madroño *et al.* 2004)
- 65 birds stranded between northern Portugal and southern France (53 in Galicia) during the *Prestige* oil spill (2002-2003)

The *Prestige* oil spill, November 2002



Prestige oil spill: from beach to laboratory



Objectives

- Provide an accurate estimate of the Galician population, its phenology, and habitat use
- Estimate the impact of the *Prestige* oil spill at the population level
- Measure levels of standing genetic diversity
- Identify the possible breeding origin of this small population, at the southern edge of its European wintering range



The Galician coastline



Figure 1. Map of the Galician coast showing the main topographical features and coastline sectors mentioned throughout the text.



Provide an accurate estimate of the Galician wintering population, its phenology and habitat use

Data sources:

- Authors' own observations (1974–2010)
- Galician and Asturian Annual Bird Reports (1992–2004)
- Galician January waterfowl censuses in 1987–2007, and censuses conducted in Spain in 1967–2003



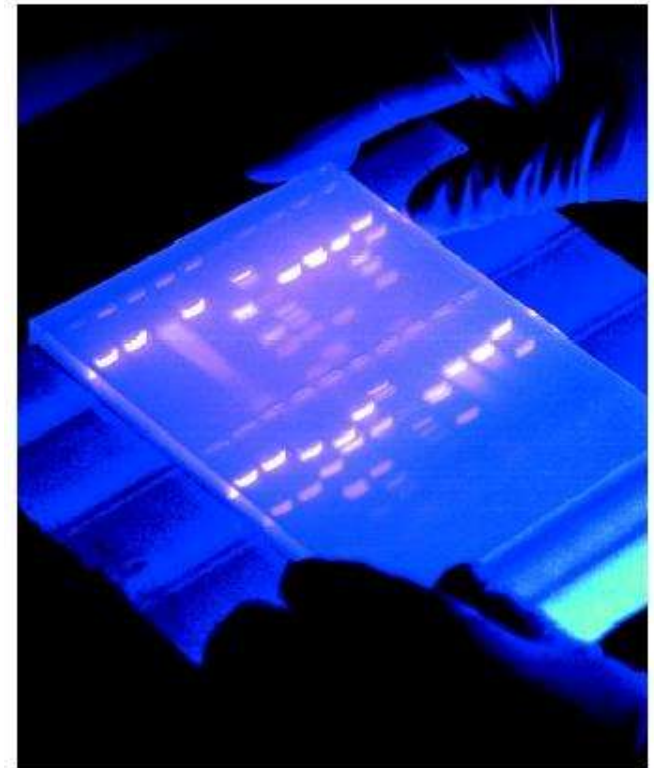
Estimate the impact of the *Prestige* oil spill at the population level

- **Population trends before and after the oil spill:**
 - log loglinear regression (TRIM 3.51; Pannekoek & van Strien 2001) of January counts from eight wintering sites (average of 16 counts for the period 1994–2010)
- **Population structure:**
 - Necropsies of 41 corpses for sex and age determination



Measure levels of standing genetic diversity

- Heart tissue of 33 corpses from the *Prestige* oil spill
- DNA sequencing:
 - cytochrome b (*cytb*)
 - cytochrome oxidase I (*COI*)
 - Noncoding mitochondrial control region
- Diversity indices:
 - Nei- Gojobori algorithm
 - Watterson's estimator
 - number of haplotypes (h)
 - haplotype diversity (Hd)
 - Tajima's D
 - Fst



Identify the possible breeding origin of this small population, at the southern edge of its European wintering range

- Comparison of mtDNA patterns of Galician birds (n=33) with available sequences in GenBank from locations elsewhere
- Biometrics of birds killed in the *Prestige* oil spill
- Incidence of embedded gunshot (x-ray)



Seasonal occurrence in Galicia

- Quasi-bimodal distribution of records
- Peak number of observations: early November to late April
- Observations of birds in prebreeding moult: February to May

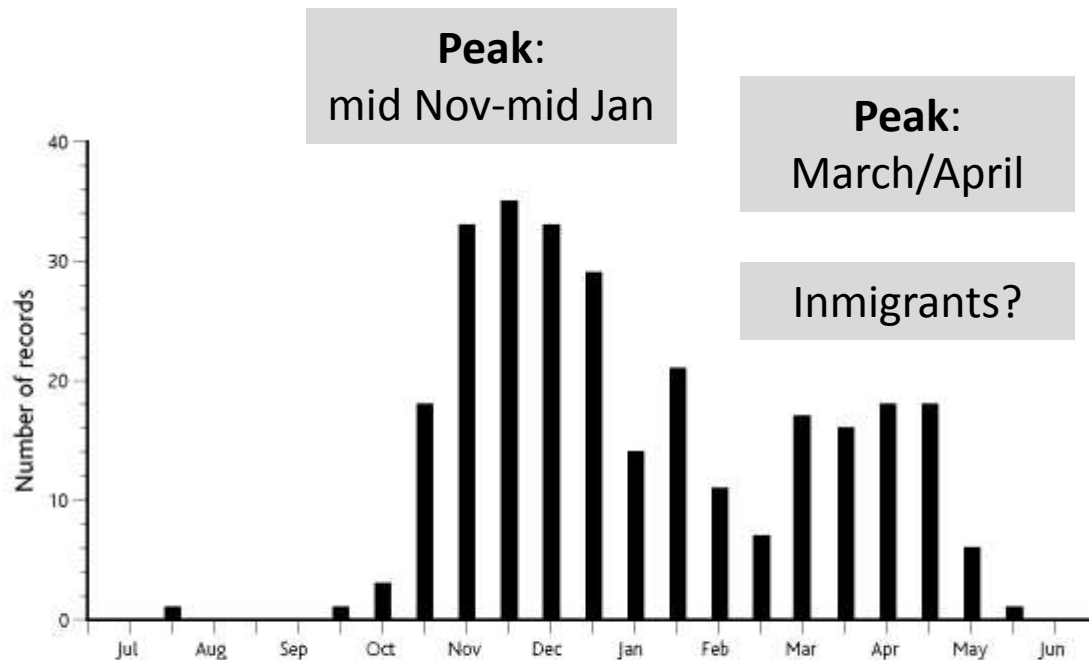


Figure 2. Fortnightly distribution of the number of records of Great Northern Diver *Gavia immer* in Galicia. Data were obtained from Galician Annual Bird Reports (1992–2004). Only one record per site and per fortnight has been used.



Habitat use (seasonal % of all records)

- **Most observations (% of all records) were from open, sandy coasts and the sheltered waters of the *rías***
- **Human disturbance in the *rías* may cause birds to move from sheltered to open coasts for the pre-breeding moult (flightless)**

Habitat (sites)	Autumn	Winter	Spring
Open sandy coast (9)	34.5	31.9	56.1
Open rocky coast((4)	4.5	9.6	10.6
Open mixed coast (3)	4.5	5.3	7.6
Total open coast (16)	43.6	46.8	74.3
Sheltered sandy coast/rías ((11)	30.0	27.7	12.1
Sheltered rocky coast (2)	1.8	4.2	1.5
Sheltered mixed coast (10)	24.5	21.3	12.1
Total sheltered coast (23)	56.3	53.2	25.7

Wintering numbers and distribution (1996-2001)

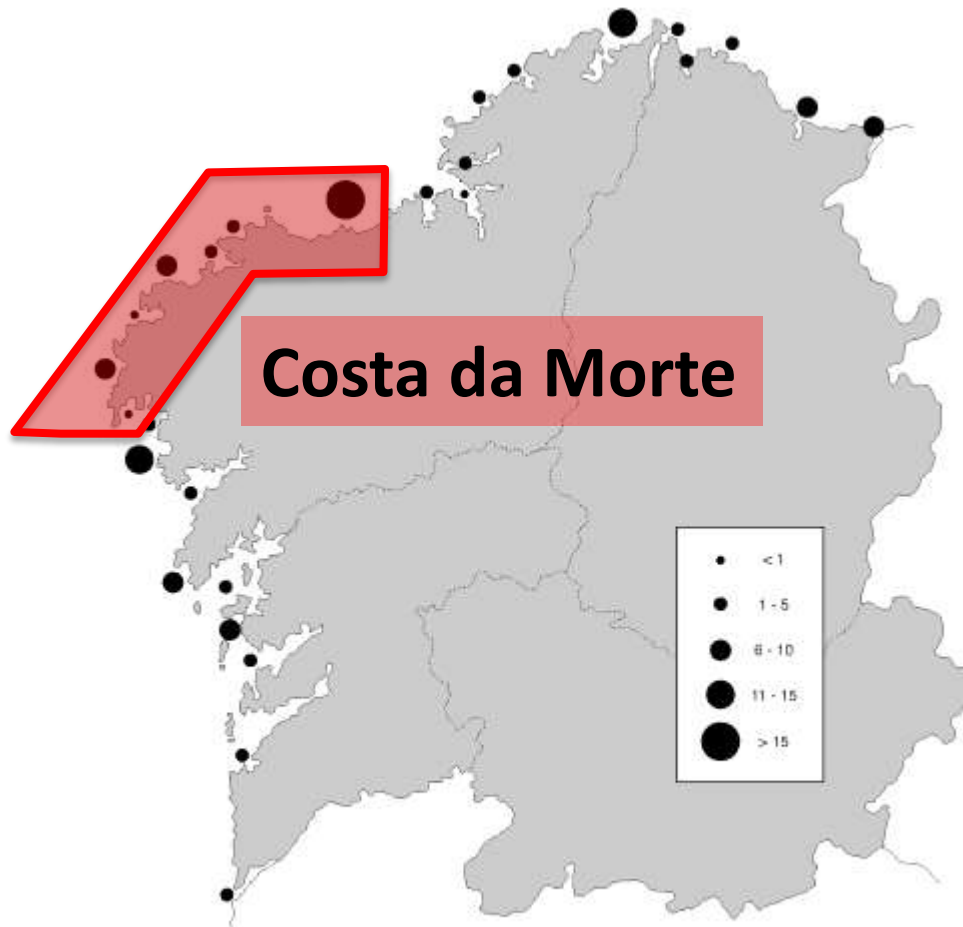


Figure 6. Estimated average number of Great Northern Divers *Gavia immer* in 1996–2001 along the Galician coast.

- Average winter estimate = 123 ind. (95% CI = 76–166), not corrected for detectability
- Overall linear density 0.17 birds/km (95% CI = 0.12–0.26)
- Galician wintering population represents 4–8% of the European breeding population
- Site of Community Importance ES1110005 Costa da Morte could qualify as internationally important

Population trend (1996-2010)

- Three major trends:
 - 1996-2001: stable
 - 2001-2005: downwards
 - 2005-2010: recovery
- 57% reduction between 2002 (*Prestige*) and 2005
- Real recent recovery or immigrants from the neighbouring northern Spanish coast?

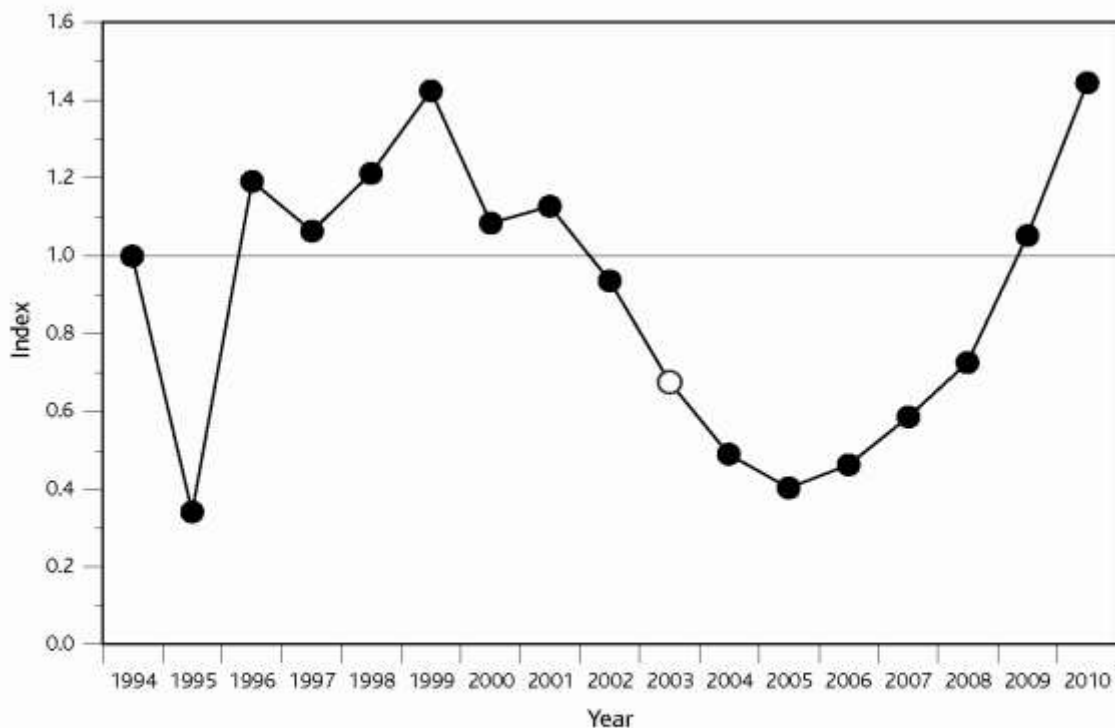


Figure 5. Population trend of Great Northern Diver *Gavia immer* in Galicia, 1994–2010. Imputed time indices correspond to the linear trend model developed with TRIM. The white dot shows the winter in which the *Prestige* oil spill took place.

Age and sex structure of the *Prestige* mortality

- 53 birds found dead in Galicia, at least 43% of the estimated pre-spill (1996-2001) population of 123 birds

Table 2. Month of retrieval, from approximate finding dates, and age of 41 Great Northern Divers *Gavia immer* found in Galicia following the *Prestige* oil spill, 2002/03.

Age	Nov	Dec	Jan	Feb	Mar	Apr	No date	Totals
Adult	3	10	6			1	2	22
Immature		1						1
Juvenile	1	10	2			1	2	16
Unknown	1	1						2
Totals	5	22	8	0	0	2	4	41

- Most dated specimens found in December and January
- 56% adults, 3% immatures, 41% juveniles (n=39)
- Sex ratio = 50:50 in both adults and juveniles

Biometrics (mean \pm SD, mm) of adult Great Northern Divers from the *Prestige* oil spill: males are larger

Measurement	Adults males	Adult females	Signif.
Bill length, tip-feathers	83.7 \pm 3.0 (n = 10)	80.2 \pm 4.8 (n = 9)	P = 0.035
Bill length, tip-nostril	64.5 \pm 5.2 (n = 10)	60.4 \pm 2.2 (n = 9)	P = 0.022
Bill depth at base	26.3 \pm 1.1 (n = 10)	24.6 \pm 1.8 (n = 9)	P = 0.010
Bill depth at gonys	21.5 \pm 1.0 (n = 10)	21.9 \pm 1.6 (n = 8)	n.s.
Tarsus length	92.1 \pm 2.3 (n = 9)	87.5 \pm 3.6 (n = 8)	P = 0.003
Wing length	381.8 \pm 10.3 (n = 9)	367.5 \pm 10.2 (n = 7)	P = 0.017

Age and sex structure of Great Northern Divers examined in 4 major European oil spills

	<i>Esso Bernicia</i>	<i>Amoco Cadiz</i>	<i>Erika</i>	<i>Prestige</i>
Location Date	Shetland, Jan-Mar 1979	Brittany, Mar-Apr 1978	Brittany, Dec-May 1999/00	Galicia, Nov-Apr 2002/03
Birds	68	41	29	41
% adult	97% (n=68)	72% (n=36)	71% (n=17)	56% (n=39)
% adult males	40% (n=57)	50% (n=26)	44% (n=23)	50% (n=18)

- **Latitudinal gradient in age structure?**
- **No bias in adult sex ratio in any of the samples**

Other causes of death in Galicia

7% of birds (n=41) suspected of being drowned in gill nets



Drowned? Good physical condition; no oiling (pre- or post-mortem); soaked plumage; prey remains in stomach; organs in good health except for watery lungs



Levels of genetic diversity

Very low levels of genetic diversity in the species

Average π_s value for the Class Aves = 0.0266-0.0400

Table 2 Mitochondrial nucleotide diversity in *Gavia immer*. π Pairwise nucleotide diversity at silent (π_s) and nonsynonymous sites (π_a); θ nucleotide site variability based on the number of segregating sites (silent = θ_s and nonsynonymous = θ_a , respectively); S number of

silent (S_s) and nonsynonymous sites (S_a), Sg : number of segregating sites (silent= Sg_s and nonsynonymous= Sg_a , respectively); D Tajima's D value (silent= D_s and nonsynonymous= D_a , respectively); h number of haplotypes; Hd haplotype diversity

Locus	Dataset	π_s	π_a	θ_s	θ_a	S_s	Sg_s	S_a	Sg_a	N^a	D_s	D_a	h	Hd
<i>COI</i>	<i>Prestige</i>	0	0.0001	0	0.0005	186.00	0	519.00	1	33	-	-1.14	2	0.06
	GenBank ^b	0	0	0	0	156.00	0	432.00	0	4	-	-	1	0
	Both	0	0.0001	0	0.0006	156.00	0	432.00	1	37	-	-1.13	2	0.05
<i>cytb</i>	<i>Prestige</i>	0.0010	0.0001	0.0032	0.0004	231.65	3	662.35	1	33	-1.55	-1.14	5	0.28
	GenBank	0.0079	0.0003	0.0120	0.0006	200.00	7	580.00	1	11	-1.40	-1.13	5	0.71
	Both	0.0029	0.0002	0.0104	0.0008	199.99	9	580.02	2	44	-2.06	-1.48	9	0.41
<i>MRC</i>	<i>Prestige</i>	0.0004	-	0.0010	-	486.00	2	-	-	33	-1.27	-	3	0.17

^a Number of sequences analyzed

^b GenBank data from Stanley and Harrison 1999; Wink et al. 2002; Hebert et al. 2004; Baker et al. 2006; Kerr et al. 2007; Brown et al. 2008

Breeding origin of Galician birds: genetic analysis

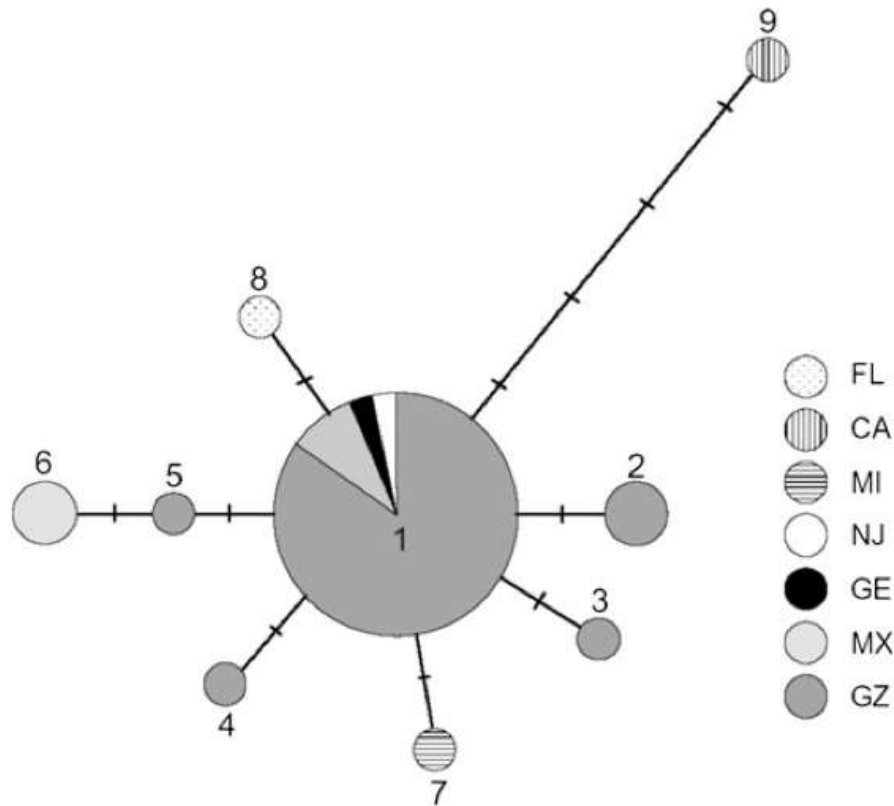


Fig. 1 Haplotype network constructed using the median joining method. Haplotype numbers are indicated. Circle patterns represent coastal sampling locations: *GZ* Galicia, Spain, *MX* Mexico, *GE* Germany, *NJ* New Jersey, US, *MI* Michigan, US, *CA* Canada, *FL* Florida, US. Circle surfaces are roughly proportional to the number of individuals with each haplotype (Table 3)

- Single panmictic population of small effective population size as compared with other seabirds
- Identification of the breeding regions not possible relying solely on genetic data
- Little genetic variation lost in the *Prestige* oil spill

Breeding origin of Galician birds: wing length

Wing lengths of Galician sample best match Greenland and Iceland populations, once adjusted for shrinkage of museum specimens

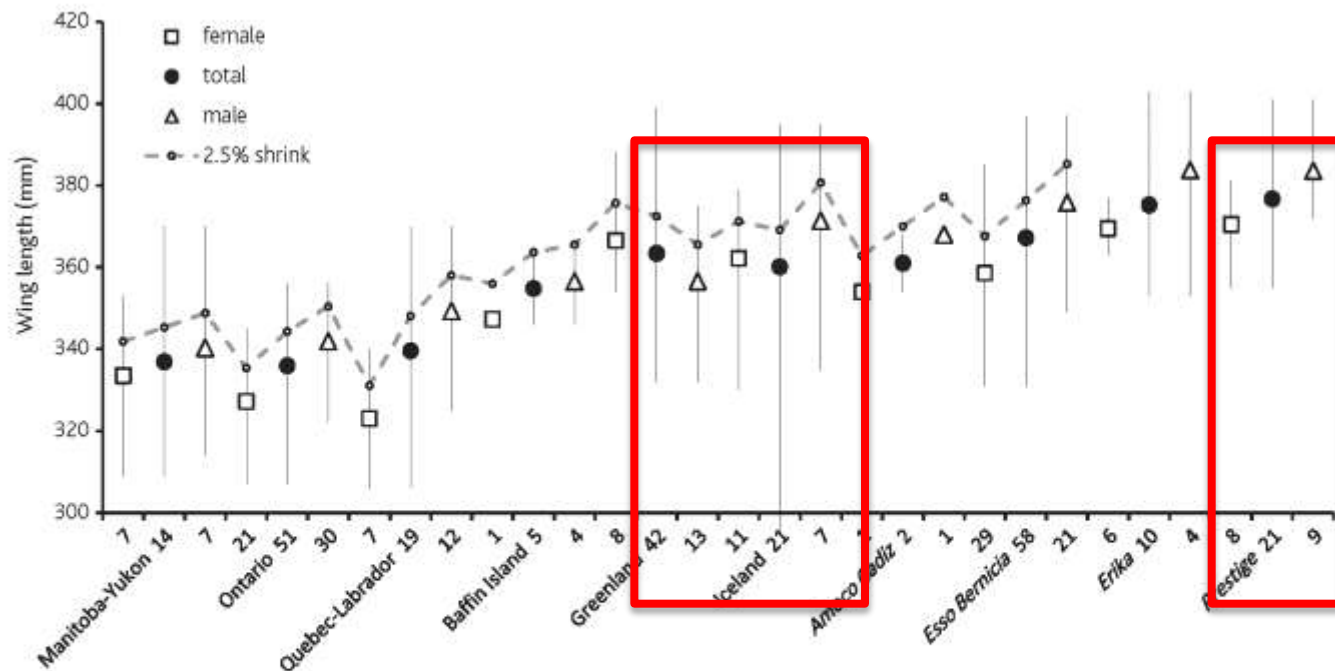


Figure 2. Wing length (mean, range, sample size (n) indicated) of adult Great Northern Divers *Gavia immer* from breeding locations in Canada, Greenland and Iceland (see Acknowledgements), compared with wing length in non-moulting adults collected during the *Amoco Cadiz*, *Esso Bernicia*, *Erika* and *Prestige* oil spills in Europe. The dotted line indicates means corrected for 2.5% shrinkage in museum specimens. Only *Prestige* and *Erika* birds were measured fresh. Note few data for the *Amoco Cadiz* oil spill, where most adults were in active wing moult.

Breeding origin of Galician birds: incidence of embedded gunshot

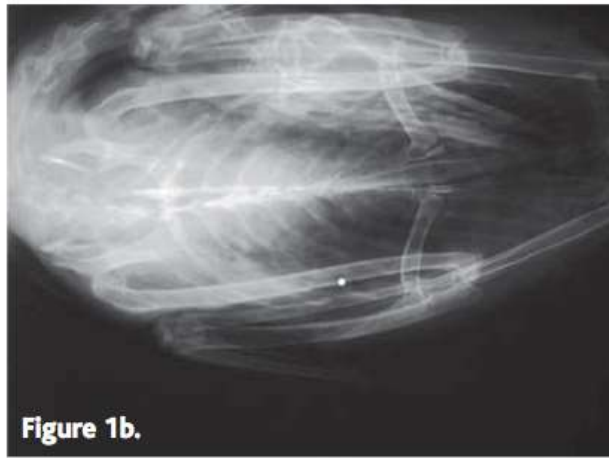


Figure 1. X-rays of four Great Northern Divers *Gavia immer* revealing non-lethal shot embedded in tissue: (a) double shot in the back, adult male, wing length 382 mm; (b) single shot in the wing, adult unsexed, wing length 389 mm; (c) four scattered shot, adult female, wing length 377 mm; (d) single shot in the neck, adult female, wing length 379 mm. © Andrés Barreiro Lois and Ana López Beceiro.

- Non-lethal shotgun pellets (1-4) found in 4/14 birds, all adults ($4/22 = 18\%$), similar to incidence in Shetland adults ($12/61 = 19\%$)
- Species still legally hunted in Greenland at the time, bag of 918 reported for 2003-08; (Anon 2009)

Acknowledgements

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