SC/68B/SM/06 Rev1

Harbour porpoise (Phocoena phocoena) and fisheries interactions in the north-west Iberian Peninsula

Fiona L. Read, M. Begona Santos, Marisa Ferreira, Alfredo Lopez and Graham J. Pierce

INTERNATIONAL WHALING COMMISSION

Harbour porpoise (*Phocoena phocoena*) and fisheries interactions in the north-west Iberian Peninsula

Fiona L. Read[1,2*], M. Begoña Santos[3], Marisa Ferreira[4], Alfredo López[5], and Graham J. Pierce[1,2]

1) School of Biological Sciences, Zoology Building, Tillydrone Avenue, AB24 2TZ Aberdeen, United Kingdom
2) Instituto de Investigaciones Marinas (C.S.I.C), Eduardo Cabello 6, 36208 Vigo, Spain
3) Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, PO Box 1552, 36200, Vigo, Spain
4) CBMA/SPVS, Departamento de Biologia, Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal
5) CEMMA, Apdo. 15, 36380, Gondomar, Spain

*corresponding author fiona.louise.read@gmail.com

This paper is adapted from Read, 2016 (PhD thesis, Chapter 4).

Abstract

The North West Iberian Peninsula (NWIP) (north-west Spain and north-central Portugal) is one of the world's main fishing areas and cetaceans are very abundant in the area. The Iberian harbour porpoise (*Phocoena phocoena*) is a genetically distinct population with a population size of less than 3000 and is classified as 'vulnerable'. Between 1990-2010, a total of 305 harbour porpoises were recorded as stranded along the NWIP coastline and a further eight porpoise carcases were handed in by fishermen. Around 60% of these porpoises showed evidence of fisheries interactions, although there is high annual variation in the number of porpoises classified as bycaught. No differences in the proportion of bycaught porpoises was observed seasonally, and males and females were equally likely to be bycaught. The majority of bycaught porpoises were immature, although the proportion of mature and immature animals bycaught was not significantly different, and adult females bycaught included pregnant and lactating animals. Combining results of the life table and necropsies suggest that there was between 4.3 and 11% annual mortality in the Iberian porpoise population due to fisheries interactions. These values greatly exceed the recommendations by the IWC and ASCOBANS. Beach seines and gillnets are the most problematic gears for porpoises in the NWIP and are used in areas of high abundance of porpoises. Although no decline in porpoise numbers was detected between surveys in 2005 and 2016, the low reproductive output and high mortality rate of porpoises, combined with the bycatch of pregnant and lactating females, as recorded in the 1990-2010 data, suggest that fishery bycatch may represent a significant threat to this population.

Introduction

The North West Iberian Peninsula (NWIP), as defined for the present study, extends from the northern limit of Galicia (north-west Spain) (43°3′N,7°2′W) southwards through north-central Portugal to as far south as Nazaré (39°5’N, 9°2’W) (Figure 1). The NWIP is an area of high productivity and high biodiversity due to the seasonal upwelling (Fraga, 1981). Almost 300 species of fish (Solørzano *et al*., 1988) and over 75 species of cephalopods (Guerra, 1992) have been recorded. The area is also an important nursery ground for several commercially important fish species including hake (*Merluccius merluccius*), sardine (*Sardina pilchardus*), scad (*Trachurus* spp.) and blue whiting (*Micromesistius poutassou*) (Pereiro *et al*., 1980; Fariña *et al*., 1985).

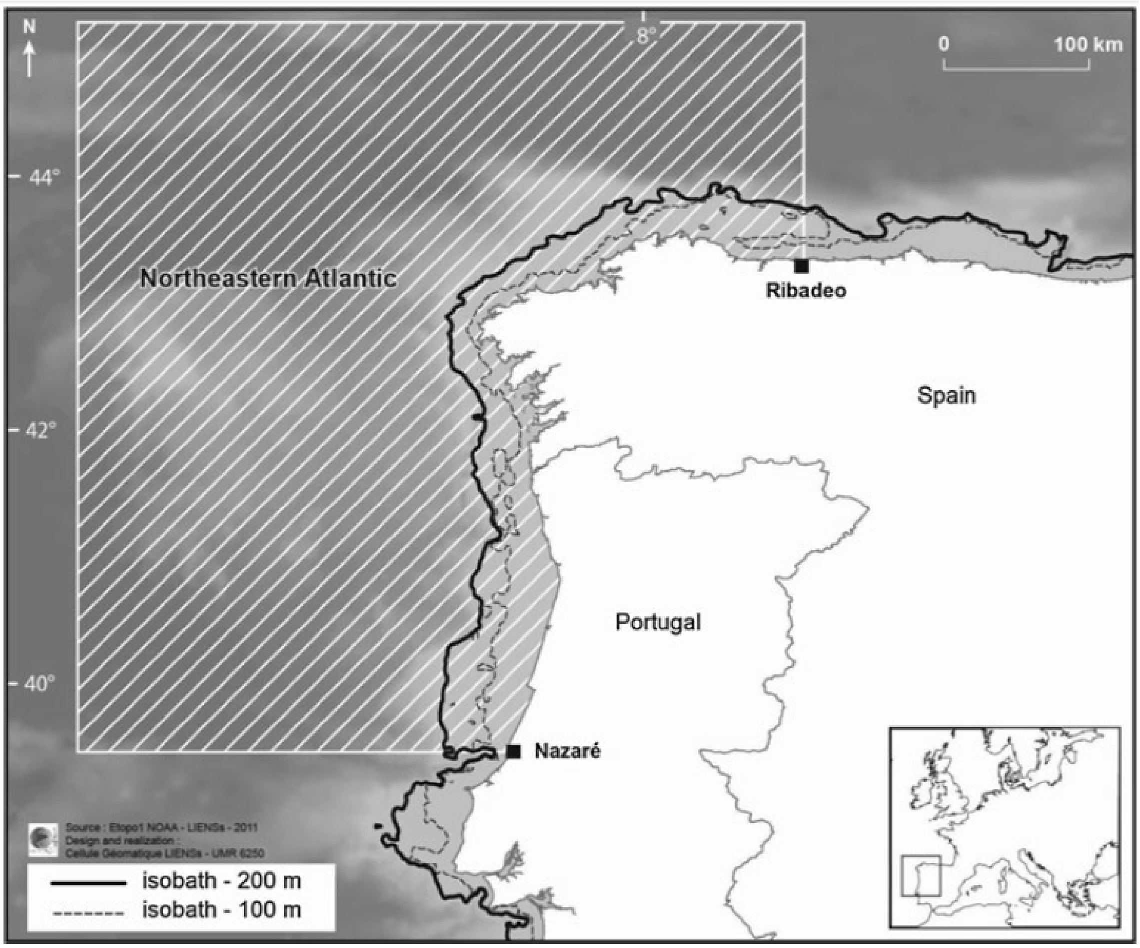


Figure 1. The study area, the North-West Iberian Peninsula (NWIP), with 100m and 200m isobaths. The sampling area is framed in white, representing the north and south limits for the strandings and the western latitude of the bycatches. Map from Méndez-Fernandez *et al*. (2013).

In Galicia, at least 19 species of marine mammals (16 cetaceans and 3 pinnipeds) have been recorded (Penas-Patiño and Piñeriro-Seage, 1989; Fernández de la Cigoña, 1990; López *et al*., 2002) and 20 species of cetaceans in Portugal (Sequeira *et al*., 1992; Sequeira *et al*., 1996). More species have been recorded in recent years and census database for Galicia and Portugal is currently 26 and 28 species, respectively (CEMMA and SPVS, unpublished data).

Spain and Portugal are traditionally fishing nations, with the largest and fifth largest fishing fleets within the European Community[1], respectively, and over half of the Spanish fishing fleet is based in Galicia. The NWIP is one of the world's main fishing areas, with an estimated 1.5 million fishing trips per annum from over 120 fishing harbours. Fisheries in the NWIP are highly diverse, exploiting a large number of species and using a large variety of fishing gears including traps, purse-seines, beach seines (Portugal only), single and pair trawls and several different types of gillnets.

The global status of the harbour porpoise is classified as being of Least Concern by the International Union for Conservation of Nature (IUCN) (Hammond *et al*., 2008) however, in Portugal the harbour porpoise is listed as vulnerable (Cabral *et al*., 2005). Harbour porpoise is included in Annex II of the EU Habitats Directive and require strict protection, including the designation of Special Areas of Conservation by Member States. Harbour porpoise is also included in Appendix II of the Convention of Migratory Species (CMS), however it only covers populations in the North and Baltic Seas. Read *et al*. (2018) submitted a document to the 24th ASCOBANS Advisory Committee requesting that the Iberian harbour porpoise be i) listed as a separate population and ii) included in Appendix I and Appendix II of CMS, also that iii) the range of the harbour porpoise is extended to include the Northeast Atlantic on CMS Appendix II (the true species' range). The CMS 13th Conference of Parties (COP) in February 2020 adopted Concerted Action for Harbour Porpoise Baltic and Iberian populations.[2] Concerted Action (CA) includes activities implemented in a coordinated way in more than one country and implies a commitment of the proponents to undertake activities and the CMS COP and CMS Scientific Committee to oversee their implementation and give them legitimacy and visibility within a given timeframe.

A number of European and international agreements and directives require EU Member States to carry out monitoring of small cetaceans and develop measures to ensure that good conservation status is achieved and maintained, while mitigating effects of specific threats such as fishery bycatches (*e.g.*, EU Habitats Directive, EU Common Fisheries Policy including the Data Collection Framework (DCF) following the repeal of EC Regulation 812/2004, EU Marine Strategy Framework Directive (MSFD) and the Convention on Migratory Species and its daughter agreements: Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) and the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS)). However, implementation of marine mammal monitoring by Member States is patchy and the vast majority of current monitoring in the NWIP is conducted by two non-governmental organizations (NGOs) 'Coordinadora para o Estudio dos Mamiferos Mariños' (CEMMA) and the 'Sociedade Portuguesa de Vida Selvagem' (SPVS), in Galicia and Portugal, respectively.

The Iberian harbour porpoise population appears to be genetically distinct from harbour porpoises (*Phocoena phocoena*) in the rest of the European East Atlantic (Fontaine *et al*., 2007; 2010) and a new ecotype for Iberian porpoises, *Phocoena phocoena meridionalis* was proposed in 2014 by Fontaine *et al*. In 2009 the ICES Working Group on Marine Mammal Ecology recommended that the Iberian harbour porpoise is treated as a separate management unit and advised urgent action to monitor and ensure the conservation the population by the Spanish and Portuguese governments

[1] http://ec.europa.eu/fisheries/index_en.htm
[2] https://www.cms.int/en/document/proposal-concerted-action-harbour-porpoise-phocoena-phocoena

(ICES, 2009). As part of the requirements for monitoring of the MSFD, the Iberian harbour porpoise has been selected in Spain as a management unit to be used as indicator that the Good Environmental Status (GES) of marine waters is achieved (or maintained) (MAGRAMA, 2012).

In the 19th Century, porpoises were reported to be a common species in the NWIP, entering rías, rivers and estuaries in large groups (Bocage, 1863; Norbre, 1895, 1935; Sequeira, 1996). Several more recent surveys have recorded porpoise sightings from observers placed on fishing boats (Aguilar, 1997; López *et al*., 2004; Vingada *et al*., 2011; Goetz *et al*., 2015), boat-based opportunistic surveys (Spyrakos *et al.*, 2011) and coastal sightings (Pierce *et al.*, 2010) in the NWIP. Porpoise sightings have always been low (*e.g.*, 1.6 to 8.5% of total sightings). However, porpoises are notoriously easy to miss even in calm sea states partly due to their short surfacing interval and small size (Embling *et al*., 2010).

Harbour porpoises are generally found in waters of less than 30 m depth in Portugal (Sequeira, 1996) and although most sightings in Galicia are in coastal waters (López *et al.*, 2004; Pierce *et al.*, 2010), porpoises have been recorded in waters of up to around 150 m depth (Spyrakos *et al.*, 2011).

In Portugal, harbour porpoises are mostly sighted around Aveiro and Figueira da Foz (Sequeira, 1996; Vingada *et al*., 2011). Coastal sightings data from Galicia suggest that the highest abundances are found in the Ría de Pontevedra (Martínez *et al.*, 1995), near the Asturian and Portuguese borders and around Cape Finisterre, the most westerly point in Galicia (Pierce *et al*., 2010). These are all areas with high fishing activity.

Using mark-recapture line transect methods, the Small Cetacean Abundance in the European Atlantic and North Sea projects in 2005 (SCANS-II) and 2016 (SCANS-III) estimated the absolute abundance of harbour porpoises for the Iberian Peninsula ICES area to be 2357 (CV=0.92) and 2898 individuals (CV=0.32), respectively (Hammond *et al*., 2013; 2017). Although both SCANS surveys covered a larger area than our study area, they are the region's only existing estimates of absolute population size. In the 1990s, a decreasing trend in harbour porpoise sightings in Portugal and the northern Atlantic coast of Spain was observed (Pérez *et al*., 1990; Lens, 1997; Silva *et al*., 1999). Pérez *et al*. (1990) suggested that the range of porpoise within the NWIP has contracted and more recently analysis of genetic data signal a loss of genetic diversity which is indicative of a declining population (North Atlantic Marine Mammal Commission and the Norwegian Institute of Marine Research, 2020).

The NWIP has one of the highest rates of marine mammal strandings in Europe and, due to the high intensity of fishing activity, a high number of bycatches is reported (*e.g.*, Sequeira, 1996; López *et al*., 2002, 2003; Silva and Sequeira, 2003; Ferreira, 2007; Vingada *et al*., 2011; Goetz *et al*., 2014). Harbour porpoises make up 7% of strandings in Galicia (López *et al*., 2002) and 13% of strandings in central-north Portugal (Ferreira, 2007). During 1990-1999, 22% of harbour porpoise strandings in Galicia showed evidence of fisheries interactions (López *et al*., 2002), whilst in central-north Portugal, 58% of porpoise strandings between 2000-2005 showed evidence of fisheries interactions. Bycatches have continued to represent a high proportion of the stranded animals in both countries (CEMMA and SPVS, unpublished data)

ASCOBANS (1997) and the International Whaling Commission (IWC) (1995) respectively state that an anthropogenic removal of more than 1.7 or 2% of the best available population estimate, or more than half the net growth rate of a population, represents an '*unacceptable interaction*'. Based on available information (*e.g.*, López *et al.*, 2002, 2003; Ferreira, 2007), harbour porpoise bycatch in the NWIP is likely to substantially exceed these limits.

Successful conservation measures require a sound knowledge of population status (*e.g.*, Murphy *et al*., 2009). Monitoring of life-history traits (*e.g.*, age at sexual maturity, pregnancy rate) can provide important information on population status and as long as possible biases are accounted for, these data from stranded and by-caught cetaceans can be used to estimate overall mortality and fishery mortality rates.

The objectives of the present work are to:

1. Use age-at-death data to estimate total and fisheries mortality rate for porpoises in the NWIP
2. Examine trends in fisheries interactions of the Iberian harbour porpoise
3. Provide recommendations on conservation of the Iberian harbour porpoise.

Materials and Methods

Necropsies and sample collection

In the NWIP, monitoring of strandings is conducted by two non-governmental organizations (NGOs) 'Coordinadora para o Estudio dos Mamiferos Mariños' (CEMMA) in Galicia and the 'Sociedade Portuguesa de Vida Selvagem' (SPVS) in cooperation with the Instituto de Conservação da Natureza e Florestas, in north-central Portugal. The Galician and Portuguese stranding networks have been operational since 1990 and 2000, respectively. Over the study period, the stranding networks also received eight carcasses of by-caught porpoises from fishers.

All harbour porpoises were necropsied following the standard European Cetacean Society (ECS) necropsy protocol (Kuiken and Hartmann, 1991). Basic biometric data were recorded and in addition to samples for other studies, teeth and gonads were collected for life history analysis. Necropsies are generally conducted on the beach, therefore body mass is not measured. Teeth samples were stored in 70% alcohol and reproductive organs (ovaries and testes) were stored in 10% buffered formalin. Evidence of fisheries interactions were recorded for carcasses with a state of decomposition 2-3, in compliance with the ECS protocol for determining evidence of fisheries interactions (Kuiken, 1994). For the present project, causes of death were classified as follows:

1. known bycatch (carcass handed over by fishermen or observed being caught)
2. evidence of fisheries interactions
3. no evidence of fisheries interactions
4. undetermined

It should be noted that in the present study, when cause of death is mentioned, this only refers to in relation to fisheries interactions, no other causes of death have been established, except where stated.

Age estimation

Teeth were prepared following a revised methodology from Hohn and Lockyer (1995). Two teeth from each individual were rinsed in water and the gum tissue was removed. The teeth were stored in water for 24 hours to rehydrate before being fixed in formalin for 24 hours and then thoroughly rinsed in water. Using the commercial decalcifying agent *Rapid Decalcifier* (RDO©), teeth were decalcified until slightly pliable. Decalficied teeth were then rinsed thoroughly in water for at least 8 hours. Sections of 25 µm thickness were cut using a cryostat set at -12°C. From each individual, one tooth was sectioned parallel to the mandible (the 'porpoise cut') and the second was sectioned perpendicular to the mandible (the 'dolphin cut'). Sections were stained with Mayer's haematoxylin using the formula in Myrick *et al*. (1983) and 'blued' in a weak ammonia solution. The most central sections (those cut through the centre point of the pulp cavity and crown) were selected, mounted on glass slides and sealed to the slide using the mounting medium DPX.

Using a binocular microscope (x10-50 magnification), age was estimated by counting the growth layer groups (GLGs) in the dentine of the tooth sections. All ages were estimated by two independent readers without reference to biological data. Age was estimated to the nearest 0.5 year interval for animals under 2 years and to the nearest year for animals over 2 years old. If the two readers estimated age differed by more than 1 year, the readings were repeated. For difficult teeth (*e.g.*, teeth with ambiguous increments), both readers discussed the readings and either reached an agreed age or classified the tooth to be unreadable. Porpoises for which no age could be estimated or the age estimated was considered to be questionable were excluded from further analysis.

For some of the analysis porpoises were put into sub-groups based on age-at-death data: < 1, 1 to 5, 6-10 and ≥ 11 years old.

Female reproductive status

During the necropsy, females were examined for evidence of pregnancy and/or lactation. For pregnant porpoises, the length and sex of the foetus was recorded. Formalin-fixed ovaries were weighed and examined externally for the presence of *corpora lutea* (CL) and *corpora albicantia* (CA) using a magnification lamp. The ovaries were sectioned at 1-2 mm intervals along the broad ligament and examined internally. Individual reproductive status and history was determined based on the presence CL and CA. For the present study, females were classified as 1) immature (no *corpus*) and 2) mature (if the ovaries contained at least one *corpus*).

Male reproductive status

Testes with attached epididymis were weighed and measured. A central cross-section of each testis was fixed in formalin. Following a standard histological method, the sections were trimmed and paraffin-embedded. Sections were cut at 5-8 µm and stained with Mayer's haematoxylin and eosin. The diameter of seminiferous tubules and cell activity (sertoli cells, interstitial tissue, and germinal cells such as spermatogonia, spermatocytes, spermatids and spermatozoa) were investigated microscopically to determine the maturity status of individuals. Males were classified as 1) immature (seminiferous tubule diameters were < 68.50 µm) and 2) mature (seminiferous tubule diameter measurements were > 93.00 µm (Read, 2016).

Data analysis

Following Zuur *et al*. (2010), all data series were explored for outliers, collinearity, interactions, etc.

For all porpoises with a cause of death established (*e.g.*, porpoises classified as bycaught and non-bycaught) a Chi-squared test was used to see if the sex ratio of the harbour porpoises differed from the ratio 1:1 (females:males). Further Chi-square tests were performed to investigate if the frequency of strandings (with a cause of death) changed over time, annually for 1990-1999 (when only CEMMA was operational) and 2000-2010 (when CEMMA and SPVS were operational). The frequencies of bycaught and non-bycaught porpoises from different time periods (1990-95, 1996-2000, 2001-05 and 2006-10), seasons, sexes, and age and maturity classes were also investigated.

Where possible, the fishing gear and number of animals involved in the interaction were identified. Evidence of fisheries interactions was classified as:

1. No evidence of fisheries interactions
2. Incomplete carcass (but missing parts not specified)
3. Missing beak
4. Missing tail fluke
5. Missing head
6. Missing fin(s)
7. Missing flanks
8. Cuts or marks from fishing gear
9. Gear present on animal
10. Other evidence

Life tables and estimated mortality rate

Age data were used to construct life tables and survivorship curves. The methodology largely follows the non-parametric Kaplan-Meier approach to estimating survivorship (see Krebs (1989) for a full description). In order to examine possible differences in survivorship, life tables were created separately for by-caught and non by-caught porpoises. The reliability/survivorship routines in *Minitab* (Minitab Inc.) were used for statistical comparison of survivorship in the different sub-sets of data, based on log-rank and Wilcoxon tests.

Results

Strandings and bycatches

Between 1990 and 2010 a total of 305 harbour porpoises were recorded as stranded in the NWIP and eight porpoise carcases were known bycatches (handed in by fishermen or observed being bycaught). A further three porpoises were reported as being bycaught and released alive. Due to the small number of known by-caught porpoises, for further analysis on fisheries interactions porpoises by-caught (excluding the live released animals) and porpoises with evidence of fisheries interactions have been grouped together except where specified and classified as ‘bycaught’ and ‘non-bycaught’. Table 1 gives an overview of the sample composition of porpoises.

Table 1. Sample composition and data available for stranded and bycaught harbour porpoises from the North-west Iberian Peninsula (1990-2010).

Sample	**Females**	**Males**	**Unknown sex**	**Total**
All stranded & bycaught porpoises	127	139	47	313
Known bycatch	3	5	-	8
Evidence of fisheries interactions	33	35	3	71
No evidence of fisheries interactions	28	23	2	53
Undetermined	9	15	11	35
Autolysed	54	61	31	146

Known bycatch

Over the study period, eleven porpoises were reported by fishermen as being bycaught in fishing gears and three of these were released alive. The known bycaught animals were five males, four females and two of undetermined sex. Two animals were caught in bottom-set gillnets in Spain and six animals (including two mother and calf pairs) were caught in beach seines in Portugal. With the exception of the two adult females assumed to be the mothers of the calves they were bycaught with, the other known bycaught porpoises were immature based on either analysis of the gonads (n = 2) and/or body length (n = 7). See Table 2 for an overview of known bycaught porpoises.

Trends in strandings of bycaught and non-bycaught porpoises

Porpoises with an advanced state of autolysis (n = 146) and evidence of fisheries interactions classified as undetermined (n = 35) were excluded from analysis of strandings. There was no significant difference in the proportion variation in number of porpoises reported as strandings (including known bycaught animals) between 1990-1999 (Chi-squared test, X^2 = 14.083, DF = 9, P = 0.119) or 2000-2010 (Chi-squared test, X^2 = 13.167, DF = 10, P = 0.215).

The sex ratio of bycaught and non-bycaught porpoises was 1:1.11 females to males, which is not significantly different from 1:1 (Chi-squared test, X^2 = 0.211, DF = 1, P = 0.646).

When the years were grouped (1990-95, 1996-2000, 2001-05 and 2006-10), there was significant variation in the proportion bycaught and non-bycaught porpoises (Chi-squared test, X^2 = 12.248, DF = 3, P = 0.007). More porpoises were classified as bycaught (*i.e.*, had evidence of fisheries interactions) in more recent years (Figure 2). There was no difference in the proportion of bycaught and non-bycaught porpoises seasonally (Chi-squared test, X^2 = 5.487, DF = 3, P = 0.139).

Table 2. Known by-caught animals either observing being bycaught or handed over by the fishermen

Country of capture	Area of capture	Date	Body length (cm)	Sex	Age (years)	Maturity status	Gear type	Comments
Spain	Sanxenxo	12/12/1991	155	F	-	-	Bottom-set gillnet	Caught at approx. 79 m depth. Auctioned in Portonovo for 700 pesetas (approx. 4€)
Spain	Vigo	24/08/1995	130	M	-	-	-	
Spain	Cangas	23/06/1999	125	M	0	Immature	-	
Spain	Sanxenxo	22/06/1999	155	M	3	-	-	Net marks on carcase
Portugal	Mira	13/09/2000	182	F	-	Mature	Beach seine	Mother of mother and calf pair
Portugal	Mira	13/09/2000	116	M	0	Immature	Beach seine	Calf of mother and calf pair
Portugal	Cantanhede	23/08/2002	-	-	-	-	Beach seine	Released alive
Portugal	Mira	19/10/2002	-	F	-	Mature	Beach seine	Mother of mother and calf pair. Released alive
Portugal	Mira	19/10/2002	-	-	0	Immature	Beach seine	Calf of mother and calf pair. Released alive
Portugal	Figueira da Foz	13/07/2004	156	F	3	Immature	Beach seine	
Spain	Vigo	12/02/2009	146	M	2	-	Bottom-set gillnet	

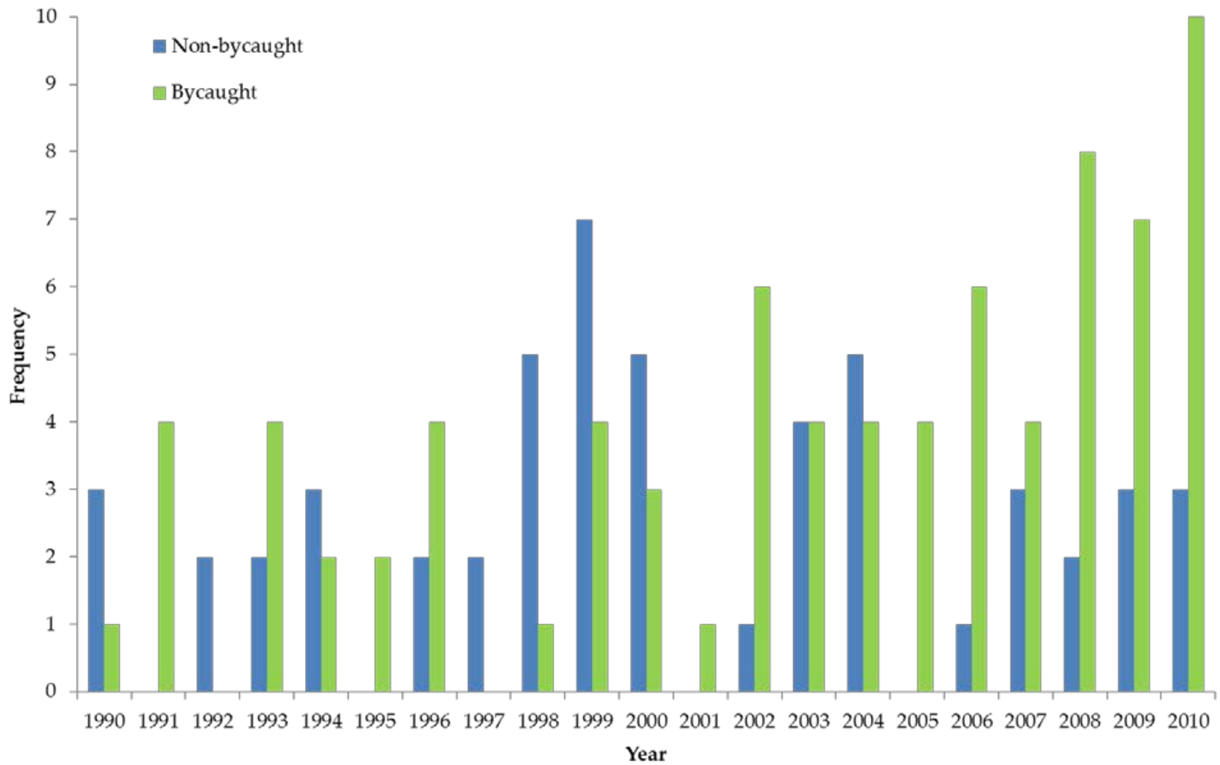


Figure 2. The annual frequency of bycaught and non-bycaught harbour porpoises in the North-West Iberian Peninsula.

Age was estimated for 151 harbour porpoises, 71 females, 77 males and 3 of undetermined sex. Age estimates ranged from 0-18 years old for females and 0-19 years old for males. The three animals of undetermined sex were aged 3, 15 and 21 years old. Age was estimated for 44 females and 44 males with cause of death established, of which 26 females and 29 males were diagnosed as dying due to fisheries interactions. There was no significant difference in the age structure of bycaught and non-bycaught porpoises (Chi-squared test, $X^2 = 4.487$, DF = 3, $P = 0.213$) and males and females were equally likely to be bycaught (Chi-squared test, $X^2 = 4.159$, DF = 3, $P = 0.245$).

Maturity status was obtained for 41 females and 33 male harbour porpoises with cause of death established. Immature ($n = 52$) and mature animals ($n = 22$) were equally likely to be bycaught (Chi-squared test, $X^2 = 0.019$, DF = 1, $P = 0.891$).

There was no significant difference in the age structure of porpoises bycaught in gillnets ($n = 16$) and beach seines ($n = 17$) (Chi-squared test, $X^2 = 2.972$, DF = 1, $P = 0.085$) and immature ($n = 24$) and mature animals ($n = 9$) were equally likely to be bycaught in both gears, although the difference was only marginally significant (Chi-squared test, $X^2 = 3.557$, DF = 1, $P = 0.059$).

Based on applying life table methodology to age-at-death data for all porpoises ($n = 151$), there is an estimated annual mortality rate of 18% for the population. Using only animals classified as bycaught or non-bycaught ($n = 88$), there is an estimated annual mortality rate of 19.7%. When age-at-death were examined separately, the estimated annual mortality rates were 17.5% for bycaught porpoises ($n = 55$) and 24.8% for non-bycaught porpoises ($n = 33$) (Figure 3). The difference in survivorship between bycaught and non-bycaught porpoises was marginally significant (Wilcoxon signed-ranks test, log rank test, $P = 0.088$; Wilcoxon test, $P = 0.037$).

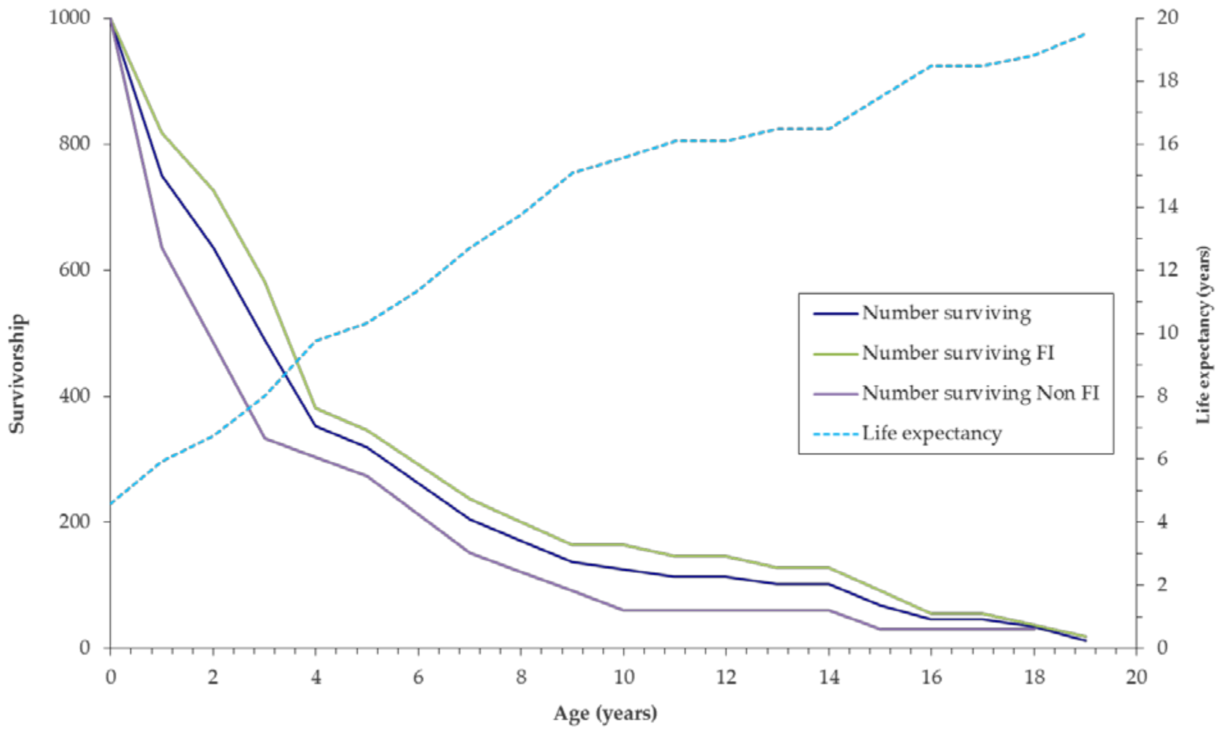


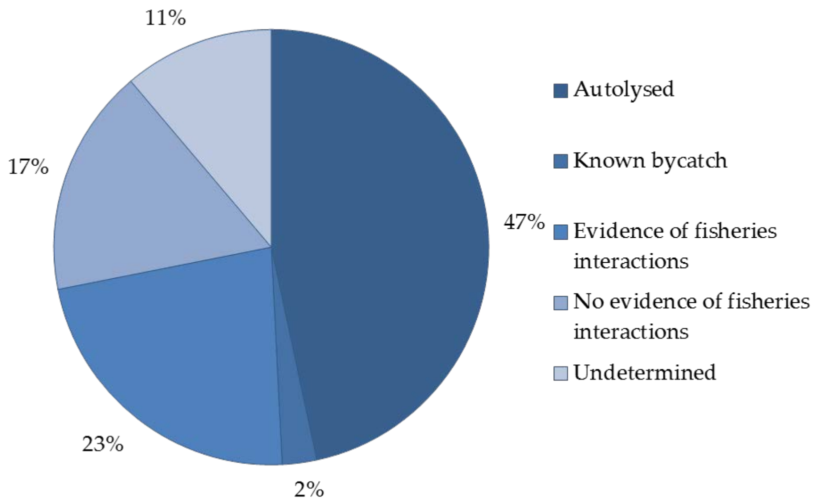
Figure 3. Survivorship curve for all harbour porpoises stranded in the North-West Iberian Peninsula between 1990-2010 and the associated life expectancy, also showing separate survivorship curves for bycaught and non-bycaught animals.

Causes of mortality and importance of fisheries interactions

As mentioned previously, 313 porpoises were stranded or bycaught in the NWIP between 1990 and 2010. Autolysed porpoises contributed 47% (n = 146) of the sample and undetermined cause of death 11% (n = 35). Evidence of fisheries interactions was determined for 23% (n = 71), 2% were known to have been bycaught (n = 8) and a further 17% of porpoises (n = 53) had no evidence of fisheries interactions (Figure 4a).

When only porpoises with a cause of death determined were included in the analysis (n = 132), 54% (n = 71) of porpoises had evidence of fisheries interactions, 6% (n = 8) were known bycatch and 40% (n = 53) had no evidence of fisheries interactions (Figure 4b).

a)



b)

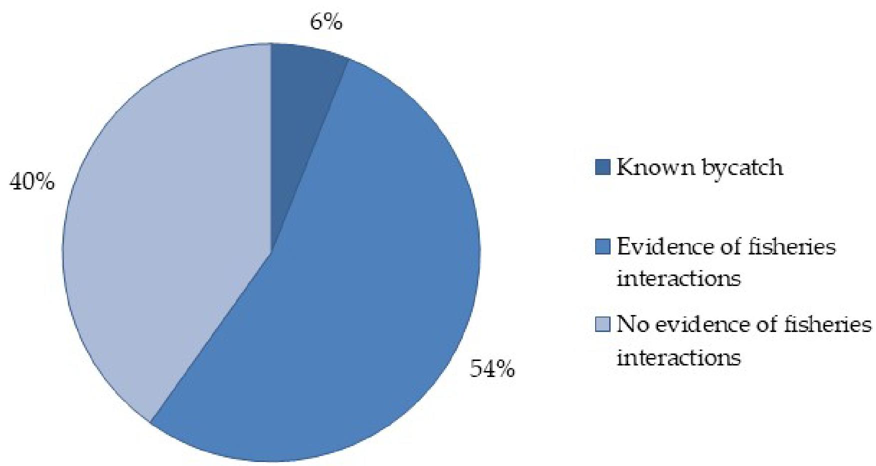


Figure 4. Overview of the frequency different causes of death fora) all harbour porpoises stranded and bycaught in the North-West Iberian Peninsula, and b) harbour porpoises with a cause of death determined (based on fisheries interactions only).

Cause of death due to fisheries interactions could be determined for around 40% of harbour porpoise strandings (including known bycaught animals) in the NWIP. When the countries were analysed separately (see Table 3a for an overview), and porpoises with a fresh-mild state of decomposition but undetermined cause of death were included in the analysis, 35% (*n* = 32) and 63% (*n* = 47) of porpoises in Galicia and Portugal were diagnosed with evidence of fisheries interactions (including known bycaught animals), respectively (Table 3b). Excluding porpoises with an undermined cause of death, 40% (*n* = 32) of porpoises in Galicia and 91% (*n* = 47) in Portugal were diagnosed to have died due to fisheries interactions (excluding porpoises with an advanced state of decomposition and undetermined cause of death) (Table 3c). Overall for the NWIP, around 60% of harbour porpoise mortality is attributed to fisheries interactions. Therefore, if we assume unbiased sampling, 18% (annual mortality rate) × 60% (fisheries interactions) = 11% of the Iberian harbour porpoise population dies annually due to fisheries interactions. If we assume that none of the undiagnosed deaths were due to bycatch, the mortality rate due to fisheries interactions is 4.3% (18% x 60% x 40% = 4.32%).

Table 3a. Classification based on determined cause of death (CoD) for all stranded and bycaught harbour porpoises from the North-West Iberian Peninsula by country (1990-2010).

Sample	**Galicia (*n*)**	**Galicia (%)**	**Portugal (*n*)**	**Portugal (%)**	**Total**
All stranded & bycaught porpoises	213	-	100	-	313
Known bycatch	5	2	3	3	8
Evidence of fisheries interactions	27	13	44	44	71
No evidence of fisheries interactions	48	22	5	5	53
Undetermined	12	6	23	23	35
Autolysed	121	57	25	25	146

Table 3b. Classification based on cause of death (CoD) for stranded and bycaught harbour porpoises (excluding autolysed animals).

Sample	**Galicia (*n*)**	**Galicia (%)**	**Portugal (*n*)**	**Portugal (%)**	**Total**
All porpoises with cause of death	92	-	75	-	167
Known bycatch	5	6	3	4	8
Evidence of fisheries interactions	27	29	44	59	71
No evidence of fisheries interactions	48	52	5	7	53
Undetermined	12	13	23	30	35

Table 3c. Classification based on cause of death (CoD) for stranded and bycaught harbour porpoises (excluding autolysed and animals with undetermined CoD).

Sample	**Galicia (*n*)**	**Galicia (%)**	**Portugal (*n*)**	**Portugal (%)**	**Total**
All porpoises with cause of death	80	-	52	-	132
Known bycatch	5	6	3	6	8
Evidence of fisheries interactions	27	34	44	85	71
No evidence of fisheries interactions	48	60	5	9	53

For the porpoises diagnosed of dying due to bycatch, 27% (*n* = 21) were due to interactions with gillnets, 24% (*n* = 19) due to interactions with beach seines and for 49% (*n* = 39) the gear was unknown, including two, three and three porpoises known to be bycaught in gillnets, beach seines and unknown gear, respectively.

Data on the evidence of fisheries interactions *e.g.*, missing fins, marks on the carcase, etc. were only available for porpoises from Galicia (*n* = 32). Five porpoises were known to be bycaught, two in gillnets and three in unknown gear. However, only two porpoises had evidence of fisheries interactions, one from a gillnet and the other from an unknown gear, and both had cuts and marks from the net. All porpoises thought to have been bycaught in gillnets (*n* = 5) showed evidence of fisheries interactions, mainly missing fins (*n* = 4). The majority of porpoises diagnosed as dying due to fisheries interactions but for which the gear was not known (*n* = 22) showed evidence of fisheries interactions (*n* = 19).

Discussion

Strandings data

Data from strandings is subject to possible biases, including the fate of animals that die at sea and if strandings are representative of the living population. The proportion of carcases that strand on the coast will be relatively small and biased towards animals dying near the coast (Peltier *et al*., 2012), and that there will be some northwards movement related to the seasonal upwelling system and prevailing currents in the study area. Ideally, modelling of carcass drift is needed to interpret spatial trends in bycatch and strandings in the NWIP especially given the likelihood of transport between countries because it is thought that due to the oceanography of the area, some of the porpoise strandings in Galicia are bycaught in Portugal. Another difficult to quantify source of bias is the efficacy of the programme for detection and reporting of carcases and whether this has changed over time. Usually, reporting and data collection improve after the first few years of a strandings scheme. In spite of these possible biases, the importance of data from strandings should not be underestimated as it potentially offers a real understanding into the nature and underlying causes of trends in population status (see Peltier and Ridoux, 2015). In addition, the use of strandings information is a relatively low cost monitoring tool when compared to boat surveys and the cost of on-board observers.

High inter-annual variation in the total number of porpoise strandings, as well as the number of porpoises classified as dying due to fisheries interactions was observed over the study period (Read, 2016). Whilst it is true that the strandings schemes in the NWIP have increased reporting and awareness from the early years when they were established in 1990 and 2000, CEMMA and SPVS do their upmost to attend as many strandings that are reported as possible. Therefore, the high annual variation cannot be explained by improved reporting alone.

The seasonal upwelling system in the NWIP means that superficial waters are driven westwards and downwards and carcases are likely to be taken offshore during summer months. However, there was no seasonal variation in the number of porpoises bycaught in the NWIP (Read, 2016). The lack of seasonal trends in the number of porpoises bycaught could be due to porpoises interacting with fisheries than are active all year round, *e.g.*, beach seines and certain gillnets or seasonal shifts in porpoise distribution and abundance in the area masking the seasonal signal.

No age- or sex-related trends were observed for bycaught porpoises in the NWIP and the proportion of immature and mature animals bycaught was not significantly different. However, it appears that immature porpoises are much more likely to be bycaught that mature porpoises. For animals where the gear was determined, 65% of porpoises bycaught in gillnets and 81% of porpoises bycaught in beach seines were immature. Sex and age segregation has been proposed to exist for harbour porpoises. Harbour porpoises are generally observed in solitary or in small groups of less than five animals (Silva *et al*., 1999) and bycatch events in gillnets generally only involves a single animal (Carlström *et al*., 2002). This potentially means that all animals have the same probability of being bycaught.

Known bycatch, evidence of fisheries interactions and cause of death

Gillnets and beach seines both have high rates of mortality. Based on interviews with fishery stakeholders in Portugal, 94% of cetaceans bycaught in beach seines and 88% in bycaught in gillnets died as a consequence of the interaction (Vingada *et al*., 2011). Four porpoises were reported by fishermen to be caught in beach seines and released alive, including a mother and calf pair. However, there is no way of knowing if these animals survived the interaction.

The small Iberian harbour porpoise population is particularly vulnerable since individuals live in heavily fished areas (Sequeira, 1996) and are frequently observed, often foraging, close to fishing nets (Silva *et al*., 1999; Goetz *et al*., 2015). Carcasses are rarely handed-in by fishermen, over the 21-year study period, only 8 porpoises were handed in for post-mortem. Sequeira and Ferreira (1994) and Silva and Sequeira (2003) both noted that fishermen almost ceased reporting by-catches in 1981 when a new law came into force in Portugal making killing cetaceans illegal. In Galicia, between 1998 and 1999, López *et al*. (2003) carried out a carcass recovery scheme but only 17 carcasses were recovered, including two porpoises, (around two orders of magnitude less than the number of cetaceans estimated to have been caught from interview data).

Sequeira and Inacio (1992) reported that many harbour porpoises found dead ashore had netting marks around their head and flippers. In the present study, data was not available for Portugal but the majority of porpoises diagnosed as bycaught in Galicia had evidence of fisheries interactions, mainly net marks and amputated body parts *e.g.*, fins/tail/head. Categorising porpoises as bycaught or non-bycaught based on such evidence can either over estimated interactions if sick animals were bycaught or animals with evidence from previous fisheries interactions, survived and died due to another cause. However, fisheries interactions maybe also be underestimated if the carcass shows no evidence of interactions as was the case in around 14% of porpoises in the present study.

Six females classified as dying due to fisheries interactions were pregnant and a further two were lactating, including two pregnant and one lactating female that were bycaught in beach seines. The gear was not identified for the other animals. When a lactating female is bycaught, the calf or dependent juvenile (even if not bycaught with the mother) is a secondary victim (Noren and Edwards, 2007). It is thought that females accompanied by calves are associated more with shallower waters (Kinze, 1994), therefore increasing their risk of bycaught in areas with high coastal activities of fisheries as is seen in the NWIP.

In the present study, over 45% of harbour porpoise strandings were significantly decomposed, meaning that our sample size was limited. When only stranded animals with a diagnosed cause of death were included, 60% of harbour porpoises in the NWIP had evidence of dying due to fisheries interactions. When the areas were analysed separately, there was however an apparent area difference: over 40% of porpoise strandings in Galicia had indications of fisheries interactions, compared to 90% in central-north Portugal. Both of these percentages are notably higher than previously reported by López *et al*. (2002) and (Ferreira, 2007). Although these figures clearly suggest that bycatch could be an increasing problem, some care in interpretation is required because methods for diagnosing bycatches have been refined over the years and the improved efficiency of the strandings networks means that more carcases are reported and examined while still relatively fresh than in former times. The considerably higher rate of bycatch in Portugal is concerning nonetheless. Whether this is a reflection of sampling effort, differences in necropsy procedures or that more animals are sampled whilst fresh needs to be investigated.

It should be noted when interpreting the temporal trends in bycatch that estimated rates of bycatch are not necessarily calculated using the same method in the present and previous studies. In the present study, animals with a state of autolysed ≥4 (following the criteria of Kuiken (1994)) were eliminated from the analysis because evidence of bycatch cannot be identified consistently, *e.g.*, twine marks on the skin might not be detected. Porpoises that had a cause of death classified as 'undetermined' were also eliminated. Therefore, only fresh and mildly decomposed animals with evidence (or no evidence) of bycatch determined and known bycaught animals were included. This may potentially give a higher percentage of bycatch rates, but as long as the methods are consistent this should not be an issue.

A possible reason for the higher recorded bycatch rate in Portugal is the continued use of beach seines. Beach seines are commonly used in north-central Portugal and are often up to 5 km long. They are an unselective gear with a mesh size similar to that of a pelagic trawl. Beach seines are illegal in most other European countries and their use stopped in Galicia over 50 years ago. A study on fisheries interactions in Portugal in the 1990s found no porpoises to be bycaught in beach seines (Sequeira, 1996). However, five individuals were observed to be bycaught in a single beach seine in 2007 (SPVS, unpublished data) and they are one of the gears to which harbour porpoises are most vulnerable (Silva *et al*., 1999; Ferreira, 2007; Vingada *et al*., 2011). Beach seines are most commonly used in Aveiro and Figueira da Foz, coinciding with the area of highest harbour porpoise abundance in Portugal (Sequeira, 1996; Vingada *et al*., 2011). Gillnets are one of the gears with the highest porpoise bycatch rate in the NWIP (Sequeira and Inacio, 1992; Silva, 1996; López and Valeiras, 1997; Silva *et al*., 1999; López *et al*., 2003; Silva and Sequeira, 2003; Vingada *et al*., 2011; Goetz *et al*., 2014). Commercially exploited fish species such as hake, scad, blue whiting and sardine are a major part of the diet of harbour porpoises in the NWIP (Read *et al*., 2013). As a consequence of the feeding habits of porpoises, interactions with fisheries, not only bycatch but also prey depletion, could put the porpoise population at risk.

Bycatch is apparently a significant cause of death for porpoises in the NWIP. Although caution is obviously needed in interpretation, the figure of 18% mortality derived from the strandings data seems to be a plausible figure for annual mortality rate. A high proportion of stranded animals died from bycatch and, taken together, the two figures suggest that the rate of bycatch mortality is unacceptably high. By comparison, in Scotland, fishery bycatch is a relatively minor cause of porpoise deaths when compared to death due to diseases and parasites, starvation and condition loss and attack by bottlenose dolphins (*Tursiops truncatus*) (Learmonth *et al*., 2014).

Goetz *et al*. (2014) estimated that around 40 harbour porpoises died as a result of bycatch in Galicia, mainly in gillnets. Assuming a population size of 2400 individuals, i.e. the SCANS-II estimate for Block W (the 2016 estimate was closer to 3000; Hammond *et al*., 2013, 2017), just 40 porpoises bycaught would be the equivalent of 1.6% of the population. This figure excludes any bycatch in Portugal. Based on results of the life table, 11% of annual mortality was attributed to fisheries interactions when a cause of death was determined. Including porpoises with an undetermined cause of death, a minimum of 4.3% annual mortality is due to fisheries interactions. Survivorship was higher in bycaught animals, probably because few age-zero animals are bycaught. Years with strandings under sampled or years when strandings are not sampling randomly, *e.g.*, young animals are not sampled, biased in the morality rate will occur.

Whilst the use of life tables has biases associated with the data, *e.g.*, age-at-death data used for life tables is assumed to be representative of mortalities in the living population and that the population is stable; nonetheless, these values for by-catch mortality greatly exceed the recommended 1.7 to 2% annual mortality due to anthropogenic caused recommended by the IWC and ASCOBANS. Scheidat *et al*. (2013) raised concerns over the use of setting limits based on fixed percentages of best estimates and suggested that their use should be limited to either a short term pragmatic approach or as an approach that is easy to explain to stakeholders. The high mortality rate and low reproductive output of population means that the pregnancy rate is unlikely to balance mortality for Iberian harbour porpoises (Read, 2016), which combined with the bycatch of pregnant and lactating females, suggests that bycatch mortality could threaten the viability of the population.

Conclusions

The small resident population size, low longevity, low reproductive output of harbour porpoises in the NWIP (Read, 2016) and apparent high bycatch rate. Thus, despite the apparent stability in population size suggested by surveys in 2005 and 2016, this separate population is likely to be at risk and conservation actions are needed.

The beach seine, whilst problematic in central and north Portugal for porpoises, is a historic fishing gear than the fisheries sector is keen to keep in operation. While eliminating fisheries interactions and bycatch of harbour porpoises in the NWIP is unlikely to be realistic, given the social and economic importance of the fishing industry, there is a need to explore ways to reduce bycatch. Thus, a reduction in the use of beach seines or restricting their use to areas with lower densities of harbour porpoises is potentially achievable. Time-area closures for problematic gears, *e.g.*, limiting the use of gillnets during the reproductive season, could also be effective in reducing bycatch.

In recent years several marine mammal-fisheries interactions ‘feed-back’ projects have been conducted in the NWIP *e.g.*, LIFE-INDEMARES and DIVULGANDO A PE DE MAR projects in Galicia and SAFESEA and MARPRO in Portugal. These projects have worked in collaboration with the fisheries sector, with the aim to improve environmental education and awareness of fisheries stakeholders whilst emphasising the scientific importance of by-caught samples. The projects have promoted the collaboration of scientists, fishermen and other stakeholders to devise ways to reduce/avoid interactions.

Improved collaboration with fisheries stakeholders for collection of carcasses from known gears and areas etc. would improve present knowledge of where interactions are occurring, the gears (or vessels) with the most interactions, the depth at which the interactions occur, and at what point during operation, e.g., when the gear is set or hauled, as well as when the interaction occurs e.g., if time of day is influential.

Acknowledgements

We thank the staff and volunteers of the Galician and Portuguese stranding networks CEMMA and SPVS for assistance with sample collection, also Jóse Manuel Antonio Durán for his assistance processing the histology samples and Ángel F. González for acting as the second reader for the age estimates. This work was part-funded by ASCOBANS (SSFA/ASCOBANS/2010/4) and EC projects MEST-CT-2005-020501and MEXC-CT-2006-042337.

References

Aguilar, A. 1997. Inventario de los cetáceos de las aguas atlánticas peninsulares: aplicación de la directiva 92/43/CEE. Memorial Final. Departamento de Biología Animal (Vert.), Facultad de Biología, Universitat de Barcelona, Spain. In Spanish.

ASCOBANS, 1997. Report of the second meeting of parties to ASCOBANS, 17-19 November 1997, Bonn, Germany. 67 pp.

Bocage, J.V.B. 1863. Liste des mammifères et reptiles observés en Portugal. Revue et Magasin de Zoologie 15: 329-333. In French.

Cabral, J., Almeida, J., Almeida, P., Dellinger, T., Ferrand, A., Oliveira, M., Palmeirim, J., Queiroz, A.I., Rogado, L. And Santos-Reis, M. (editors). 2005. Livro Vermelho dos Vertebrados de Portugal Instituto da Conservação da Natureza e Biodiversidade. Lisbon. 660pp. In Portuguese.

Calström, J., Berggren, P., Dinnétz, F. and Börjesson, P. 2002. A field experiment using acoustic alarms (pingers) to reduce harbour porpoise by-catch in bottom-set gillnets. ICES Journal of Marine Science 59: 816-824.

Embling, C.B., Gillibrand, P.A., Gordon, J., Shrimpton, J., Stevick, P.S. and P.S. Hammond. 2010. Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (*Phocoena phocoena*). Biological Conservation 143: 267-279.

Fariña, A.C., Pereiro, F.J. and Fernández, A. 1985. Peces de los fondos de arrastre de l plataforma continental de Galicia. Boletín del Instituto Español de Oceanografía 2: 89-98. In Spanish.

Fernández de la Cigoña, E. 1990. Os cabaleiros do mar: baleas e golfiños das nosas augas. Guía dos cetáceos de Galicia e Iberia. Serie Natureza Galega - Tomo III. Asociación Galega para a Cultura e a Ecoloxía (AGCE), Vigo. 162 pp. In Galician.

Ferreira, M. 2007. Ocorrência e captura acidental de cetáceos no Centro/Norte de Portugal. Master thesis, Escola de Ciências, Universidade do Minho, Portugal. 92 pp. In Portuguese.

Fontaine, M.C., Baird, S.J., Piry, S., Ray, N., Tolley, K.A., Duke, S., Burkun, A.Jr., Ferreira, M., Jauniaux, T., Llavona, A., Ozturk, B., Ozturk, A.A., Ridoux, V., Rogan, E., Sequeira, M., Siebert, U., Vikingsson, G.A., Bouquegneau, J.M. and Michaux, J.R. 2007. Rise of oceanographic barriers in continuous populations of a cetacean: the genetic structure of harbour porpoises in Old World waters. BMC Biology 5: 1-16.

Fontaine, M.C., Tolley, K.A., Michaux, J.R., Birkun, A., Ferreira, M., Jauniaux, T., Llavona, Á., Öztürk, B., Oztürk, A.A., Ridoux, V., Rogan, E., Sequeira, M., Bouquegneau, J.M. and Baird, S.J.E. 2010**.** Genetic and historic evidence for climate-driven population fragmentation in a top cetacean predator: the harbour porpoise in European water. Proceedings of the Royal Society B: Biological Sciences 277: 2829–2837.

Fontaine, M.C., Roland, K., Calves, I., Austerlitz, F., Palstra, F.P., Tolley, K.A., Ryan, S., Ferreira, M., Jauniaux, T., Llavona, Á., Öztürk, B., Oztürk, A.A., Ridoux, V., Rogan, E., Sequeira, M., Siebert, U., Vikingsson, G.A., Borrell, A., Michaux, J.R. and Aguilar, A. 2014. Postglacial climate changes and rise of three ecotypes of harbor porpoises (*Phocoena phocoena*) in western Palearctic waters. Molecular Ecology 23: 3306–3321.

Fraga, F. 1981. Upwelling off the Galician coast, Northwest Spain. In: Richards, F.A. (editor). Coastal Upwelling, American Geophysical Union, Washington DC. pp 176-182.

Goetz, S., Read, F.L., Santos M.B., Pita, C. and Pierce, G.J. 2014. Cetacean-fishery interactions in Galicia (NW Spain): results and management implications of a face-to-face interview survey of local fishers. ICES Journal Marine Science 71: 604-617.

Goetz, S., Read, F.L., Ferreira, M., Portela, J., Santos, M.B., Vingada, J., Siebert, U., Marçalo, A., Santos, J., Araujo, H., Monteiro, S., Caldas, M., Riera, M. and Pierce, G.J. 2015. Cetacean occurrence, habitat preferences and potential for cetacean-fishery interactions in Iberian Atlantic waters: results from a cooperative research involving local stakeholders. Aquatic Conservation: Marine and Freshwater Ecosystems 25: 138-154.

Guerra, A. 1992. Mollusca: Cephalopoda. In: Ramos, M.A., Alba, J., Bellés, X., Gosálvez, J., Guerra, A., Macpherson, E., Martin, F., Serrano J. and Templado, J. (editors). Fauna Ibérica, Vol. 1, Museo Nacional de Ciencias Naturales (CSIC), Madrid. 327 pp. In Spanish.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S. and Wilson, B. 2008. *Phocoena phocoena*. In: IUCN 2008. 2008 IUCN Red List of Threatened Species.

Hammond P.S., Lacey C., Gilles A., Viquerat S., Börjesson P., Herr H., Macleod K., Ridoux V., Santos M.B., Scheidat M., Teilmann J., Vingada J. & Øien N., 2017. Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Available at https://synergy.st-andrews.ac.uk/scans3/files/2017/04/SCANS-III-design-based-estimates-2017-04-28-final.pdf

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, M.L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Øien, N., Paxton, C.G.M., Ridoux, V., Rogan, E., Samarra, F., Scheidat, M., Sequeira, M., Siebert, U., Skov, H., Swift, R., Tasker, M.L., Teilmann, J., Van Canneyt, O. and Vázquez, J.A. 2013. Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164: 107–122.

Hohn, A.A. and Lockyer, C. 1995. Protocol for obtaining age estimates from harbour porpoise teeth. Reports of the International Whaling Commission Special Issue 16: 494-496.

ICES Advisory Committee. ICES Working Group on Marine Mammal Ecology (WGMME) REPORT 2009. February 2–6 2009, Vigo, Spain. ICES CM 2009/ACOM:21.

International Whaling Commission (IWC). 1995. Report of the scientific committee. Annex G. Report of the Sub-Committee on Small Cetaceans. Report of the International Whaling Commission 45: 165-186.

Kinze, C.C. 1994. Incidental catch of harbour porpoises (*Phocoena phocoena*) in Danish waters, 1986–1989. In: Perrin, W.F., Donovan, G.P. and Barlow, J. (editors). Gillnets and Cetaceans, Special Issue 15, International Whaling Commission, Cambridge. pp 183–187.

Krebs, C.J. 1989. Ecological methodology. Harper Collins Publishers, New York. 654 pp.

Kuiken, T. 1994. Diagnosis of by-catch in cetaceans. In: Kuiken, T. (editor). Proceedings of the Second ECS Workshop on Cetacean Pathology, Montpellier, France. pp 38-43.

Kuiken, T. and Hartmann, M.G. 1991. Cetacean pathology: dissection techniques and tissue sampling. Proceedings of the First European Cetacean Society Workshop on Cetacean Pathology: Dissection Techniques and Tissue Sampling, Leiden, the Netherlands. 35 pp.

Learmonth, J.A., Murphy, S., Luque, P.L., Reid, R.J., Patterson, A.P., Brownlow, A., Ross, H.M., Barley, J.P., Santos, M.B. and Pierce, G.J. Life history parameters of harbour porpoises (*Phocoena phocoena*) in Scottish waters. Marine Mammal Science 30: 1427-1455.

Lens, S. 1997. A note on the harbour porpoise (*Phocoena phocoena*) in the coastal waters of Spain. Report of the International Whaling Commission 47: 841-847.

López A, and Valeiras, X. 1997. Cause of mortality and suspected by-catches by gross post-mortem examination of cetacean strandings on the Galician coast (NW Spain). European Research on Cetaceans 11: 42-44.

López, A., Santos, M.B., Pierce, G.J., Gonzalez, A.F., Valeiras, X. and Guerra, A. 2002. Trends in strandings and by-catch of marine mammals in north-west Spain during the 1990s. Journal of the Marine Biological Association of the United Kingdom 82: 513-521.

López, A., Pierce, G.J., Santos, M.B., Gracia, J. and Guerra, A. 2003. Fishery by-catches of marine mammals in Galician waters: Results from on-board observations and an interview survey of fishermen. Biological Conservation 111: 25-40.

López, A., Pierce, G.J., Valeiras, X., Santos, M.B. and Guerra, A. 2004. Distribution patterns of small cetaceans in Galician waters. Journal of the Marine Biological Association of the United Kingdom 84: 283-294.

MAGRAMA. 2012. Estrategias Marinas. Grupo Mamíferos Marinos. Evaluación inicial y buen estado ambiental. Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA). 296 pp.
http://www.magrama.gob.es/es/costas/temas/estrategiasmarinas/0_Documento_grupo_mamiferos_marinos_def_tcm7-229902.pdf.

Martínez, E., Benavente, P. and López, A. 1995. Observación de cetáceos na ría de Pontevedra. Eubalaena 7: 12-21. In Galician.

Méndez-Fernandez, P., Pierce, G.J., Bustamante, P., Chouvelon, T., Ferreira, M., González, Á.F., López, A., Read, F.L., Santos, M.B., Spitz, J., Vingada, J. and Caurant, F. 2013. Ecological niche segregation among five toothed whale species off the NW Iberian Peninsula using ecological tracers as multi-approach. Marine Biology 160: 2825-2840.

Murphy, S., Winship, A., Dabin, W., Jepson, P.D., Deaville, R., Read, R.J., Spurrier, C., Rogan, E., López, A., González, A.F., Read, F.L., Addink, M., Silva, M., Ridoux, V., Learmonth, J.A., Pierce, G.J. and Northridge, S.P. 2009. Importance of biological parameters in assessing the status of *Delphinus delphis*. Marine Ecology Progress Series 388: 273-291.

Myrick, A.C., Hohn, A.A., Sloan, P.A., Kimura, M. and Stanley, D.D. 1983. Estimating age of spotted and spinner dolphins (*Stenella attenuata* and *Stenella longirostris*) from teeth (NOAA-TM-NMFS-SWFC-30). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center, 17 pp.

North Atlantic Marine Mammal Commission and the Norwegian Institute of Marine Research, 2020. Report of Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic. Tromsø, Norway. Available at: https://nammco.no/wp-content/uploads/2020/03/final-report_hpws_2018_rev2020.pdf

Nobre, A. 1895. Notes sur les poisons d'Algarve. Annales Des Sciences Naturelles 3: 223-32. In French.

Nobre, A. 1935. Fauna marinha de Portugal I. Verebrados: Mammíferos, Répteies e Peixes. Companhia Editora do Minho, Bacelos. 650 pp. In Portuguese.

Noren, S.R. and Edwards, E.F. 2007. Physiological and behavioural development in Delphinid calves: implications for calf separation and mortality due to tuna purse-seine sets. Marine Mammal Science 23: 15-29.

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Doremus, G., Huon, M. and Ridoux, V. 2012. The significance of stranding data as indicators of cetacean populations at sea: Modelling the drift of cetacean carcasses. Ecological Indicators 18: 278-290.

Peltier, H. and Ridoux, V. 2015. Marine megavertebrates adrift: A framework for the interpretation of stranding data in perspective of the European Marine Strategy Framework Directive and other regional agreements. Environmental Science and Policy 54: 240-247.

Penas Patiño, X.M. and Piñeiro Seage, A. 1989. Cetáceos, focas e tartarugas das costas ibéricas. Consellería de Pesca, (Xunta de Galicia), Santiago de Compostela, Spain. 379 pp. In Galician.

Pereiro, F.J., Fernández, A. and Iglesias, S. 1980. Relationships between depth and age, and recruitment indexes of hake on Galicia and Portugal shelf. International Council for the Exploration of the Sea (CM Papers and Reports), CM 1980/G.32.

Pérez, C., Nores, C. and Pis-Millán, J. 1990. Mamíferos marinos de la costa asturiana. Registros obtenidos entre los años 1987-1989. Boletin del Instituto Espanol de Oceanografia, 6: 37-144. In Spanish.

Pierce, G.J., Caldas, M., Cedeira, J., Santos, M.B., Llavona, A., Covelo, P., Martinez, G., Torres, J., Sacau, M. and López, A. 2010. Trends in cetacean sightings along the Galician coast, north-west Spain, 2003–2007, and inferences about cetacean habitat preferences. Journal of the Marine Biological Association of the United Kingdom 90: 1547–1560.

Read, F.L. 2016. Understanding Cetacean and Fisheries Interactions in the North-West Iberian Peninsula. PhD thesis, University of Vigo.

Read, F.L., Santos, M.B., González, A.F., López, A., Ferreira, M., Vingada, J. and Pierce, G.J. 2013. Understanding harbour porpoise (*Phocoena phocoena*) and fishery interactions in the north-west Iberian Peninsula. Document AC20/Doc.6.1.b, 20th ASCOBANS Advisory Committee Meeting, Warsaw, Poland, 27-29 August 2013.

Read, F.L., Evans, P.G.H., Hodgins, N., Simmonds, M.P., Carlén, I. and Dolman, S.J. 2018. Readdressing the CMS listing of species in the ASCOBANS region. Document AC24/Inf.9.3.b/Rev.1. 24th ASCOBANS Advisory Committee Meeting, Vilnius, Lithuania, 25-27 September 2018.

Scheidat, M., Leaper, R., Van Den Heuvel-Greve, M. and Winship, A. 2013. Setting maximum limits for harbour porpoises in Dutch waters to achieve conservation objectives. Open Journal of Marine Science 3: 133-139.

Sequeira, M. 1996. Harbour porpoises (*Phocoena phocoena*) in Portuguese waters. Report of the International Whaling Commission 46: 583-586.

Sequeira, M. and Inacio, A. 1992. Accidental catches of cetaceans in Portugal. European Research on Cetaceans 6: 25-28.

Sequeira, M. and Ferreira, C. 1994. Coastal fisheries and cetacean mortality in Portugal. In: Perrin, W.F., Donovan, G.P. and Barlow, J. (editors). Gillnets and Cetaceans, Special Issue 15, International Whaling Commission, Cambridge. pp 165-181.

Sequeira, M., Inácio, A., Silva, M.A. and Reiner, F. 1996. Arrojamentos de mamíferos marinos na Costa Continental Portuguesa entre 1989 e 1994. Estudos de Biologia e Conservação da Natureza 19. Instituto da Conservação da Natureza. Lisboa. 52 pp. In Portuguese.

Silva, M. 1996. Contribução para o conhecimento do regime alimentar e da biologia da reprodução do golfinho comum (*Delphinus delphis*, Linnaeus, 1758), na costa Portuguesa. Relatório de estágio de licenciatura, Universidade de Lisboa, Portugal. 64 pp. In Portuguese.

Silva, M., Sequeira, M., Prieto, R. and Alexandre, B. 1999. Observations of harbour porpoises (*Phocoena phocoena*) on the northern coast of Portugal. European Research on Cetaceans 13: 267-269.

Silva, M.A. and Sequeira, M. 2003. Patterns in the mortality of common dolphins (*Delphinus delphis*) on the Portuguese coast, using stranding records, 1975-1998. Aquatic Mammals 29: 88-98.

Solórzano, M.R., Rodríguez, J.L., Iglesias, J., Pereiro, F.X. and Alvarez, F. 1988. Inventario dos peixes do litoral galego. (Pisces: Cyclostomata, Condrichthyes, Osteichthyes). Cadernos da Area de Ciencias Biolóxicas. Seminarios de Estudios Galegos, Vol. IV: 69 pp. In Galician.

Spyrakos, E., Santos-Diniz, T.C., Martinez-Iglesias, G., Torres-Palenzuela, J.M. and Pierce, G.J. 2011. Spatiotemporal patterns of marine mammal distribution in coastal waters of Galicia, NW Spain. Hydrobiologia 670: 87-109.

Vingada, J., Ferreira, M., Marçalo, A., Santos, J., Araújo, H., Oliveira, I., Monteiro, S., Nicolau, L., Gomes, P., Tavares, C. and Eira, C. 2011. SAFESEA – Manual de Apoio para a Promoção de uma Pesca Mais Sustentável e de um Mar Seguro para Cetáceos. Programa EEAGrants – EEA Financial Mechanism 2004-2009 (Projecto 0039), Braga. 114 pp. In Portuguese.

Zuur, A.F., Ieno, E.N. and Elphick, S. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1: 3-14.