ICES Journal of Marine Science, 2025, Vol. 82, Issue 11, fsaf194
https://doi.org/10.1093/icesjms/fsaf194
Received: 31 March 2025; **revised:** 29 July 2025; **accepted:** 26 September 2025
Original Article

European stranding networks as a tool for monitoring marine mammal populations (Part I): towards optimising the functioning of networks

Marie A.C. Petitguyot[1,*,‡], Andrea Fariñas-Bermejo[1,‡], Andrew Brownlow[2], Markus P. Ahola[3,4], Elena Álvarez Neches[5], Manuel Arbelo[6], Matthieu Authier[7], Ramón Balsera Riesgo[8], Simon Berrow[9], Arne Bjørge[10], Jens Brackmann[11], Sophie Brasseur[12], Gilberto Carreira[13], Linnea Cervin[14], Cristina Claver[15], Pablo Covelo[16], Jose Luis Crespo-Picazo[17], Willy Dabin[7], Michael Dähne[18,19], Nicholas J. Davison[2], Rob Deaville[20], Mariel T.I. ten Doeschate[2], Mariano Domingo Álvarez[21], Fernando Escribano Cánovas[22], Peter G.H. Evans[23,24], Manena Fayos Martínez[25], Antonio Fernández[6], Ruth Fernández[26], Carolina Fernández-Maldonado[27], Luís Freitas[28], Anders Galatius[29], Álvaro García de los Ríos[30], Lucia Garrido Sánchez[31], Machteld I.M. Geut[32], Anita Gilles[33], Patricia Gozalbes Aparicio[34], Miguel Grilo[35], Jan Haelters[36], Sverrir Daníel Halldórsson[37], Thea Hamm[38], Jarco Havermans[39], Lonneke L. IJsseldijk[40], David Jacinto[41], Mart Jussi[42], Pepijn Kamminga[43], Tim Kåre Jensen[44], Ailbhe Sarah Kavanagh[45], Guido Keijl[43], Mardik Leopold[12], Alfredo López[16], Ana Marçalo[46], Nuno Marques[47], Jose Antonio Martínez Cedeira[16], Bjarni Mikkelsen[48], Joana Miodonski[13], Juana Maria Monasterio Iglesias[49], Jose Eugenio Montes Gómez[50], Aleksija Neimanis[51], Francisco Neves[41], Sofia I. Pardal[35], Iwona Pawliczka[52], Ignacio Peña Pascucci[31], Heidi Huus Petersen[53], Maris Plikshs[54,†], Raquel Puig-Lozano[6], Juan Antonio Raga[34], Joana I. Robalo[35,41], Anna Roos[14], Leire Ruiz Sancho[55], Camilo Saavedra[56], Guðjón Már Sigurðsson[37], Susana Simião[13], Antonia Solomando Marti[57], Jasmine Stavenow Jerremalm[58], Ole Stejskal[11], Vaida Survilienė[59], Charlotte Bie Thøstesen[60], Jaap van der Hiele[61], Jesús Varas[5], Hans Verdaat[12], Dylan Verheul[62], Gisli Arnór Víkingsson[37,†], Juanjo Villalón[63], Rosie S. Williams[20], Johnny Woodlock[64], Graham John Pierce[1]

[1]Instituto de Investigaciones Marinas, Consejo Superior de Investigaciones Científicas (IIM-CSIC), Vigo 36209, Spain
[2]Scottish Marine Animal Stranding Scheme, School of Biodiversity, One Health and Veterinary Medicine, College of Medical, Veterinary & Life Sciences, University of Glasgow, Glasgow G12 8QQ, United Kingdom
[3]Department of Population Analysis and Monitoring, Swedish Museum of Natural History, Stockholm, Sweden
[4]Marine Environment Research Group, Turku University of Applied Sciences, Joukahaisenkatu 7, FI-20520 Turku, Finland
[5]Gobierno de Cantabria, Cantabria 39011Spain
[6]Veterinary Histology and Pathology, Atlantic Center for Cetacean Research (CAIC), University Institute of Animal Health and Food Safety (IUSA), Veterinary School, University of Las Palmas de Gran Canaria (ULPGC), Trasmontaña s/n, 35413 Arucas, Canary Islands, Spain
[7]Observatoire Pelagis (UAR 3462 CNRS-LRUniv), La Rochelle Université, 5 allée de l'Océan, 17000 La Rochelle, France
[8]Servicio de Vida Silvestre, Consejería de Medio Rural y Política Agraria, Principado de Asturias, Oviedo 33005, Spain
[9]Irish Whale and Dolphin Group, Merchants Quay, Kilrush, Co Clare Ireland
[10]Institute of Marine Research, BO Box 1066, 0316 Oslo, Norway
[11]Food and Veterinary Institute Oldenburg, Lower Saxony State Office for Consumer Protection and Food Safety, Oldenburg 26133, Germany
[12]Wageningen Marine Research, Korringaweg 7, 4401 NT Yerseke, the Netherlands
[13]Regional Directorate for Maritime Policies of the Azores Government, Rua D. Pedro IV, 29, 9900-111 Horta, Portugal, 9900-111 Horta
[14]Department of Environmental Research and Monitoring, Swedish Museum of Natural History (SMNH), Stockholm 114 18, Sweden
[15]AZTI, Marine Research, Basque Research and Technology Alliance (BRTA), Sukarrieta 48395, Spain
[16]Coordinadora para o Estudo dos Mamíferos Mariños (CEMMA), R/Ceán N° 2. 36350 Nigrán
[17]Fundación Oceanogràfic de la Comunitat Valenciana, Valencia 46005, Spain
[18]Deutsches Meeresmuseum, Katharinenberg 14-20, 18439 Stralsund, Germany

[19]Federal Agency for Nature Conservation, Island Vilm, 18581 Putbus, Germany
[20]Institute of Zoology, Regents Park, London NW1 4RY, United Kingdom
[21]Universitat Autònima de Barcelona, 08193 Bellaterra, Barcelona, Spain
[22]Centro de Recuperación de Fauna Silvestre El Valle, Murcia 30150, Spain
[23]Sea Watch Foundation, Ewyn y Don, Bull Bay, Amlwch, Anglesey, LL68 9SD, United Kingdom
[24]School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, United Kingdom
[25]Centro de Recuperación de Fauna Silvestre. Villaescusa. 39690 Cantabria, Spain
[26]International Council for the Exploration of the Sea, H.C. Andersens Boulevard 44-46, 1553, Copenhagen, Denmark
[27]Seashore Environment and Fauna. Calle Sevilla n°4. Tarifa, Spain
[28]Museu da Baleia da Madeira, Rua Garcia Moniz, n° 1, 9200-031, Caniçal, Madeira, Portugal
[29]Section for Marine Mammal Research, Department of Ecoscience, Aarhus University, Frederiksborgvej 399, 4000 Roskilde, Denmark
[30]Centro de Estudios y Conservación de Animales Marinos (CECAM), Ceuta 51001, Spain
[31]Fundación por la conservación y recuperación de animals amrinos (CRAM), El Prat de llobregat 08820 Barcelona, Spain
[32]ASeal Seal Rehabilitation Centre, 3251 LD, Stellendam, The Netherlands
[33]Institute for Terrestrial and Aquatic Wildlife Research (ITAW), University of Veterinary Medicine Hannover, Foundation, Werftstraße 6, 25761 Büsum, Germany
[34]Instituto Cavanilles de Biodiversidad y Biología Evolutiva, University of Valencia, P.O. Box 22085, E-46071-Valencia, Spain
[35]Lisbon and Tagus Valley Marine Animal Stranding Network (RALVT), Instituto Universitário de Ciências Psicológicas, Sociais e da Vida (ISPA), Lisboa 1149-041, Portugal
[36]Institute of Natural Sciences, 3de en 23ste Linieregimentsplein, B-8400 Ostend, Belgium
[37]Marine and Freshwater Research Institute, 220 Hafnarfjörður, Iceland
[38]Lower Saxon Wadden Sea National Park Authority, Virchowstr. 1, 26382 Wilhelmshaven, Germany
[39]Ecomare, 1796 AZ De Koog, Texel, The Netherlands
[40]Division of Pathology, Department of Biomolecular Health Sciences, Faculty of Veterinary Medicine, Utrecht University, Yalelaan 1, 3584CL Utrecht, The Netherlands
[41]Marine and Environmental Sciences Centre (MARE) & Aquatic Research Network (ARNET), Institute for Research and Advanced Training (IIFA), Marine Sciences Laboratory, University of Évora, Sines 7521-903, Portugal
[42]ProMare MTU¨, Saula, Kose vald, 75117 Harjumaa, Estonia
[43]Naturalis Biodiversity Center, 2333 CR Leiden, The Netherlands
[44]University of Copenhagen, Department of Veterinary and Animal Sciences, Ridebanevej 3, 1870 Frederiksberg C, Denmark
[45]Marine Institute, Oranmore, Co. Galway, H91R673, Ireland
[46]Centre of Marine Sciences (CCMAR), University of the Algarve, Campus de Gambelas, FCT Ed. 7, Faro 8005–139, Portugal
[47]Regional Directorate for the Environment and Sea, Rua Dr Pestana Júnior, n° 6 - 3° Andar Dt°, 9064-506 Funchal, Madeira, Portugal
[48]Faroe Marine Research Institute, Tórshavn 100, Faroe Islands
[49]Servicio de Seguridad Alimentaria y Sanidad Ambiental, Consejería de Salud, Principado de Asturias, Oviedo 33005, Spain
[50]Consejería de Sostenibilidad y Medio Ambiente, Junta de Andalucía, Sevilla 41013, Spain
[51]Department of pathology and Wildlife Diseases, Swedish Veterinary Agency, Uppsala 751 89, Sweden
[52]University of Gdańsk, 80-309 Gdańsk, Poland
[53]Danish Veterinary and Food Administration, Glostrup, Denmark
[54]Institute of Food Safety, Animal Health and Environment (BIOR), Riga (LV-1076), Latvia
[55]Estación Marina de Plentzia, PiE-UPV/EHU, Universidad del País Vasco / Euskal Herriko Unibertsitatea, 48620 Plentzia, Spain
[56]Centro Oceanográfico de Vigo, Instituto Español de Oceanografía, Consejo Superior de Investigaciones Científicas (COV-IEO-CSIC), Vigo 36390, Spain
[57]Palma Aquarium Foundation, Carrer Manuela de los Herreros i Sorà 21, 07610 Palma de Mallorca, Balearic Islands, Spain
[58]Swedish Veterinary Agency (SVA), 756 51 Uppsala, Sweden
[59]Institute of Biosciences, Life Sciences Centre, Vilnius University, Sauletekio av. 7, LT-10257, Lithuania
[60]Museum VEST, Tangevej 6B, 6760 Ribe, Denmark
[61]Marine Animal Rescue Team Foundation (R.T.Z.), 4334 EJ Middelburg, the Netherlands
[62]Observation International – Stranding.nl, 2445 BA Aarlanderveen, the Netherlands
[63]Red de Varamientos de Alborán, Melilla 52006, Spain
[64]Irish Seal Sanctuary, R130, Tobergregan, Garristown, Co. Dublin, Ireland, A42YE38

*Corresponding author. Instituto de Investigaciones Marinas, Consejo Superior de Investigaciones Científicas (IIM-CSIC), Vigo 36209, Spain. E-mail: marie.petitguyot@palaeome.org
†Deceased
‡These two authors share first authorship

Abstract

The study of stranded animals is a valuable aid to monitoring marine mammals globally. However, the utility of strandings data depends on their quality and representativeness, which is affected by various biological, physical, social and economic factors. An analysis of how stranding networks work could help understand limitations in the data collected and facilitate correcting for or even eliminating them. In 2021, the International Council for the Exploration of the Sea's Working Group on Marine Mammal Ecology carried out an expert consultation using a questionnaire to provide insight into the contribution of European stranding networks as a monitoring tool in European countries with Northeast Atlantic and adjacent coasts (hence also including some networks operating along the Mediterranean coast). A key aim was to identify ways to improve data on mortality of marine mammals due to fishery bycatch. The present paper is the first of a two-part series based on the responses to the questionnaire by 45 organisations from 19 countries, and focuses on characterising the activities and capacities of the stranding networks surveyed, identifying differences within and between countries, highlighting strengths and weaknesses, and providing recommendations to enhance the value and credibility of the information collected. The second paper will focus on the information specifically related to mortality due to fishery bycatch. Stranding networks provide extensive spatio-temporal coverage of European coastlines, but their activities may be constrained by limited resources as well as limitations imposed by the stranding process. There is a need for better coordination and standardisation of the collection and analysis of data and samples and increased spatial coverage to fill gaps. To improve data quality, in particular to support assessment of impacts of threats such as bycatch, more necropsies and associated sample analysis are needed. It would also be advantageous to collect more information from less fresh animals, record search effort, and give greater attention to pinnipeds and non-marine mammal taxa. We also highlight the need to make information available and the potential value of a common database. Streamlining the reporting of results at the European level and providing systematic funding to stranding networks in accordance with their needs are necessary steps to optimise their role as a tool for the long-term monitoring of marine mammals and other marine megafauna in Europe.

Keywords: cetaceans; seals; strandings; questionnaire; bycatch; monitoring

Introduction

Marine mammals are legally protected in some parts of Europe under various regional, national and international agreements, directives and regulations (e.g. the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention; 1979), the Convention on Migratory Species (Bonn Convention; 1979), the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (European Habitats Directive; 1992), the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS; 1992), the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS; 1996), the European Marine Strategy Framework Directive (MSFD; 2008/56/EC), and national implementations of these). Among the requirements of these legal frameworks, a key component is the monitoring of the abundance and distribution of populations, and of the threats they face (Santos and Pierce 2015). As large marine predators (in many cases top predators), marine mammals are affected by both natural changes to the ecosystem and anthropogenic stressors, and they have a high public profile. Therefore, they have the potential to serve as climate and ecosystem sentinels, and surveillance of these species enables us to monitor and potentially predict environmental changes (Moore 2008, Schwacke et al. 2012, Hazen et al. 2019). Monitoring marine mammals at sea is logistically and financially challenging, although for certain kinds of information (e.g. abundance estimates of cetaceans, tracking of individual movements of seals and cetaceans, observations on behavior, etc.), it is the best or only option. A complementary and relatively low-cost approach to meeting many monitoring requirements, such as some of those under the MSFD, is the use of information gained from individuals that strand (Santos and Pierce 2015). Furthermore, information from stranded animals may allow the identification of mortality events, and elucidation of biological patterns and trends, that would not be detectable otherwise.

The study of stranded marine mammals has long proved its value for greatly advancing our understanding of their biology, ecology and evolution. The opportunistic acquisition of osteological material (and other samples) from stranded animals has fed European museum collections for centuries; this has benefited the field of natural history, particularly during the 19th century (e.g. van Beneden and Gervais 1880). Strandings of some larger cetacean species on European coasts are documented back to at least the 16th Century (Smeenk 1997). The systematic and organised collation of detailed information on stranded animals in Europe began in the early 20th century, when the Natural History Museum in London (United Kingdom) established the first stranding network in the British Isles in 1913 (Harmer 1914), and Anton Boudewijn van Deinse started a similar network in the Netherlands in 1914 (van Deinse 1931). In many other European countries, stranding networks emerged from the 1970s onwards, especially since the 1990s, when several countries became signatories to ASCOBANS and/or ACCOBAMS.

Data and samples from stranded animals have provided valuable insights into population structure and genetic diversity (e.g. Walton 1997, Fontaine et al. 2014, Gose et al. 2023), foraging ecology (Clarke and Pascoe 1985, Silva 1999, Santos and Pierce 2003, Méndez-Fernández et al. 2012, Plint et al. 2023, Samarra et al. 2024), the presence of rare or elusive species (e.g. Coombs et al. 2019, Grove et al. 2020, Smith et al. 2021, Stavenow et al. 2022), past and present spatial distribution, abundance and diversity (e.g. Brito and Vieira 2010, IJsseldijk et al. 2018, Coombs et al. 2019), life history parameters (e.g. van Utrecht 1978, Ólafsdóttir et al. 2003, Learmonth et al. 2014, Murphy et al. 2020), population viability and demographic trends (Mannocci et al. 2012, Read et al. 2020, IJsseldijk et al. 2020). Strandings investigations have also aided in identifying the threats faced by marine mammals in Europe. Monitoring of strandings has enabled the detection of Mass Stranding Events (MSEs) and Unusual Mortality Events (UMEs) (e.g. Aguilar and Raga 1993, Raga et al. 2008, Jepson et al. 2013, Brownlow et al. 2018, Grove et al. 2020), and the determination of causes of death, thus highlighting the incidental bycatch of marine mammals in active fishing gear as a major cause of mortality around Europe (e.g. Kuiken et al. 1994, Leeney et al. 2008, Puig-Lozano et al. 2020a, Peltier et al. 2021, IJsseldijk et al. 2022, Neimanis et al. 2022). It has also helped determine the effects of contaminants on health and reproduction (e.g. Siebert et al. 1999, Murphy et al. 2015, Nelms et al. 2019, van den Heuvel-Greve et al. 2021, Williams et al. 2023) and highlighted mortality caused by pathogens (e.g. Alzieu and Duguy 1979; Domingo et al. 1992, Foster et al. 2002, Raga et al. 2008, Mazzariol et al. 2016, Pons-Bordas et al. 2020, Fernández et al. 2022, Stokholm et al. 2023, Thorsson et al. 2023), collisions with vessels (e.g. Laist et al. 2001, Carrillo and Ritter 2010, Peltier et al. 2019), impulsive noise produced by naval activity and munitions detonation (e.g. Simmonds and Lopez-Jurado 1991, Fernández et al. 2005, Jepson et al. 2013, Siebert et al. 2022), marine debris (e.g. Puig-Lozano et al. 2018, Solomando et al. 2022), food depletion (e.g. MacLeod et al. 2007), and intra and inter-species interactions (Ross and Wilson 1996, Patterson et al. 1998, Barnett et al. 2009, Haelters et al. 2012, Puig-Lozano et al. 2020b). In addition, strandings data have been proposed as a tool to monitor climate change in European seas (e.g. MacLeod et al. 2005, Williamson et al. 2021).

Marine mammals are highly mobile animals with large distributional ranges that can span the waters of multiple countries and/or extend into international waters. As such, population assessments often need to be carried out at a large spatial scale (e.g. Hammond et al. 2002, Matsuoka et al. 2003, ICES 2014, Gilles et al. 2023). As stranding schemes collectively (and sometimes individually) cover thousands of kilometres of coastline and some have been active for decades, they have the potential to provide extensive monitoring coverage, spanning wide areas and long time-periods. Collaborations between different stranding schemes can facilitate large-scale studies and provide data and samples not easily obtainable in any other way (e.g. Jauniaux et al. 2002, Murphy et al. 2009, Peltier et al. 2013, 2014, 2016, Jepson et al. 2016, IJsseldijk et al. 2018, 2020, Stokholm et al. 2023, Gose et al. 2023).

Despite their high potential value, the reliability of information from strandings to characterise marine mammal populations and the impact of threats on them has been questioned. Stranding data have generally not been seen as suitable to contribute to statutory monitoring requirements, due to a perception that they are opportunistic, biased and of low quality, much as casual sightings are not seen as a serious alternative to dedicated abundance surveys. Nevertheless, reflecting recent advances, stranding data have gained traction as a tool for the estimation of bycatch mortality in the International Council for the Exploration of the Sea (ICES) and the International Whaling Commission (IWC) Scientific Committee only quite recently, and the use of contaminant data from stranded animals has been under discussion by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) for a number of years (ICES 2020, Pinzone et al. 2022, 2023, International Whaling Commission 2024).

A major challenge is to understand the representativeness of stranding data, which depends on (1) the percentage of dead (and dying) animals that eventually strand along the shores, (2) which of these animals are subsequently found and reported to stranding schemes, and (3) what is done with the animals that are found (i.e. are they sampled and/or necropsied?). The first point depends on a combination of biological and physical parameters, including the distribution and abundance of marine mammals at sea, oceanographic and weather conditions, the buoyancy of the carcasses, and the geomorphology of the coastline. The second component will depend at least in part on social parameters, e.g. the density of citizens in an area, the accessibility of the area, their ability to report (and interest in reporting) carcasses to stranding networks, and the extent to which networks pro-actively seek the input of citizens and authorities (see Peltier et al. 2012, Moore et al. 2020). Finally, the last point is highly (but not exclusively) dependent upon the financial resources available to stranding networks, which may impact their ability to employ and train personnel, attend strandings, perform necropsies, collect and analyse samples, and store and disseminate the samples and results. All the above may differ within and between countries, and vary over time, adding multiple layers of complexity to the issue.

There have been various efforts, especially in recent years, to improve the quality of information derived from strandings and to increase standardisation and harmonisation across networks to permit transboundary population level assessments. A series of standardised common protocols for necropsies has been produced (Geraci and Lounsbury 1993, Kuiken and Hartmann 1993, Jauniaux et al. 2019, IJsseldijk et al. 2019) and modelling frameworks developed to increase the statistical credibility of strandings data (Peltier et al. 2013, IJsseldijk et al. 2020). Work on the drift of small cetacean carcasses in the Northeast Atlantic has enabled the quantification of the percentage of animals that are likely to reach the shore, in relation to the location and condition of an animal when it died. By controlling for confounding factors, statistical analysis can help to assess the temporal stability of reporting rates (Authier et al. 2014) and to quantify baseline variability in stranding rates (ten Doeschate et al. 2018). Together these advances facilitate the use of stranding data to estimate the number of animals that die due to bycatch and to try to identify the fisheries involved (Peltier et al. 2012, 2013, 2014, 2016, 2020, ICES 2020, 2021, 2023).

Achieving and maintaining Favourable Conservation Status for marine mammals necessitates coordinated international efforts. Consequently, the development of a standardised, transboundary marine mammal strandings database has long been recognised as a critical requirement. Progress towards this goal includes obligations under ACCOBAMS for Contracting Parties to report to the Mediterranean Database of Cetacean Strandings (MEDACES; http://medaces.uv.es) and a shared commitment by ASCOBANS Contracting Parties to contribute to an international database. At the time of writing, several intergovernmental organisations (IGOs) (i.e. ASCOBANS, IWC, ICES, ACCOBAMS) are working together to create a common international marine strandings database in Europe (Deaville and Jepson 2012, Brownlow et al. 2023, 2024). Such a repository could support population assessments and conservation management, especially at international level. ICES has already used strandings data as basis for management advice on bycatch mortality in cetaceans (ICES 2020, 2022, 2023).

The different levels of national and/or regional support currently received by stranding networks imply different levels of resourcing, potentially impacting the type and quality of data and samples that can be obtained. Increased funding enables more detailed examinations (i.e. full necropsies) of stranded animals, which are essential for comprehensive health assessments supporting evaluations such as those required by the MSFD (Table 1).

The purpose of the current exercise is to assess the role that stranding networks currently play in monitoring marine mammal populations in Europe and to identify what improvements can be made to help the networks achieve their potential as a monitoring tool, especially in relation to bycatch mortality but also to determine the conservation status of marine mammal populations and the impacts of other threats.

To answer these questions, an expert consultation, based on a questionnaire was initiated in 2021 under the auspices of the ICES Working Group on Marine Mammal Ecology (WGMME), directed at countries with Northeast Atlantic coastlines and adjacent coasts (and hence, including the networks which operate along the Mediterranean coasts of Spain and France, and in the Spanish and Portuguese Macaronesian islands). The questionnaire had a particular emphasis on understanding and quantifying mortality of marine mammals due to fishery bycatch. The present paper is the first (hence hereafter referred to as "Part I") of two papers based on the responses to the questionnaire, and focuses on characterising the organisation, activities and capacities of the networks surveyed, examining their strengths and weaknesses and differences within and between countries. The second paper ("Part II," Fariñas-Bermejo et al. submitted), focuses on the information collated by stranding networks specifically related to mortality due to fishery bycatch. It is intended that the results will lead to recommendations to optimise the role of stranding networks as

Table 1. Scenarios for examination of stranded animals according to budget and personnel constraints, and their utility in the context of MSFD monitoring.

Scenario	Type of data	Type of analysis	Use of data for biological assessments	Relevant for MSFD descriptor/criterion	Examples reference/case study	Time and financial cost of data/sample collection	Time and financial cost of data/sample analysis	Personnel
1	Basic data collection (e.g. species, location, date, body length, sex, decomposition state)	Distribution/local abundance models, basic population models, drift models	Presence of species, seasonality and relative abundance in coastal waters, indicators of sex ratio, population length distribution	D1 (D1C2; D1C3; D1C4; D1C5)	(1)	Low	Low	Trained volunteers/general public
2	1 + External inspection + additional measurements and sample collection (e.g. girth, blubber thickness, weight, skin, muscle, blubber, teeth, whiskers, bone if advanced carcass decomposition, evidence of possible cause of death)	1 + Nutritional condition, genetics, stable isotopes, contaminants, age, age population models with age structure, possible preliminary diagnosis of health status and cause of death	1 + Population age structure, population genetics, nutritional condition, foraging ecology, chemical/pollution threats, probable cause of death	1 + D4; D8; D9; D10	1 + (2); (3); (4); (5); (6); (7)	Medium	Medium	Trained personnel (veterinarians and biologists)
3	2 + Internal inspection + sample collection (e.g. stomach content, gastro-intestinal tract, gonads)	2 + Stomach content analysis, macro/micro-debris, parasitology, maturity and reproductive status, fully parameterised population models, additional evidence about cause of death	2 + Diet/foraging ecology and potential competition with fishing sector, basic health status, life history traits and population dynamics, plastic pollution threat, probable cause of death (increased confidence)	2 + D2	2 + (8); (9); (10)	High	High	Trained personnel (veterinarians and biologists)
4	3 + Full necropsy and sample collection (e.g. blood, organs such as liver, kidney, brain, fluids, swabs/biopsies)	3 + Pathology (incl. histopathology), detailed contaminant analysis, hormone analysis, toxin analysis, improved evaluation of sampling biases	3 + Cause of death, complete individual health status, assessment of population level threats, description of—and potential correction for—sampling biases	3 + D5; D11	3 + (11); (12); (13); (14)	Very high	Very high	Veterinary pathologist(s)

Adapted from Table 4.2 in ICES (2023). Note that, strictly speaking some types of analysis and some uses of the results are theoretically possible under any of the scenarios (e.g. by using literature information to supplement data collected)—we indicate the scenario under which we consider the analysis or use can be fully implemented based on the data collected from strandings (sample size permitting). MSFD descriptors and criteria: D1: Biological diversity (D1C1 Mortality rate from incidental bycatch, D1C2 Population abundance, D1C3 Population demographic characteristics, D1C4 Population distributional range and pattern, D1C5 Habitat for the species); D2: Non-indigenous species (e.g. parasites and prey of marine mammals); D4: Food web; D5: Eutrophication (i.e. Harmful Algal Blooms); D8: Contaminants; D9: Contaminants in seafood (applicable to countries where human consumption of marine mammal meat occurs); D10: Marine litter; D11: Underwater noise. Relevant references: (1) IJsseldijk et al. 2020; (2) Gose et al. 2023; (3) Méndez-Fernandez et al. 2022; (4) Albrecht et al. 2024; (5) Samarra et al. 2024; (6) Nelms et al. 2019; (7) Solomando et al. 2022; (8) Hernández-Gonzalez et al. 2024; (9) Pons-Bordas et al. 2020; (10) Mannocci et al. 2012; (11) Peltier et al. 2016; (12) Stokholm et al. 2023; (13) Peltier et al. 2019; (14) Siebert et al. 2022.

a tool for the long-term monitoring of marine mammals in Europe.

Material and methods

A consultation exercise was proposed and designed to collect information about the quality of data available from stranding networks, in the context of the work of the ICES WGMME. Coordinators of organisations and networks involved in attending strandings of marine mammals within ICES member countries with European Atlantic coastlines, including their Mediterranean regions and Atlantic archipelagos, as identified by ICES WGMME members, were invited to participate in this expert consultation, as respondents and as co-authors of the resulting papers. To structure the expected input, a subgroup of co-authors designed a questionnaire which was then distributed in both English and Spanish versions to the coordinators, between 2021 and 2023. It should be noted that several European countries do not have a centralised network at the country level, and some have multiple regional networks. Networks in a country or region may also involve more than one organisation. In two countries (Ireland and the Netherlands), different organisations are responsible for the strandings of cetaceans and seals. The questionnaire was therefore sent to the coordinators of all relevant organisations, and this resulted in multiple responses from some countries and sometimes more than one response about the same network.

The questionnaire was developed to provide insights into the potential contribution of European stranding networks to monitoring requirements of relevant environmental legislation, with a particular focus on understanding and quantifying mortality of marine mammals due to fishery bycatch. The questionnaire first explored the organisation, activities and capacities of the networks, before focusing on bycatch-specific information, and was structured into six sections:

1) Organisation of the networks (including the type of organisation, staffing, funding, limitations);
2) Procedures involved in attending strandings of live and dead animals (e.g. reporting system, decision-making process, search effort and changes over time);
3) General information about stranded marine mammals (e.g. species composition, number of strandings per year, numbers of live and dead animals);
4) Types of data and samples collected (e.g. teeth for age determination, photographic documentation, gonads for maturity state determination);
5) Nature and frequency of necropsies (e.g. proportion of animals necropsied, protocols followed, determination of causes of death);
6) Incidence of bycatch mortality (e.g. frequency, trends, and information collected from collaboration with fishers).

The questionnaire contained 40 questions (see Supplementary Material S1). It included questions with closed and open-ended formats, the latter helping to ensure that respondents could share their expert opinions and make recommendations. When providing numerical responses, respondents were asked to focus on the year 2019 (if possible) in order to avoid potential bias due to the effect of the COVID-19 pandemic on their activities during 2020–21. Networks that started their activities after the end of the year 2019 were asked to provide information for the most recent full year of activity. For questions with numerical responses, the sum, mean, median, minimum and maximum values are reported. Regarding open-ended questions, we aimed to report on the range of views expressed. The respondents were consulted if there were any doubts about the interpretation of the responses. If doubts could not be resolved, the responses in question were not considered, in order to avoid the inclusion of potentially incorrect information.

The total number of responses is given for each question analysed, as this number varies due to instances of missing information, unresolved doubts about an answer or when a question was not applicable (e.g. specific questions on necropsies when respondents indicated that they did not perform necropsies).

Maps were generated using ArcGIS software (ArcMap 10.4.1, ESRI 2016). Shapefiles for the European countries covered in this study were obtained from Sevdari and Marmullaku (2023) and www.gadm.org. For the purpose of contextualising the data extracted from the questionnaires, these shapefiles were used to estimate the length of the coastline of the regions where the stranding networks operate. These values, included in Table 4, should be interpreted as approximations. The fine scale of these shapefile means that coastline features such as estuaries are included in the estimates.

A redundancy analysis was performed to investigate geographic patterns in the species composition of strandings reported by each network. The analysis used estimates of the overall numerical importance of each species, expressed as a percentage of stranded marine mammals (both dead and alive), within the spatial and temporal scope of each network. To minimise the impact of rare species, the data were Hellinger-transformed prior to analysis. The dataset can be consulted in Supplementary Material S2.

Results

A total of 45 organisations reported information acquired from stranded animals in 17 countries and two self-governing territories in the European ICES region. Some of these countries have islands and/or coasts outside of the ICES region, i.e. the archipelago of Madeira (Portugal) and the Balearic and the Canary Islands (Spain), and the Mediterranean coasts of France and Spain. Among the 45 respondents, 40 (from 14 countries) provided a completed questionnaire (Sweden (1), France (1), United Kingdom (2), Iceland (1), Denmark (1), Belgium (1), the Netherlands (4), Spain (15), Germany (3), Poland (1), Portugal (5), the Republic of Ireland (3), Latvia (1), and Lithuania (1)). Two of these responses were from countries which lack a formally constituted stranding network (Latvia and Lithuania) but for which some information is collected about stranded animals; these responses were therefore included in the analyses. The remaining five respondents (from three countries—Finland, Estonia and Norway—and two self-governing territories—Greenland and the Faroe Islands) did not complete the questionnaire but provided short responses noting the absence of an active stranding network and indicating what information was available on strandings.

Characterisation of stranding networks activities

Organisation of the networks

In total, 12 countries in the ICES area currently have at least one active stranding network: Portugal (including networks in the autonomous regions of Azores and Madeira), Spain (including networks in the autonomous communities of the Canary Islands and the Balearic Islands, as well as the autonomous cities of Ceuta and Melilla), France (the French network includes the island of Corsica), the United Kingdom (including a network in Scotland, and another covering England, Wales and Northern Ireland, as well as two (non-UK) Crown dependencies, i.e. the Channel Islands and the Isle of Man), the Republic of Ireland, Belgium, the Netherlands, Germany, Denmark, Poland, Sweden and Iceland, whereas five countries (i.e. Latvia, Lithuania, Finland, Estonia and Norway) and two self-governing territories (Greenland and the Faroe Islands) do not have an active and formally constituted stranding network, but do carry out investigations on stranded animals.

Reasons mentioned for the absence of active networks were (1) fragmented coastlines which makes it difficult to obtain a good coverage, (2) a lack of funding or interest from governments, (3) low numbers of strandings reaching the shore, (4) a high percentage of carcasses in an advanced decomposition stage, which makes examination of the animals less useful, and (5) since sampling and data collection mainly come from freshly hunted animals, there is little interest in examining strandings. Of note, respondents from Norway and Lithuania both indicated that there is interest in creating a stranding network in their country in the future.

The organisation of the networks differs among the 12 countries (Fig. 1). Some stranding networks such as those from France and Poland have a centralised organisation, whereby several entities are part of one single network, with a single institution in charge of coordinating activities and collating all the information. Other countries, such as the Republic of Ireland, the Netherlands, Belgium, Sweden, Iceland, and Denmark, have a national stranding network constituted of several entities that each have a specific distributed role (e.g. some of the entities are focusing on cetaceans only, others on seals, some are doing the necropsies, and others are in charge of collecting the carcasses). Finally, some countries have two or more regional networks, which is the case for the United Kingdom (one network covering Scotland, and another covering England, Wales, and Northern Ireland, as well as the non-UK Crown Dependencies of the Channel Islands and the Isle of Man), Germany (one network in Schleswig-Holstein, one in Mecklenburg-Prepomerania, and one in Lower Saxony), Spain (one or more networks in each of the autonomous communities/cities), and Portugal (one or more networks covering at least one region/autonomous region). In practice, some regional networks incorporate or have incorporated the activities and data of more localised networks within the region (as occurs in England with for example the stranding network run by the Cornwall Wildlife Trust Marine Strandings Network) and the work of regional networks may be coordinated by a national organisation (as in mainland Portugal).

Stranding networks may be constituted from and coordinated by various types of organisations, or combination thereof, e.g. universities, museums, charities, Non-Government Organisations, animal rescue centres, government-funded research institutes, and government agencies/departments/organisations. In some cases, attending strandings is simply a task or a project carried out by an institution. The majority of these organisations are public and/or non-profit bodies, although some are private and/or for profit. Most stranding networks (72%) consist of a relatively small core staff team of between 1 and 10 people, while the remaining (28% of) networks each have a team of between 11 and 40 people. Some of the organisations also run a network of volunteers distributed along the coast (for example, up to ~800 volunteers working with Seal Rescue Ireland). Some of the respondents indicated that part of their core staff team were unpaid staff working on a voluntary basis.

Collaborations between stranding networks and other organisations in their area are important to their functioning, whether or not such organisations are formally part of the network. Approximately 82% of the respondents (32/39) indicated that other organisations are involved in responding to stranded animals in their area. These other organisations have various roles, such as being in charge of carrying out the necropsies, attending live strandings, attending the stranding of larger animals (i.e. baleen whales) and/or other taxa that may not be considered by the networks themselves (e.g. seabirds, sea turtles, seals), dealing with the disposal of carcasses, transportation of carcasses, analyses of samples collected, providing material resources, or the dissemination of the networks' activities to inform the wider public.

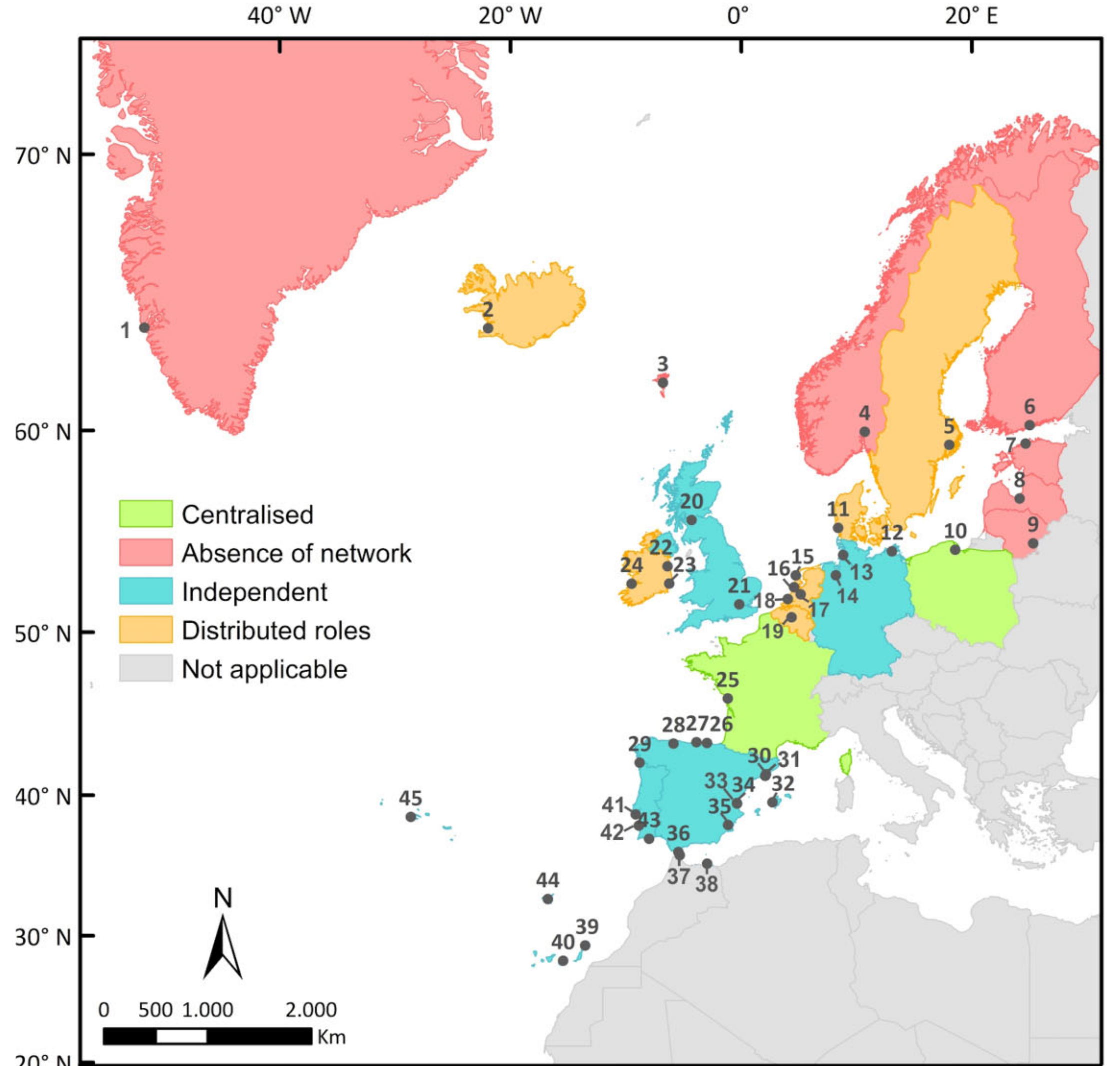
Organisations use various types of funding to carry out their activities, but a majority depend on voluntary work and support from national or regional governments. A small minority charges fees to members, volunteers and/or visitors and one is self-funded (Fig. 2a). Stranded animals are most often reported through local authorities, the public and/or via a dedicated phone number. A minority of networks mentioned use of their own volunteers, and/or reporting via social media, websites, and/or mobile phone apps (Fig. 2b).

Effort over time and the effects of COVID-19

The majority of European organisations carrying out work on strandings, and which responded to the questionnaire, were created in the early 1990s, and have thus been carrying out their activities for approximately three decades (Fig. 3). Seven organisations were created prior to 1990, and thus have collated information over a longer period (e.g. more than a century in the case of the Dutch stranding network). In addition, the Natural History Museum in London (United Kingdom) started collating strandings data and samples in the British Isles in 1913 (Harmer 1914). The two stranding networks currently active in the United Kingdom (i.e. CSIP and SMASS) date from the early 1990s but may be considered as having continued the activities carried out by the Natural History Museum in London. Five organisations (all in Spain and Portugal) were recently created, having completed fewer than five years of activities at the time they responded (Fig. 3).

Most of the respondents considered that their effort devoted to discovering/reporting and collecting stranded animals had been stable over time, although some networks indicated that the effort had changed (due to, for instance, changes in funding availability, or public awareness) (see Fig. 3). This perceived stability of effort over time should be considered as indicative, as it is based on the respondents' perception, with the exception of the French stranding network, which has statistically tested for consistency in their reporting effort over time (Authier et al. 2014).

Replies to the previous point notwithstanding, few respondents (32%; 11 out of 34) reported gathering information on



1	GINR	**Greenland**	16	DSN-RTZ		31	XRFM-CRAM	
2	MFRI	**Iceland**	17	DSN-UWNO	**Netherlands**	32	FPAQ	
3	FAR-HFMRI	**Faroe**	18	DSN-A Seal		33	RVCTMCV-UV	
4	NOR-IMRN	**Norway**	19	MARIN	**Belgium**	34	RVCTMCV-FO	
5	SMNH-SVA	**Sweden**	20	SMASS	**United Kingdom**	35	RVCTMRM	**Spain**
6	FIN-SMNH	**Finland**	21	CSIP		36	RVCTMA	
7	EST-MARE	**Estonia**	22	IR-ISS	**Republic of Ireland**	37	RVM	
8	LAT-BIOR	**Latvia**	23	IR-SRI		38	RVC	
9	LIT-VU	**Lithuania**	24	IWDG		39	RVCIC-OAPN	
10	PSN	**Poland**	25	RNE	**France**	40	RVCIC-IUSA	
11	NCP	**Denmark**	26	RVE		41	RALVT	
12	MPDM		27	ReVarCa		42	ARROJAL	
13	SH	**Germany**	28	RVA	**Spain**	43	RAAlg	**Portugal**
14	GM		29	RVG		44	RACAM	
15	DSN-ECOMARE	**Netherlands**	30	XRFM-UAB		45	RACA	

Figure 1. Map showing the location and acronym of each of the 45 respondents that provided information regarding their activities in relation to strandings. The full name of each organisation that responded to the questionnaire is provided in Table S1, together with details regarding the organisation and activities of the stranding networks. Countries are classified according to how their stranding networks are organised (green: centralised organisation, orange: distributed functional roles, blue: regional organisation, red: absence of network, grey: not applicable).

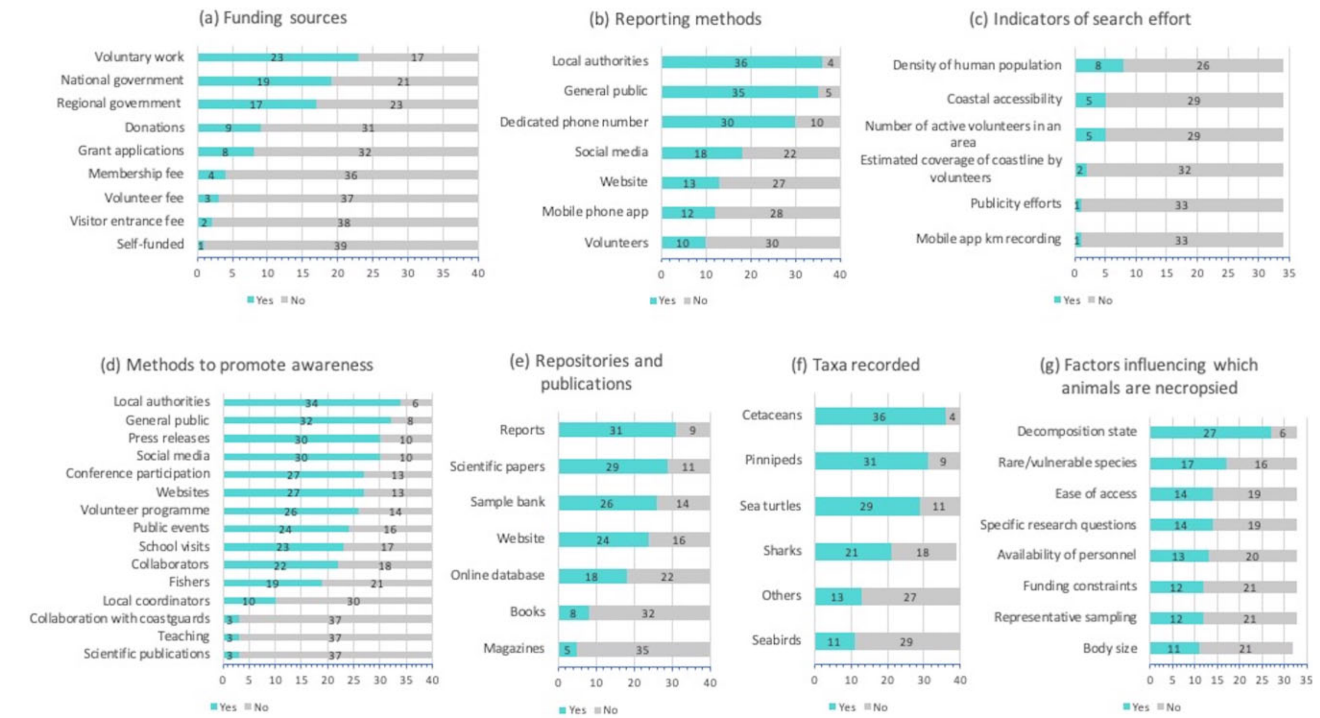


Figure 2. Results from the questionnaire on (a) Types of funding received to carry out network activities, (b) How stranded animals are reported; (c) Indicators used to estimate effort in searching for stranded animals; (d) Methods to promote awareness of activities and facilitate collaborations; (e) How data and samples are made available to interested parties; (f) Taxa recorded by networks and (g) Factors influencing how networks decide which animals to necropsy. Networks responded "yes" or "no" to each option under the seven headings and in each case the total number of responses is equal to the sum of the "yes" and "no" answers.

the amount of search effort applied to locate stranded animals. The most commonly mentioned indicator of search effort was the density of the human population in an area, followed by accessibility of the coastline and the number of active volunteers in an area. Very few networks directly measure search effort. Where this is done, it involves volunteers estimating the kilometres of the coastline covered or use of an App to record the kilometres of the coastline covered (Fig. 2c).

The COVID-19 pandemic negatively impacted the activities of 57% of the respondents (21/37), for instance by restricting their ability to collect the carcasses and perform necropsies. The most recently created organisations (those created during or after the year 2020) indicated they were not impacted by the pandemic. Three respondents mentioned that the reporting of stranded animals had increased during the pandemic due to more people being out walking on the beach, and one respondent considered that this had a positive effect on their activities. The impact of the pandemic on network activity evidently changed over time and differed between countries, in particular according to the severity of restrictions imposed on people's movements.

Availability of the information collected

An important part of the work carried out by stranding networks is raising awareness of strandings and fostering collaborations. A majority of the networks report their work to the authorities and the public, and use press releases, social media and websites. Other commonly mentioned outreach efforts include participation in conferences, volunteer programs, public events, school visits, and sharing information with collaborators and fishers (Fig. 2d). As seen in the next section, a majority of the networks produce scientific publications but three respondents mentioned this as a means of promoting their activities, along with teaching, and collaboration with coast guards. One respondent noted that the ability of the organisation to publicise its work was specifically restricted by its funders (the regional government).

Most networks make their results, data and samples available to interested parties through reports and/or scientific papers, while a few networks publish this material in books or magazines (Fig. 2e; and see Table S1 for information on network websites and where to access data and reports). Over half the networks share information on websites and slightly fewer than half the networks provide online databases (Fig. 2e), usually providing information such as location, time, species, and basic biological data (e.g. external measurements, sex). More detailed information such as necropsy findings may be accessible but sometimes this requires a collaboration agreement. Samples are typically made available to researchers upon request via a sample bank (Fig. 2e). In some cases, published content is available only in the national language.

Information on strandings may be reported multiple times, to various entities (e.g. to the local authorities, ICES, the European Commission, ASCOBANS, IWC, the Baltic Marine Environment Protection Commission (Helsinki Commission; HELCOM), etc.), which can increase the workload of networks and lead to duplication of effort. The possibility of streamlining the reporting of information to involve a single receiving entity was explored as part of this consultation exercise, with ICES (which already requests bycatch information from strandings for use by the Working Group on Bycatch of protected species (WGBYC) in recent

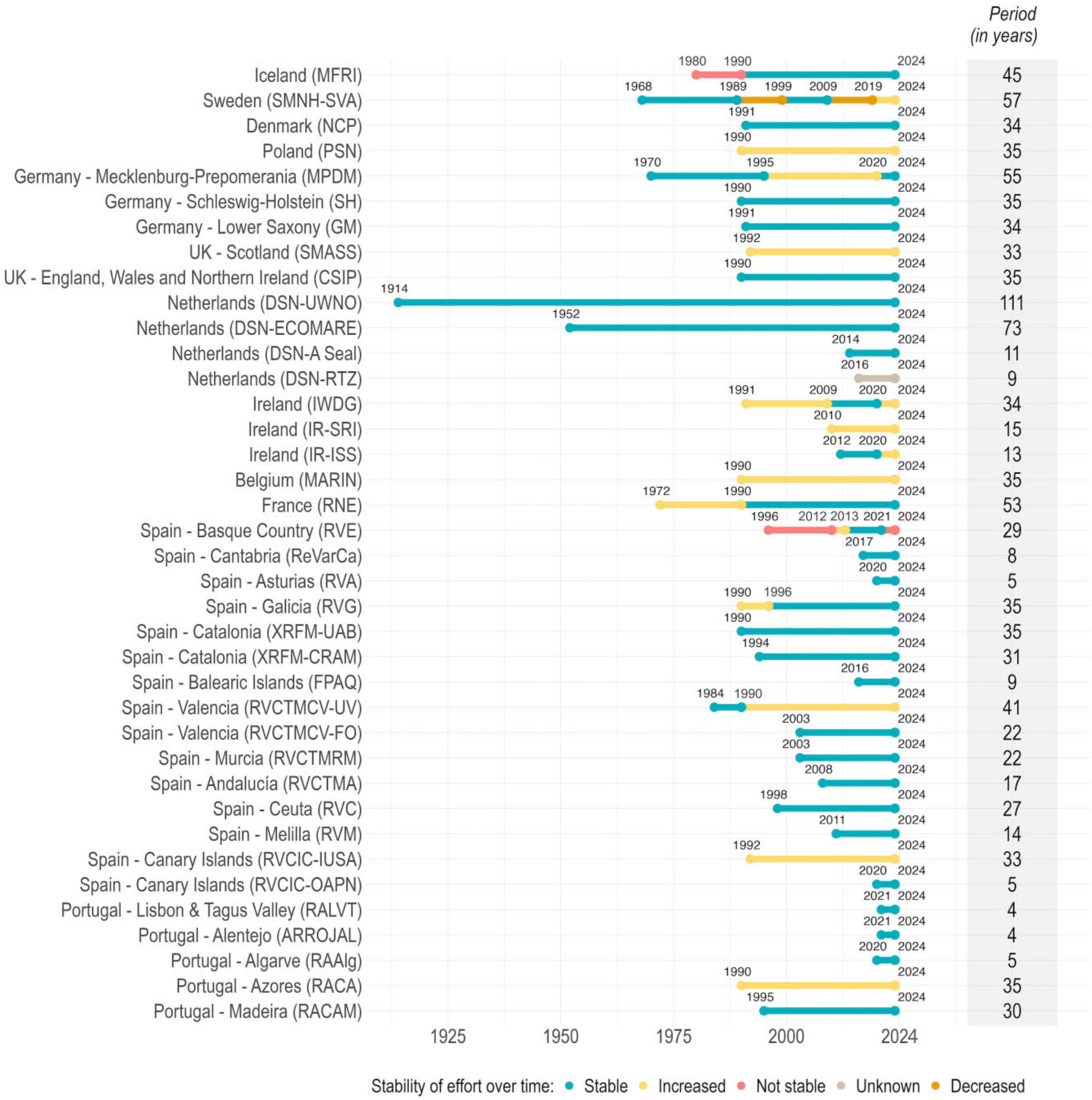


Figure 3. Period of activity of the 38 active organisations involved in marine mammal strandings monitoring, that provided the starting date of their activity and reported on the perceived stability of effort over time. The different colours of the bars represent different levels of effort over time. Although respondents from Latvia and Lithuania have completed a questionnaire providing information regarding their research activities on stranded animals, these were not included in the present figure since neither country has stranding *networks* as such. Note that the strandings in the UK have been monitored since 1913, but the current networks have a more recent origin.

reports), mentioned as a possible host. If a common data format were agreed by the different organisations currently requesting stranding data, a strong advantage for stranding networks would be the need to report their data only once, to a single organisation, with the prospect of producing a single database that is accessible to interested parties. A large majority of the respondents (95%; 35/37) indicated that they were willing to provide detailed data on strandings and diagnosed bycatch mortality in the future, if there were to be a regular formal data call from ICES or a similar organisation, which would then maintain the resulting database.

Information obtained from strandings

Taxa and species recorded

Most of the 40 respondents collect information on strandings of multiple animal taxa. Cetaceans were recorded by most networks, followed by pinnipeds, sea turtles, sharks and seabirds. Several networks mentioned recording other taxa, such as otters, sunfish and large cephalopods (Fig. 2f). One network reported collecting information solely on cetaceans, four collected information solely on pinnipeds, and three mentioned that information on seabirds was collected by other institutions.

Thirty-seven respondents provided information about the marine mammal species that had stranded in the area which they cover, albeit indicating that some species that were very rarely stranded, or for which there is only anecdotal evidence of strandings, were not included in their response. In total, 38 marine mammal species were reported by the respondents: 33 species of cetaceans and 5 species of seals (Table S2). Spain was the country where the highest diversity of species was reported (26 species in mainland Atlantic waters, 25 in the Canary Islands, and 22 in Mediterranean waters). The lowest diversity was in Latvia and Lithuania ($n = 2$) (see Table S2 for further detail).

Among the small cetaceans (i.e. dolphins and porpoises), striped dolphin (*Stenella coeruleoalba*) was reported by the most respondents ($n = 28$); fin whale (*Balaenoptera physalus*) was the most reported baleen whale ($n = 26$) and goose-beaked whale (*Ziphius cavirostris*) was the most reported beaked whale ($n = 19$). The species of pinniped reported by the most respondents was the grey seal (*Halichoerus grypus*) ($n = 21$); see Table S2 for further detail. The 37 respondents also provided estimates of the overall numerical importance of each species (as a percentage) among the stranded marine mammals (dead and alive) for the area and time-period covered by their network (Table S2). Redundancy analysis based on these estimates revealed geographical structuring in species composition across monitoring networks (Fig. 4). After Hellinger transformation to reduce the influence of rare species, networks grouped by region showed distinct clustering, reflecting differences between the Northeast Atlantic and Mediterranean Sea. The strongest apparent trend seems to be a difference between the north and the south. In southern waters, pinnipeds were largely absent, and Delphinidae were the most important family of cetaceans in terms of numbers of strandings (Figure S1).

Attending strandings

Respondents most often base their decision about whether to attend a stranded animal on the decomposition state of the carcass but several other factors are also considered to be important (Fig. 5a). Two respondents indicated that live animals, and animals presenting signs of entanglements or injuries due to human activities, were considered to be of high importance. Others also highlighted the issue that the number of stranded animals in their region plays a role in the decision process. When there are high numbers of strandings in a short time period, it is often not possible to attend them all and, thus, priorities are adapted according to the circumstances. On the other hand, in regions where there are very few strandings, networks may try to attend all stranded animals.

Some data collection from strandings benefits from the availability of specialist expertise, notably trained veterinarians to carry out complete necropsies. Staffing varies between networks and, as noted above, different levels of data and sample collection may be selected depending on whether the animal is dead or alive, the decomposition status of the animal (if dead), the staff available, the size of the animal, etc. It should also be noted that the need for permits and/or health and safety considerations may limit what a particular person is allowed to do with a stranded marine mammal.

Most respondents reported that when necropsies were performed after the animal had been transported to a specialist facility, they were always or usually performed by veterinary pathologists and/or other trained personnel (e.g. experienced biologists). While full post-mortem examinations of carcasses at the stranding location seem to be relatively infrequent, they are also usually carried out by veterinary pathologists and/or other trained personnel (Table 2). Taking measurements and/or photos and collecting samples from carcasses on site mainly involves other trained personnel, although several respondents indicated that untrained personnel (i.e. volunteers), third-party organisations (e.g. local authorities) and/or members of the public are sometimes involved in these tasks (Table 2). Several respondents reported that their network did not have routine access to veterinary/pathology expertise. One of them specifically referred to financial limitations on the work they could do.

Type of data and samples collected

Several types of basic data (i.e. location, date, species, sex, length, decomposition code) are routinely collected on most stranded animals (regardless of whether they are necropsied, sampled or simply recorded) (Fig. 6). Respondents often take photographs of the stranded animals and, on average, 84% of the reported strandings are photographed, although the figure varies across networks from 10% to 100%, and 97% of the photographs taken are subsequently archived. The presence of external evidence of bycatch is assessed on most stranded animals that are necropsied but the frequency of recording this information is markedly lower for animals that are sampled on the beach and drops below 50% for animals which are neither sampled nor necropsied. Information on body condition (e.g. nutritional condition code, girth, weight, and/or blubber thickness) is rarely taken from animals that are not necropsied. Samples are mainly collected from necropsied animals, with skin, blubber and teeth being the samples most often collected; see Fig. 6 for further details of samples collected. Some respondents indicated that they collect other types of samples either routinely or on an *ad-hoc* basis, depending on pathological signs and specific research/collaboration requirements. Such samples included bone, spleen, serum, central nervous system tissue, parasites, heart tissue, and (seal) whiskers.

Types of analysis performed on collected data and samples

The majority (82%) of networks perform some necropsies (31/38 respondents). Based on numbers provided by 29 of the respondents, on average 1075 marine mammals are necropsied per year (between 1 and 130 per network, excluding networks which perform no necropsies), corresponding on average to approximately 40% of the recorded dead marine mammals (range 3% to 100% based on 28 of the 31 respondents who carry out necropsies). Of note, two respondents indicated that there is an upper limit on the number of animals on which they are allowed to perform necropsies per year, due to funding constraints.

Most networks consider the decomposition state of the carcasses when deciding whether to necropsy an animal. Other key factors include whether the animal is from a rare or vulnerable species, its relevance to specific research questions, ease of access to the carcasses, staff availability, funding constraints (e.g. funding for a fixed number of necropsies), the need for representative sampling, and the body size of the animal, as larger ones are harder to transport (Fig. 2g).

Around 75% of the networks have specific facilities for performing necropsies (27/36), 74% have facilities for freezing the animals (26/35), and 80.5% have facilities for sam-

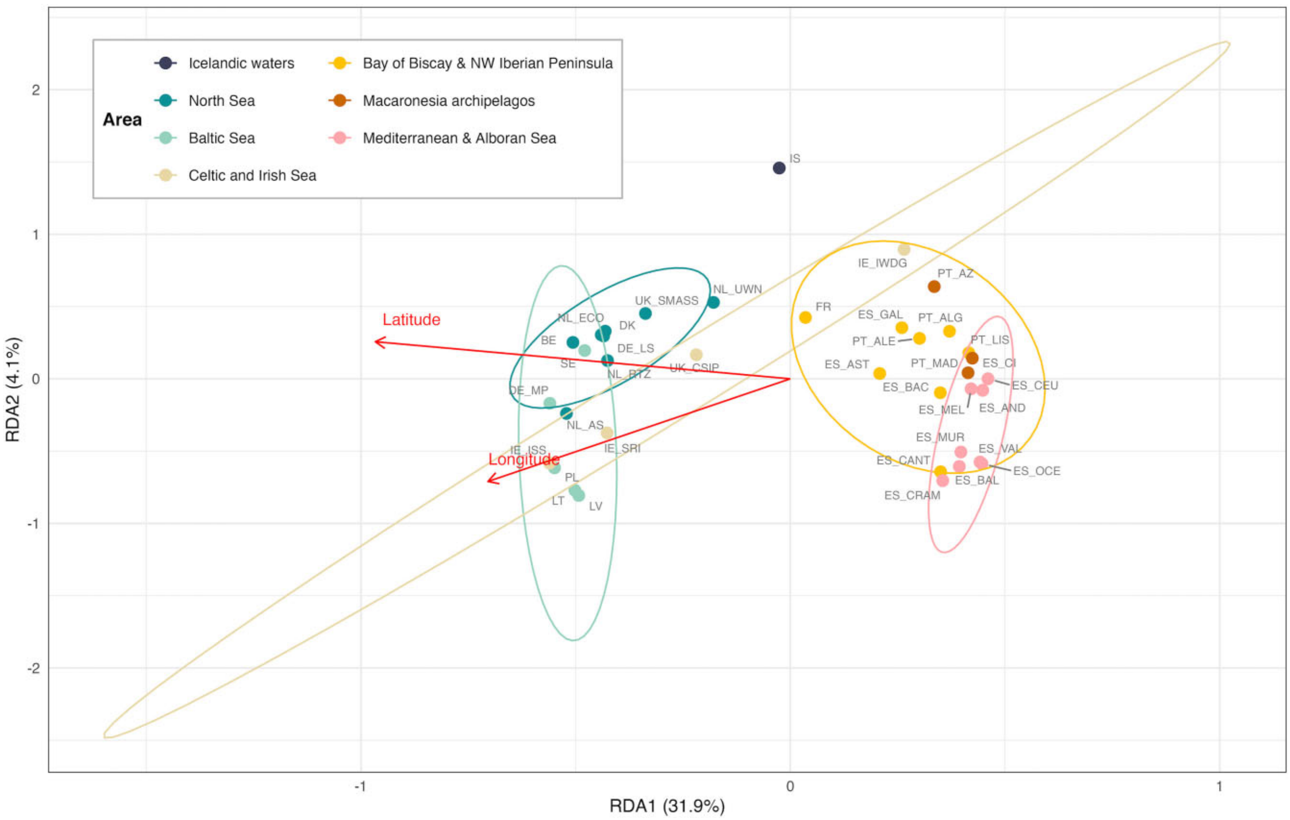


Figure 4. Biplot from a redundancy analysis (RDA) of species composition of marine mammal strandings as reported by the various networks, illustrating geographical patterns. Each point represents a monitoring network, identified by a two-letter country code. The analysis is based on the relative numerical importance (percentage of total) of each species, combining both live and dead strandings as reported by the networks over their respective periods of activity. To reduce the influence of rare species, the data were Hellinger-transformed prior to analysis. Geographical clustering of species composition is visualised with 95% confidence ellipses, corresponding to predefined regions in the Northeast Atlantic and Mediterranean Sea. The dataset can be consulted in Supplementary Material S2.

ple storage (29/36). On average, 32% of necropsied animals are stored frozen prior to necropsy; percentages for individual networks range from 0% to 100%.

Necropsies are most frequently carried out by experienced veterinarians (on average 65% of necropsies (range 0% (4 cases) to 100% (16 cases)) or experienced biologists (on average 36%, range 0% (17 cases) to 100% (4 cases)). In three cases, experienced veterinarians and experienced biologists worked together on necropsies. Necropsies were never carried out solely by inexperienced staff, although in eight networks such staff assisted experienced veterinarians/biologists with necropsies (in 8% and 1.5% of cases on average, respectively). In one organisation (a seal rescue centre), inexperienced veterinarians performed 80% of the necropsies but very few necropsies are carried out (e.g. only 3 in 2019). Another respondent indicated that although 100% of necropsies had been carried out by experienced veterinarians (45 necropsies in 2019), this relied on specific funding, which had now ended.

In relation to protocols for carrying out necropsies, most networks use the European Cetacean Society (ECS) (Kuiken and García Hartmann, 1993) and/or ASCOBANS/ACCOBAMS (IJsseldijk et al. 2019) protocols (19/31 and 13/31 respondents, respectively). Three out of the 31 respondents reported using the Society for Marine Mammalogy (Pugliares et al. 2007) protocol. Six respondents use a combination of the above-mentioned necropsy protocols. One respondent reported using the HELCOM protocol while another used a national protocol. Six Spanish respondents reported that they adapt or modify the published protocols according to their needs. Two Spanish respondents indicated that they collect various samples from the dead animals but do not follow any specific necropsy protocol.

Networks perform various types of diagnostic investigations on necropsied animals to determine their health state. Only gross pathology is normally determined routinely, although histopathology, parasitology, bacteriology, virology and analysis of persistent pollutants were carried out routinely or *ad-hoc* by most respondents (Fig. 5b). In relation to use of data and samples to determine life history and diet, routine analyses of female reproductive status and maturity state are the most frequently reported but fewer than half of the networks do these analyses routinely. Nevertheless, a majority of networks reported that they determine female and male reproductive status, maturity status, age and diet at least on an *ad-hoc* basis, e.g. when funding is available through specific research projects (Fig. 5c). Fewer networks responded to questions about how age and maturity were determined but, of those which responded, these characteristics were usually inferred from body length using published relationships between length, age and maturity rather than by analysing teeth and gonads (Fig. 5d). Of note, two respondents reported using

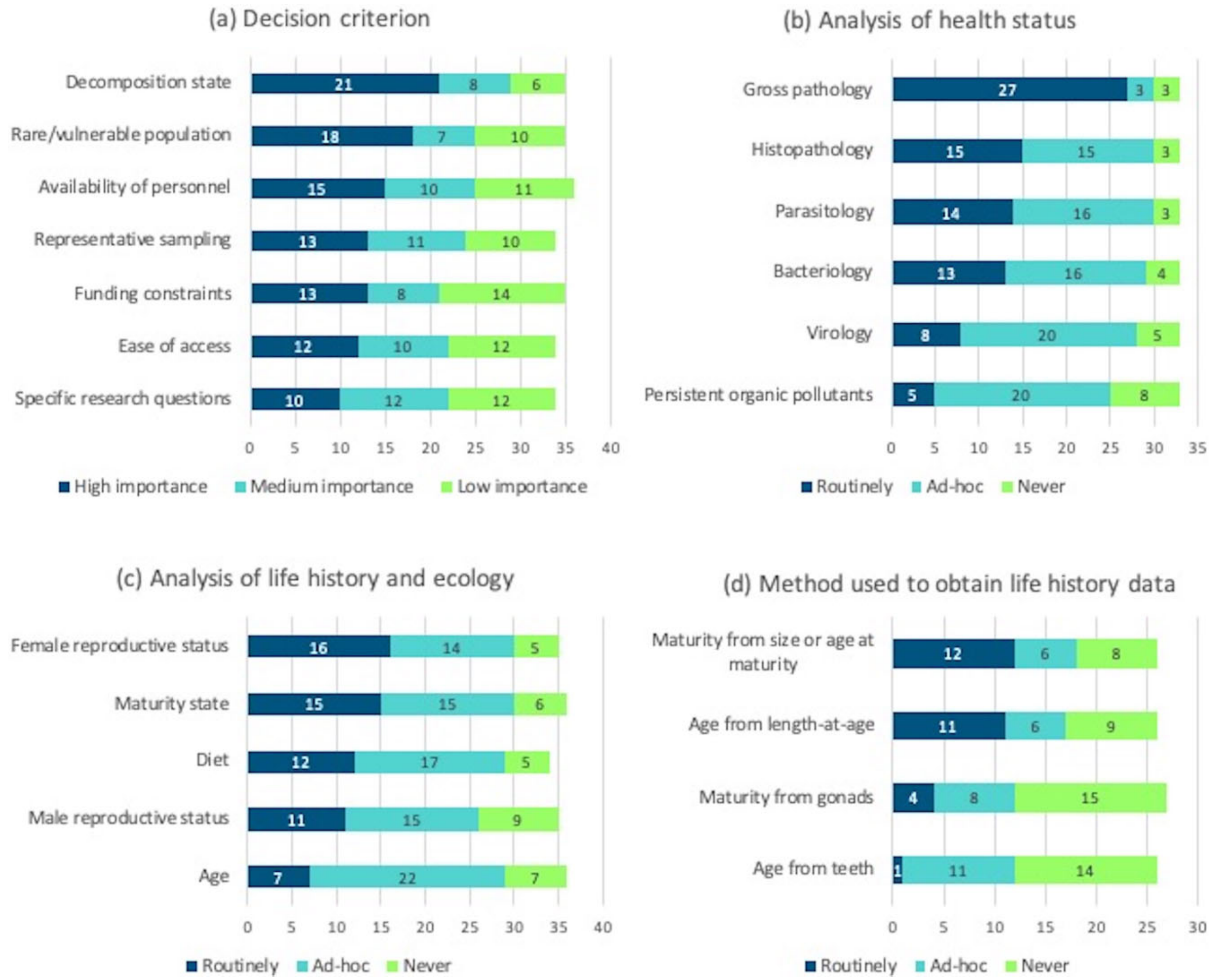


Figure 5. Results from the questionnaire on (a) Number of respondents indicating the importance (high, medium and low) of various factors in determining their decisions about which stranded animals to attend; (b) Frequency of diagnostic investigations carried out on necropsied animals to determine health state; (c) Frequency of analysis of reproductive status, maturity state, age and diet from stranded animals; (d) Frequency of use of different methods to determine maturity state and age of stranded animals. The total number of organisations who responded to each category is indicated in the bars.

Table 2. Persons involved in examining carcasses on the sea shore, and/or performing necropsies at a specialist facility, and/or taking measurements and photographs of the stranded animal, and/or collecting samples from carcasses on the sea shore.

Who does what?	Post-mortem examination on the shore					Necropsy at a specialist facility				
	A	U	S	N	Total	A	U	S	N	Total
Veterinary pathologist	2	7	15	12	36	11	9	9	8	37
Other trained personnel	4	9	14	11	38	9	4	7	16	36
Untrained personnel	0	2	5	28	35	0	1	1	34	36
Third party organisation	0	0	3	31	34	0	1	3	31	35
Members of the public	0	0	0	34	34	0	0	0	35	35
Who does what?	**Measurements/photos on the shore**					**Collecting samples on the shore**				
	A	U	S	N	Total	A	U	S	N	Total
Veterinary pathologist	2	4	18	12	36	1	5	13	16	35
Other trained personnel	11	16	7	4	38	5	10	10	12	37
Untrained personnel	1	5	17	13	36	0	2	6	27	35
Third party organisation	3	1	17	16	37	0	1	10	24	35
Members of the public	1	2	14	19	36	0	0	2	33	35

Frequency of attendance: A = Always, U = Usually, S = Sometimes, N = Never. Total = the number of respondents.

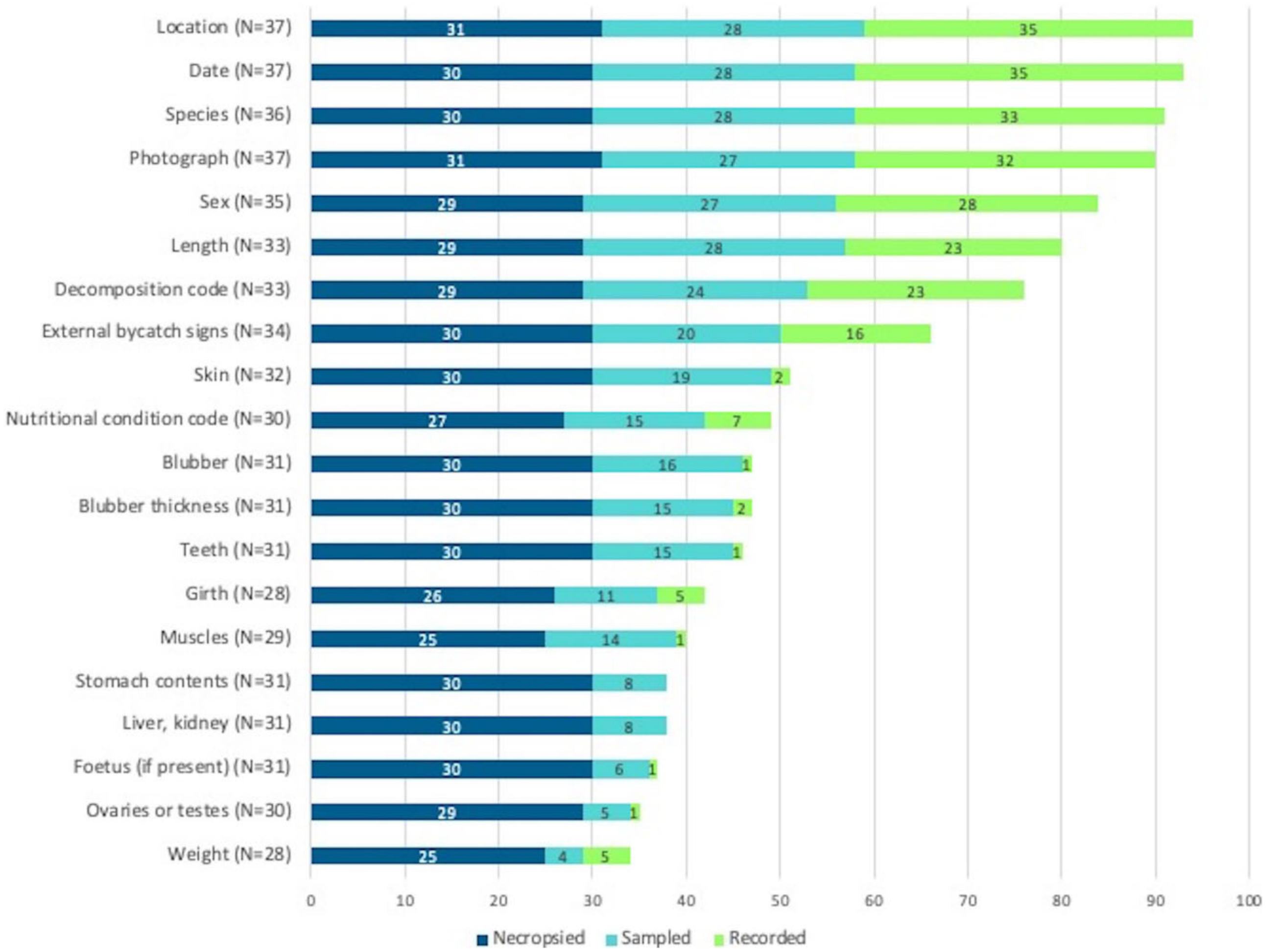


Figure 6. Frequency of data and samples collected from dead stranded animals during their necropsy (dark blue), sampling (light blue) and/or recording (green). For each data or sample type, the number of positive respondents is noted in the coloured bars, while the total number of respondents to each category is provided in parentheses. The list of data and samples presented in this figure is not a comprehensive list, as other types of data and samples may be taken routinely or on an *ad-hoc* basis by the networks.

Table 3. Summary of the numbers of individual marine mammals (cetaceans and pinnipeds pooled together) (i) reported (alive and dead pooled together), (ii) attended (alive and dead pooled together), (iii) which were dead or died and (iv) necropsied or partially-necropsied per year (data mainly from the year 2019 but from 2020 or 2022 in the case of more recently created organisations).

	Reported	Attended	Dead/died	Necropsied (wholly or partially)
Sum	8777	4072	6812	1143
Mean	274	145	220	36
Median	119	48	62	25
Range	2–2282	2–1791	1–2181	0–144

In each case the table shows the sum across all networks and the mean, median and range of values for individual networks. Since figures are based on responses to the questionnaire, the true sums are likely to be higher.

alternative techniques to determine the age, i.e. using x-rays to determine the degree of fusion of epiphyseal plates or the hyoid complex. Out of 33 respondents, only two indicated that a life table with age-specific fecundity and survival rates had been produced using age-at-death data and reproductive status data collected from stranded animals (see Mannocci et al. 2012, Read et al. 2020, Pierce et al. 2020).

Trends and patterns obtained

In total, 8777 stranded marine mammals (alive and dead cetaceans and seals pooled together) were reported for the year 2019 (or 2020 or 2022 for those organisations created more recently) by 34 respondents (Table 3). Of those animals, at least 4072 (46%) were attended (this should be considered as a minimum estimate as several respondents did not provide numbers for this category). Around 78% ($n = 6812$) of the reported animals were dead when stranded or died afterwards (although several respondents did not provide numbers for this category), and necropsies or partial necropsies were performed on 17% ($n = 1143$) of the dead animals. The proportion of animals necropsied varied among countries (see Table 4), and the respondents indicated that they also varied over time. Indeed, some respondents mentioned that numbers for 2019 were not representative of a "typical" year. The "necrop-

Table 4. Percentages of reported marine mammals (cetaceans and pinnipeds pooled together) that are necropsied (or partly necropsied) per country, as reported by 34 respondents (data mainly from the year 2019, and from 2020 or 2022 (*) for recently created organisations).

Country/Respondent	Reported	Necropsied (wholly or partially)	% necropsied (wholly or partially)	Km coastline	Density (reported strandings/km)
France *(RNE)*	2282	144	6.3	9193	0.25
United Kingdom	1912	166	8.7	24742	0.08
Scotland (SMASS)	770	52	6.8	16564	0.05
England, Wales and Northern Ireland (CSIP)	1142	114	10	8178	0.14
Republic of Ireland	923	78	8.5	7660	0.12
Entire country—cetaceans only (IWDG)	263	45	17.1	7660	0.03
Entire country—seals only (IR-SRI)	660	33	5	7660	0.09
Spain	876	274	31.3	9647	0.11
Galicia (RVG)	393	90	22.9	1843	0.21
Andalucía (RVCTMA)	145	28	19.3	1538	0.09
Canary Islands (RVCIC-IUSA)	104	59	56.7	1813	0.06
Basque Country (RVE)	48	9	18.8	283	0.17
Cantabria (ReVarCa)	37	22	59.5	394	0.09
*Asturias (RVA)**	36	14	38.9	493	0.07
Valencia (RVCTMCV-UV/FO)	31	12	38.7	684	0.05
Ceuta (RVC)	30	20	66.7	29	1.03
Balearic Islands (FPAQ)	23	9	39.1	1426	0.02
Catalonia (XRFM-UAB/CRAM)	20	8	40	788	0.03
Murcia (RVCTMRM)	7	3	42.9	344	0.02
Melilla (RVM)	2	0	0	12	0.17
Netherlands	798	96	12	1320	0.60
Entire country—cetaceans only (DSN-UWNO)	518	55	10.6	1320	0.39
Texel island—seals only (DSN-ECOMARE)	114	3	2.6	88	1.30
Ijmuiden to Cadzand—seals only (DSN-A Seal)	166	38	22.9	536	0.31
Denmark *(NCP)*	406	66	16.3	8252	0.05
Sweden *(SMNH-SVA)*	400	22	5.5	23559	0.02
Germany	436	93	21.3	4457	0.1
Mecklenburg-Prepomerania (MPDM)	145	93	64.1	1878	0.08
Lower Saxony (GM)	291	0	0	1417	0.21
Poland *(PSN)*	270	30	11.1	1924	0.14
Iceland *(MFRI)*	150	50	33.3	6453	0.02
Belgium *(MARIN)*	125	55	44	140	0.89
Portugal	121	69	57	3487	0.03
*Alentejo (ARROJAL)**	34	16	47.1	324	0.10
*Lisbon and Tagus Valley (RALVT)**	62	47	75.8	635	0.10
Azores (RACA)	14	0	0	941	0.01
Madeira (RACAM)	11	6	54.5	382	0.03
Lithuania *(LIT-VU)*	78	0	0	1195	0.07

In countries where there was more than one respondent, numbers are also provided for each respondent. Since figures are based on responses to the questionnaire, the true sums are likely to be higher. Data source for the calculation of the coastline length: Sevdari and Marmullaku (2023) and www.gadm.org. The coastline lengths calculated should be interpreted as approximations. The fine scale of these shapefile means that coastline features such as estuaries are included in the estimates sied" category included some animals that were opened to collect specific samples but not subject to full necropsy. The figures shown in Tables 3 and 4 should be considered as minimum estimates, particularly in Portugal, Germany, the Netherlands and Spain, as (1) not all of the respondents answered this question, (2) some of the respondents who answered did not provide numbers for all categories, and (3) some of the networks in these countries did not respond to the questionnaire. In addition, not all stranded animals will have been recorded by the networks, e.g. due to parts of the coast being difficult to access, low population density, etc.

Based on 32 responses, on average only a small proportion of cetaceans stranded alive (9%, ranging from 0% to 26%), of which 56% (range 0% to 100%) subsequently died or were euthanised on the shore. In comparison, 44% (range 1% to 100%) of seals stranded alive of which on average 21% (range 0% to 100%) died or were euthanised. The overall picture disguises wide regional variation, albeit without any obvious pattern. It should be borne in mind that the term "live stranding" may be misleading for seals, since some animals reported may simply have been hauled out. Conversely, an animal found dead may have stranded alive and died subsequently. Some respondents reported that other organisations hold or might hold further information about live strandings.

Based on the questionnaire, on average approximately 12% of the stranded marine mammals were live strandings (range 0%–80%), 22% stranded as "fresh" (1%–63%) carcasses, 22% were moderately decomposed (5%–44%), 31% were in an advanced state of decomposition (5%–85%), and the decomposition state of 14% was not determined (0%–67%). It is worth noting that IJsseldijk *et al*. (2019) proposed a 5-point decomposition scale, which differs from the above classification, and recommended standardisation of the way such data are collected. However, at present, different networks use different classification schemes. The decomposition classification used above was devised to incorporate the various different classification systems.

Approximately three-quarters of respondents (29 out of 38) reported having detected patterns or trends in numbers of stranded marine mammals in recent years. Nine respondents did not detect any patterns or trends, in three cases due to the recent creation of their organisations. Just over half of the respondents (55%; 21 out of 38) reported changes over time in the numbers of strandings of several species (e.g. an increase in common dolphin (*Delphinus delphis*) strandings over time in France). Some reported changes in seasonal patterns (29%, 11/38) and/or spatial patterns (16%, 6/38). For example, in addition to the commonly reported winter peak, there appears to have been a recent increase of strandings of common dolphins during the summer months in countries around the Bay of Biscay and Iberian coasts. One respondent reported an increase in the frequency of UMEs and MSEs (in Scotland). A few respondents mentioned that some of the observed variation in mortality was linked to fisheries interactions ($n = 4$), epizootic events ($n = 2$), fatal inter-species interactions with grey seals ($n = 1$) or bottlenose dolphins (*Tursiops truncatus*) ($n = 1$), and to parasite infestations (i.e. lungworms; $n = 1$). One respondent hypothesised that the shifts in distribution of strandings of some species could reflect responses to climate change (see Williamson et al. 2021).

Twenty-one out of 35 respondents (60%) reported the occurrence of MSEs in their areas during the course of their activity. For the purposes of the questionnaire, MSEs were defined as events involving ten or more animals stranding at the same place and time but it should be noted that other studies have defined MSEs as any stranding involving more than two individuals (e.g. in Geraci and Lounsbury 2005). Pilot whales (long and short-finned, *Globicephala melas* and *G. macrorhynchus*, combined) were the most commonly reported marine mammals involved in MSEs (by 8 out of 21 networks), followed by sperm whales (*Physeter macrocephalus*) (7/21), common dolphins and harbour seals (*Phoca vitulina*) (both 4/21), striped dolphins, beaked whales and grey seals (all 3/21), and bottlenose dolphins (2/21). The other species involved in MSEs (reported once each) were Fraser's dolphins (*Lagenodelphis hosei*), Risso's dolphins (*Grampus griseus*), spinner dolphins (*Stenella longirostris*), rough-toothed dolphins (*Steno bredanensis*), false killer whales (*Pseudorca crassidens*), and northern bottlenose whales (*Hyperoodon ampullatus*).

Four respondents indicated that they recorded several stranding events involving between 2 and 9 individuals from various species, and thus not qualifying as MSEs according to the strict definition used in the questionnaire. Seven respondents indicated having detected UMEs (defined as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response" under the US Marine Mammal Protection Act (www.fisheries.noaa.gov)), during the course of their activity. The reported frequency of MSEs and UMEs should be treated with caution. Although we provided a specific definition of an MSE, several respondents mentioned that the terms MSE and an UME were generally used interchangeably, and some of the authors were aware of two UMEs in countries where respondents did not report any UMEs.

Constraints on stranding network activities

The most frequently cited limitation affecting the activities of stranding networks was the availability of financial resources, with 68.5% of respondents indicating that this is a problem of high or medium importance (Fig. 7). Other frequently mentioned limitations included a lack of human resources, the absence of a volunteer network, carcasses often being found substantially decomposed (which limits the collection of data and samples), problems with carcass recovery, low numbers of carcasses being reported to the networks, a lack of veterinary expertise, administrative issues, difficulties with accessing remote areas, the distribution of volunteers, and issues with carcass examination (Fig. 7). It should be noted that, for most of these limitations (a notable exception being the relevance of decomposed carcasses), a substantial number of respondents did not state the importance of the different limitations. In addition, three respondents mentioned that their activities were limited by other factors, specifically fishers' mistrust, a lack of territorial continuity and/or a lack of governmental support.

Some of the limitations faced are directly related to funding availability (e.g. lack of human resources, lack of veterinary expertise), whereas others relate more to the nature of strandings, (e.g. the advanced decomposition state of carcasses discovered). Of course, these limitations are not entirely independent of each other: lack of human resources or a volunteer network, or the distribution of volunteers, may all contribute to some carcasses being reported and/or visited only after they have been ashore for some time.

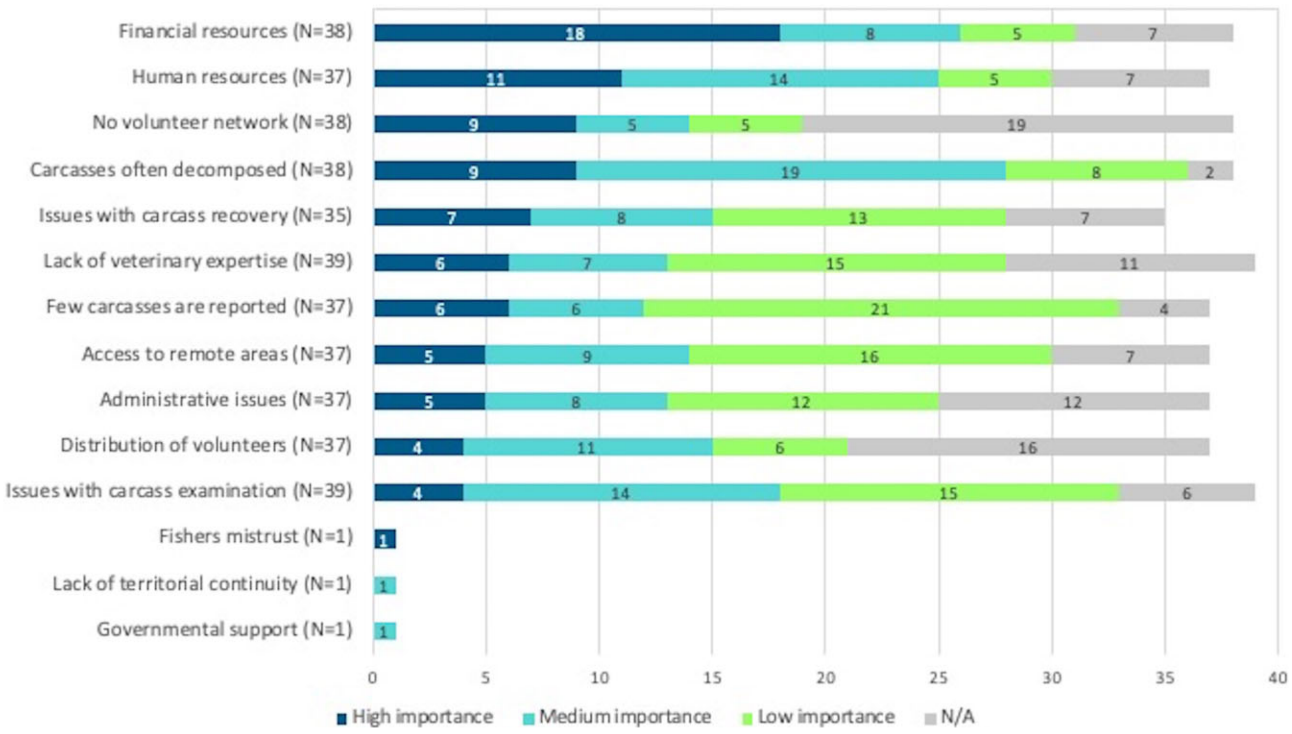


Figure 7. Importance of the main limitations identified by the respondents in relation to determining the incidence of bycatch mortality in marine mammals. The respondents' views about the importance of each category of limitation are colour coded (dark blue: high, light blue: medium, green: low, grey: importance was not stated (was not applicable; N/A). The number of responses for each category is indicated on the bars. The total number of respondents to each category is provided in parentheses.

Discussion

The consultation exercise enabled the description and comparison of various aspects of the monitoring activity of many European stranding networks. The data collected by the networks appear to be reasonably representative of the large-scale species distribution patterns of marine mammals in Europe (see Fig. 4, Figure S1, Table S2), and monitoring of strandings clearly provides a wealth of information on many different species, including rare or elusive ones, on causes of death, life history, ecology and health. Such data can be used to detect patterns and trends in fisheries interactions, epizootic events, fatal inter-species interactions, parasitic infestations, etc., and can help to determine conservation status and the impact of stressors and threats. Strandings monitoring has a sentinel role, notably via unusual and mass stranding events. There are of course many aspects of strandings monitoring, and the resulting data and samples, which could be examined in more detail (e.g. best practice for necropsy procedures, the representativeness of stranded animals, etc.), but this was beyond the scope of the present exercise.

Information from strandings provides a valuable contribution to the various national and international monitoring and reporting obligations. For instance, at the regional seas scale, they can support EU Member States in meeting the requirements of the MSFD and Habitats Directive (see Table 1). Similarly, within the European Atlantic, strandings' data currently inform assessments conducted under the OSPAR Convention, including the Quality Status Reports (QSR) and the Intermediate Assessments. The most recent QSR incorporated several indicators that rely on stranding data from marine megafauna (OSPAR 2023). Examples include "Marine Litter Ingested by Sea Turtles" (Galgani et al. 2022), "Plastic Particles in Fulmar Stomachs in the North Sea" (Kühn et al. 2022), and a pilot indicator on the "Status and Trends of Persistent Chemicals in Marine Mammals" (Pinzone et al. 2022). Such indicators would not be achievable without the systematic data and sample collection undertaken by stranding networks. The conservation value of such information has become more widely recognised since its use in estimating bycatch mortality of common dolphins and harbour porpoises in the northern Bay of Biscay (Peltier et al. 2016, 2024, ICES 2023, 2024a, 2024b). Currently, several international organisations, including ASCOBANS, ACCOBAMS, IWC, HELCOM, the North Atlantic Marine Mammal Commission (NAMMCO) and (more recently) ICES, routinely request and/or use strandings data annually for various purposes—also illustrating the potential value of ensuring a unified process for collecting, processing and reporting information from strandings.

Many of the constraints identified through the consultation are also observed globally (Gulland et al. 2025), such that there is limited integration of stranding data into conservation management. Enhancing the utility of stranding data for management remains a critical need (e.g. Oliveira et al. 2024). Hence, based on the present study, we provide some recommendations on how to enhance the value of the information collected in Europe.

Spatial coverage

Respondents provided information regarding the strandings monitoring in 19 countries with Northeast Atlantic and adjacent coastlines. Gaps in spatial coverage were identified in some Nordic and Baltic countries. Reasons given for the lack of an active stranding network include a discontinuous coastline, very few animals stranding in an area, the predominance of animals in an advanced state of decomposition when discovered, the availability of data and samples from freshly hunted marine mammals, and a lack of funding and/or interest from relevant authorities. However, some of these issues also apply in countries that already have stranding networks. While hunted animals can provide information on individual health and population status (e.g. Bäcklin et al. 2011, Kauhala et al. 2015), evidently, they are not useful to investigate other causes of trauma-related mortality, such as bycatch, and are unsuitable to assess broader threats. In Sweden, the Swedish Museum of Natural History not only collects data and samples from stranded animals but also gathers information from hunted seals under a mandatory reporting scheme, and routinely receives bycaught seal carcasses from fishers. It is recommended that those Baltic and Nordic countries and self-governing territories that currently lack stranding networks should establish them. More generally, we encourage the integration of information from different sources, including strandings, carcasses received from fishers, and hunting—while emphasising the importance of accounting for the source in any analysis. Thus, data from the three aforementioned sources cannot be combined when estimating bycatch mortality rate.

Credibility and quality of the data

A range of factors affect the likelihood that an animal which dies (or becomes incapacitated) at sea will arrive at the coast and be reported to a stranding network. These factors include environmental variables (e.g. wind-driven currents), coastal topography, carcass buoyancy, and the spatial and seasonal distribution of a species at sea (and how it varies, e.g. between years and between different population components). In addition, reporting of carcasses depends on the accessibility of the coast, local human population density and the importance of tourism, prevailing weather conditions, the efforts of the stranding networks, the levels of public interest and awareness, and the engagement of local authorities. In addition, the COVID-19 pandemic affected the effort of some of the networks. All these factors potentially cast doubt on the representativeness of stranding data, raising concerns about the quality and credibility of such data.

There is a need for a standardised approach to measuring search effort, to increase the credibility of the data produced, and as far as possible reduce or at least account for potential biases and uncertainties when drawing conclusions about, for example maturation, fecundity, sex ratio, age distribution, mortality rate and the relative frequency of different causes of death.

Most respondents reported that the effort devoted to monitoring strandings was relatively stable over time, albeit with small fluctuations, for example due to changes in funding availability, increasing public awareness, and increasing access to mobile phones and social media. However, there has been little analysis of the distribution of effort over time (see Authier et al. 2014) and the intensity of effort expended in monitoring of marine mammal strandings almost certainly has been variable in space and time. Search effort is difficult to quantify, e.g. because strandings may be reported to a network via multiple routes and many networks rely at least to some extent on reporting of strandings by members of the public.

Efforts to date to account for uncertainty and bias in data from strandings address both the arrival of dead animals at the coast and the likelihood of them being discovered, both separately and together. A combination of better understanding of at-sea distribution and drift modelling of the transport of cetacean carcasses, accounting for the effects of carcass buoyancy and ocean currents, is helping us to understand whether and where carcasses will reach the coastline (e.g. Peltier et al. 2016, Saavedra et al. 2017, Moore et al. 2020). Reverse drift modelling can be used to estimate the number of mortalities at sea which would have given rise to the number of dead animals discovered on the coast as well as providing an indication of where they died (Peltier et al. 2016). Mobile phone applications can record the distance covered by app users while searching along the coast, as is done in Scotland (Beach Track—https://beachtrack.org/, Scottish Marine Animal Stranding Scheme; ten Doeschate et al. 2024). Statistical analyses can be used to quantify the effect of variation in reporting rates on trends in stranding records (Authier et al. 2014). Trends in strandings can also be compared with trends in sightings (IJsseldijk et al. 2021). However, if networks record search effort by volunteers and staff, there is a need to capture effort by other coast users. In principle, given data at appropriate temporal and spatial scales, a modelling approach could be used to express the reported number of strandings as a function of cetacean distribution and abundance at sea, search effort by app users, indices of human use of the coast and environmental factors, such that unexplained variation could then be attributed to variation in mortality rates due to different causes. Further work is needed in this area but, minimally, the universal use of apps to record search effort by network volunteers would be a good first step.

It should be borne in mind that, if strandings are representative, evidently what they represent is the dead animals rather than the living population and as such, for example, very sick animals will tend to be relatively more frequent among strandings than in the living population. Life table methodology (Krebs 1989) allows the estimation of the age distribution of the living population based on the age distribution of the dead animals, given a stable age structure (see, e.g. Mannocci et al. 2012, Read et al. 2013, Pierce et al. 2020, 2024), and can be used to estimate annual mortality rate. The smallest animals are likely under-represented in strandings and it is possible to compensate for this bias by applying a mortality model such as the Siler model (Siler 1979, Saavedra 2017, Rouby et al. 2020). Birth rate can also be estimated, given data on the sex, maturity status and pregnancy of the dead animals. To avoid underestimating birth rate, the subset of trauma deaths is likely to be more representative of the living population and it is also important to avoid animals stranded during the implantation period, when fetuses may be too small to detect (Murphy et al. 2009).

Pinnipeds and other taxa

While most of the networks that were consulted collect information on stranded cetaceans, fewer collect information on other taxa. This emphasis on cetaceans is probably in part a consequence of the requirements of ASCOBANS and ACCOBAMS, which mandate the collection of stranding data for these species. Although 77.5% of respondents reported collecting information on seals, several of them noted that there seemed to be less funding available for and/or interest in collation of detailed information on seals. Thus, relatively few seals are necropsied or sampled. Arguably, more effort should be devoted to pinnipeds, as they face many of the same threats as cetaceans and can also be used as indicator of climate change and/or ecosystem change (Blanchet et al. 2021). Some seal species in European seas, notably the Mediterranean Monk seal (*Monachus monachus*), are also listed as vulnerable on the IUCN Red List (Karamanlidis et al. 2023), and protected under several international conventions and laws (e.g. Bonn Convention, Bern Convention, Habitats Directive). While obtaining an overview of seabird strandings was not an objective of the questionnaire—and hence organisations devoted to seabird strandings were not consulted—some of the respondents included seabirds in their monitoring activities. In regions where there is no dedicated scheme for monitoring stranded seabirds, the collation of data on seabirds by marine mammal stranding networks would be particularly relevant at present for monitoring pathogen circulation. For example, since 2021, there have been significant outbreaks of highly pathogenic avian influenza (HPAI) (Wille and Waldenström 2023), which is a disease known to spread to marine mammals and, although (until recently) rarely, to humans (European Food Safety Authority et al. 2023, Puryear et al. 2023, Thorsson et al. 2023, Murawski et al. 2024, Plaza et al. 2024). Consequently, in addition to tracking HPAI through marine mammal strandings, monitoring stranded birds—and carrying out full necropsies—would also provide valuable insights.

Coordination at national level

Responses highlighted differences in how networks are organised in each country. To some extent this may be a consequence of geographical constraints (the length and type of the coastline, including the different challenges posed by mainland coastlines and islands) and differing political landscapes. Thus, it may be administratively more challenging to centralise the coordination in larger countries and in those countries where regions have a certain degree of autonomy, and for scattered islands and archipelagos (e.g. in Macaronesia). In Spain, there is at least one network per autonomous region, and these networks sometimes collect and analyse data and samples using different protocols. There has been a recent initiative to provide national funding and coordination of these Spanish networks, as well as a national protocol for cetacean strandings (MITECO 2022). Such support could benefit the networks in several ways, by facilitating standardisation of data collection, encouraging collaboration between regions, and potentially reducing administrative burden and providing more stable financial support.

Funding

The main constraint on the activities of stranding networks identified was the availability of financial resources. In general, the networks are mainly funded via national and regional authorities, while some networks receive income from projects, donations, volunteer fees, visitor entries, and private funding, which may not come on a regular basis. In addition, almost 60% of the respondents reported relying on volunteer work to conduct at least some of the network activities, for example the reporting of carcasses to stranding coordinators. Importantly, some respondents indicated that some of their core staff were unpaid volunteers, a situation that sometimes persists for extended periods of time. The amount and continuity of funding available inevitably impacts the networks on many levels, e.g. their ability to hire, train and retain personnel (perhaps the most important aspect to ensure continuity of the work), access veterinary expertise, attend strandings, collect data and samples, conduct necropsies, analyse samples and disseminate results. Such constraints were reported by many respondents throughout the study area. Since the questionnaire was launched in 2021, there have been initiatives, e.g. in Spain and Portugal, to provide funding for the creation and maintenance of stranding networks (e.g. Fundo Ambiental 2020, Fundación Biodiversidad 2021).

Monitoring requirements under environmental legislation may be difficult to achieve in the absence of continuous and adequate funding. Only full necropsies of stranded animals can provide a comprehensive understanding of individual and population health, causes of mortality and associated threats. While the cost of sample collection and analysis for this purpose is undoubtedly high (Table 1), adequate national funding is essential to support monitoring, detailed examinations, and reporting commitments. Some combination of national and regional governments is needed to support stranding networks. It is difficult to specify a required level of funding—this is very much dependent on the number of stranded animals and the nature of threats in each region—but without such support our ability to monitor the status of marine mammal populations and manage the threats they face is much reduced.

Standardisation and harmonisation of samples and data collection

A wide range of data and samples is collected by networks but details vary between networks regarding exactly what is collected and how it is collected. While the ECS necropsy protocol (Kuiken and Garci´a Hartmann, 1993) is the most frequently used protocol in the networks surveyed, other and/or modified protocols are also used. Such differences can create inconsistencies in the data, in turn affecting conclusions from data analyses. An obvious example is the detection of bycatch mortality, which may be achieved both more reliably and more frequently following a full necropsy and associated sample analysis, which can also provide important context concerning the health, condition, age and reproductive status of the bycaught animals. Ideally, all networks should follow the same protocol for the collection of data and samples, e.g. using the updated ECS protocol developed by IJsseldijk *et al.* (2019), supported by regular calibration and standardisation exercises.

Increase emphasis on necropsies and analysis of data and samples

While it is evidently true that sometimes the cause of death can be determined based on external examination, this can also lead to misdiagnosis and an absence of relevant supporting information. A full necropsy by a trained veterinary pathologist (and subsequent sample analysis, e.g. for histopathology) should ensure an accurate and credible diagnosis of cause of death—accompanied by information on any associated uncertainties (including the possibility that cause of death cannot be determined, in the context of a comprehensive understanding of an animal's health status (Table 1)). A large majority of networks perform necropsies, even if only on selected stranded marine mammals. Nonetheless, there are a few networks that do not perform necropsies (see Table 4), potentially hindering our understanding of the threats faced by marine mammals in some regions—and, as noted above, different necropsy protocols are in use. These regional differences may be related to funding, but also the fact that some countries, such as France, receive very large numbers of strandings per year, and so it is logistically impossible to necropsy all animals. Necropsies are mainly performed by veterinarians (mainly veterinary pathologists) and trained biologists. However, some networks indicated that they lacked veterinary pathology expertise, principally due to a lack of funding to hire trained personnel. Access to funding can also limit a network's ability to access appropriate facilities to perform necropsies, store dead animals and samples and carry out subsequent analyses. Thus, among other factors, the decision to perform a necropsy may depend on resources, i.e. the personnel and/or the funding available.

The analysis of basic data (e.g. species, location, date, body length, sex, decomposition state) and data arising from external examination and limited sampling collection (e.g. measurements of girth, blubber thickness, and weight, samples of skin, muscle, blubber, teeth, whiskers, and, in cases of advanced decomposition, bone) from stranded animals can be very useful to obtain information on population status and contribute to fulfilling certain monitoring requirements. However, more comprehensive examinations, such as full necropsies combined with extensive sample collection and analysis, can substantially enhance the extent to which these requirements are met (Table 1). In the context of the EU MSFD, the analysis of data and samples derived from comprehensive examinations can inform assessments for a range of MSFD descriptors and indicators (e.g. Mannocci et al. 2012, Peltier et al. 2016, 2019, Samarra et al. 2024, Nelms et al. 2019, IJsseldijk et al. 2020, Pons-Bordas et al. 2020, Méndez-Fernandez et al. 2022, Siebert et al. 2022, Solomando et al. 2022, Gose et al. 2023, Stokholm et al. 2023, Albrecht et al. 2024, Hernández-González et al. 2024). This includes indicators for descriptors D1, D2, D4, D5, D8, D9, D10, and D11 (see Table 1, and Santos and Pierce 2015).

The consultation revealed that many networks determine gross pathology for necropsied animals to provide information on health status but other procedures that are important to fully assess health status, such as histopathology, parasitology, bacteriology, virology, and analysis of persistent organic pollutants, are less likely to be carried out regularly and are often project-dependent. This is also the case for the determination of age, maturity, reproductive status, and diet. As noted above, age, maturity and reproductive status data are essential to estimate age-specific fecundity and mortality rates, which contribute to a better understanding of both the level of threats that marine mammals face and their impacts (Mannocci et al. 2012, Cervin et al. 2020, IJsseldijk et al. 2020, Read et al. 2020), and to provide essential context for results on contaminant levels, parasite burdens, other health issues and diet. We recommend that such analyses should become part of routine baseline monitoring, implying an appropriate level of funding—and we emphasise that shortcuts such as using length as an indicator of age and maturity status are degrading the quality of information available and indeed preventing us from detecting spatio-temporal variations in life history parameters that are critical determinants of population status and our understanding thereof (e.g. Murphy et al. 2020).

The value of decomposed animals

Aside from funding, arguably the most important factor (which almost 75% of respondents regarded as of high or medium importance) influencing the decision as to whether to attend a stranded animal is its decomposition state, for the obvious reason that this limits what data and samples can be collected from the carcasses. Evidently, this is largely beyond the control of the networks or their funding bodies, except insofar as increased search effort could lead to earlier discovery of some carcasses and hence the availability of more fresh carcasses—bearing in mind that in some countries most animals reach the coast in a moderate to advanced state of decomposition. Nonetheless, useful information often can be collected from decomposed animals, such as species, body length, sex and some indications about the cause of death, as well as samples of bones, teeth and stomach contents. A range of analytical investigations can be performed on samples collected from carcasses in advanced stages of decomposition (e.g. genetics, diet, marine debris, life history, stable isotopes, parasitology, see IJsseldijk et al. 2019). For example, identifiable hard remains of prey can persist within the stomachs of even highly decomposed carcasses. Therefore, monitoring of strandings in regions with a low proportion of fresh carcasses can still provide useful scientific insights into regional marine mammal populations.

It is also important to understand whether fresh carcasses are representative of strandings as a whole, e.g. when they are compared to the more decomposed animals, they have a similar species composition, size distribution, sex ratio, proportion of animals that have obvious signs of bycatch, etc. Of course, this may not be the case, as different types of mortality may occur more frequently in different locations and the time taken for carcasses to reach the coast (if they do so) may differ according to location. For example, many bycatch mortalities may occur in offshore fisheries, and will tend to be under-represented in the strandings and, when they do strand, they are likely to be highly decomposed. Another point to keep in mind is that, all other things being equal, it is likely that those networks which have more limited resources will tend to focus more on the freshest carcasses.

In order to evaluate the importance and feasibility of carrying out more investigation of moderately and highly decomposed carcasses, we recommend that all stranding networks consider undertaking the following exercises:

(i) Carry out a series of additional beach walks/surveys, covering the whole coastline and whole calendar year as far as possible, to assess the frequency with which carcasses strand and how long they remain on the shore before being reported;
(ii) Compare the fresh, moderately decomposed and highly decomposed carcasses in terms of the various characteristics mentioned above: species composition, size distribution, sex ratio, frequency of external bycatch indications, etc., to assess the extent to which fresh animals are representative;
(iii) Develop and apply drift models to assess the likely origins (in space and time) of stranded marine mammals, and to establish the relationship, if any, between point of origin of the carcass and its decomposition state upon reaching the shore;
(iv) Depending on the outcomes of these exercises, consider increasing efforts to collect data and samples

(and, when feasible, undertake necropsies) from moderately and even highly decomposed carcasses, especially to reduce any biases detected due to focusing on fresh carcasses. Ideally, this additional work would not result in fewer necropsies being conducted on fresh animals;

(v) Develop a common protocol for the choice of which animals to necropsy, acknowledging the geographical and resourcing differences between networks while attempting to minimize unplanned biases and differences in the sampling regimes of different networks.

Availability and publicising of results

In general, stranding networks have developed efficient strategies to promote awareness of their existence and their activities, and to facilitate collaboration with other parties—an essential aspect of their work. Most networks make their results, data and samples available to other interested parties, often via data-sharing agreements. However, only a handful of networks make at least some of their data publicly available (see Table S1), and what is shared is mainly summary data (e.g. time, location, species) and some basic biological data. This tends to be in the form of annual reports, and sometimes through online databases. Detailed necropsy findings are rarely publicly available, and access to them often requires the establishment of collaboration agreements. Progress is needed to make findings more readily available to researchers and policy-makers as well as to the general public, in reports and/or databases. To facilitate international collaboration, it would be useful if at least metadata were available in English as well as the relevant native language.

There are barriers to be overcome, even if information that was collected by making use of public funds should, arguably, be publicly available, e.g. under the FAIR principles of findability, accessibility, interoperability, and reusability. One respondent noted that the dissemination of content on strandings to the public was limited by their agreement with their funding body, in this case the regional administration. The knowledge, data and samples held by a network also potentially increases its prospects of attracting external research funding. Noting that the work of some networks is also supported by private funding, we nevertheless urge further efforts to adopt the FAIR principles.

Streamlining the reporting

Respondents made clear that reporting their findings to multiple entities every year increased their workload, and that there is a need to streamline the reporting. The questionnaire explored the willingness of networks to report to a single entity (e.g. ICES), for example via an annual data call, a suggestion which was largely supported in principle by the respondents. Several ongoing initiatives are exploring the feasibility of creating a common marine strandings database in Europe (Brownlow et al. 2023, 2024) and discussions already involve several interested parties (e.g. ICES, ASCOBANS, IWC). The creation of such a database for the ICES area would encourage the standardisation and harmonisation of data and sample collection and analyses, support the work of various stakeholders, and benefit European marine wildlife research and conservation. Work is still needed to define the scope, ambition, governance, and format of the database. Evidently, funding will be needed, not only for the creation of a database, but also to maintain it. Once up and running, the system would imply timely uploading of stranding data, while recognising that data based on analysis of collected samples might become available only at a later date.

Quality control is undoubtedly an issue and there will be a need for comparability exercises (something that is already routine in relation to, say, monitoring of pollutant levels in marine organisms). Advantages of an existing international body such as ICES hosting the database could include benefitting from the existing infrastructure and experience with handling data calls, as well as existing protocols for processing and screening data. Comparable streamlining efforts are underway globally. In the United States, for example, the forthcoming Marine Mammal Health Monitoring and Analysis Platform (Health MAP; https://www.mmc.gov/priority-topics/marine-mammal-health-and-strandings/marine-mammal-health-and-monitoring-analysis-platform-marine-mammal-health-map/) represents a parallel initiative. Additionally, there has been a recent call to establish a Global Marine Mammal Stranding Network, comprising regional chapters and supported by both public and private sectors (Gulland et al. 2025).

Conclusions

Stranding networks have proven to be an important tool to monitor marine mammals in Europe, providing extensive spatio-temporal coverage and generating information that has contributed to shaping our knowledge of marine mammal populations for several decades. The main constraint on the activities of stranding networks that was identified by this survey is the availability of financial resources, which impacts all their activities, from hiring personnel, attending strandings, collecting data and samples, and conducting necropsies, to analysing samples and reporting the results. The monitoring of marine wildlife in Europe is required under multiple national, European and international laws, directives and agreements. Ideally, funding from some combination of national and regional governments should support stranding networks to carry out the necessary monitoring. Many networks are able to raise funds via donations, volunteer fees, visitor entries, etc., applying for grants, as well as benefitting from the work of volunteers. However, the unpredictability (and often relatively low level) of such funding is itself a major constraint.

Other constraints (e.g. related to the decomposition state, accessibility and size of carcasses) cannot be avoided to any great extent but the resulting limitations and biases can and should be taken into account. We recommend various further efforts towards better coordination, standardisation and harmonisation of data/sample collection and analysis, and to improve the accessibility of the resulting information. The requirement to report results to multiple entities could be eliminated by streamlining reporting at the European level, and may be achievable through current initiatives such as the implementation of an international common stranding database.

We recommend an increase in the number of necropsies (and associated sample analyses) performed—while this is probably the most expensive type of activity, it also generates the best data—as well as making more use of less fresh carcasses. It is difficult to recommend a minimum number of necropsies per species per network that is acceptable: it depends on the status of the populations, the importance of different threats in the area, the number and decomposition state of stranded animals, and indeed the indicator that is being quantified, among other factors. However, just as the ICES WKPETSAMP workshops have addressed onboard monitoring requirements to assure adequate quantification of bycatch under a range of circumstances (ICES 2019, 2024c,d), such an exercise could ultimately be done for stranding data.

Other measures to improve the quality and credibility of data collected could include the quantification of search effort, the more general use of drift models and modelling the probability of carcasses reaching the coast to understand and account for the representativeness of stranded animals. We also recommend extending strandings monitoring to those Baltic and Nordic countries and self-governing territories which do not currently have stranding networks—while hunting can, by definition, yield valuable data, it is not an effective means of obtaining information on other causes of mortality in marine mammals. More attention needs to be given to seals, and (albeit beyond the remit of the present paper) to other endangered, threatened and protected species such as seabirds, sea turtles and sharks.

Finally, wider understanding of the value of stranding data, by scientists, authorities and the general public, could facilitate both better funding and improved standardised data delivery. Ultimately, this will facilitate the better integration of these data into environmental assessment and their use in conservation management, to the benefit of all parties, as well as contributing to the knowledge base on marine wildlife such as marine mammals.

Acknowledgements

The authors thank Robyn Leslie and Nikki Cotterill from Seal Rescue Ireland, as well as Aurelio Centellas and Maria Isabel López Pérez from Centro Isla La Graciosa (Organismo Autónomo Parques Nacionales) for their contribution to this study. We thank Aqqalu Rosing-Asvid from the Greenland Institute of Natural Resources for providing information on Greenland's activities regarding strandings of marine mammals. We are grateful to members of ICES WGMME for helpful and supportive discussions. The authors thank the hundreds of people, both staff and volunteers, who contributed their time and effort to collect information on strandings around the ICES area. The Galician stranding network has the support of the Biodiversity Foundation of the Spanish Ministry for Ecological Transition, through the Revargal project, which is financed by the European Union - NextGenerationEU, through the Recovery, Transformation and Resilience Plan; and also has the support of the Xunta de Galicia - Galician Ministry of the Environment, that also provided the legal permits for the management of cetacean species and the collection of biological samples. A.L. is supported by the CESAM by FCT/MCTES. (UIDP/50017/2020+UIDB/50017/2020+LA/P/0094/2020), through national funds and by national funds (OE), through FCT-I.P., in the scope of the framework contract foreseen in the numbers 4, 5 and 6 of the article 23, of the Decree-Law 57/2016, of August 29, changed by Law 57/2017, of July 19. We thank the entire Coordinadora para o Estudo dos mamíferos Mariños (CEMMA) volunteer team, Uxía Vázquez as coordinator, Xavi Pin, and Mónica González. Prior to 2022, the stranding network Red de varamientos de Euskadi (RVE) was managed by the NGO AMBAR Elkartea, which received funding from the Basque Government (Department of Environment and Spatial Planning). The Asturian stranding network is part of the Administration of the Principality of Asturias. The CAIC-IUSA-ULPGC is supported by the Canary Islands Regional Government. The stranding network of Murcia is supported by the Dirección General y Acción Climática, Gobierno de la Región de Murcia. A.G.R. thanks the volunteers at the Centro de Estudios y Conservación de Animales Marinos (CECAM) in Ceuta. Fundación Oceanogràfic has the support of the Biodiversity Foundation of the Spanish Ministry for Ecological Transition, through the Sanimar project, which is financed by the European Union - NextGenerationEU, through the Recovery, Transformation and Resilience Plan. Fundación Oceanogràfic also thanks ZOETIS Spain for supporting veterinary diagnosis and stranding medical response. The work of J.A.R. and P.G.A. at University of Valencia has been supported by the VARACOMVAL project of the Biodiversity Foundation of the Ministry for the Ecological Transition and Demographic Challenge (MITECO) of Spain under the NextGenerationEU Recovery, Transformation and Resilience Plan (PRTR). The Algarve Centre of Marine Sciences (CCMAR) is supported by the Portuguese Science and Technology Foundation (FCT) through projects UIDB/04326/2020, UIDP/04326/2020 and LA/P0101/2020. As of 2020, the Rede de Arrojamentos do Algarve (RAAlg) is supported by Fundo Ambiental from the Portuguese Environmental Ministry. The project "ARROJAL - Apoio à Rede Nacional de Arrojamentos - Rede Regional Alentejo") is coordinated by the university of Évora in collaboration with the Portuguese Institute for Nature Conservation and Forests (ICNF), being funded by the Fundo Ambiental; MARE and ARNET are supported by the Portuguese Foundation for Science and Technology (FCT), through the strategic projects UID/MAR/ 04292/2019 and LA/P/0069/ 2020; We thank all the researchers and volunteers who have contributed to our regional stranding network in Alentejo, Portugal (ARROJAL). The work of Rede de Arrojamentos de Lisboa e Vale do Tejo (RALVT) was supported by Fundo Ambiental, under a financial and technical cooperation agreement between Fundo Ambiental, ISPA IU and ICNF. J.I.R. thanks MARE/UIDB/MAR/04292/2020, MARE/UIDP/04292/2020 and LA/P/0069/2020 granted to MARE/ARNET. The Azoreans stranding network (RACA) is supported by the Regional Government of the Azores and financed through EU funding, namely MARCET (Interreg Mac 14-20, MAC/1.1b/149), MARCET II (Interreg Mac 14-20, MAC2/4.6c/392), and LIFE IP Azores Natura (Active Protection and Integrated management of NAtura 2000 Network in Azores; LIFE17 IPE/PT/000010). The Azorean Stranding Network would like to thank Marco Santos for all his valuable work and dedication. The Rede de Arrojamentos de Cetáceos do Arquipélago da Madeira (RACAM) is supported by the Machico Municipality and had the partial funding from Projects MARCET (Interreg Mac 14-20, MAC/1.1b/149) and MARCET II (Interreg Mac 14-20, MAC2/4.6c/392). Pelagis Observatory and the French stranding network are funded by the Ministère de la Transition Ecologique and by the Office Français de la Biodiversité as part of the implementation of the Marine Strategy Framework Directive monitoring programme. The work at the Swedish Museum of Natural History (SMNH) and Swedish Veterinary Agency (SVA) are supported by the Swedish Agency for Marine and Water Management (SwAM) and European Maritime, Fisheries and Aquaculture Fund, as part of Sweden's environmental monitoring. The Cetacean Strandings Investigation Programme (CSIP) is co-funded by Defra and the Welsh Government- we thank all CSIP partners and those who support the programme across the country. The Scottish Marine Animal Stranding Scheme (SMASS) is supported by the Scottish Marine Directorate. The Cetacean Stranding Scheme in Ireland is part-funded by NPWS of the Department of Housing, Local Government and Heritage. The stranding network in Schleswig-Holstein is supported by the Schleswig-Holstein Ministry for Energy Transition, Climate Protection, Environment and Nature (MEKUN) and the Schleswig-Holstein Agency for Coastal Defense, National Park and Marine Conservation (LKN.SH). A.Gi. was partly funded by the German Federal Agency for Nature Conservation (project IEMAS, grant no. 3521532207). The dissections and stranding network at the Deutsches Meeresmuseum in Mecklenburg-Prepomerania are supported by several grants from the Landesamt für Umwelt-, Naturschutz und Geologie, Mecklenburg-Vorpommern. A.Bj. thanks the Norwegian Ministry of Fisheries. C.B.T. thanks all the parties in the National Contingency Plan concerning strandings of marine mammals in Denmark: Danish Environmental Protection Agency, the Danish Nature Agency, the Fisheries and Maritime Museum in Esbjerg, the Natural History Museum of Denmark in Copenhagen, the Department of Ecoscience, Aarhus University in Roskilde and the Department of Veterinary and Animal Sciences, University of Copenhagen, and the Department of Chemistry and Bioscience, Aalborg University in Aalborg (the latter only until mid-2023). The Netherlands stranding registration platform Stranding.nl is funded by the Dutch Ministry of Agriculture, Fisheries, Food Security and Nature. The Stranding Research Program of Utrecht University is supported by the Dutch Ministry of Agriculture, Fisheries, Food Security and Nature.

Author contributions

Conceptualisation and Methodology: G.J.P, M.A.C.P., A.F.-B., A.Br., M.Ah., M.Au., S.B., P.G.H.E., R.F., A.Ga., A.Gi., and J.H.; Data collection: A.Br., M.Ah., E.A.N., M.Ar., M.Au., R.B.R., S.B., A.Bj., J.B., G.C., L.C., C.C., P.C., J.L.C.-P., W.D., M.D., N.J.D., R.D., M.D.A., F.E.C., M.F.M., A.F., C.F.-M., L.F., A.G.R., L.G.S., M.I.M.G., P.G.A., M.G., J.H., S.D.H., T.H., J.H., L.L.I., D.J., M.J., P.K., T.K.J., A.S.K., G.K., M.L., A.L., a.m., N.M., J. a.m.C., B.M., J.M., J.M.M.I., J.E.M.G., A.N., F.N., S.I.P., I.P., I.P.P., H.H.P., M.P., R.P.-L., J.A.R., J.I.R., A.R., L.R.S., G.M.S., S.S., A.S.M., J.S.J., O.S., V.S., M.T.I.t.D., C.B.T., J.v.d.H., J.V., H.V., D.V., G.A.V., J.V., R.W., J.W., M.A.C.P., and A.F.-B; Data analysis: M.A.C.P., A.F.-B., and G.J.P; Writing—Original Draft: M.A.C.P. and A.F.-B.; Writing—Review & Editing: coordinated by M.A.C.P. and G.J.P.; all co-authors contributed critically to the drafts and gave final approval for publication.

Supplementary data

Supplementary data is available at *ICES Journal of Marine Science* online.

Conflict of interest: Authors declare no conflict of interest.

Funding

M.A.C.P. and G.J.P. were supported by funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement No. 813383 ("SeaChanges – Thresholds in human exploitation of marine vertebrates"), and CetAMBICion (Coordinated strategy for the assessment, monitoring and management of cetaceans in the Bay of Biscay and Iberian coast subregion; EU, DG-ENV/MSFD 2020). A.F.-B. was supported by the predoctoral grant (number PRE2019-089740) associated with the TRANSITION project (TRansfers of Anthropogenic and Natural Stressors Involving Trophic Interactions of Ocean Nekton) funded by the Ministerio de Ciencia, Innovación y Universidades (Proyecto Individual, Plan Nacional, RTI2018-099607-B-I00). The authors acknowledge funding from CIBBRiNA (Coordinated Development and Implementation of Best Practice in Bycatch Reduction in the North Atlantic, Baltic and Mediterranean Regions; LIFE22-NAT-NL-LIFE-CIBBRiNA/101114301), and REDUCE (Reducing bycatch of threatened megafauna in the East Central Atlantic, HORIZON-CL6-2023-BIODIV-01-5, Proposal ID: 101135583).

Data availability

The datasets generated and analysed during the current study will be shared on reasonable request to the corresponding author with permission of the stranding network coordinators.

References

Aguilar A, Raga JA. The striped dolphin epizootic in the Mediterranean Sea. *Ambio*, 1993:524–8.

Albrecht S, Minto C, Rogan E *et al.* Emaciated enigma: decline in body conditions of common dolphins in the Celtic Seas ecoregion. *Ecology and Evolution*, 2024;**14**:e70325. https://doi.org/10.1002/ece3.70325

Alzieu C, Duguy R. Teneurs en composés organochlorés chez les Cétacés et Pinnipèdes fréquentant les côtes françaises. *Oceanolog Acta*, 1979;**2**:107–120

Authier M, Peltier H, Dorémus G *et al.* How much are stranding records affected by variation in reporting rates? A case study of small delphinids in the Bay of Biscay. *Biodivers Conserv*, 2014;**23**:2591–612. https://doi.org/10.1007/s10531-014-0741-3

Bäcklin BM, Moraeus C, Roos A *et al.* Health and age and sex distributions of Baltic grey seals (*Halichoerus grypus*) collected from bycatch and hunt in the Gulf of Bothnia. *ICES J Mar Sci*, 2011;**68**:183–8. https://doi.org/10.1093/icesjms/fsq131

Barnett J, Davison N, Deaville R *et al.* Postmortem evidence of interactions of bottlenose dolphins (*Tursiops truncatus*) with other dolphin species in south-west England. *Vet Rec*, 2009;**165**:441–4. https://doi.org/10.1136/vr.165.15.441

Blanchet MA, Vincent C, Womble JN *et al.* Harbour seals: population structure, status, and threats in a rapidly changing environment. *Oceans*, 2021;**2**:41–63. https://doi.org/10.3390/oceans2010003

Brito C, Vieira N. Using historical accounts to assess the occurrence and distribution of small cetaceans in a poorly known area. *Journal of the Marine Biological Association of the United Kingdom*, 2010;**90**:1583–8. https://doi.org/10.1017/S0025315410000585

Brownlow A, ASCOBANS Secretariat, and ICES. 2023 Scoping the development of a European marine strandings database. *Paper presented at the 28th Meeting of the Advisory Committee, ASCOBANS/AC28/Doc.8.1*. Bonn, Germany, 26-28 September 2023. https://www.ascobans.org/sites/default/files/document/ascobans_ac28_doc8.1_scoping-strandings-database.pdf (7 September 2025, date last accessed).

Brownlow A, Davison N, ten Doeschate M. 2018 Scottish Marine Animal Stranding Scheme 2018 Annual Report. https://strandings.org/wp-content/uploads/2021/05/SMASS_Annual_Report_2018.pdf(8 September 2025, date last accessed).

Brownlow A, Lennon R, Renell J. 2024 Report of the ECS-ASCOBANS workshop: development of a European marine strandings database (workshop 2). *Held at the 35th Annual Conference of the European Cetacean Society Catania*, Sicily, Italy. https://www.ascobans.org/en/meeting/ecs-ascobans-workshop-no2-development-european-marine-strandings-database (7 September 2025, date last accessed).

Carrillo M, Ritter F. Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions. *Journal of Cetacean Research and Management*, 2010;**11**:131–8.

Cervin L, Harkonen T, Harding KC. Multiple stressors and data deficient populations; a comparative life-history approach sheds new light on the extinction risk of the highly vulnerable Baltic harbour porpoises (*Phocoena phocoena*). *Environ Int*, 2020;**144**:106076. https://doi.org/10.1016/j.envint.2020.106076

Clarke MR, Pascoe PL. The stomach contents of a Risso's dolphin (*Grampus griseus*) stranded at Thurlestone, south Devon. *Journal of the Marine Biological Association of the United Kingdom*, 1985;**65**:663–5. https://doi.org/10.1017/S0025315400052504

Coombs EJ, Deaville R, Sabin RC *et al.* What can cetacean stranding records tell us? A study of UK and Irish cetacean diversity over the past 100 years. *Marine Mammal Science*, 2019;**35**:1527–55. https://doi.org/10.1111/mms.12610

Deaville R, Jepson P. 2012 ASCOBANS Project Report (SSFA2010-2) Interest and feasibility of a web accessed database for marine mammal strandings and necropsy data in the ASCOBANS region. *19th ASCOBANS Advisory Committee Meeting*. https://www.ascobans.org/sites/default/files/document/AC19_6-05_ProjectReport_DatabaseZSL_1.pdf

Domingo M, Visa J, Pumarola M *et al.* Pathologic and immunocytochemical studies of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*). *Vet Pathol*, 1992;**29**:1–10. https://doi.org/10.1177/030098589202900101

European Food Safety Authority, European Centre for Disease Prevention and Control, European Union Reference Laboratory for Avian Influenza, Adlhoch C, Fusaro A, Gonzales JL *et al.* Scientific report: avian influenza overview June–September 2023. *EFSA Journal*, 2023;**21**:8328, 53 pp. https://doi.org/10.2903/j.efsa.2023.8328

Fariñas-Bermejo A, Petitguyot MAC, Brownlow A *et al.* European stranding networks as a tool for monitoring marine mammal populations (Part II): quantifying bycatch mortality and understanding its impact. *Under review*

Fernández A, Edwards JF, Rodriguez F *et al.* Gas and fat embolic syndrome" involving a mass stranding of beaked whales (family Ziphiidae) exposed to anthropogenic sonar signals. *Vet Pathol*, 2005;**42**:446–57. https://doi.org/10.1354/vp.42-4-446

Fernández A, Sierra E, Arbelo M *et al.* First case of brevetoxicosis linked to rough-toothed dolphin (*Steno bredanensis*) mass-mortality event in eastern central Atlantic Ocean: a climate change effect? *Frontiers in Marine Science*, 2022;**9**:237.

Fontaine MC, Roland K, Calves I *et al.* Postglacial climate changes and rise of three ecotypes of harbour porpoises, *Phocoena phocoena*, in western Palearctic waters. *Mol Ecol*, 2014;**23**:3306–21. https://doi.org/10.1111/mec.12817

Foster G, MacMillan AP, Godfroid J *et al.* A review of *Brucella* sp. infection of sea mammals with particular emphasis on isolates from Scotland. *Vet Microbiol*, 2002;**90**:563–80. https://doi.org/10.1016/S0378-1135(02)00236-5

Fundación Biodiversidad. 2021 Subvenciones de la Fundación Biodiversidad FSP para el refuerzo de redes de varamientos y rescate de especies marinas en el marco del Plan de Recuperación, Transformación y Resiliencia. https://fundacion-biodiversidad.es/convocatorias_del_pr/convocatoria-de-subvenciones-para-el-refuerzo-de-redes-de-varamientos-y-rescate-de-especies/. (1st of September 2024, date last accessed).

Fundo Ambiental 2020 Funda Conservação da Natureza e da Biodiversidade—Apoio à Rede Nacional de Arrojamentos. https://www.fundoambiental.pt/avisos-anteriores/avisos-2020/conservacao-da-natureza-e-biodiversidade.aspx. (1st of September 2024, date last accessed).

Galgani F, Darmon G, Pham C *et al.* 2022 Marine Litter ingested by Sea Turtles. In: *OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic*. OSPAR Commission, London. Available at:https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/litter-sea-turtles/ (8 September 2025, date last accessed).

Geraci JR, Lounsbury VJ. *Marine mammals ashore*. Galveston, TX: Texas A&M Sea Grant Publication, 1993, 133–43.

Geraci JR, Lounsbury VJ. *Marine mammals ashore: a field guide for strandings*. National Aquarium in Baltimore: Texas A&M University Sea Grant College Program, 2005, 344.

Gilles A, Authier M, Ramirez-Martinez NC *et al.* 2023 Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023. pp. 64. https://tinyurl.com/3ynt6swa (9 September 2025, date last accessed).

Gose MA, Humble E, Brownlow A *et al.* Stranding collections indicate broad-scale connectivity across the range of a pelagic marine predator, the Atlantic white-sided dolphin (*Lagenorhynchus acutus*). *ICES J Mar Sci*, 2023;**80**:1120–8. https://doi.org/10.1093/icesjms/fsad050

Grove T, Senglat C, Petitguyot M *et al.* Mass stranding and unusual sightings of northern bottlenose whales (*Hyperoodon ampullatus*) in Skjálfandi Bay, Iceland. *Marine Mammal Science*, 2020;**36**:1033–41. https://doi.org/10.1111/mms.12689

Gulland FM, Asmutis-Silvia R, Boehm J *et al.* Marine Mammal Stranding Networks in the 21st Century: whence and Whither? *Marine Mammal Science*, 2025;**41**, p.e70016. https://doi.org/10.1111/mms.70016

Haelters J, Kerckhof F, Janiaux T *et al.* The grey seal (*Halichoerus grypus*) as a predator of harbour porpoises (*Phocoena phocoena*)? *Aquatic Mammals*, 2012;**38**:343–53. https://doi.org/10.1578/AM.38.4.2012.343

Hammond PS, Berggren P, Benke H *et al.* Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *J Appl Ecol*, 2002;**39**:361–76. https://doi.org/10.1046/j.1365-2664.2002.00713.x

Harmer SF. 1914 *Report on Cetacea stranded on the British coasts during 1913 (with one text-figure and three maps)*. British Museum (Natural History), London.

Hazen EL, Abrahms B, Brodie S *et al.* Marine top predators as climate and ecosystem sentinels. *Frontiers in Ecology and the Environment*, 2019;**17**:565–74. https://doi.org/10.1002/fee.2125

Hernández-Gonzalez A, Saavedra C, Read FL *et al.* Feeding ecology of harbour porpoises *Phocoena phocoena* stranded on the Galician coast (NW Spain) between 1990 and 2018. *Endangered Species Research*, 2024;**54**:105–22. https://doi.org/10.3354/esr01328

ICES. 2014 *Report of the Working Group on Marine Mammal Ecology (WGMME), 10–13 March 2014*, Woods Hole, Massachusetts, USA. ICES CM 2014/ACOM:**27**:234.

ICES. 2019 *Joint WGBYC-WGCATCH Workshop on sampling of bycatch and PET species (WKPETSAMP), 24–26 April 2018*, SLU Aqua, Lysekil, Sweden, ICES CM 2018/EOSG:**35**:76. https://doi.org/10.17895/ices.pub.8183

ICES. Workshop on Fisheries Emergency Measures to minimize BYCatch of short-beaked common dolphins in the Bay of Biscay and harbour porpoise in the Baltic Sea (WKEMBYC). *ICES Scientific Reports*, 2020;**2**:295. https://doi.org/10.17895/ices.pub.7472

ICES. 2022 *ICES Roadmap for bycatch advice on protected, endangered and threatened species (2022)*. Copenhagen, Denmark: ICES

Technical Guidelines. Report. https://doi.org/10.17895/ices.advice.19657167.v3

ICES. Workshop on mitigation measures to reduce bycatch of short-beaked common dolphins in the Bay of Biscay (WKEMBYC2). *ICES Scientific Reports*. 2023;**5**:96. https://doi.org/10.17895/ices.pub.21940337

ICES. Working Group on Bycatch of Protected Species (WGBYC). *ICES Scientific Reports*. Copenhagen, Denmark. 2024a;**6**:235. https://doi.org/10.17895/ices.pub.27762723

ICES. 2024b Bycatch of endangered, threatened and protected species of marine mammals, seabirds and marine turtles, and selected fish species of bycatch relevance. In *Report of the ICES Advisory Committee, 2024*. Copenhagen, Denmark. : ICES Advice, **2024**, byc.eu. https://doi.org/10.17895/ices.advice.27999401

ICES. Second Workshop on appropriate sampling schemes for Protected Endangered and Threatened Species bycatch (WKPETSAMP2). *ICES Scientific Reports*. 2024c;**6**:68. https://doi.org/10.17895/ices.pub.25061459

ICES. Third Workshop on appropriate sampling schemes for Protected, Endangered and Threatened Species bycatch (WKPETSAMP3). *ICES Scientific Reports*. 2024d;**6**:96. https://doi.org/10.17895/ices.pub.25061522

IJsseldijk LL, Brownlow A, Davison NJ *et al.* Spatiotemporal trends in white-beaked dolphin strandings along the North Sea coast from 1991-2017. *Lutra*, 2018;**61**:153–64.

IJsseldijk LL, Brownlow A, Mazzariol S. Best practice on cetacean post-mortem investigation and tissue sampling. *Joint ACCOBAMS and ASCOBANS document*, 2019;**2019**; 71. Available at:https://osf.io/zh4ra/

IJsseldijk LL, Camphuysen CJ, Keijl GO *et al.* Predicting Harbor Porpoise Strandings Based on Near-Shore Sightings Indicates Elevated Temporal Mortality Rates. *Frontiers in Marine Science* 2021;**8**:668038. https://doi.org/10.3389/fmars.2021.668038

IJsseldijk LL, Leopold MF, Begeman L *et al.* Pathological findings in stranded harbor porpoises (*Phocoena phocoena*) with special focus on anthropogenic causes. *Frontiers in Marine Science* 2022;**9**:997388. https://doi.org/10.3389/fmars.2022.997388

IJsseldijk LL, ten Doeschate MT, Brownlow A *et al.* Spatiotemporal mortality and demographic trends in a small cetacean: strandings to inform conservation management. *Biol Conserv*, 2020;**249**:108733. https://doi.org/10.1016/j.biocon.2020.108733

International Whaling Commission. Report of the Scientific Committee (SC69B), Bled, Slovenia, 22 April –3 May 2024. *J. Cetacean Res. Manage (Supp.)* 2024;**26**:1–90.

Jauniaux T, André M, Dabin W *et al.* 2019 *Marine Mammals Stranding: Guidelines for Post-mortem Investigations of Cetaceans & Pinnipeds, & 13rd Cetacean Necropsy Workshop: Special Issue on Necropsy and Samplings (Liège 2019)*. Liège, Belgium: Presses de la faculté de médecine vétérinaire de l'Université de Liège.

Jauniaux T, Petitjean D, Brenez C *et al.* Post-mortem findings and causes of death of harbour porpoises (*Phocoena phocoena*) stranded from 1990 to 2000 along the coastlines of Belgium and Northern France. *J Comp Pathol*, 2002;**126**:243–53. https://doi.org/10.1053/jcpa.2001.0547

Jepson PD, Deaville R, Acevedo-Whitehouse K *et al.* What caused the UK's largest common dolphin (*Delphinus delphis*) mass stranding event? *PLoS One*, 2013;**8**:e60953. https://doi.org/10.1371/journal.pone.0060953

Jepson PD, Deaville R, Barber JL *et al.* PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Sci Rep*, 2016;**6**:18573. https://doi.org/10.1038/srep18573

Karamanlidis AA, Dendrinos P, Fernandez de Larrinoa P *et al. Monachus monachus*. *The IUCN Red List of Threatened Species* 2023;**2023**:e.T13653A238637039. https://doi.org/10.2305/IUCN.UK.2023-1.RLTS.T13653A238637039.en. Accessed on 26 February 2025.

Kauhala K, Kurkilahti M, Ahola MP *et al.* Age, sex and body condition of Baltic grey seals: are problem seals a random sample of the population? *Annales Zoologici Fennici*, 2015;**52**:103–14. https://doi.org/10.5735/086.052.0209

Krebs CJ. 1989 *Ecological Methodology*. New York: Harper Collins Publishers, 654.

Kühn S, Van Franeker JA, Van Loon W. 2022 Plastic Particles in Fulmar Stomachs in the North Sea. In: *OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic*. OSPAR Commission, London. Available at:https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/plastic-in-fulmar/(8 September 2025, date last accessed).

Kuiken T, García Hartmann M. Cetacean pathology: dissection techniques and tissue sampling. *ECS Newsletter* 1993;**17**.1–43.

Kuiken T, Simpson VR, Allchin CR *et al.* Mass mortality of common dolphins (*Delphinus delphis*) in south west England due to incidental capture in fishing gear. *Vet Rec*, 1994;**134**:81–9. https://doi.org/10.1136/vr.134.4.81

Laist DW, Knowlton AR, Mead JG *et al.* Collisions between ships and whales. *Marine Mammal Science*, 2001;**17**:35–75. https://doi.org/10.1111/j.1748-7692.2001.tb00980.x

Learmonth JA, Murphy S, Luque PL *et al.* Life history of harbor porpoises (*Phocoena phocoena*) in Scottish (UK) waters. *Marine Mammal Science*, 2014;**30**:1427–55. https://doi.org/10.1111/mms.12130

Leeney RH, Amies R, Broderick AC *et al.* Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot. *Biodivers Conserv*, 2008;**17**:2323–38. https://doi.org/10.1007/s10531-008-9377-5

MacLeod CD, Bannon S, Pierce G *et al.* Climate change and the cetacean community of north-west Scotland. *Biol Conserv*, 2005;**124**:477–83. https://doi.org/10.1016/j.biocon.2005.02.004

MacLeod CD, Santos MB, Reid RJ *et al.* Linking sandeel consumption and the likelihood of starvation in harbour porpoises in the Scottish North Sea: could climate change mean more starving porpoises? *Biol Lett*, 2007;**3**:185–8. https://doi.org/10.1098/rsbl.2006.0588

Mannocci L, Dabin W, Augeraud-Véron E *et al.* Assessing the impact of bycatch on dolphin populations: the case of the common dolphin in the Eastern North Atlantic. *PLoS One* 2012;**7**:e32615. https://doi.org/10.1371/journal.pone.0032615

Matsuoka K, Ensor P, Hakamada T *et al.* Overview of minke whale sightings surveys conducted on IWC/IDCR and SOWER Antarctic cruises from 1978/79 to 2000/01. *Journal of Cetacean Research and Management*, 2003;**5**:173–201

Mazzariol S, Centelleghe C, Beffagna G *et al.* Mediterranean fin whales (*Balaenoptera physalus*) threatened by dolphin morbillivirus. *Emerg Infect Dis*, 2015;**22**:302. https://doi.org/10.3201/eid2202.150882

Méndez-Fernandez P, Pierce GJ, Bustamante P *et al.* Foraging ecology of five toothed whale species in the Northwest Iberian Peninsula, inferred using carbon and nitrogen isotope ratios. *J Exp Mar Biol Ecol*, 2012;**413**:150–8. https://doi.org/10.1016/j.jembe.2011.12.007

Méndez-Fernandez P, Spitz J, Dars C *et al.* Two cetacean species reveal different long-term trends for toxic trace elements in European Atlantic French waters. *Chemosphere*, 2022;**294**:133676. https://doi.org/10.1016/j.chemosphere.2022.133676

MITECO 2022 *Protocolo nacional de actuación ante varamientos de cetáceos*. Madrid, Spain: Ministerio para la Transición Ecológica y el Reto Demográfico, 44.

Moore MJ, Mitchell GH, Rowles TK *et al.* Dead cetacean? Beach, bloat, float, sink. *Frontiers in Marine Science*, 2020;**7**:333. https://doi.org/10.3389/fmars.2020.00333

Moore SE. Marine mammals as ecosystem sentinels. *J Mammal*, 2008;**89**:534–40. https://doi.org/10.1644/07-MAMM-S-312R1.1

Murawski A, Fabrizio T, Ossiboff R *et al.* Highly pathogenic avian influenza A (H5N1) virus in a common bottlenose dolphin (Tursiops truncatus) in Florida. *Commun Biol*, 2024;7:476. https://doi.org/10.1038/s42003-024-06173-x

Murphy S, Barber JL, Learmonth JA *et al.* Reproductive failure in UK harbour porpoises *Phocoena phocoena*: legacy of pollutant exposure? *PLoS One*, 2015;**10**:e0131085. https://doi.org/10.1371/journal.pone.0131085

Murphy S, Petitguyot MAC, Jepson PD *et al.* Spatio-temporal variability of harbor porpoise life history parameters in the North-East Atlantic. *Frontiers in Marine Science*, 2020;**7**:502352. https://doi.org/10.3389/fmars.2020.502352

Murphy S, Winship A, Dabin W *et al.* Importance of biological parameters in assessing the status of *Delphinus delphis*. *Marine Ecology Progress Series*, 2009;**388**:273–91. https://doi.org/10.3354/meps08129

Neimanis A, Stavenow J, Ågren EO *et al.* Causes of Death and Pathological Findings in Stranded Harbour Porpoises (*Phocoena phocoena*) from Swedish Waters. *Animals*, 2022;**12**,369. https://doi.org/10.3390/ani12030369

Nelms SE, Barnett J, Brownlow A *et al.* Microplastics in marine mammals stranded around the British coast: ubiquitous but transitory? *Sci Rep*, 2019;**9**:1075. https://doi.org/10.1038/s41598-018-37428-3

Ólafsdóttir D, Víkingsson GA, Halldórsson DS *et al.* Growth and reproduction in harbour porpoises (*Phocoena phocoena*) in Icelandic waters. *NAMMCO Scientific Publications*, 2003;**5**:195–210. https://doi.org/10.7557/3.2747

Oliveira BS, Santos RG, Santos BA. Improving the knowledge management of marine megafauna strandings. *J Environ Manage*, 2024;**351**:119815. https://doi.org/10.1016/j.jenvman.2023.119815

OSPAR 2023: *The 2023 Quality Status Report for the North-East Atlantic*. OSPAR Commission, London. Available at:https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023 (9 September 2025, date last accessed).

Patterson IAP, Reid RJ, Wilson B *et al.* Evidence for infanticide in bottlenose dolphins: an explanation for violent interactions with harbour porpoises? *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 1998;**265**:1167–70. https://doi.org/10.1098/rspb.1998.0414

Peltier H, Authier M, Caurant F *et al.* In the wrong place at the wrong time: identifying spatiotemporal co-occurrence of bycaught common dolphins and fisheries in the Bay of Biscay (NE Atlantic) from 2010 to 2019. *Frontiers in Marine Science*, 2021;**8**:617342. https://doi.org/10.3389/fmars.2021.617342

Peltier H, Authier M, Dabin W *et al.* Can modelling the drift of bycaught dolphin stranded carcasses help identify involved fisheries? An exploratory study. *Global Ecology and Conservation*, 2020;**21**:e00843. https://doi.org/10.1016/j.gecco.2019.e00843

Peltier H, Authier M, Deaville R *et al.* Small cetacean bycatch as estimated from stranding schemes: the common dolphin case in the northeast Atlantic. *Environ Sci Policy*, 2016;**63**:7–18. https://doi.org/10.1016/j.envsci.2016.05.004

Peltier H, Baagøe HJ, Camphuysen KC *et al.* The stranding anomaly as population indicator: the case of harbour porpoise *Phocoena phocoena* in North-Western Europe. *PLoS One* 2013;**8**:e62180. https://doi.org/10.1371/journal.pone.0062180

Peltier H, Beaufils A, Cesarini C *et al.* Monitoring of marine mammal strandings along French coasts reveals the importance of ship strikes on large cetaceans: a challenge for the European Marine Strategy Framework Directive. *Frontiers in Marine Science*, 2019;**6**:486. https://doi.org/10.3389/fmars.2019.00486

Peltier H, Dabin W, Daniel P *et al.* The significance of stranding data as indicators of cetacean populations at sea: modelling the drift of cetacean carcasses. *Ecol Indic*, 2012;**18**:278–90. https://doi.org/10.1016/j.ecolind.2011.11.014

Peltier H, Jepson PD, Dabin W *et al.* The contribution of stranding data to monitoring and conservation strategies for cetaceans: developing spatially explicit mortality indicators for common dolphins (*Delphinus delphis*) in the eastern North-Atlantic. *Ecol Indic*, 2014;**39**:203–14. https://doi.org/10.1016/j.ecolind.2013.12.019

Peltier H, Laran S, Dabin W *et al.* From the sky and on the beaches: complementary tools to evaluate common dolphin bycatch in the Bay of Biscay. *Endangered Species Research*, 2024;**53**:509–22. https://doi.org/10.3354/esr01310

Pierce GJ, Petitguyot MAC, Gutierrez-Muñoz P *et al.* An endangered population of harbour porpoise *Phocoena phocoena* hidden in plain sight: biology, ecology and conservation of the Iberian porpoise. *In Oceanography and Marine Biology*, 2024;**62**:1–119.

Pierce GJ, Weir C, Gutiérrez P *et al.* 2020 Is Iberian harbour porpoise (*Phocoena phocoena*) threatened by interactions with fisheries? *Paper SC/68B/SM04 Rev2. Online*. https://archive.iwc.int/pages/search.php?search=%21collection29958 (7 September 2025, date last accessed).

Pinzone M, Parmentier K, Siebert U *et al.* 2022 Pilot Assessment of Status and Trends of persistent chemicals in marine mammals. In: *OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic*. London: OSPAR Commission. Available at:https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/pcb-marine-mammals-pilot (8 September 2025, date last accessed).

Plaza PI, Gamarra-Toledo V, Euguí JR *et al.* Recent Changes in Patterns of Mammal Infection with Highly Pathogenic Avian Influenza A(H5N1) Virus Worldwide. *Emerg Infect Dis*, 2024;**30**:444–52. https://doi.org/10.3201/eid3003.231098

Plint T, ten Doeschate MTI, Brownlow AC *et al.* Stable isotope ecology and interspecific dietary overlap among dolphins in the Northeast Atlantic. *Frontiers in Marine Science*, 2023;**10**:1111295. https://doi.org/10.3389/fmars.2023.1111295

Pons-Bordas C, Hazenberg A, Hernandez-Gonzalez A *et al.* Recent increase of ulcerative lesions caused by *Anisakis* spp. in cetaceans from the north-east Atlantic. *J Helminthol*, 2020;**94**:e127. https://doi.org/10.1017/S0022149X20000115

Pugliares K, Herzke S, Bogomolni A *et al.* 2007 Marine mammal necropsy: an introductory guide for stranding responders and field biologists. In: *Woods Hole Oceanographic Institution Technical Document 2007-06*. Woods Hole, USA, 117.

Puig-Lozano R, de Quirós YB, Díaz-Delgado J *et al.* Retrospective study of foreign body-associated pathology in stranded cetaceans, Canary Islands (2000–2015). *Environ Pollut*, 2018;**243**:519–27. https://doi.org/10.1016/j.envpol.2018.09.012

Puig-Lozano R, Fernández A, Saavedra P *et al.* Retrospective study of traumatic intra-interspecific interactions in stranded cetaceans. *Frontiers in Veterinary Science*, 2020b;**7**:107. https://doi.org/10.3389/fvets.2020.00107

Puig-Lozano R, Fernández A, Sierra E *et al.* Retrospective study of fishery interactions in stranded cetaceans, Canary Islands. *Frontiers in Veterinary Science*, 2020a;**7**:567258. https://doi.org/10.3389/fvets.2020.567258

Puryear W, Sawatzki K, Hill N *et al.* Highly pathogenic avian influenza A (H5N1) virus outbreak in New England seals, United States. *Emerg Infect Dis*, 2023;**29**:786–91. https://doi.org/10.3201/eid2904.221538

Raga JA, Banyard A, Domingo M *et al.* Dolphin morbillivirus epizootic resurgence, Mediterranean Sea. *Emerg Infect Dis*, 2008;**14**:471. https://doi.org/10.3201/eid1403.071230

Read FL, Santos MB, Ferreira M *et al.* 2020 Harbour porpoise (*Phocoena phocoena*) and fisheries interactions in the north-west Iberian Peninsula. *Paper presented at the Scientific Committee of the International Whaling Commission SC/68B/SM/06*.

Read FL, Santos MB, González AF *et al.* 2013 Understanding harbour porpoise (*Phocoena phocoena*) and fishery interactions in the north-west Iberian Peninsula. *Final Report to the 20th ASCOBANS Advisory Committee Meeting*. Warsaw, Poland, 27–29 August 2013.

Ross HM, Wilson B. Violent interactions between bottlenose dolphins and harbour porpoises. *Proc. R. Soc. Lond. B.*, 1996;**263**:283–6.

Rouby E, Ridoux V, Authier M. Flexible parametric modeling of survival from age at death data: a mixed linear regression framework. *Population Ecology*, 2021;**63**:108–22. https://doi.org/10.1002/1438-390X.12069

Saavedra C, Pierce GJ, Gago J *et al.* Factors driving patterns and trends in strandings of small cetaceans. *Mar Biol*, 2017;**164**:1–17. https://doi.org/10.1007/s00227-017-3200-3

Saavedra Penas C. 2017 Multispecies population modelling of the common dolphin (*Delphinus delphis*), the bottlenose dolphin (*Tursiops truncatus*) and the southern stock of European hake (*Merluccius merluccius*), in Atlantic waters of the Iberian Peninsula. *PhD thesis*, Universidad de Vigo, Spain.

Samarra FIP, Borrell A, Selbmann A *et al.* Trophic ecology, based on stable isotope values, of long-finned pilot whales *Globicephala melas* stranded on the Icelandic coast. *Marine Ecology Progress Series*, 2024;**748**:163–74. https://doi.org/10.3354/meps14708

Santos MB, Pierce GJ. The diet of harbour porpoise (*Phocoena phocoena*) in the northeast Atlantic: a review. *Oceanography and Marine Biology: an Annual Review*, 2003;**41**:355–90.

Santos MB, Pierce GJ. Marine mammals and good environmental status: science, policy and society; challenges and opportunities. *Hydrobiologia* 2015;**750**:13–41. https://doi.org/10.1007/s10750-014-2164-2

Schwacke LH, Gulland FM, White S. 2012 Sentinel species in oceans and human health. In *Environmental toxicology: selected entries from the encyclopedia of sustainability Science and technology*, pp.503–28. Ed. by E. Laws. Springer, New York, NY.

Sevdari K, Marmullaku D. 2023 *Shapefile of European countries*. Kongens Lyngby, Denmark: Technical University of Denmark. Dataset. https://doi.org/10.11583/DTU.23686383 This dataset is distributed under a CCBY-NC-SA 4.0 license

Siebert U, Joiris C, Holsbeek L *et al.* Potential relation between mercury concentrations and necropsy findings in cetaceans from German Waters of the North and Baltic Seas. *Mar Pollut Bull*, 1999;**38**:285–95. https://doi.org/10.1016/S0025-326X(98)00147-7

Siebert U, Stürznickel J, Schaffeld T *et al.* Blast injury on harbour porpoises (*Phocoena phocoena*) from the Baltic Sea after explosions of deposits of World War II ammunition. *Environ Int*, 2022;**159**:107014. https://doi.org/10.1016/j.envint.2021.107014

Siler W. A competing-risk model for animal mortality. *Ecology* 1979;**60**:750–7. https://doi.org/10.2307/1936612

Silva MA. Diet of common dolphins, *Delphinus delphis*, off the Portuguese continental coast. *Journal of the Marine Biological Association of the United Kingdom*, 1999;**79**:531–40. https://doi.org/10.1017/S0025315498000654

Simmonds MP, Lopez-Jurado LF. Whales and the military. *Nature*, 1991;**351**:448. https://doi.org/10.1038/351448a0

Smeenk C. Strandings of sperm whales *Physeter macrocephalus* in the North Sea: history and patterns. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Biologie* 1997;**67**:15–28.

Smith KJ, Mead JG, Peterson MJ. Specimens of opportunity provide vital information for research and conservation regarding elusive whale species. *Environ Conserv*, 2021;**48**:84–92. https://doi.org/10.1017/S0376892920000521

Solomando A, Pujol F, Sureda A *et al.* Evaluating the presence of marine litter in cetaceans stranded in the Balearic Islands (Western Mediterranean Sea). *Biology*, 2022;**11**:1468. https://doi.org/10.3390/biology11101468

Stavenow J, Roos AM, Ågren EO *et al.* Sowerby's Beaked Whales (*Mesoplodon bidens*) in the Skagerrak and Adjacent Waters: historical Records and Recent Post-Mortem Findings. *Oceans*, 2022;**3**:250–67. https://doi.org/10.3390/oceans3030018

Stokholm I, Baechlein C, Persson S *et al.* Screening for influenza and morbillivirus in seals and porpoises in the Baltic and North Sea. *Pathogens*, 2023;**12**:357. https://doi.org/10.3390/pathogens12030357

ten Doeschate MTI, Brownlow AC, Davison NJ *et al.* Dead useful; methods for quantifying baseline variability in stranding rates to improve the ecological value of the strandings record as a monitoring tool. *Journal of the Marine Biological Association of the United Kingdom*, 2018;**98**:1205–9. https://doi.org/10.1017/S0025315417000698

ten Doeschate MTI, Brownlow AC, Davison NJ *et al.* 2024 Eyes on the prize; a framework to assess and quantify reporting effort and novel citizen science tools for stranding surveillance. *Conference presentation, SMM Conference 2024*, November 11-15, Perth, Western Australia.

Thorsson E, Zohari S, Roos A *et al.* Highly Pathogenic Avian Influenza A(H5N1) Virus in a Harbor Porpoise. *Emerg Infect Dis*, 2023;**29**:852–5. https://doi.org/10.3201/eid2904.221426

van Beneden PJ, Gervais P. 1880 *Ostéographie des cétacés vivants et fossiles, comprenant la description et l'iconographie du squelette et du système dentaire de ces animaux, ainsi que des documents relatifs à leur histoire naturelle*. Paris: Ed. Arthus Bertrand.

van Deinse AB. 1931 De fossiele en recente Cetacea van Nederland. *PhD Thesis*, Universiteit Utrecht, H.J. Paris, Amsterdam, The Netherlands.

van den Heuvel-Greve MJ, van den Brink AM, Kotterman MJ *et al.* Polluted porpoises: generational transfer of organic contaminants in harbour porpoises from the southern North Sea. *Sci Total Environ*, 2021;**796**:148936. https://doi.org/10.1016/j.scitotenv.2021.148936

van Utrecht WL. Age and growth in *Phocoena phocoena* Linnaeus, 1758 (Cetacea, Odontoceti) from the North Sea. *Bijdragen tot de Dierkunde* 1978;**48**:16–28. https://doi.org/10.1163/26660644-04801002

Walton MJ. Population structure of harbour porpoises *Phocoena phocoena* in the seas around the UK and adjacent waters. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 1997;**264**:89–94. https://doi.org/10.1098/rspb.1997.0013

Wille M, Waldenström J. Weathering the storm of high pathogenicity avian influenza in waterbirds. *Waterbirds*, 2023;**46**:100–9.

Williams RS, Brownlow A, Baillie A., *et al.* Evaluation of a marine mammal status and trends contaminants indicator for European waters. *Sci Total Environ*, 2023;**866**:161301. https://doi.org/10.1016/j.scitotenv.2022.161301

Williamson MJ, ten Doeschate MTI, Deaville R *et al.* Cetaceans as sentinels for informing climate change policy in UK waters. *Mar Policy*, 2021;**131**:104634. https://doi.org/10.1016/j.marpol.2021.104634

Handling editor: Margaret Siple