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Conservation management of common dolphins: Lessons learned from the North-East Atlantic

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Abstract

1. The short-beaked common dolphin is one of the most numerous cetacean species in the North-East Atlantic and plays a key functional role within the ecosystem as a top predator. However, in 2013, its conservation status for the European Marine Atlantic, under Article 17 of the Habitats Directive, was assessed as 'Unfavourable-Inadequate'. Of key concern for this species is fishery bycatch, with pollution also being an issue. There are, however, major knowledge gaps concerning the extent of the effects of such pressures on the species.
2. Implementation of national observer bycatch programmes and bycatch mitigation measures under EC Regulation 812/2004 has been important. The responsibility for this is currently being transferred to the EU fisheries Data Collection Framework and Technical Measures Framework, the potential advantages and disadvantages of which are discussed. Collection of data and samples through national stranding schemes in some countries has enabled assessments of life-history parameters, dietary requirements, and the effects of stressors such as pollutants.
3. Nevertheless, in order to improve the conservation status of the North-East Atlantic population, a number of key actions are still required. These include the implementation of a species action plan, finalization of a management framework procedure for bycatch, and coordination between member states of monitoring programmes. It is important that there is monitoring of the state of the common dolphin population in the North-East Atlantic management unit through regular surveys spanning the range of the management unit, as well as continued assessment of the independent and interactive effects of multiple stressors. Above all, conservation status would be improved through application and enforcement of existing legislation in European waters.
4. This paper provides a summary of the current state of our knowledge of common dolphins in the North-East Atlantic along with recommendations for conservation management that may also be relevant to the species in the Mediterranean Sea.

KEYWORDS

conservation evaluation, monitoring, Habitats Directive, mammals, fishing, pollution, climate change

1 | INTRODUCTION

The short-beaked common dolphin (*Delphinus delphis*, hereafter referred to as common dolphin) is one of the most abundant and widespread cetacean species in the North-East (NE) Atlantic, inhabiting both continental shelf and offshore waters. Thirty years ago, our knowledge of the biology and ecology of this species in the region was poor, similar to the case for most other cetacean species. Since then, this has improved as a result of European and national research funding, prompted by both legislative requirements and public concern (Murphy, Pinn, & Jepson, 2013). However, owing to the environment that the species inhabits and the difficulties in sampling and surveying animals offshore (high costs and low sample availability), large data gaps remain. Though this places some limits on possible approaches to conservation management, it is possible to identify and potentially manage some important threats to common dolphins. Of these, fishery bycatch is perhaps the most obvious and well known, based on observations on board fishing vessels and on strandings (e.g. Cruz, Machete, Menezes, Rogan, & Silva, 2018; Fernández-Contreras, Cardona, Lockyer, & Aguilar, 2010; Goujon, Antoine, Collet, & Fifas, 1993; Mannocci et al., 2012; Northridge & Kingston, 2009; Peltier et al., 2016; Silva & Sequeira, 2003; Tregenza, Berrow, & Hammond, 1997). For example, approximately 800 common dolphins stranded in France during February and March of 2017, of which 'a vast majority showed trauma generally attributed to by-catch, including amputation of fins or tail fluke, broken jaws, perforation at the rear of the mandible, as well as mesh and rope marks on the skin' (Peltier et al., 2016). As a previous French study reported that approximately 84% of dead cetaceans released by fisheries in the Bay of Biscay would sink and not strand on shore (Peltier et al., 2012), actual bycatch rates for common dolphins in the Bay of Biscay may have been of a magnitude higher during early 2017. Fishery bycatch mortality remains a widespread issue for many marine species, but it is one that can be managed.

This paper is part of a special issue on the conservation of the common dolphin in the Mediterranean Sea that focuses on new findings and perspectives on the status, biology, ecology' and threats to common dolphins in that region. The purpose of this paper is to summarize the advances that have been made in our knowledge of common dolphins in the NE Atlantic over the last few decades to see whether lessons may be learned that can be applied to the species in the Mediterranean Sea, particularly in relation to conservation management.

2 | DISTRIBUTION AND POPULATION STRUCTURE

The common dolphin has a worldwide distribution in oceanic and shelf-edge waters of tropical, subtropical and temperate seas, occurring in both hemispheres. It is abundant and widely distributed in the NE Atlantic, mainly occurring in deeper waters from Macaronesia and north-west Africa north to waters west of Norway and off the Faroe Islands. It is rare north of 62°N, although numbers have been gradually increasing in more recent years (Murphy et al., 2013; Murphy, Evans, & Collet, 2008; Oien & Hartvedt, 2009; Reid, Evans, & Northridge, 2003). It occurs westwards at least to the mid-Atlantic ridge (40°W) (Cañadas, Donovan, Desportes, & Borchers, 2009; Doksæter, Olsen, Nøttestad, & Fernö, 2008; Murphy et al., 2013; Ryan et al., 2013), but is rare in the eastern English Channel, the North Sea, Danish Belt seas, and the Baltic Sea (Camphuysen & Peet, 2006; Evans, Anderwald, & Baines, 2003; Kinze, 1995; Kinze, Jensen, Tougaard, & Baagøe, 2010; Murphy et al., 2013; Reid et al., 2003). Its abundance in the North Sea has been highly variable in recent decades (indeed, it is more or less absent in some years), but there have been movements into the northern sector, related to the main driver of climate variability in the region, the North Atlantic Oscillation (NAO) (Camphuysen & Peet, 2006; Evans et al., 2003; Evans & Scanlan, 1989; Murphy, 2004; Murphy et al., 2013), and the spread into the North Sea of warm-water prey species such as sardine and anchovy (Beare et al., 2004; Evans & Bjørge, 2013). The NAO is a climatic phenomenon in the North Atlantic driven by latitudinal variations in atmospheric pressure that determines the strength and direction of warm westerly winds and associated currents and may thus affect both sea temperature and the distribution of fish species upon which the dolphins feed. However, in more recent years, it has become difficult to disentangle the effects of large-scale ocean climate changes captured by indices such as the NAO and Atlantic Multidecadal Oscillation (currently positive), including effects on warm-water fish species like sardine and anchovy, and the recent anthropogenic CO_2-induced global warming (Alheit, Voss, Mohrholz, & Hinrichs, 2007; Alheit et al., 2012; Montero-Serra, Edwards, & Genner, 2015), thus making it difficult to predict future shifts in the distribution of common dolphins in the NE Atlantic (although see Lambert et al., 2011). At the time of writing, recent papers in the journal *Nature* have provided evidence of recent weakening of the Gulf Stream (Caesar, Rahmstorf, Robinson, Feulner, & Saba, 2018; Praetorius, 2018; Thornally et al., 2018). Reduced inflow of warm and nutrient-rich Atlantic waters would lead to both cooling and loss of productivity in the seas off Europe's Atlantic coasts.

On the basis of genetic and cranial morphometric analyses, common dolphins appear to form one large panmictic population in the NE Atlantic (Amaral et al., 2012; Moura, Natoli, Rogan, & Hoelzel, 2013; Murphy, Herman, Pierce, Rogan, & Kitchener, 2006; Quérouil et al., 2010). The observed panmixia in the NE Atlantic may be explained by long-distance dispersal of females from natal areas, whereas male common dolphins exhibit some degree of site fidelity (in waters off Portugal) based on genetic analysis (Ball, Shreves, Pilot, & Moura, 2017). Although sampled groups of both sexes were not composed of closely related individuals, close kin of males were observed in the same geographic area (Ball et al., 2017).

A marginal level of differentiation was reported in the species between the central-east and the NE Atlantic (Amaral et al., 2012; Natoli et al., 2006), whereas a separate genetically and morphologically distinct population exists in the North-west (NW) Atlantic (Mirimin et al., 2009; Natoli et al., 2006; Westgate, 2007). However, the relatively low observed level of genetic differentiation across the whole North Atlantic suggests a recent population split or high level of gene flow between two or more populations (Mirimin et al., 2009; Murphy et al., 2009). As samples assessed to date were obtained from continental shelf and contiguous waters, the ranges of the NE and NW Atlantic populations are unknown. The possibility of one large population inhabiting the North Atlantic has not been ruled out, however; testing this hypothesis would require samples from the entire species range in the North Atlantic (International Council for the Exploration of the Sea [ICES] Working Group on Marine Mammal Ecology [WGMME], 2009; Murphy, Natoli, et al., 2009).

The species occurs in the western Mediterranean, with genetic studies indicating a significant level of divergence between Mediterranean (Alborán Sea) and Atlantic populations, although directional estimates of gene flow suggest some movement of females out of the Mediterranean Sea (Natoli et al., 2008). Differences in contaminant levels between dolphins from the Alborán Sea and NE Atlantic Ocean also suggest a certain degree of isolation (Borrell, Cantos, Pastor, & Aguilar, 2001). Isolated populations have also been reported in the eastern Mediterranean and Black Sea (Bearzi et al., 2003; Moura et al., 2013; Natoli et al., 2008; Notarbartolo di Sciara & Birkun, 2010).

A meeting of experts held in 2007, under the auspices of the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) and the Baltic Marine Environment Protection Commission, concluded that, for the time being, the NE Atlantic common dolphin population should be viewed as a single management unit (Murphy, Natoli, et al., 2009). In 2014, the ICES WGMME reached the same conclusion for the area encompassing Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Regions II, III, and IV (ICES WGMME, 2014; see Figure 1). Stable isotope, fatty acid, and contaminant analyses have indicated some structuring of common dolphin populations within the NE Atlantic region, with the possible existence of neritic and oceanic

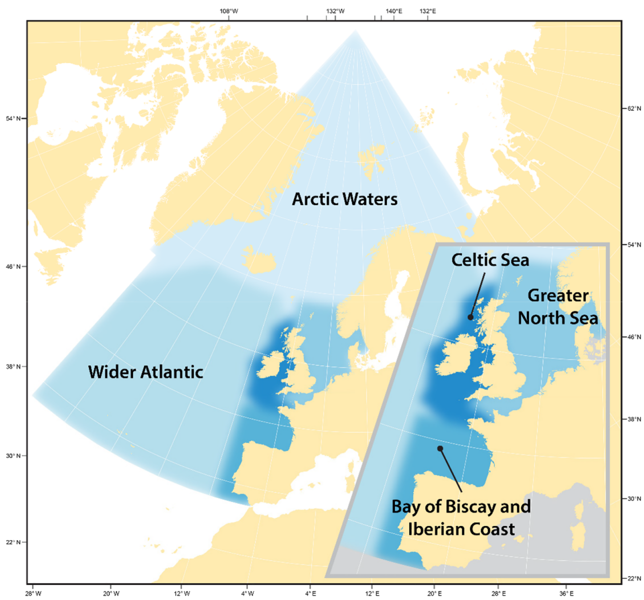

FIGURE 1 Proposed management unit area for common dolphins in the North-east Atlantic covers OSPAR Regions II (Greater North Sea), III (Celtic Sea) and IV (Bay of Biscay and Iberian coast). Taken from www.ospar.org.

ecological stocks (Caurant et al., 2009; Lahaye et al., 2005). However, prior to designation of ecological stocks, it is important to address potential limitations of studies to date, such as small sample sizes, sex bias in sampling, and temporal differences among the samples (International Whaling Commission [IWC], 2009). One of the difficulties in interpreting population structure and delineating ecological stocks is that sampling is very patchy in space and time, and often dependent upon animals washed ashore whose origins are unknown. Until there is a wide-ranging biopsy sampling programme of living animals and obligatory landing of bycaught individuals, this will remain an issue.

3 | ABUNDANCE AND TRENDS

There have been several cetacean abundance surveys in various parts of the NE Atlantic, although none spanning the entire species distribution in the North Atlantic; for example, the Mesure de l'Impact des Captures Accessoires survey in 1993 (Goujon et al., 1993), the ATLANCET aerial survey in 2001 (Ridoux, Van Canneyt, Doremus, & Certain, 2003), the Suivi Aérien de la Mégafaune Marine (SAMM) aerial surveys in 2011–2012 (Laran et al., 2017), and the MARPRO™ surveys in 2007–2012 (Marçalo et al., 2018). The most recent abundance estimate is from the Small Cetaceans in European Atlantic waters and the North Sea (SCANS)-III survey (July 2016), which estimated 467,673 (coefficient of variation CV = 0.26; 95% confidence interval [CI]: 281,100–778,000) common dolphins in European continental shelf and UK offshore waters (Hammond et al., 2017). This estimate did not include contemporaneous aerial survey data from the Irish Exclusive Economic Zone that were just recently published (Rogan et al., 2018). These authors reported 33,215 (CV = 41.52; 95% CI: 19,844–55,595) possible common dolphins in this area. This included 3,214.8 common dolphins identified to species and undifferentiated common/striped dolphins (but these were likely to have been almost all common dolphins) (Rogan et al., 2018). The ObSERVE survey results from 2015–2017 for the Irish Exclusive Economic Zone showed considerable variation between seasons and years. During the July 2016 aerial survey flights in both ObSERVE and SCANS-III, no common dolphins were seen in the Irish Sea (in contrast to the results in July 2004 from SCANS-II), suggesting that, at the time, common dolphins may have been concentrated further south in the Bay of Biscay and around the Iberian Peninsula, where abundance estimates were highest (Hammond et al., 2017).

The combined abundance estimate (467,673 plus 33,215 individuals) for common dolphins for July 2016 is considerably larger than that recorded in 2005/2007 for an area of somewhat comparable size. The SCANS-II survey estimated 56,221 (CV = 0.23; 95% CI: 35,700–88,400) common dolphins for shelf waters for the year 2005 (Hammond et al., 2013), and the Cetacean Offshore Distribution and Abundance (CODA) survey estimated 116,709 (CV = 0.34; 95% CI: 61,400–221,800) common dolphins for offshore waters for the year 2007 (CODA, 2009). The combined 2016 SCANS-III and ObSERVE abundance estimate is consistent with results from the SAMM aerial surveys in French waters of the Bay of Biscay and the English Channel in summer 2012 (Laran et al., 2017). It should be noted that the largest abundance estimates all come from aerial surveys, whereas the earlier SCANS-II and CODA surveys in these areas were ship-based.

The apparent large increase in abundance between 2005/2007 and 2016 and the wide confidence limits attached to most of the abundance estimates highlight the challenges faced when attempting to survey such a highly mobile species, the range of which extends well beyond the survey area and which shows responsive movements to survey vessels. It is very likely that the apparent differences largely reflect variation between years (and quite possibly between months, given that these surveys, particularly aerial ones, are undertaken over a short period of time) in the distribution and movements of common dolphin groups. These may include latitudinal or offshore–inshore movements, or a mixture of the two. Surveys undertaken from 2007–2016 in north-west Spanish waters, for example, have reported a high interannual variability in abundance, ranging between 5,533 animals (density 0.16; CV = 0.62) in 2008 and 22,662 (density 0.61; CV = 0.36) in 2010 (Saavedra et al., 2017).

Beyond the European Atlantic shelf seas, a historical abundance estimate of 273,159 common dolphins was reported for the North Atlantic Sighting Survey (NASS)-west survey block in 1995 (Cañadas et al., 2009). An additional 77,547 common dolphins were estimated for the NASS-east block in the same year, although this latter estimate was not considered reliable due to limitations in the survey. However, such high numbers of individuals were not observed when some of those areas were surveyed in 2000–2001 and 2007, including surveys such as Trans-NASS, during which a more southern distribution of common dolphins was observed compared with earlier NASSs (CODA, 2009; IWC, 2009; Lawson et al., 2009; Murphy et al., 2013; Ó Cadhla, Mackey, Aguilar de Soto, Rogan, & Connolly, 2003). With a recent influx of common dolphins into the management unit area, possibly from offshore waters, further genetic analysis is required to ascertain whether there is any evidence of genetic differentiation among these individuals. It should be noted that a higher abundance of common dolphins in the management unit area, particularly in more southern waters, means more individuals are now exposed to anthropogenic activities in western European waters.

4 | LIFE-HISTORY PARAMETERS

A large-scale study assessing reproductive parameters in stranded and bycaught female common dolphins in the NE Atlantic (ranging from Portugal to Scotland) revealed a low overall annual pregnancy rate of 26% and an extended calving interval of approximately 4 years, on average, for the period 1990–2006 (Murphy et al., 2009). Although the low annual pregnancy rate reported throughout the 16-year sampling period may suggest either that the population is at carrying capacity or that their prey base is declining at approximately the same rate as the dolphin population (Murphy, Winship, et al., 2009), exposure to endocrine-disrupting pollutants could be a contributing factor to the lower reproductive output in the NE Atlantic population (Murphy et al., 2010; 2018).

The average age and length at sexual maturity in females were 8.2 years and 188 cm respectively (Murphy, Winship, et al., 2009). For males in the NE Atlantic, sexual maturity was attained at an average age of 11.9 years and average length of 206 cm (Murphy, Collet, & Rogan, 2005). A mean generation time of 12.94 years was determined for the population (Murphy et al., 2007). The species' maximum recorded longevity was 30 years in the NE Atlantic (Murphy et al., 2010), although 98% of the females sampled were less than 20 years old (Murphy, Winship, et al., 2009). Together, these figures suggest a low lifetime reproductive output of possibly four to five calves per female, if an older age was attained (Murphy, Winship, et al., 2009). No significant differences were observed when comparing reproductive parameters in females from the 1990s with data collected during the 2000s, although comparisons with all other available data for this species showed that the NE Atlantic population had a lower pregnancy rate than populations in the NW Atlantic, South Africa, the western Pacific and New Zealand (Table 1).

Life-history parameters have also been determined from a large sample of common dolphins stranded along the coast of Galicia, north-west Spain, between 1990 and 2009 (Read, 2016). Females reached up to 252 cm in length and 24 years of age, and males up to 240 cm and 29 years. Females in the region attained sexual maturity at an average age of 8.4 years and 187 cm length, and males at 10.5 years and 204 cm length. Using a sample size of 80 mature females, estimates of the annual pregnancy rate varied between 31% and 38% (the higher estimate did not exclude females that were sampled during the mating period), equivalent to a calving interval of 2.5–3 years (Read, 2016). The annual mortality rate was estimated at 12.8%, with no significant differences observed between males and females. Although this equates to an average life expectancy at birth of 7.2 years and 7.6 years for females and males respectively, which is lower than the age at sexual maturity, potential biases need to be explored and the assessment undertaken at the population level. There was no evidence of senescence in mature females (as previously reported by Murphy, Winship, et al., 2009), and no evidence of changes in the proportion of mature females over the time series.

The higher pregnancy rate reported for the Galician region may be attributed to a higher number of bycaught (and thus possibly healthy) individuals within the sample. For example, Murphy, Winship, et al. (2009) also estimated an annual reproductive rate of 33% for bycaught individuals from UK waters using data from 46 mature females. Thus, excluding stranded females, whose reproduction may be compromised, increases the pregnancy rate estimate. As all wild populations contain individuals that are both 'healthy' and 'unhealthy' and some 'unhealthy' females may not associate with fishing activities, this should be accounted for when producing estimates of population life-history parameters. Bycatch samples can also show bias through bycatch selectivity for particular age–sex classes, and older females exhibiting a lower reproductive rate may be underrepresented (Murphy et al., 2013; Murphy, Winship, et al., 2009). Thus, the lower estimate of 26%, obtained using a large sample size of 248 mature females sampled from throughout the NE Atlantic, may still be more representative of the pregnancy rate for the NE Atlantic population (Murphy, Winship, et al., 2009).

TABLE 1 Published data on mating/calving period, annual pregnancy rate (APR), calving interval (CI), average age attained at sexual maturity (ASM), and average body length attained at sexual maturity (LSM) in *Delphinus delphis.* NA: not analysed. Updated from Murphy et al., 2009.

Area	Climate	Sample period	Mating/calving period	APR (presence of foetus only)	APR (mature sample, *n*)	CI (years) (1/APR)	ASM (years) [*n*]	LSM (cm) [*n*]	Source
Eastern North Atlantic	Temperate	1990–2006	May–September	26%	248	3.79	8.22[d] [379]	188.8[a] [597]	(Murphy, Winship, et al., 2009)
Western North Atlantic	Temperate	1989–1998	July–August	28%[e]	39	3.57	8.33[a] [64]	NA	(Westgate & Read, 2007)
Eastern tropical Pacific	Tropical	1979–1993	Calve all year round	47%[f]	440	2.14	7.8[d] [405]	187[a] [700]	(Danil & Chivers, 2007)
North Pacific	Temperate	1990–1991	May–June	NA	NA	NA	8[b]	172.8[a]	(Ferrero & Walker, 1995)
New Zealand	Temperate	1992–2012	Primarily austral summer	36%	17	2.8	NA	183.4[a]	(Institute of Zoology, 2015)
South Africa	Temperate	1969–1988	Austral summer	40.2%[c]	93	2.5[c]	~8–9[b]	NA	(Mendolia, 1989; Murphy, Winship, et al., 2009) (*Delphinus capensis*)

[a]Using adjusted Sum-of-fraction of immature method (SOFI)

[b]Only an approximate ASM; SOFI method not used.

[c]Calculated by Murphy, Winship, et al. (2009) using data presented in Mendolia (1989).

[d]Generalized linear model (GLM) approach.

[e]Did not exclude females that died during the mating period.

[f]Abundance of 2,963,00 common dolphins in the whole eastern tropical Pacific.

Both sexes exhibit reproductive seasonality with a unimodal calving/mating period extending from April to September in the NE Atlantic, with a possibly more active period in July and August (Murphy et al., 2005; Murphy, Winship, et al., 2009). The existence of moderate sexual dimorphism in the species and the development of enlarged testes in seasonally active mature males suggests post-mating competition among males (i.e. sperm competition) resulting from a promiscuous mating system (Murphy et al., 2005; Murphy & Rogan, 2006).

5 | THREATS

At the request of OSPAR, ICES WGMME (2015) compiled a 'threat matrix' for the main marine mammal species in each regional seas area covered by the EU Marine Strategy Framework Directive (MSFD). Incidental capture in fishing gear was identified as the most important threat to common dolphins in the Celtic Seas and Bay of Biscay/Iberian Peninsula areas, a conclusion that is consistent with findings of many previous publications. Across the Atlantic regions, contaminants, underwater noise, prey depletion, and vessel collision were also considered to be of concern, albeit with differing levels of importance.

5.1 | Incidental capture

The areas within the NE Atlantic where common dolphin bycatch is thought to be greatest include the Celtic Sea and Western Approaches to the English Channel (ICES Area VIIh), the western English Channel (ICES Area VIIe), Bay of Biscay (ICES Area VIIIa), and along the shelf edge of Atlantic Spain and Portugal (ICES Areas VIIIc, IXa) (Fernández-Contreras et al., 2010; ICES Working Group on Bycatch of Protected Species [WGBYC], 2015; Marçalo et al., 2015). Bycatch has been reported in pelagic trawl and purse seine fisheries targeting a range of fish, including albacore tuna, sea bass, blue whiting, horse mackerel, sardine, and anchovy, and 'very high vertical opening' bottom-pair trawl fisheries targeting hake, as well as (bottom-)set gillnets (Fernández-Contreras et al., 2010; Marçalo et al., 2015; Morizur, Gaudou, & Demaneche, 2014; Morizur, Pouvreau, & Guenole, 1996; Morizur, Tregenza, Heesen, Berrow, & Pouvreau, 1996; Murphy et al., 2013; Northridge & Kingston, 2009; Tregenza, Berrow, & Hammond, 1997; Tregenza & Collet, 1998; Wise, Silva, Ferreira, Silva, & Sequeira, 2007). Annual bycatch mortality levels across the NE Atlantic have been estimated in the hundreds or low thousands from independent observer programmes, though not all fisheries have been assessed (ICES WGMME, 2016; Murphy et al., 2013). This reflects the fact that, although bycatch monitoring has been driven by EU Regulation 812/2004, there has been a focus on specific fisheries and areas requiring monitoring rather than comprehensive monitoring, and not all EU member states have implemented the required monitoring. Although bycatches of common dolphin were thought to be highest in the trawl fisheries, they also occur in relatively high numbers in static nets, purse seine nets, other seine nets (including beach-seines), and long-lines (Cosgrove & Browne, 2007; ICES WGBYC, 2011, 2012, 2015, 2016; Murphy et al., 2013; Northridge & Kingston, 2009; Tregenza, Berrow, & Hammond, 1997; Tregenza, Berrow, Hammond, & Leaper, 1997).

Additional evidence regarding bycatch mortality of common dolphins arises from interview surveys with fishers and the monitoring of strandings (e.g. Goetz, Read, Santos, Pita, & Pierce, 2014; López, Pierce, Santos, Gracia, & Guerra, 2003; Mannocci et al., 2012; Peltier et al., 2016). Between 2005 and 2016, overall numbers of common dolphin strandings have been increasing along the coasts of Ireland, the UK, and France (see Figure 2). Over 53% of French common dolphin strandings in 2016 were diagnosed as bycatch (Dars et al., 2017). For the UK, 19% of necropsied stranded animals in 2016 were identified as bycatch (Deaville, in press). Evidence from strandings and from interviews with fishers has shown that bycatch mortality is frequent and widespread along the Galician coast, north-west Spain (Goetz et al., 2014; López et al., 2002; 2003; Read, 2016), and the coast of Portugal (Goetz et al., 2015; Silva & Sequeira, 2003).

Efforts to reduce bycatch are ongoing. Acoustic deterrent devices have been employed in both static and trawl gear with varying success (reviewed in Murphy et al., 2013). Excluder devices in trawl gear, such as separation grids and escape panels, have been trialled, but most have been rather ineffective (e.g. 20% reduction in bycatch at best; Northridge, 2006). Other bycatch mitigation techniques include changes in operational procedures; for example, the implementation of a number of avoidance techniques (e.g. lowering the trawl headline and cessation of fishing activities when dolphins were in the vicinity) that contributed to a reduction in the incidental capture of common dolphins in the Irish tuna pelagic trawl fishery (Murphy et al., 2013).

In 2016, based on the most recent review of national reports (for the years 2009–2013) and available abundance data from the SCANS-II survey, ICES advised the European Commission that bycatches of common dolphins may be unsustainable (ICES Advice, 2016a). This advice took into account the uncertainty in the assessment, due to ambiguities in recording fishing effort, unrepresentative

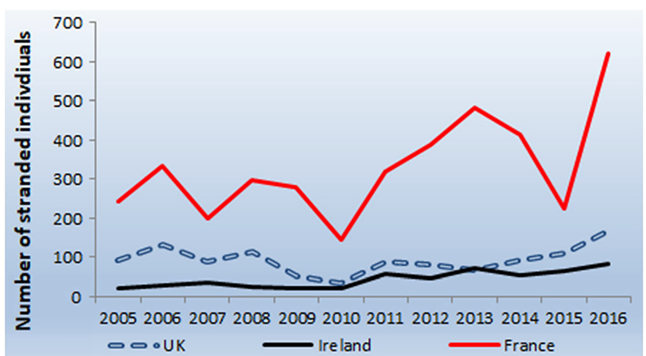

FIGURE 2 Interannual variation in strandings of common dolphins in north-west European waters (2005–2016). Data provided by the UK Cetacean Strandings Investigation Programme, the Irish Whale and Dolphin Group, and the Centre de Recherche sur les Mammifères Marins, Université de La Rochelle, France.

sampling by gear type, and a lack of statutory reporting from some major fishing nations (ICES Advice, 2016a). In 2018, ICES advised that that the total bycatch in mid-water trawls and in nets in subareas 27.7 and 27.8 (southern part of Celtic Seas area and in the Bay of Biscay) for the year 2016 was (likely) between 153 and 904 and between 1607 and 4355 individuals, respectively. This was based on data provided following an ICES data call in which only one country provided extrapolated estimates, while some other countries failed to provide any data at all. Using abundance data from SCANS-III, the bycatch rate in the subarea 27.8 was found to exceed the threshold of 1.7% of abundance (ICES Advice, 2018). ICES noted that, from the numbers of bycaught common dolphins stranding on the shores of the Bay of Biscay, a dedicated bycatch observer programme and further bycatch mitigation measures are required—and that current mitigation employed in the region may not be adequate (ICES Advice, 2018).

Though a sufficiently comprehensive, well-designed and implemented on-board observer programme could in theory deliver the required results in practice, a combination of issues (inadequate legislation, incomplete implementation, lack of funding, self-selection of cooperating vessels, and changes in fisher behaviour when observers are on board) essentially makes this unachievable. In order to obtain robust estimates of bycatch rates, there is a need for greater (and better distributed) sampling effort using independent dedicated observers, while also integrating data from fishery observers (under the EU Data Collection Framework [DCF], which is expected to assume a more important role in cetacean bycatch monitoring in the future), along with others sources of information, such as voluntary reporting by skippers, remote electronic monitoring, strandings monitoring, interview surveys, and/or some other means. Also, fishing effort itself needs to be better quantified, including information on fishing gear/activity with appropriate spatial and temporal resolution, target prey species, immersion duration of gear and area swept, net dimensions (total length of set nets, aperture of trawl), fishing locations, and use of mitigation devices (presence/absence, type, setting interval) (ASCOBANS, 2015d; ICES WGBYC, 2011, 2012, 2013a, 2013b, 2014, 2015, 2016).

Though all this makes effective bycatch management sound ever more distant, this is not necessarily so. During the 1990s, the albacore tuna (*Thunnus alalunga*) driftnet fishery in the NE Atlantic caught very large numbers of common dolphins—over 2,000 individuals in 1999 alone (and this was not the only bycaught species of concern in this fishery)—until a ban was introduced in 2002 (Goujon, 1996; Goujon et al., 1993; Rogan & Mackey, 2007). So, in part, it is a question of priorities. It is increasingly recognized that 'data-poor' situations are not necessarily a barrier to management. The precautionary principle should be applied, requiring mitigation measures unless monitoring shows them to be unnecessary. Mitigation measures could include modification or phasing out of some fishing gears and fishing practices, especially those associated with high bycatch rates; for example, night-time pair trawling (Fernández-Contreras et al., 2010) and very high vertical opening trawls (Morizur, Berrow, Tregenza, Couperus, & Pouvreau, 1999; Morizur, Pouvreau, et al., 1996). Other mitigation options include closed areas, setting of bycatch limits for particular fisheries, education and publicity campaigns, and ecological certification of dolphin-safe fishing, an example of both market measures and 'management by results'.

The history of managing fishery bycatch includes both important successes, such as the greatly reduced dolphin mortality in tuna fishing in the eastern tropical Pacific (Lewison, Crowder, Read, & Freeman, 2004), and spectacular failures, such as the (presently) near extinction of the vaquita (Comité Internacional para la Recuperación de la Vaquita, 2018; Rojas-Bracho & Reeves, 2013). The generally high standard of fishery governance in EU waters suggests that we should be closer to the former situation than the latter, but regulation, compliance, and monitoring of compliance with regulations continue to be issues in some regions and fisheries. The Mediterranean Sea faces an even greater challenge to reduce bycatch, since it is fished by a larger number of nations, some of which are poorly regulated and outside the EU. At the time of writing, responsibility for monitoring bycatch of cetaceans and other Protected, Endangered and Threatened species in EU waters is in the process of being transferred to the Fishery DCF. This offers both the prospect of obtaining data from a wider range of fisheries (including fisheries in the Mediterranean) and a risk that data quality is compromised.

5.2 | Persistent organic pollutants

The main pollutants of concern within the NE Atlantic are still the legacy persistent organic pollutants (POPs), including polychlorinated biphenyl (PCBs; OSPAR, 2010). PCBs were originally synthesized in the 19th century but came into widespread use in the 1930s and were used commercially for over five decades until their use was banned in Europe in the 1980s (Council Directive 85/467/EEC) and by the Stockholm Convention in 2001. However, in 2016, the Stockholm Convention reported that, globally, 14×10^6 tons of PCB-contaminated waste (83% of the total produced) still required disposal (United Nations Environment Programme/Division of Technology, Industry and Economics, 2016). This includes 415,464 t of the liquids and equipment containing or contaminated with PCBs in the 'western Europe and other groups' region, though it should be noted that open applications were not included in the inventories of many countries. Further, many countries in the region did not supply quantitative data on the liquids and equipment containing PCBs that were already disposed (as this may have occurred prior to most of the available sources of information), and full estimates for 'eliminated' PCBs in Europe includes 200,000 t that were landfilled. Overall, it has been estimated that approximately one-third of globally produced PCBs has been released to the environment (United Nations Environment Programme/Division of Technology, Industry and Economics, 2016). These contaminants cause adverse health effects in marine mammals, including reduced immunocompetence and endocrine disruption, potentially resulting in infertility (Aguilar, Borrell, & Pastor, 1999; Jepson et al., 2005; Jepson et al., 2016; Jepson & Law, 2016; Murphy et al., 2018; Reijnders, 2003; Tanabe, Iwata, & Tatsukawa, 1994). These effects are aggravated by propensity of these chemicals to both bioaccumulate in individuals and biomagnify in food webs (Diamanti-

Kandarakis et al., 2009; European Environment Agency [EEA], 2012). PCBs are also extremely persistent in the environment, with long half-lives of up to 100 years being reported for some congeners (Hickie, Ross, Macdonald, & Ford, 2007; Jonsson, Gustafsson, Axelman, & Sundberg, 2003; Sinkkonen & Paasivirta, 2000).

Factors contributing to the slow decline of PCBs in the marine environment include global cycling (Wenning & Martello, 2015), ongoing inputs through dredging of PCB-laden sediment, and leakage from old landfills and PCB-containing precast buildings (Jepson & Law, 2016). The scale of the problem is reflected in the EEA's assessment of hazardous substances in marine organisms. For all European waters, only 14% of the 319 data sets for mussels and fish showed a significant downward trend in PCBs (EEA, 2015). A similar picture was observed for dichlorodiphenyltrichloroethane, a banned persistent organochlorine pesticide, with generally moderate (to high) concentrations found at stations throughout European waters (EEA, 2015). In the 2017 Intermediate Assessment undertaken by OSPAR for the MSFD, the concentration of CB118, one of the most toxic congeners, in fish liver and shellfish was close to or above a critical value defined under the environmental assessment criteria (EAC) in eight of the 11 assessment areas, which indicates possible adverse effects on marine life in those areas (OSPAR Commission, 2017). Concentrations of the six other congeners included in the assessment for MSFD Descriptor 8 (concentrations of contaminants) were below critical EAC values. PCB contamination was declining slowly in nine out of 10 assessment areas between 1995 and 2014 (where data were available), apart from the Celtic Sea, where no statistically significant change was detected—though concentrations of CB118 were below the critical EAC value in that assessment area (OSPAR Commission, 2017).

Law et al. (2012) reported a slow decline in PCB concentrations in UK harbour porpoise blubber over the period 1991 to 1998, following which the decline stalled. In contrast, significant ongoing declines in blubber concentrations of dichlorodiphenyltrichloroethane (and dieldrin) were observed in UK porpoises. Although common dolphins have been shown to carry lower levels of PCBs than some other European cetaceans (e.g. harbour porpoise, bottlenose dolphin, and killer whale; Jepson et al., 2016), the effects of exposure to lower doses of endocrine-disrupting chemicals may be similar, particularly when exposure occurs during critical periods of development (Murphy et al., 2018). Endocrine-disrupting chemicals (i.e. chemicals that interfere with any aspect of hormone action) have the ability to act at low doses, show delayed effects (sexual dysfunction and physical abnormalities) that are not evident until later in life or even until future generations, and have the potential to show combination effects when animals are exposed to multiple pollutants (Bergman, Heindel, Jobling, Kidd, & Zoeller, 2013; Ingre-Khans, Ågerstrand, & Rudén, 2017; Murphy et al., 2018). Work undertaken to date on female common dolphins in the NE Atlantic suggested that high PCB burdens, above a threshold for the onset of adverse health effects in marine mammals (9 mg kg^{-1} ΣPCB lipid) (Jepson et al., 2016; Kannan, Blankenship, Jones, & Giesy, 2000), did not inhibit ovulation, conception, or implantation (Murphy et al., 2010, 2018). However, reproductive failure, manifested in mid to late-term abortion and/or newborn mortality, and reproductive dysfunction in common dolphins inhabiting UK waters may be linked to exposure to PCBs (Murphy et al., 2018).

Reproductive failure was reported to occur in at least 30% of a 'control' group sample composed of mature female common dolphins that stranded dead along the UK coastline and were identified as bycatch mortalities from necropsy examinations (Murphy et al., 2018). Reported incidences of reproductive dysfunction are rare in cetaceans; however, within a large sample of bycaught and other stranded females (control and non-control samples), 16.8% (18 out of 107) presented with reproductive system pathologies, including conditions such as vaginal calculi (5.6%), suspected precocious mammary gland development (5.6%), and ovarian tumours (2.8%) (Murphy et al., 2018). Individual females also presented with an ovarian cyst, atrophic ovaries in a 17-year-old sexually immature individual, and the first reported case of an ovotestis in a cetacean species (Murphy et al., 2018; Murphy, Deaville, Monies, Davison, & Jepson, 2011). Where pollutant data were available, all observed cases of reproductive tract pathologies were recorded in females with ΣPCB burdens >22.6 mg kg^{-1} ΣPCB lipid (Murphy et al., 2018). Unlike females, males are unable to rid themselves of their lipophilic pollutant burden (through offloading during gestation and lactation) and accumulate high PCB concentrations; the effect of this is not fully understood in male cetaceans, as very few studies have been undertaken, and none on common dolphins (Murphy et al., 2018). Studies on humans have reported effects on male fertility are likely (Meeker & Hauser, 2010; Sidorkiewicz, Zaręba, Wołczyński, & Czerniecki, 2017).

Further work is required to understand the population-level effects of PCB-induced reproductive impairment in common dolphins in this region, taking into consideration not only the level of contemporary PCB exposure but also inherited maternal pollutant burdens in first-born offspring and generational epigenetic effects (Murphy et al., 2018).

5.3 | Plastic ingestion

Marine litter, notably plastics, has become an increasing concern owing to its observed impact on a wide range of marine life (Baulch & Perry, 2014; Derraik, 2002; IWC, 2013; O'Hanlon, James, Masden, & Bond, 2017; OSPAR Commission, 2014; Ryan, Moore, van Franeker, & Moloney, 2009). Impacts occur either through entanglement (e.g. in plastic sheeting), which can lead to drowning, or through ingestion, which can lead to blockages in the digestive tract and subsequent starvation.

Most plastics are extremely durable materials and can persist in the marine environment, in some form (e.g. macro-, micro-, or nano-sized), for a considerable period, possibly even hundreds of years (OSPAR Commission, 2014). Ingestion of plastics can expose biota to a cocktail of chemicals, which may act independently and/or interact with other pollutants to cause adverse health effects. These chemicals include the polymers and additives in the plastic debris itself, and a range of hydrophobic chemicals from the surrounding environment that sorb to the bulk polymer (Kärrman, Schönlau, & Engwall, 2016). POPs can accumulate on, for example, microplastics (MPs) in concentrations up to 10^5–10^6 times higher than in the surrounding water (Mato et al., 2001), possibly contributing to the source of such contamination in top predators. However, there are some discussions that ingested MPs may act as 'passive samplers' of POPs in the digestive tract rather than 'vectors' for POPs (Herzke et al., 2016), and the impact of delivery of pollutants into the digestive tract via MPs remains essentially unknown.

Necropsies have revealed several deaths linked to the ingestion of macroplastic waste in cetaceans in UK waters (Deaville, 2016). Limited work has been undertaken on levels and impacts of MPs in common dolphins. Trophic transfer of MPs (1 μm–5 mm) to marine top predators has been reported (Nelms, Galloway, Godley, Jarvis, & Lindeque, 2018). Though a study assessing MP burdens in the digestive tracts of 50 marine mammals (cetaceans and pinnipeds) in UK waters reported that, although they were ubiquitous, a relatively low number per animal were observed (mean 5.5 MPs), predominately in the stomachs (Nelms et al., 2019). In the sample of 16 common dolphins within the study, the total number of MPs was in the range 1–12 (mean 5.7 MPs; Nelms et al., 2019). A recent study in Galicia (NW Spain) reported small numbers of MP particles in 100% of 25 common dolphin stomachs analysed (94% if MPs potentially representing airborne contamination of samples were excluded), although their presence appeared non-obstructive to the normal functioning of the digestive tract (Hernandez-Gonzalez et al., 2018). In Irish waters, the incidence of ingestion of MPs in stranded and bycaught common dolphins was 2.5 times higher than what was reported in the Atlantic Ocean and on a global scale (Lusher, Hernandez-Milian, Berrow, Rogan, & O'Connor, 2018). In fish, MPs have been observed in, having translocated to, the liver (e.g. Collard et al., 2017), which has not been assessed to date in the common dolphin.

Nanoplastics (<100 nm), which have not been assessed in common dolphins, have the potential, for example, to cause particle stress by translocating to tissues in the lymphatic and circulatory systems, leading to cellular damage and thrombosis (Hussain, Jaitley, & Florence, 2001; Kärrman et al., 2016).

5.4 | Prey depletion

Common dolphins eat a wide range of fish and cephalopods (e.g. Brophy, Murphy, & Rogan, 2009; Pusineri et al., 2007; Santos et al., 2013), with several studies pointing to an apparent preference for 'fatty', i.e. higher calorific value, species (e.g. Meynier et al., 2008; Spitz, Mourocq, Leauté, Quéro, & Ridoux, 2010). This may be responsible for seasonal movements within the NE Atlantic, particularly in relation to the energetic demands of pregnant and lactating females (Brophy et al., 2009). Though marine mammals are not included in all marine ecosystem models, a number of ecosystem models developed for European seas include cetaceans (ICES WGMME, 2015). Efforts have been made to quantify the amount of fish removed by common dolphins (e.g. Marçalo et al., 2018; Santos, Saavedra, & Pierce, 2014) as well as to include common dolphin–fishery interactions (both direct as a result of bycatch and indirect from prey removal) in ecological models (e.g. Lassalle et al., 2012; Saavedra et al., 2017).

Fish stock assessment and provision of fishery management advice for North Atlantic fish stocks are carried out under the auspices of ICES. In the Mediterranean Sea, this function is assumed by the General Fisheries Commission for the Mediterranean. Assessment and advice from both bodies passes to the Scientific, Technical and Economic Committee for Fisheries. The European Commission recently reported that 93% of Mediterranean fish stocks are overfished (EU Science Hub, 2017). However, the figure depends on the number of stocks considered as well as the precise criteria used. The EEA's 2015 report on the status of European fish stocks in the context of the MSFD considered 186 assessed stocks, 40% from the NE Atlantic and Baltic Sea and 60% from the Mediterranean Sea and Black Sea. Good environmental status (GES) was assessed on two criteria: whether fishing effort was consistent with that required to achieve maximum sustainable yield (MSY), and whether reproductive potential, as measured by spawning stock biomass, was consistent with that at MSY. Around 76% of Atlantic stocks met at least one GES criterion, compared with 14% of Mediterranean stocks (EEA, 2015). It should be borne in mind that a stock fished at MSY can rapidly pass to being overfished and that current assessments normally refer only to commercial stocks and do not consider the effects of fishing on non-target bycatch species and the wider ecosystem. Furthermore, GES criteria are generally based on recent 'baselines', so fishing at MSY does not imply that ecosystem productivity could not be increased through, for example, restoration of damaged habitats.

Prey depletion is a potential issue for common dolphins, at least for some prey species in some areas. For example, among the likely 'preferred' prey of common dolphins in Europe, the abundance of the Iberian sardine stock is currently very low, an issue exacerbated by poor recruitment in recent years. Indeed, ICES recommended zero catches in 2018 (ICES Advice, 2018). Between 1990 and 2016, 4.5% (32 of the 694) of necropsied common dolphins died as a result of starvation in the UK, although this rose to 9.7% (10 of 103 post mortem investigations) for the period 2012 to 2016 (Deaville, 2012, 2013, 2014, 2015, 2016, in press; Deaville & Jepson, 2011a). This excludes neonate deaths as a result of starvation/hypothermia because that may be a consequence of maternal separation for dependent neonates rather than due to prey depletion. In Ireland, a recently re-established cetacean stranding necropsy programme reported starvation/hypothermia as the cause of death in 21% (4/19) of necropsied common dolphins for the period June to November 2017, and this includes one case of starvation/hypothermia in a neonate (Levesque et al., 2018).

Given the high proportion of Mediterranean fish stocks that are overfished, prey depletion is likely to be a more serious issue for common dolphins in the Mediterranean, and Bearzi et al. (2008) considered prey depletion to be the most likely cause of the decline of this species in the Mediterranean since the 1960s.

5.5 | Underwater noise

Over the last three decades, attention has increasingly focused on the possible effects of underwater noise on marine mammals. At close range, loud sounds may cause hearing damage, permanent threshold shifts, or temporary threshold shifts; at greater distances, they may lead to behavioural disturbance or masking of acoustic communication (Richardson, Greene, Malme, & Thomson, 1995). Shipping is one of the main sources of non-impulsive sound, whereas impulsive sound sources include geophysical seismic surveys, pile driving in association with industrial activities (e.g. harbour developments, offshore windfarm construction), and mid-frequency active sonar emitted during military exercises (Nowacek, Thorne, Johnston, & Tyack, 2007; OSPAR Commission, 2009).

Full audiograms have not been generated for the common dolphin. Largely on the basis of sound production data, common dolphins have been classified as medium–high-frequency odontocetes with a generalized hearing range of 150 Hz to 160 kHz (Finneran, 2016; Houser et al., 2017). Based on electro-encephalogram measurements in common dolphins, Popov and Klishin (1998) reported highest sensitivity at around 60–70 kHz. Large vessels typically have sound source levels of 160–220 dB re 1 μPa @ 1 m over a bandwidth of 5–100 Hz, with peak energy at around 25 Hz (National Research Council, 2003; Richardson et al., 1995). A study in the Santa Barbara Channel (California, USA) reported different sound levels and spectral shapes according to vessel type, with bulk carriers having higher source levels near 100 Hz, whereas container ship and tanker noise was predominantly below 40 Hz (McKenna, Ross, Wiggins, & Hildebrand, 2012). Common dolphin whistle frequencies range from 0.3 to 44 kHz, which suggests that, for the most part, shipping is unlikely to directly disturb the species or mask communication.

Airgun arrays used in seismic surveys may produce sound pulses up to 260–262 dB re 1 μPa @ 1 m, generally below 250 Hz; with the strongest energy in the range 10–120 Hz and peak energy between 30 and 50 Hz, although sound frequencies up to 100 kHz have been recorded (National Research Council, 2003; OSPAR Commission, 2009). There is little evidence that common dolphins are disturbed by seismic sounds (Stone, 2015; Stone, Hall, Mendes, & Tasker, 2017; Stone & Tasker, 2006). Although avoidance reactions have been noted in the immediate vicinity, the species generally appears to tolerate the pulses at 1 km distance from the array (Goold, 1996; Goold & Fish, 1998). In the UK, the Joint Nature Conservation Committee has introduced mitigation guidelines for the industry, which were updated most recently in 2017 (Joint Nature Conservation Committee, 2017). These include deployment of marine mammal observers (with or without passive acoustic monitoring) to alert crew to the close presence of cetaceans and ramp up of airgun sounds to enable undetected animals in the vicinity to move away without physical damage to hearing.

Concerns have been raised regarding the effects on marine mammals of pile driving, particularly in the construction of windfarms (Evans, 2008; Madsen, Wahlberg, Tougaard, Lucke, & Tyack, 2006; Mann & Teilmann, 2013; Saidur, Rahim, Islam, & Solangi, 2011; Teilmann, Carstensen, & Dietz, 2006; Thomsen, 2010). Large mono-pile designs with diameters of between 4 and 6 m have the potential to give rise to peak-to-peak source levels in excess of 250 dB re 1 μPa @ 1 m, at peak frequencies of 100–500 Hz, although sounds up to 20 kHz can be produced (Nedwell et al., 2008; OSPAR Commission, 2009). By its nature, piling tends to occur in relatively shallow (<50 m) waters, and therefore in areas not normally inhabited by common dolphins, although concerns were raised about effects of pile driving in Broadhaven Bay (Co. Mayo, Ireland) where a pipeline was constructed from an offshore gas field. Construction-related activity reduced harbour porpoise (*Phocoena phocoena*) and minke whale (*Balaenoptera acutorostrata*) presence but not that of common dolphins, although an increase in vessel numbers (independent of construction-related activity) was associated with reduced common dolphin presence (Culloch et al., 2016). However, it is possible that this association was coincidental, since common dolphin presence in the region is highest in winter whereas boat activity was highest in summer, and there was also spatial separation of dolphins and boats, with common dolphins rarely entering the bay (Anderwald et al., 2012, 2013).

Active sonar, operating with sound source levels up to 245 dB re 1 μPa @ 1 m at frequencies mainly between 1 and 150 kHz, is frequently used for fish-finding, oceanography, charting, and in military activities (e.g. to locate submarines). The use of military sonars has been causally linked with a number of cetacean mass stranding events, predominantly involving beaked whales (Brownell, Yamada, Mead, & van Helden, 2004; Cox et al., 2006; DeRuiter et al., 2013; Fernández et al., 2005; Frantzis, 1988; Jepson et al., 2003). It has been proposed that cetaceans show hazardous behavioural changes in response to some sonar frequencies, potentially leading to nitrogen supersaturation and risk of gas and fat embolism similar to decompression sickness in humans (Fernández et al., 2005; Hooker et al., 2012; Jepson et al., 2003, 2013; Jepson et al., 2005). A small number of cases of acute and chronic gas embolism (3 of 694 [0.4%] post-mortem investigations) have been reported in common dolphins stranding in the UK but not specifically linked to military activity (e.g. Jepson et al., 2003; Jepson, Deaville, et al., 2005). In June 2008, a mass stranding of 26 common dolphins occurred in the Fal Estuary, Cornwall, UK (Jepson et al., 2013). All animals examined were in good condition, although they had empty stomachs, and there was no evidence of significant infectious disease or acute physical injury. An international naval exercise using mid-frequency active sonar had been conducted in the South Coast Exercise Area prior to the mass stranding event. The most intensive activity of the exercise occurred 4 days before the mass stranding event, and helicopter exercises resumed on the morning of the stranding event (Jepson et al., 2013). In the absence of other causes of the mass stranding event, it was believed that the naval exercises played a part in a behavioural response causing the animals to enter Falmouth Bay and ultimately led them to strand en masse (Jepson et al., 2013).

Although a number of sound sources have the potential to impact upon common dolphins, the predominantly pelagic range of the species, which places it at some distance from many of these activities, should help to mitigate against negative effects.

5.6 | Vessel strikes

The seas around western Europe are some of the busiest in the world (ASCOBANS, 2011). Shipping, particularly if travelling at speeds exceeding 10 kn, poses a collision risk to cetaceans (Evans, Baines, &

Anderwald, 2011; Laist, Knowlton, Mead, Collet, & Podesta, 2001; Pesante, Panigada, & Zanardelli, 2002; Vanderlaan & Taggart, 2007). Nine out of 694 (1.3%) post-mortem examinations of common dolphins in the UK (1990–2016) revealed signs of blunt trauma attributable to vessel strike, and there were a further 19 cases in which it was not possible to determine the cause of the physical trauma (other potential candidates include bottlenose dolphin attack and physical damage in the stranding process) (Deaville, 2012, 2013, 2014, 2015, 2016, in press; Deaville & Jepson, 2011a, 2011b).

The areas with the highest shipping densities are in the southern North Sea, eastern English Channel (particularly the Strait of Dover), and across the Bay of Biscay (Evans et al., 2011). Common dolphins are rare in all but the last of these areas, so one might expect strike risk to be highest in that region. However, common dolphins are also fast swimmers and often attracted to vessels, and therefore presumably both able and accustomed to taking avoidance action where necessary, which would suggest that mortality from this cause is probably quite low (Evans et al., 2011).

6 | LEGISLATIVE INSTRUMENTS TO AID CONSERVATION

Within the NE Atlantic, the conservation of common dolphin is covered by a wide range of European and international legislation, much of which has only been in force since the 1990s. Three keys pieces of European legislation are discussed in the following: the EU Habitats Directive, the bycatch regulation, and the MSFD.

Compliance with legislative requirements has varied by country, depending on the pressures imposed both internally and internationally, through bodies such as the European Commission, as well as national administrations, policymakers, stakeholders, and lobbyists. It has taken a number of years for environmental legislation to mature to an extent that any tangible protection is provided, and issues remain. For example, because of reporting requirements for European legislation such as the Habitats Directive, member states have focused at the national level, which is inappropriate for common dolphins and other mobile marine species, which range across national boundaries and beyond EU waters. The need for greater collaborative effort between countries and for a transboundary approach for conservation management of the species is clear. In this context, regional agreements such as OSPAR, ASCOBANS, and the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) potentially have an important role to play. European environmental legislation, in contrast to legislation in the USA (e.g. the Marine Mammal Protection Act [MMPA]), often has little to say about specific conservation objectives or the mechanisms by which the goals will be achieved (Lonergan, 2011; McDonald, Lewison, & Read, 2016; Santos & Pierce, 2015). This makes effective and robust implementation extremely difficult. There is also a tendency to set baselines to refer to the time when the legislation was enacted, often resulting in unambitious conservation targets that suffer from the 'shifting baseline' syndrome (Pauly, 1995).

6.1 | EU Habitats Directive

The Habitats Directive (European Directive on the Conservation of Natural Habitats and Wild Fauna and Flora, 92/43/EEC) is one of the more strongly enforced pieces of European environmental legislation, such that failures by member states to implement its requirements carry a financial penalty. The overarching aim of the Habitats Directive is to achieve favourable conservation status for the species and habitats listed, which includes the common dolphin (listed as a species in need of strict protection, Annex IV).

Conservation status is defined as 'the sum of the influences acting on the species that may affect the long-term distribution and abundance of its populations', and it can be considered favourable if 'population dynamics data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitats; the natural range of the species is neither being reduced nor is likely to be reduced in the foreseeable future; and there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis'. Thus, in principle, the assessment covers parameters such as abundance, population dynamics, range, habitat status, pressures and threats, and future prospects.

Species are considered to be at favourable status if their abundance is at or above the favourable reference population (FRP) value. It is up to individual member states to set the FRP for their waters and, for most member states and for most species this has tended to be set at the population size within a member state's territory in 1992, when the legislation was enacted (McConville & Tucker, 2015). The status is considered unfavourable if abundance has fallen to 25% or more below the FRP value (European Topic Centre on Biological Diversity, 2014). The European Commission is currently reviewing FRPs to establish more appropriate criteria, since there are many cases where, by 1992, species populations and habitats had already become significantly reduced (Bijlsma et al., 2018). This is particularly relevant for common dolphins in the Mediterranean Sea and Black Sea, which historically have experienced major declines in range and/or numbers (Bearzi et al., 2003; Notarbartolo di Sciara & Birkun, 2010).

Though member states are required to present support for their overall conclusions based upon scientific evidence, those assessments are still often founded on value and expert judgments (Epstein, López-Bao, & Chapron, 2015). In the case of the common dolphin, there are two major challenges to address in determining favourable conservation status (FCS). The first is that the species has a range well beyond the collective waters of EU member states, and the second is that there are only two recent abundance estimates covering part of this range, making it impossible to determine population trends. These challenges are exemplified by the variable manner in which conservation status has been assessed by member states in the two rounds of assessment that have taken place since 1992 (Table 2). In 2007, the overall assessment was 'unknown' for common dolphin in the Marine Atlantic region, which was updated to 'unfavourable-inadequate' (U1) in 2013 (http://bd.eionet.europa.eu). The unfavourable-inadequate condition has been assessed largely on

TABLE 2 EU member states conservation status assessments for the common dolphin, undertaken for reporting under Article 17 of the Habitats Directive in 2007 and 2013. Overall conclusions for the European Marine Atlantic are highlighted in bold.

Country	2007	2013
UK	Unknown	Favourable
Ireland	Favourable	Favourable
France	Unknown	Unfavourable-bad
Spain	Unknown	Unfavourable-bad
Portugal	Favourable	Unfavourable-inadequate
Marine Atlantic	**'Unknown'**	**'Unfavourable-inadequate'**

the basis of the known human pressure of fishery bycatch, but the evidence base for the population impact of bycatch is limited because neither population bycatch rates nor population trends can be robustly determined. For any particular member state, it is nigh on impossible to establish whether the observed trend in local abundance of common dolphin represents a real change in abundance or a shift in distribution. This issue was raised by ICES in its advice to the European Commission after the first reporting round for Article 17 of the Habitats Directive in 2007 (ICES Advice, 2009b). The abundance estimates also have wide confidence limits, which makes statistical detection of change problematic.

Article 12 of the Habitats Directive concerns conservation measures to ensure protection of species listed in Annex IV of the directive (including all cetaceans), such as the outlawing of deliberate killing, as well as a requirement to ensure that incidental killing and capture (i.e. bycatch) does not have a negative impact on conservation status. In relation to common dolphins, the most (and indeed, arguably, only) relevant provision for member states is this requirement to monitor the incidental capture and killing of these species and to take (unspecified) further conservation measures 'as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned'. This aspect of the legislation has, however, rarely been challenged or enforced. Though member states were required to report on implementation of Article 12 for the first time in the second reporting round (2013), this requirement was removed for the forthcoming 2019 round of reporting.

6.2 | Bycatch regulation

EU Council Regulation (EC) No. 812/2004 (the 'bycatch' regulation) encompasses requirements for bycatch monitoring schemes with independent on-board observers to be set up for vessels ≥15 m in length, and the implementation of pilot studies for vessels less than this size. The regulation further stipulates the application of measures for bycatch mitigation in the form of mandatory use of acoustic deterrent devices in those areas and fisheries that are either known or foreseen to have high levels of bycatch, although this is only applicable to vessels ≥12 metres in length deploying gill nets and drift nets.

The regulation stipulates bycatch monitoring objectives for member states, whereby estimated bycatch rate (numbers of animals per unit fishing effort) for a given fleet should have a CV of ≤0.3. However, this is almost impossible to achieve if bycatch rates are low, and for this reason the UK, in its pilot studies and for fisheries of concern, has tried to adhere to the 5% and 10% thresholds for the proportion of fishing activity monitored. Several member states have not met their reporting requirements, and pilot studies overall have been poorly implemented (ICES WGBYC, 2011, 2016). Member states have not applied sufficient monitoring effort on an annual basis to yield robust bycatch estimates and, as noted earlier, fishing effort as currently measured (normally based on days at sea) has not adequately described the risk of bycatch. The legislation is specific to larger vessels, and there is no requirement for on-board observers for vessels <15 m in length or for vessels deploying driftnets operating in coastal areas, including recreational fisheries, which has raised concerns with respect to small cetacean bycatch (ASCOBANS, 2015d). In addition, the only mobile fishing gears covered by the legislation are trawls, and then only certain specific area–gear combinations. Other gears, such as purse seines, are not covered.

Since its introduction, mitigation measures under Regulation 812/2004 have achieved mixed success (ASCOBANS, 2015d; ICES WGBYC, 2011, 2015, 2016). Implementation has focused, understandably, on addressing harbour porpoise bycatch, which had been estimated to be at unsustainable levels during the 1990s. The measures have not necessarily targeted the highest risk fisheries for common dolphins, which increasingly have included vessels of smaller size than 12 m. In Europe for the year 2017, vessels <12 m in length comprise 85% (70,709 of 83,117 vessels) of registered fishing vessels (https://ec.europa.eu/fisheries/2-fishing-fleet_en). Thus, controversy has arisen over the mandatory employment of certain measures for some fisheries/fishers and not others, especially as bycatch is not a function of vessel length (ICES WGBYC, 2012). The deployment of pingers has also not been without its problems, including operational failure, low durability, high cost, practical issues of deployment, health and safety issues, and difficulties to ensure compliance. Some commercially available pingers have been found not to be very successful at deterring common dolphins in various behavioural states from the vicinity (Berrow et al., 2008). However, the development of more powerful units (DDD-03) that can be deployed with a much wider spacing along the net (4 km apart) can be effective during fishing operations, and thus reduce issues related to their deployment (Kingston & Northridge, 2011; Northridge, Kingston, & Thomas, 2017).

It should be noted that use of pingers in Regulation 812/2004 relates only to bottom-set gillnets and entangling nets, and no mitigation measures are specified for other types of fishing gear. The text of the regulation does, however, refer to the requirement under Article 12 of the Habitats Directive for member states to implement conservation measures to ensure that incidental capture does not have a significant impact on the species concerned. The monitoring of bottom-set nets in the Celtic Shelf and English Channel (ICES subarea VIId–j) is not required as pinger deployment is mandated by the regulation in this region. This has prevented evaluation of not only bycatch rates in these fisheries but also the effectiveness of pingers as a mitigation measure for some Member States (Murphy et al., 2013). Notably though, the UK has continued monitoring in this area with sufficient coverage to estimate common dolphin bycatch rates for relevant sectors of the fleet. In contrast, in the Mediterranean Sea, Regulation 812/2004 only applies to monitoring pelagic trawlers (single and pair) in the western Mediterranean, east of line 5°36′W, and there are no requirements to implement mitigation measures in the region.

EU Regulation 812/2004 is due to be repealed, with bycatch monitoring becoming integrated into the more generalized fishery DCF and for mitigation measures to be integrated within the Technical Measures Framework of the Common Fisheries Policy. The reformed Common Fisheries Policy (Regulation EU No. 1380/2013) aims to take a precautionary approach to fisheries management, with a devolved and regionalized decision-making approach to implementation, targeting monitoring, and mitigation in those areas and fisheries that are considered high risk (European Parliament, 2016). Although a regional approach to high-risk fisheries is to be welcomed, with the DCF offering the possibility to monitor cetacean bycatch in a much wider range of fisheries, there have been concerns that monitoring cetacean bycatch may not target the right fisheries/areas and incidences of bycatch may be missed if there are no dedicated observers monitoring cetacean bycatch (ASCOBANS, 2015a, 2015c, 2015d). It is also unclear whether additional resources will be made available to cover the additional monitoring required.

ICES continues to advise that any move to integrate monitoring of the bycatch of protected species in all EU waters within the DCF will require very careful consideration of sampling regimes and, as such, monitoring will require significant adjustments from that used for commercial fish bycatch (ICES Advice, 2018). For example, the on-board fish sampling duties of fishery observers are very likely to compromise their ability to record cetacean data, and they may lack training in cetacean identification. As observer effort would be spread across all fisheries under each country's DCF programme, fisheries with medium-to-high cetacean bycatch rates may receive less attention than would be desirable. Additionally, further concerns have been raised that member states would not submit a comprehensive report on monitoring and mitigation of cetacean bycatch to the European Commission on an annual basis, as currently required under Regulation 812/2004 (ASCOBANS, 2015d). Some member states, such as the UK and Ireland, will employ an augmented sampling scheme, with additional sampling effort allocated to those fisheries that may pose a risk of cetacean bycatch (Marine Institute, 2016; Northridge et al., 2017). However, for the most part, DCF funding is arguably fully utilized to meet requirements for monitoring of commercial fish stocks. Thus, new requirements that are perceived as not specifically linked to fish stock assessment and fishery management advice are likely to be assigned a low priority. Given that bycatch is considered the most significant anthropogenic impact affecting common dolphins, this is of great concern.

6.3 | Marine Strategy Framework Directive

The EU MSFD (2010/477/EU) establishes a 'framework within which Member States shall take the necessary measures to achieve or maintain good environmental status (GES) in the marine environment by the year 2020 at the latest'. By July 2012, a series of environmental targets and associated indicators were to be established, with monitoring programmes for assessments due to be in place by July 2014. A programme of measures designed to achieve GES was to be established by member states by 2015, with implementation of the programme by 2016. Although promoted as a key instrument for marine conservation in Europe, the MSFD has been criticized due to poor implementation and legal vagueness, including its definition of GES (e.g. Santos & Pierce, 2015). There is a risk that conservation targets will generally ultimately be set to maintain the status quo (in the absence of historical abundance data) and that the MSFD will only make use of existing monitoring. How indicators will be integrated across species, functional groups, countries, and descriptors to provide an overall assessment of GES for MSFD subregions has yet to be decided, though in 2016 ICES did advise the EU on a 'species approach' framework for aggregating mammal indicators to species group level (ICES Advice, 2016b). Consideration has been given to a range of integration methods such as one-out–all-out, averages, weighted averages, proportional and probabilistic methods (ICES WKD1Agg, 2016; ICES WKDIVAGG, 2018).

A key aspect of this legislation is the requirement for member states to coordinate work (marine strategies) at the regional seas level rather than focus on national waters. However, it is up to member states to decide whether to report at the regional seas scale using agreed 'common' indicators or to report at the national waters scale. At a national level, member states have fallen behind schedule in their development of marine strategies, including the development of targets and associated mammal indicators (ASCOBANS, 2014, 2015b), a process that is still ongoing (European Commission, 2018). For the NE Atlantic, regional work is being coordinated by OSPAR, and an intermediate assessment (IA) of GES was published in 2017 (OSPAR Commission, 2017). Through OSPAR ICG-COBAM, 'common' mammal state indicators have been developed for Descriptors 1 (biodiversity is maintained) and 4 (elements of food webs ensure long-term abundance and reproduction) (OSPAR Commission, 2017). The common indicators for marine mammals are largely based on what is feasible under current monitoring, i.e. monitoring trends in distribution and abundance, already in place to meet requirements of other European legislation, such as the Habitats Directive. Under Descriptor 1, the common dolphin is one of the species covered by the common OSPAR indicator 'abundance and distribution of cetaceans' (OSPAR Commission, 2017). In principle, the indicator and associated target should refer to the whole population (ICES WGMME, 2014). This extends well beyond MSFD jurisdiction for the common dolphin in the North Atlantic; as a result, the indicator only covers part of the population's distributional range. Furthermore, as there are only two abundance estimates available for common dolphin in the NE Atlantic, there was insufficient information to assess changes in distribution and abundance over time. The IA defines threshold values for declining, increasing, and stable trends in cetaceans: declining refers to a significantly decreasing trend of ≥5% over 10 years ($P < 0.05$); increasing refers to a significantly increasing trend of ≥5% over 10 years ($P < 0.05$); and stable refers to population changes of <5% over 10 years (OSPAR Commission, 2017). Notably, however, power analysis indicates that, even with annual surveys (decadal surveys currently undertaken) for common dolphins, a minimum total decline of 8.3% is detectable over a 10-year timeframe; that is, for common dolphin it is not possible to assess against the current thresholds (K. MacLeod, personal communication, May 2018). Such trends can be detected over much longer timeframes of data collection: Assuming CV = 0.26, five decadal surveys (i.e. 50 years for data collection) are required before trends in the population can be determined with any degree of reliability using the currently employed monitoring strategy.

As apex predators, cetaceans have been reported as 'keystone species', 'sentinel species', 'umbrella species', and 'flagship species'; overall, they are therefore considered to be good indicator species to measure progress towards the achievement of GES. However, there is a lack of common pressure-related indicators for cetaceans within the OSPAR region. Time series of pressure indicators are needed to help interpret changes in population status, and to successfully implement a programme of measures to achieve GES. More recently, Commission Decision (EU) 2017/848, laying down criteria and methodological standards for GES of marine waters and specifications and standardized methods for monitoring and assessment, and repealing Decision 2010/477/EU, was adopted in May 2017. This stipulated that, for marine mammal species, state (abundance, distribution, habitat, and population demographic characteristics) indicators should be developed, as well as pressure indicators (bycatch, contaminants, and marine litter) for those species that at are at risk (ICES WKDIVAGG, 2018). It also proposed using favourable reference population values for those species covered by the Habitats Directive but failed to recognize that these are set for national waters and not regional seas. For many cetacean species, including the common dolphin, it is important that countries collaborate to ensure a coordinated approach, something supported by several intergovernmental instruments and organizations, such as OSPAR, ASCOBANS, and ICES in relation to reducing anthropogenic impacts on cetaceans. Such instruments will become especially important in the future if the UK leaves the European Community.

7 | MONITORING

7.1 | Surveys to determine distribution and abundance

Wide-ranging pelagic cetaceans like the common dolphin present real problems for monitoring. Aside from the issue of spatial coverage, such surveys are very costly; therefore, in practice, they are conducted at decadal intervals (or less frequently) and serve only as snapshots, so that there is little information on status and distribution for other months and other years. Thus, they can provide misleading evidence on trends, and conservation actions could then be delayed until years after a problem arises. Smaller-scale surveys at greater frequencies have been proposed as a solution, but shifts in distribution can have a greater influence on their results.

To date, no surveys have covered the entire range of the common dolphin in the North Atlantic. The best coverage was achieved by the NASS and T-NASS surveys in the northern North Atlantic (Lockyer & Pike, 2009), involving collaboration between several countries on both sides of the Atlantic Ocean. Extending these surveys to the whole North Atlantic would be extremely costly and is unlikely. Furthermore, the relatively low density of small cetaceans, their overdispersed nature, and variable detection rates due to varying environmental conditions and varying dolphin behaviour would, at best, result in abundance estimates with very wide confidence intervals and, consequently, low statistical power to detect trends (as highlighted earlier). Such issues impact upon our ability to robustly assess FCS or GES.

Several research groups have been conducting aerial or ship-based-surveys at more frequent intervals over smaller spatial scales within European waters. Some of these, which used standardized methodologies, were combined within a Joint Cetacean Protocol and analysed to establish whether broader trends in distribution and abundance could be determined (Paxton, Scott-Hayward, Mackenzie, Rexstad, & Thomas, 2016). However, this approach does not overcome the lack of survey effort in waters far offshore. Additionally, a recent study assessing these data from 38 disparate surveys from throughout north-western European waters over a 17-year period reported that a reduction of over 50% in common dolphin population size would have to occur between reporting periods (i.e. over a 4 to 10-year interval) before the decline could be detected statistically with a power of 80% (Paxton et al., 2016).

There has also been extensive discussion about appropriate abundance indicators. In particular, the maximum amount and rate of decline that should be permissible for cetaceans with different reproductive rates, the time period over which declines should be measured, and the approach to identifying appropriate baselines, all remain to be fully resolved (e.g. ICES Advice, 2014, 2016a). In the Mediterranean and Black Sea, any new or recent abundance estimates for common dolphin would reflect the degraded state of these seas relative to, say, the 19th century or even the 1960s and would be unsuitable as a baseline. Though this may also be the case in the NE Atlantic, evidence for the Mediterranean is more compelling (e.g. Bearzi et al., 2003, 2008). Coupled with the limitations of large; and small-scale abundance surveys, this suggests that, although large-scale abundance surveys represent a valuable monitoring tool, an alternative approach is potentially needed. This needs to be one that does not depend on decades of data collection in order to adequately detect trends in the population and, therefore, potentially delay conservation action until it is too late.

7.2 | Strandings monitoring programmes

Strandings monitoring potentially provides three important contributions to monitoring: (a) a sentinel role to identify emerging threats and help quantify the impact of existing threats; (b) a source of life-history data to estimate population dynamics parameters; and (c) inferences about relative abundance trends and changes in distribution. In relation to bycatch, strandings data have mainly been viewed as a means to provide a minimum estimate of bycatch mortality; that is, by simply summing up the number of known bycatch mortalities. However, strandings data could in principle be used to provide estimates of population mortality rate due to bycatch, by estimating annual population mortality rates from the age structure of strandings (using life tables) and combining this with the estimated proportion of stranded animals killed by bycatch in order to derive an annual mortality rate due to bycatch (e.g. Read, 2016). However, both components of this calculation are potentially biased.

The derivation of reliable estimates of population parameters such as reproductive and mortality rates from strandings requires information on factors affecting the representativeness of strandings, not least the role of marine currents in determining the likelihood of a dead animal reaching the coast and its location relative to where it died, but also the likelihood that it is found and subsequently necropsied—which can depend on factors such as weather conditions, remoteness of the site, and the amount of funding available to retrieve carcasses and carry out necropsies. Recent modelling studies have attempted to address some issues, such as carcass drift and buoyancy (e.g. Mannocci et al., 2012; Peltier et al., 2012, 2014, 2016; Saavedra et al., 2017) and the underrepresentation of the youngest animals amongst strandings (Saavedra et al., 2017). Recently, the IWC Human-Induced Mortality subcommittee reviewed cetacean drift modelling work that has been undertaken to date, and the subcommittee 'recommended further work to address uncertainties in the analysis arising from parameters that either don't appear to have been quantified directly in the analysis to date, or that have been assessed directly but with either very limited sample size or samples obtained in potentially unrepresentative contexts' (IWC, 2018). The subcommittee highlighted uncertainties in the estimation of immersion level, the probability of being buoyant, the probability of stranding, the time of death, and potential sensitivity of this approach to application beyond the Bay of Biscay.

In relation to life-history parameters, a good estimate of the pregnancy and birth rates requires a sufficiently large sample size to eliminate bias due to inclusion of animals that had been in poor health prior to their death. In this context, samples from animals dying from trauma are more suitable, as they will likely provide a more representative health status profile. For common dolphins in the NE Atlantic, most animals that strand along European coastlines have died as a result of incidental capture in fishing gear and may thus provide a representative sample of the population for estimation of demographic characteristics (Murphy, Winship, et al., 2009). However, as noted earlier, bycatch is sometimes associated with particular age classes, e.g. juveniles/sub-adults (Murphy et al., 2007; Murphy & Rogan, 2006). Assessment of trends in demographic characteristics such as the population pregnancy rate, age at sexual maturity, and nutritional status should be continued, accounting for biases as far as possible, with consideration of adequate sample sizes across all age–sex classes as well as inclusion of additional data (e.g. trends in abundance, bycatch rates, pollutant levels) to aid interpretation (Murphy et al., 2013; Murphy, Winship, et al., 2009). For inclusion of a population demographics indicator within MSFD Descriptor 1, owing to a lack of baseline data (i.e. lack of knowledge of population parameters prior to anthropogenic impacts), Murphy et al. (2013) proposed a target of 'no statistically significant deviation from long-term variation'. Such an approach will, however, require a collated assessment across member states in order to obtain sufficient sample sizes and statistical power for the analyses.

7.3 | Pollutant monitoring and management

Pollution has been identified as a threat to common dolphins throughout much of their known range in Europe (ICES WGMME, 2015). A European-based risk list of priority pollutants for monitoring specifically in cetaceans should be devised, and research should continue into monitoring effects from exposure to pollutants on health and reproductive status in common dolphins. Screening of contaminants of concern on the updated EU surface water watchlist for emerging pollutants (European Commission, 2018), particularly those pollutants identified as endocrine-disrupting chemicals, needs to be undertaken at a European level. Furthermore, hazardous substances such as legacy pollutants should continue to be monitored in available stranded and bycaught specimens. For locations where suitable dead specimens are not accessible, particularly offshore waters, biopsy sampling could be employed. Within the MSFD Descriptor 8 (concentrations of contaminants are at levels not giving rise to pollutant effects), a common mammal blubber PCB toxicity indicator with associated thresholds has been proposed and is being discussed by OSPAR.

Kannan et al. (2000) proposed a threshold for the onset of physiological (immunological and reproductive) endpoints in marine mammals of 17 mg kg^{-1} PCB lipid weight (lw) for Aroclor 1254 (or 9 mg kg^{-1} for ΣPCBs as determined by Jepson et al. (2016)), based on observed effects in experimental studies on seals, otters, and mink. Helle, Olsson, and Jensen (1976) determined one of the highest PCB toxicity thresholds for marine mammals, 77 mg kg^{-1} for Clophen 50 (or 41 mg kg^{-1} lipid weight for ΣPCB by Jepson et al. (2016)), which was associated with profound reproductive impairment in Baltic ringed seals (*Pusa hispida*). Mean concentrations of ΣPCBs for male and female common dolphins in the NE Atlantic are shown in Figure 3. Seventy-six per cent of sexually immature individuals (males and females) had ΣPCB levels above the 9 mg kg^{-1} threshold, and 17% had levels greater than the 41 mg kg^{-1} threshold. Higher mean levels are seen in sexually mature males (mean ΣPCB 45.8 mg kg^{-1}; range 7.0–119.8 mg kg^{-1} lipid) compared with sexually mature females (Murphy et al., 2018). In sexually mature females, who are capable of offloading their total organochlorine load (Borrell & Aguilar, 2005;

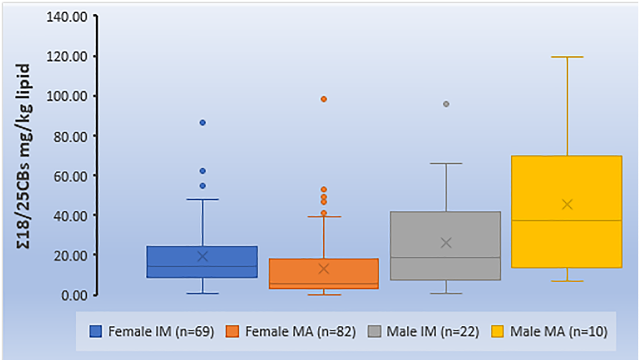

FIGURE 3 Box plots of male and female common dolphin reproductive status (IM: sexually immature; MA: sexually mature) and ΣPCB from stranded and bycaught common dolphins (1990–2013, n = 183). The dark horizontal line indicates the median, × markers indicate the mean, and outliers are highlighted by circles. Figure taken from Murphy et al. (2018).

Mongillo et al., 2016), 41% had blubber ΣPCB levels greater than the 9 mg kg^{-1} threshold and 7% had levels greater than 41 mg kg^{-1} (Murphy et al., 2018).

Current global rates of PCB elimination or mitigation will not achieve the 2025 and 2028 targets of the Stockholm Convention, and thus, in the short-term, the Conference of Parties needs to conclude negotiations on a compliance mechanism for the convention (Stuart-Smith & Jepson, 2017). Management of pollution is a major societal challenge. Where additional management might specifically benefit certain cetacean species is by reducing the input of plastics into the marine environment—and indeed by removing plastics from the ocean, especially if it is true that there will be more plastics than fish (by weight) in the ocean by 2050 (World Economic Forum, Ellen MacArthur Foundation, & McKinsey & Company, 2016).

7.4 | Bycatch monitoring and management

Fishery bycatch mortality of cetaceans has generally been quantified using on-board observers (e.g. Fernández-Contreras et al., 2010; ICES WGBYC, 2015, 2016; Morizur, Gaudou, & Demaneche, 2014; Tregenza, Berrow, Hammond, & Leaper, 1997; Tregenza & Collet, 1998). However, monitoring of cetacean bycatch in EU waters has never been sufficient to derive robust estimates across all relevant fisheries. A summary of results from recent monitoring makes clear that we are still some way from a comprehensive and reliable bycatch monitoring programme (ICES Advice, 2016a, 2018; ICES WGBYC, 2016). As already discussed, Regulation 812/2004 covers only certain gears, fleets, and fishing areas; not all fisheries that may cause bycatch are sampled and not all the 'required' sampling actually takes place. Further, member states have not been challenged in their level of implementation of Article 12 of the Habitats Directive. ICES WGBYC (2016) identified key issues as inconsistent submission and content of annual reports for Regulation 812/2004 on cetacean bycatch by some member states and the limited availability of accurate and appropriate data on total fishing effort. The emphasis given by Regulation 812/2004 to monitoring larger vessels imposes a further constraint, particularly when high-risk fishing fleets have increasingly included smaller vessels. In addition, small vessels often lack space to carry a dedicated observer. In the case of larger vessels, since carrying observers is usually not compulsory (in contrast to the situation in the USA under the MMPA), vessels sampled may be essentially self-selecting. A major difficulty is that the occurrence of bycatch is largely unpredictable, and the factors causing high bycatch are many and varied (Northridge, Coram, Kingston, & Crawford, 2016). Better understanding of these factors could enable better targeting and stratification of observer effort.

Even if the aforementioned issues are addressed, the cetacean bycatch rate is usually very low relative to the number of fishing trips or fishing events, and hence a very large number of trips or events must be sampled to obtain precise estimates (i.e. with a low CV), which is logistically infeasible (Northridge & Thomas, 2003). For example, López et al. (2003) noted that the (mainly small-scale fishing) fleets sampled in NW Spain undertook as many as 1 million fishing trips a year, and they estimated that between 500 and 2,000 observer trips per year would be needed to obtain reasonably precise estimates of cetacean bycatch. There is, therefore, a need to consider alternative approaches to bycatch monitoring to be used in conjunction with observer schemes.

In Norway, the Institute of Marine Research contracted two small (<15 m) fishing vessels in each of nine coastal statistical areas to provide detailed information on their fishing effort and their catches of all target and non-target species, including marine mammals and birds (Bjørge, Skern-Mauritzen, & Rossman, 2013). These data were used to calculate bycatch rates, which were then extrapolated to the entire fleet. Another approach increasingly being used is to deploy remote electronic monitoring (i.e. closed-circuit television cameras). Once fishers have accepted remote electronic monitoring use (e.g. after addressing privacy issues and aided by incentives), some such systems have yielded reliable estimates of bycatch, particularly when they are set up to record animals that fall out of the net as it is being brought back on board (Course, 2015; Kindt-Larsen, Dalskov, Stage, & Larsen, 2012; Marçalo et al., 2015). A number of attempts at spatial and temporal risk assessment have been made, relating cetacean distribution to the distribution of fishing effort (e.g. Brown, Reid, & Rogan, 2013, 2014; Evans & Baines, 2013), illustrating an approach that could inform the design of bycatch monitoring programmes as well as optimize mitigation measures.

Under the US MMPA, a take reduction plan must be put in place for those strategic stocks (i.e. 'threatened' or 'endangered' under the Endangered Species Act, or 'depleted' under the MMPA) that interact with a Category I or II fishery. Fisheries are classified as Category I if marine mammals are frequently taken (>50% of a stock's potential biological removal [PBR]), and Category II if marine mammals are occasionally taken (1–50% of stock's PBR) (Marine Mammal Commission, n.d.). Within the reduction plans, take reduction teams, composed of a wide range of stakeholders including state agencies, fisheries management organizations and researchers, are responsible for developing recommendations for mitigation measures and monitoring requirements for implementation of the plan and measuring goals. Ultimately the goals of the reduction plan are: (1) to reduce serious injury and mortality to less than a marine mammal stock's PBR within 6 months of the plan's implementation date, and (2) to reduce serious injury and mortality to insignificant levels, approaching a zero rate within 5 years. That insignificance threshold is defined by the National Marine Fisheries Service as less than 10% of PBR, or the zero mortality rate goal (Marine Mammal Commission, n.d.). Though mitigation measures are outlined (e.g. required use of alternative commercial fishing gear or techniques, time/area closures, acoustic deterrent devices, and bycatch limits), the approach taken is essentially 'management by results', backed up by the threat of removal of authorization to fish. If these take-reduction measures were employed in the EU, they would need to be supported by adequate monitoring both to measure bycatch rates and to evaluate the efficacy of mitigation, allowing measures to be adjusted accordingly. This, in turn, would require the cooperation of the industry and adequate enforcement and penalties, including compulsory observer monitoring and/or use of on-board observation mechanisms and regular inspection. A review of reduction plans in the USA reported an uneven record of meeting statutory requirements, and ultimately the plans that were successful were those with high rates of compliances among fishers in employing mitigation measures as well as straightforward regulations with measurable targets (McDonald et al., 2016).

At the time of writing, the introduction of the landings obligation potentially offers an opportunity to address cetacean bycatch, since it has led to a new focus on ways to monitor and enforce regulations that cover the at-sea behaviour of fishermen. There are obviously cost implications (e.g. of introducing and maintaining cameras and examining the information collected), and there is a need to ensure that good practice (e.g. cooperation with bycatch reduction) is incentivized rather than penalized (e.g. by promoting 'dolphin-safe' labelling for European caught fish).

7.5 | Establishing a management framework for cetacean conservation

In the NE Atlantic, several bodies are advancing the debate on conservation management for cetaceans, including ASCOBANS, ICES, and the North Atlantic Marine Mammal Commission, as well as global organizations such as the IWC. ICES WGMME (2010) recommended to 'move away from implicit and automated conservation targets and towards the explicit definition and justification of target population sizes and management objectives'. As of writing, this has not been acted upon and to date there are no agreed European-wide conservation objectives for cetaceans. Such objectives provide the essential underpinning for management frameworks. In the absence of legislative conservation objectives, many member states have adopted those of ASCOBANS 'to restore and/or maintain stocks/populations to 80% or more of the carrying capacity' (Resolution 3.3 of 2000 on Incidental Take of Small Cetaceans). ASCOBANS also proposed an 'unacceptable interactions' limit of 1.7% of the best available estimate of abundance for total anthropogenic removals (i.e. all anthropogenic removals and not just mortality from bycatch) in the case of harbour porpoise and a 'precautionary objective to reduce bycatch to less than 1% of the best available abundance estimate and the general aim to minimize bycatch (i.e. to ultimately reduce to zero)'. It should be noted that, even for porpoises, the 1.7% limit is somewhat arbitrary. It was derived using a simple deterministic population dynamics model, assumed an R_{MAX} of 4% in a single stock with more-or-less independent dynamics, and did not incorporate any biological information on the species, nor uncertainties in population estimates (ICES WGMME, 2008, 2012). Following the introduction of Regulation 812/2004, the EU Scientific, Technical and Economic Committee for Fisheries tacitly adopted the 1.7% of best population estimate as the threshold against which bycatch would be assessed.

Based on member state FCS reporting for the Habitats Directive, there is wide agreement that fishery bycatch is a serious threat to common dolphins. However, although 'harbour porpoise bycatch' is being developed as a common indicator for the MSFD, there has been no such development for common dolphins. Options for thresholds and management frameworks are being discussed in a variety of fora (e.g. ASCOBANS, 2015c; ICES WGMME, 2016); and with the 2017 European Commission decision indicating the need for pressure–state indicators in relation to bycatch, now is the time to finalize such discussions and implement the conclusions.

The European Parliament (2013) stated that: in view of the requirement for Member States to take the necessary measures to establish a system of strict protection for cetaceans, in view of the shortcomings of Regulation (EC) No 812/2004 and its implementation (as identified by the Commission in its Communication on cetacean incidental catches in fisheries and by ICES in its related 2010 scientific advice), and in view of the lack of integration of Council Directive 92/43/EEC ('the Habitats Directive'), the Commission should, before the end of 2015, submit a legislative proposal for a coherent, overarching legislative framework for ensuring the effective protection of cetaceans from all threats. Considering the imminent repeal of the bycatch Regulation 812/2004, in 2015 the ASCOBANS parties recommended to the European Commission: (i) the creation of an overarching regulation for the protection of cetaceans that provides specific conservation objectives, while leaving decisions on bycatch monitoring and mitigation requirements and technical details on how to achieve these objectives under the Common Fisheries Policy; and (ii) implementation of a management framework defining the threshold of 'unacceptable interactions' or 'bycatch triggers' and 'bycatch limits', to help safeguard the favourable conservation status of European cetaceans in the long term, and move towards the ASCOBANS overall aim of reducing bycatch to zero (ASCOBANS, 2015a). ASCOBANS (2015a) stated that 'a management framework procedure producing robust triggers and limits should enable specified conservation objectives to be met by allowing the impact of anthropogenic removal within and across Member States to be more fully assessed and effectively managed'. This framework would define 'trigger' levels of anthropogenic removal (bycatch) which would signal a need for urgent management action, as well as defining anthropogenic removal (bycatch/environmental) limits (i.e. a 'critical' or 'unacceptable' point; ASCOBANS, 2015c). ASCOBANS parties also recommended a risk-based regional approach, accounting for regional differences in species composition, density and spatial distribution of cetaceans, and the different types of fisheries operating (ASCOBANS, 2015a).

For small cetaceans in European waters, two candidate bycatch management procedures are being assessed: the US PBR method and an adaptation of the IWC Catch Limit Algorithm (CLA) approach of the IWC's Revised Management Procedure (ASCOBANS, 2013; Winship et al., 2009). Both candidate procedures have pros and cons (see Table 3), which ultimately depend on the available data and uncertainties in those data. In its advice to the European Commission on this matter, ICES favoured a CLA-based approach (ICES Advice, 2009a). However, prior to selection of an appropriate management framework, a number of key policy decisions have to be made, including whether to set anthropogenic limits to achieve the ASCOBANS conservation objective of 80% or more of carrying capacity and, if so, (1) if it should be met on average or some other percentage of the time (e.g. >50%), (2) the specific timeframe over which this should be achieved (e.g. 100 years), and (3) at what proportion of carrying capacity triggers should be set (ASCOBANS, 2013). Work is ongoing in the UK to develop a management procedure, termed the Removals Limit Algorithm, which is a modified CLA approach (ASCOBANS, 2018).

Recognizing that fishery bycatch is likely to be the most serious current anthropogenic threat to common dolphins, appropriate bycatch mitigation measures should be introduced by all member states both in fisheries with known high bycatch levels and, on a precautionary basis, in those fisheries thought likely to pose a medium-to-high bycatch risk for common dolphins, accompanied by appropriate monitoring to establish the efficacy of the actions. Mitigation measures may include: (1) gear modifications and alternative gear types; (2) time-area fishing restrictions or closures; (3) implementation of bycatch 'triggers' and 'limits'; and (4) acoustic deterrents (ASCOBANS, 2015a). The first three of these essentially limit fishing effort or fishing practices for areas, fishing practices, and/or boats and fleets of concern. Incentive-based management, which 'rewards low impact operators while simultaneously driving poorly performing operators to adopt better practices or leave the industry', represents an additional option (Dolman, Baulch, Evans, Read, & Ritter, 2016). Such approaches have been successful. For example, in the eastern tropical Pacific tuna fishery, identification of vessels with high bycatches, education of skippers, implementing a bycatch monitoring programme, and developing modified fishing methods (notably the backdown procedure to release encircled dolphins) were all key to tackling the problem (National Research Council, 1992), as well as the implementation of legislation surrounding the purchasing of 'dolphinsafe' tuna in the USA (NOAA Fisheries, Southwest Fisheries Science Center, 2016). Employing 'dolphin-safe' labelling in medium

TABLE 3 Approaches to setting bycatch limits

Approach	Pros	Cons
Percentage of abundance	● Easy to assess—Compared with maximum net productivity rate if known (and should be less than the maximum net productivity rate)	● Harbour porpoise '1.7% of best population estimate' assumes a single stock with more or less independent dynamics ● Assumed a maximum annual rate of increase of 4% ● Did not incorporate any biological information on the species ● Does not incorporate uncertainty in estimates of population size or bycatch ● Does not include natural mortality
US potential biological removal (PBR) level	● Incorporates uncertainty in estimates of population size ● Incorporates a recovery factor (if unknown status, a recovery factor of 0.5 is used)	● Uses only a single current value of absolute population size N_{min}; though in a model-based approach N_{min} is based on estimates of abundance from all previous surveys and Bayesian methods (Moore & Barlow, 2014) ● Does not incorporate estimates of bycatch ● Does not include natural mortality
Catch Limit Algorithm approach*	● Incorporates estimates of population size and bycatch ● Incorporates uncertainty in estimates of population size and bycatch ● Estimates relative population level (depletion) and allows implementation of a 'protection level' below which limits to removals can be set to zero. This can shorten recovery time to target population levels ● More conservative than PBR ● Safe bycatch limits can be calculated for multiple management units for a species	● If a time series of data on population size and bycatch rates are unavailable, it performs similar to the PBR ● Does not include natural mortality

*Developed as part of SCANS-II project and based on the framework for the International Whaling Commision's revised management procedure (Winship et al., 2009).

to high-risk European fisheries would allow a social and market-based incentive management approach that could be used in combination with other financial and market-based instruments, all targeted at reducing bycatch in marine megafauna and charismatic species (Pascoe et al., 2010). There are many other incentivizing approaches, including 'payments for ecosystem services', outlined in detail in Lent and Squires (2017).

8 | RECOMMENDATIONS

Many actions are required for adequately conserving common dolphins and managing human activities in the NE Atlantic, and implementation will ultimately depend upon levels of funding available as well as the willingness of the numerous stakeholders involved to work together. Ten recommendations are proposed here to protect common dolphin in the long term; and, in many cases, similar recommendations are applicable to other small cetaceans within the region. The recommendations are presented in a logical order, but not necessarily in a chronological order.

Recommendation 1. Implementation of a species action plan for common dolphins and an associated steering committee: This would aim to ensure cooperation between all stakeholders, including national governments in the NE Atlantic, the European Commission, intergovernmental organizations such as regional fisheries bodies, and relevant bodies such as non-governmental organizations, universities, institutes, and appropriate industry representatives. Implementation of such a plan will encourage member states to harmonize their national efforts, including allocation of funding. Required actions include appointment of a steering committee that will implement, communicate, and evaluate the effectiveness of such a plan. The effectiveness of the species action plan should be evaluated at least every 5 years, which should include a full assessment of the status of the population/management unit—as exemplified by the US National Marine Fisheries Service and US Fisheries and Wildlife Service marine mammal stock assessment reports. An adaptive management approach should be employed and, where necessary, recommendations and actions in the species action plan be revised. In order to function effectively, such a body would need the legal remit and power to carry out these actions or require them to be carried out. At the time of writing, a species action plan for the common dolphin in the NE Atlantic is in the process of being intersessionally adopted by range states of ASCOBANS—though this does not include Ireland, Spain, and Portugal, who are not signatories of the agreement.

Recommendation 2. Assessment of management unit boundaries: This includes an assessment of the range boundary of the NE Atlantic population from transatlantic surveys and genetic analysis, and the possible existence of inshore/offshore ecological stocks. Actions required include skin and blubber biopsy sampling of offshore common dolphins (i.e. inhabiting waters beyond the continental shelf) for genetic analysis and markers focusing on evaluation of ecological stocks/management units. Biopsy sampling of common dolphins inhabiting shelf waters during the summertime will enable an assessment of possible movements of offshore animals into these waters, which has likely occurred in recent years. Whole-genomic analyses using single nucleotide polymorphisms should be used for finer grain determination of population structure in the region. This could also be complemented with other markers/tracers, such as cadmium in kidney tissues, stable isotopes in hard tissues, and, in male dolphins (who do not offload their lipophilic pollutant burden), POPs such as PCBs in blubber tissue (Evans & Teilmann, 2009; Murphy et al., 2013). For remote biopsying, novel ways for assessing ecological stocks need to be developed. Strategic sampling approaches need to be employed, which requires sampling different age–sex–maturity classes, as well as a statistical power analysis to determine appropriate sample sizes required to detect the existence of ecological stocks. Good spatial and temporal sampling coverage is important to better describe the genetic structure of the population in western European waters during both the summertime (breeding period) and wintertime (when increased bycatch has generally been reported).

Recommendation 3. Finalize a bycatch management framework: The framework procedure will clearly outline research and monitoring programmes required to obtain the scientific information necessary to inform management. As stipulated repeatedly by organizations such as ICES and ASCOBANS, there is a need for policymakers to define the conservation objectives for European cetaceans, as well as the timeframe over which it should be modelled to achieve the specified conservation objectives. Actions include involvement of all relevant stakeholders in the development of the management framework procedure, most notably the regional fisheries authorities, and engagement with ongoing development and implementation of the reformed Common Fisheries Policy for management and monitoring of anthropogenic triggers and limits.

Recommendation 4. Assessment of the bycatch level: Member states should adopt a coordinated approach to bycatch monitoring. As outlined by ASCOBANS (2015d), production of a standardized bycatch monitoring protocol with a clearly defined fishing effort metric should be used by member-state fishing vessels, irrespective of size (including vessels <10 m in length) and activity (including recreational fishing vessels). At the outset, low, medium, and high-risk fisheries should be identified, as well as fisheries where no data exist, and/or fisheries that may be a cause for concern. This will enable careful targeting of available resources for bycatch monitoring to those priority vessels where a potential risk exists. This monitoring is already required through Article 12 of the Habitats Directive. In the absence of mandatory observer coverage of medium to high-risk fisheries, incentives for fishers could be introduced for accepting dedicated observers and/or remote electronic monitoring. Bycatch monitoring programmes should be designed for optimum level of coverage to enable the collection of sufficient data for robust statistical analysis in a cost-effective manner. As DCF obligations may not achieve this objective, national independent marine mammal observer bycatch programmes should be implemented. Bycatch observation programmes should be frequently reviewed in order to ensure adequate data for enabling effective management decisions. Mechanisms should be developed to integrate other sources of bycatch data (e.g. strandings), at least to provide minimum estimates.

Recommendation 5. Mitigation of bycatch: Mitigation should be introduced on a precautionary basis in all fisheries where substantial bycatch of common dolphins is known or thought to occur; that is medium to high-risk fisheries. Decisions on the mitigation measures to be employed should involve all relevant stakeholders, both in the planning and implementation, as part of an integrated spatial planning management approach. Continued evaluation of the processes and factors that influence bycatch rates is required. All alerting devices (i.e. pingers) should be experimentally trialled, and fishers' selection based on those that significantly reduce bycatch with a high level of confidence. Other mitigation strategies, such as alternative fishing gear and/or practices, as well as time–area fishing restrictions or closures, should continue to be evaluated and their potential for use in combination (with pingers) assessed. Where appropriate mitigation strategies have been identified, they should be strictly enforced on all relevant vessels or incentives developed for those fishers employing their use.

Recommendation 6. Monitoring of abundance and distribution: Given that common dolphins in the North Atlantic range well beyond European waters, the scale at which the population can be effectively monitored poses real challenges. A combination of methods is desirable to achieve as full a picture as possible, including both visual (aerial and vessel based) and acoustic survey approaches. Wider-scale synoptic surveys along the lines of SCANS and North Atlantic Marine Mammal Commission NASS (and T-NASS) should take place at intervals of no more than 10 years. There is a need for a new mechanism to collate these data from the variety of regional surveys undertaken within the NE Atlantic in order to provide a more general picture of trends in abundance and distribution through space and time, utilizing modelling approaches that incorporate environmental variables. Abundance estimates can be both design based and model based, accounting, where possible, for responsive movement of common dolphins that can strongly influence the final estimates. A better understanding is needed of population sizes inhabiting waters far offshore well beyond the continental shelf to better establish whether seasonal (and long-term) movements occur offshore–onshore and/or latitudinally. There is also a need for more winter surveys, when the issue of bycatch is usually greatest. Strong cooperation should be encouraged between member states to integrate surveys and their findings. This work would then enable investigations into the relationships between distribution and trends and human activities such as fishing, as well as climate-related indicators (e.g. changes in prey availability), through risk assessment mapping.

Recommendation 7. Monitor health and nutritional status, reproductive parameters, pollutant burdens and causes of mortality: Indicators should be employed that focus on changes in demographic characteristics and population condition, including temporal trends in exposure to anthropogenic toxins. Population condition needs to be assessed in order to determine potential causes of long-term demographic change. It is important to understand the root-cause for any observed population decline if a programme of measures for achieving GES or improving conservation status of the species is to be successfully implemented. For assessments at the population level, this requires coordinating research among member states' stranding schemes, bycatch observer programmes, pollutant monitoring, and biopsy programmes.

A European risk-based list of priority pollutants for monitoring in (specifically) cetaceans should be devised. Screening and assessment of the occurrence and effects of priority hazardous substances are required, including emerging pollutants and legacy pollutants such as PCBs and their potential links to plastic ingestion. Research should continue into monitoring the effects of exposure to pollution on health and reproductive status in common dolphins.

Assessments of population mortality rates based on strandings data (accounting for biases in the latter using model-based approaches) could enable a more thorough assessment of the pressure–state–response framework for this key human pressure.

Recommendation 8. Investigate the effects of anthropogenic sound: Audiometric studies are needed to better describe the hearing sensitivity of the common dolphin. Although it is likely to fall within the frequency range of related species for which measurements exist, it would be helpful to verify this, and to establish whether masking of communication signals might be a problem. Further investigation of behavioural responses of common dolphins to anthropogenic sound with the potential to cause disturbance is required. Any significant effects of noise disturbance should be incorporated in models to determine population consequences of such disturbance.

Recommendation 9. Evaluate the functional role of common dolphins in the ecosystem: The collection of stomach and intestine contents of common dolphins should continue, along with tissue sampling for stable isotope and fatty acid analysis, in order to investigate further the diet of different age–sex classes of both stranded and bycaught common dolphins. Sampling should span the range of the common dolphins, including animals inhabiting both neritic and offshore environments. These data will allow monitoring of contemporary temporal changes in diet, as well as temporal trends in incidences of starvation in the population, possibly due to reduced prey availability/quality. In order to better understand the functional role of common dolphins within the marine ecosystem, data on abundance, prey preferences, and estimates of predation rates should be integrated within ecosystem models of predator–prey relationships.

Recommendation 10. Cumulative impacts of pressures: Studies of cumulative impacts of pressures are at an early stage, focusing largely upon attempts to integrate sublethal effects relating to disturbance (mainly through noise) on physiological and behavioural changes (e.g. King et al., 2015). They have not yet been applied to the common dolphin. Following an assessment of the main pressures affecting the species, attempts should be made to estimate exposure rates to key pressures, and the dose–response relationship of each. As a means to assess effects upon vital rates, health indicators should be developed that can be applied to free-swimming and stranded animals. Candidate pressures could include indirect effects of fishing and climate change resulting in prey depletion, and effects of anthropogenic pollutants on reproduction and development.

8.1 | Recommendations in the context of the Mediterranean Sea common dolphin

By contrast to the NE Atlantic, the Mediterranean Sea is a semi-enclosed basin. The positive implications are that, with more discrete population boundaries, it should be easier to monitor abundance and trends, and then to apply management measures to mitigate against potential threats. Besides a small amount of movement of common dolphins between the Mediterranean and Atlantic through the Strait of Gibraltar, the populations in the Mediterranean appear to be genetically distinct, with further differentiation between the western and eastern sub-basins (Natoli et al., 2008). The negative implications, however, are that common dolphins are less likely to evade human pressures, whether it be high pollutant levels, prey depletion, or bycatch—pressures that are outlined further in other papers in this Mediterranean Sea Common Dolphin Special Issue.

Common dolphins in the Mediterranean are thought to have experienced a major decline since the mid-20th century (Bearzi et al., 2003) and, as a result, have been assessed as Endangered on the International Union for Conservation of Nature's Red List. The causes of the decline are unclear, but in recent times may have included prey depletion from overfishing and incidental mortality in fishing gear (Bearzi et al., 2016).

There are both parallels and differences between the situation in the NE Atlantic and that in the Mediterranean Sea. All of the recommended actions to aid conservation of common dolphins in the NE Atlantic could apply also to the Mediterranean (and Black Sea). The need for international collaboration both in monitoring and conservation measures is all the more challenging given the varied cultural and political backgrounds of the countries bordering the region. Several are outside the EU, so that its environmental legislative directives do not apply, many face serious economic difficulties, and some are embroiled in political conflict. A further practical constraint is that a great variety of coastal zones subject to national jurisdiction apply beyond the territorial sea, with only a limited number of treaties so far concluded by Mediterranean coastal states (Scovazzi, 2016). Several boundaries are still to be agreed upon by the states concerned. On the other hand, ACCOBAMS is binding on 23 out of the 29 states that border the marine waters to which it applies. The states of the region that are not yet parties to ACCOBAMS are Bosnia and Herzegovina, Israel, Palestine, the Russian Federation, Turkey, and the UK (Gibraltar). The need remains for specific legally binding provisions directly addressing at least those threats such as fisheries conflicts (prey depletion and bycatch) considered to be of greatest concern for common dolphins.

9 | CONCLUSIONS

The last round of reporting for the Habitats Directive in 2013 reported the common dolphin as 'unfavourable-inadequate'. The next round of reporting is upon us, and based on the increased abundance of animals in the management unit area, possibly due to offshore–inshore and/or latitudinal movements, member states will more than likely report this species as overall 'favourable' in relation to increases in national waters. Increased abundance in the management unit area means more individuals are now exposed to anthropogenic activities, such as fisheries interactions (as seen in recent mass strandings of dead dolphins along the French Atlantic coast), chemical pollutants, and noise pollution, and more individuals may now experience nutritional stress due to depletion within the region of their preferred 'fatty' prey. The outcome of all of this may not become apparent until the 2026 or 2032 reporting periods (or later) for the Habitats Directive.

Despite the fact that our knowledge of the biology and ecology of common dolphins in the NE Atlantic has improved greatly in the last three decades, there are still many important gaps, the filling of which (applying a precautionary approach notwithstanding) could improve our ability to effectively apply conservation management to the species. This will only result from compliance monitoring of current European environmental legislation, and the creation of a new 'overarching legislative framework for ensuring the effective protective of cetaceans from all threats' as recommended by the European Parliament and ASCOBANS parties. Where EU environmental legislation for cetaceans has failed thus far is that it defines the goal but not the mechanism to arrive there, explicit conservation goals are not articulated, and is often focused on national rather than transboundary implementation. Providing precise definitions for the desired status of cetacean populations and identifying appropriate criteria for triggering management action, all at an appropriate biological scale, will enable us to meet the legislative goals set.

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