Preliminary assessment and bycatch limits for northeast Atlantic common dolphins

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ABSTRACT

Bycatch of common dolphins *Delphinus delphis* in the Northeast Atlantic is an international conservation issue. We assessed the impact of previous bycatch on this population and calculated preliminary bycatch limits that would be expected to achieve a specific conservation objective. The main result of the assessment was that the combination of data and model used was not informative about the main population parameters of interest: population growth rate, maximum population growth rate and carrying capacity. Given the shortcomings of the assessment, a preferable approach to calculating bycatch limits is a fully-tested procedure that can be expected to achieve conservation objectives in the face of the large uncertainties. We developed tunings of two such procedures (PBR and CLA) for common dolphins in the Northeast Atlantic. Preliminary bycatch limits ranged from 0.1-1.1% of the most recent point estimate of abundance depending on the procedure and the tuning to meet specific conservation objectives.

ATLANTIC OCEAN, COMMON DOLPHIN, CONSERVATION, INCIDENTAL CATCHES, MODELLING

INTRODUCTION

Common dolphins, *Delphinus delphis*, are incidentally caught (bycaught) in a range of fisheries operating in the Northeast Atlantic conducted by several countries (Tregenza *et al.*, 1997; Tregenza and Collet, 1998; Northridge, 2006; Northridge *et al.*, 2006; Northridge *et al.*, 2007; Rogan and Mackey, 2007). The objectives of this study were to assess the impact of previous bycatch on this common dolphin population and to calculate bycatch limits that would be expected to achieve conservation objectives in the future. This work was conducted as part of the Cetacean Offshore Distribution and Abundance in the European Atlantic (CODA) project. Further details of that project and the work presented here are documented in CODA (2009) and SC/61/FI27.

METHODS

Assessment

We developed an integrated population dynamics model for assessing the impact of previous bycatch on the state and dynamics of the common dolphin population in the Northeast Atlantic. The full specifications of the model are described in CODA (2009) and SC/61/FI27. In brief, the model was an age-structured model of the female component of the population that allowed for density-independent or density-dependent dynamics and multiple subpopulations.

The model was fitted to several datasets on common dolphins in the Northeast Atlantic. The SCANS-II and CODA surveys provided absolute abundance estimates for shelf waters in July 2005 and offshore waters in July 2007, respectively (Fig. 1) (SCANS-II, 2008; CODA, 2009; SC/61/FI27). The SCANS-II design-based abundance estimate was 63,366 (CV=0.46). Density surface modelling improved the precision of the CODA design-based estimate and the model-based abundance estimate was 116,709 (CV=0.337). There are also historical estimates of abundance for common dolphins in the Northeast Atlantic (see Murphy *et al.*, 2009; Cañadas *et al.*, In press). We did not incorporate these historical abundance estimates because the areas that were surveyed differed from the SCANS-II/CODA survey area. Life history data were available for stranded and bycaught females from the UK and Ireland including sexual maturity status of known-aged females (n = 129), pregnancy status of mature females (n = 129), and age-at-death of females dying as a result of natural causes (n = 7) and bycatch (n = 75) (Murphy *et al.*, In review). Finally, estimates of previous bycatch of common dolphins in several fisheries in the Northeast Atlantic were available from the literature (Tregenza *et al.*, 1997; Tregenza and Collet, 1998; Northridge, 2006; Northridge *et al.*, 2006; Northridge *et al.*, 2007; Rogan and Mackey, 2007). These bycatch estimates were treated as known input to the model (Table 1). It is important to recognise that the bycatch estimates are extrapolations that are subject to substantial uncertainty. Furthermore, the bycatch estimates do not comprise complete time-series for any of the fisheries, and bycatch occurs in other fisheries for which estimates were not available. Thus, these bycatch estimates are probably best considered as minimum estimates of previous bycatch, although bycatch estimates for individual fisheries in individual years could be overestimates.

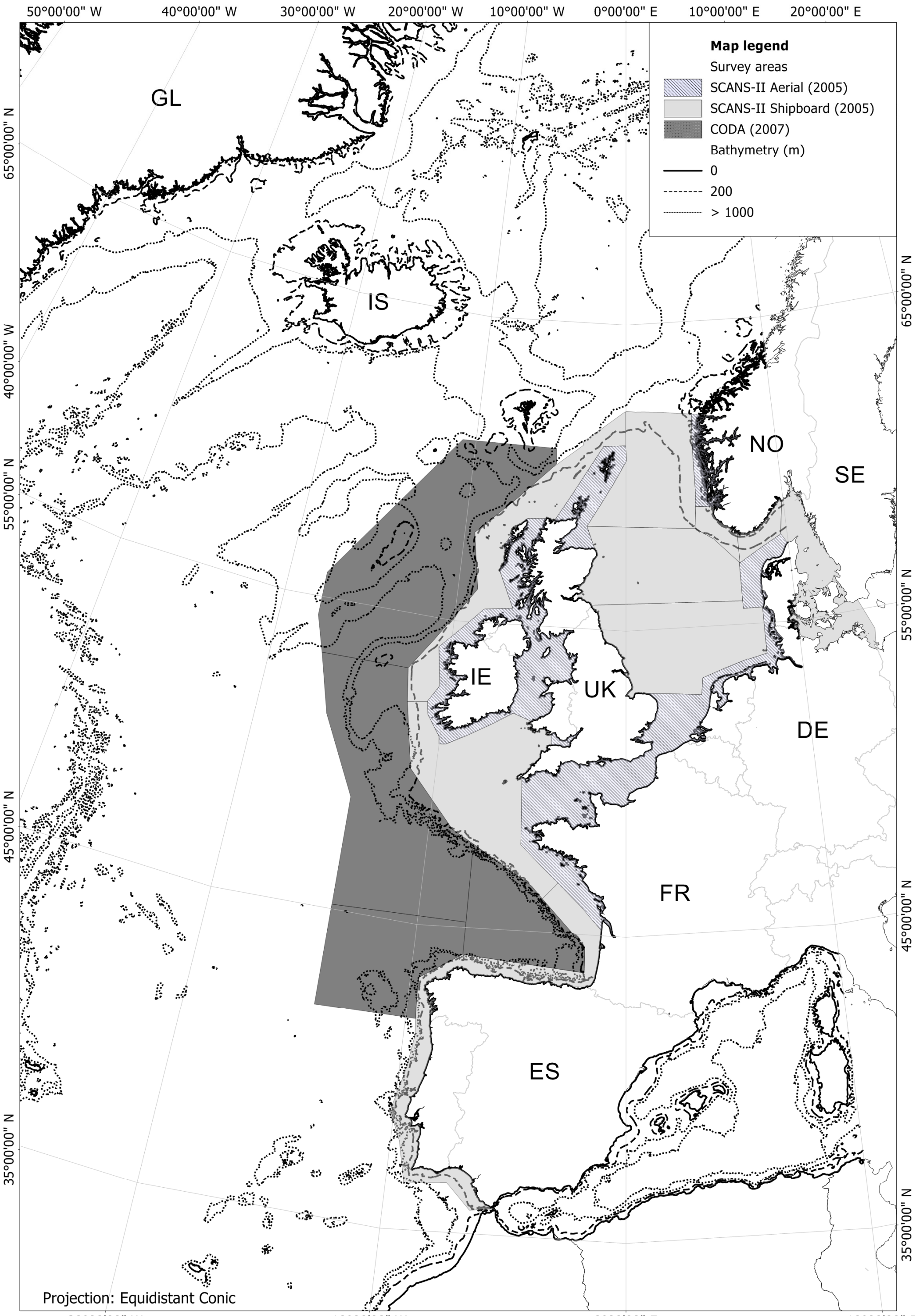

Figure 1. Map of SCANS-II and CODA survey areas.

Table 1. Estimates of common dolphin bycatch used in the assessment. Estimates are for years of life (1 July – 30 June) beginning in the year indicated.

Year	Fishery										Total
	Driftnet	Gillnet		Tanglenet	Pelagic trawl						
	Tuna (France, Ireland, UK)[1]	UK	Ireland	UK	Bass pair (UK)	Bass Area VII (European not including UK bass pair)	Bass Area VIII (European not including UK bass pair)	Hake (France)	Horse mackerel (Netherlands)	Tuna (European)	
1990	243										243
1991	390										390
1992	608										608
1993	1347	55[2]	179[2]								1581
1994	1580					25[3]		203[3]	101[3]	95[3]	2004
1995	666										666
1996	546										546
1997	947										947
1998	1706										1706
1999	2101										2101
2000	1589				190[4]						1779
2001					38[4]						38
2002					115[4]						115
2003					503[4]	60[5]	410[5]			128[5]	1101
2004		41[6]		86[6]	139[4]	60[5]	410[5]			128[5]	864
2005		98[6]		306[6]	84[4]						488
2006		57[6]		221[6]	20[6]						298

[1] Rogan and Mackey (2007)
[2] Tregenza *et al*. (1997); not clear whether these are annual values; bass and tuna estimates are for French fleet only; bass estimate is for all areas
[3] Tregenza and Collet (1998); not clear whether these are annual values
[4] Northridge (2006)
[5] Northridge *et al*. (2006)
[6] Northridge *et al*. (2007); estimates for calendar years were divided in half and allocated to the corresponding years of life

The assessment was conducted for the time period 1990-2007. The population was treated as a single, panmictic population inhabiting the Northeast Atlantic. Murphy *et al*. (2009) reviewed information on common dolphins in the Northeast Atlantic and concluded that these animals can be considered a single population ranging from waters off Scotland to Portugal. The SCANS-II and CODA abundance estimates were combined into a single abundance estimate for this population, 180,075 (CV=0.272). The CV for the combined estimate was derived by assuming that the errors were independent between the two surveys and summing the variances of the estimates from the two surveys. The combined abundance estimate was assigned to the year between the two surveys, July 2006. If common dolphins were distributed differently between the SCANS-II and CODA survey areas in 2005 and 2007, then the combined estimate would be inaccurate. Ideally, the error arising from annual variability in spatial distribution should be incorporated in the CV of the combined abundance estimate (Skaug *et al.*, 2004), but this was not possible as we only had two estimates from mutually exclusive areas and years. Common dolphins are also found outside the combined SCANS-II/CODA area during the summer so the combined abundance estimate that we used is a minimum estimate for this population.

Four model scenarios were considered with respect to model parameterisation and population dynamics. The first three scenarios modelled density-dependent population dynamics. In Scenarios 1 and 2 the population was assumed to be at carrying capacity at the beginning of the study period (i.e., 1990). Scenarios 1 and 2 differed in the parameterisation of age-specific natural survival rates: Scenario 1 modelled age-specific survival with the Siler competing-risk model (Siler, 1979) while Scenario 2 modelled survival with five discrete age-class-specific survival rates. In Scenario 3 the population was allowed to be below carrying capacity in 1990 (e.g., due to bycatch prior to 1990) so that initial population size was an extra estimated parameter. Scenario 4 modelled density-independent population dynamics. Scenarios 3 and 4 both modelled survival using discrete age-class-specific rates.

The model was fitted in a Bayesian statistical framework using a Markov chain Monte Carlo method.

Bycatch limits

We used two existing procedures to calculate bycatch limits that would be expected to achieve conservation objectives for common dolphins in the Northeast Atlantic in the future: the Potential Biological Removal procedure of the US Government (PBR; Wade, 1998) and the Catch Limit Algorithm procedure of the International Whaling Commission (CLA; Cooke, 1999). We developed a computer-based simulation model, or operating model, to test and compare the performance of the two procedures and to tune the procedures so that one would expect to meet specific conservation objectives in practice. Full specifications of our implementations of these procedures and the operating model are described in CODA (2009), SC/61/FI27 and Winship (2009).

The first step in calculating bycatch limits for this common dolphin population is the establishment of conservation objectives in quantitative terms. This is a management decision. European policymakers have not established specific conservation objectives for small cetaceans in the CODA study region, or indeed anywhere. Therefore, for the purposes of this work we followed the approach taken in SCANS-II (2008) and adopted the interim conservation objective of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS): to allow populations to recover to and/or maintain 80% of carrying capacity in the long term. We defined carrying capacity as the population size that would theoretically be reached by a population in the absence of bycatch. The ASCOBANS interim conservation objective is partially quantitative but two factors are not fully defined. First, 'long term' is not specified. We adopted a period of 200 years for tuning the procedures. This period was chosen to allow sufficient time for a heavily depleted population to recover if the natural rate of increase was low. The performance of the tuned procedures with respect to short-term delay in recovery was also examined. Second, the phrase 'recover to and/or maintain 80% of carrying capacity' can be interpreted in several ways. This is important because the procedures developed must be tuned to achieve an exact quantitative conservation objective. We developed three tunings of the procedures based on three interpretations of the conservation objective. The first tuning achieved the conservation objective 50% of the time (median population status after 200 years was 80%). This tuning is appropriate for a conservation objective of maintaining the population *at* 80% of carrying capacity in the long term. The second tuning achieved the conservation objective ≥95% of the time (95% probability that population status was ≥80% after 200 years). This tuning is appropriate for a conservation objective of maintaining the population *at or above* 80% of carrying capacity in the long term. The third tuning was identical to the second tuning except that the objective was still achieved in a worst-case scenario. This tuning is therefore appropriate for a conservation objective of maintaining the population *at or above* 80% of carrying capacity in the long term *under a worst-case scenario*.

For the first and second tunings of the procedures all parameters of the operating model were set at their baseline values. Initial population status (population size as a proportion of carrying capacity) was set to 0.99. For the CLA procedure an accurate 15-year historical time-series of bycatch estimates was assumed that reduced the population to 99% of carrying capacity at the beginning of the simulation period. Maximum population growth rate was assumed to be 4% per year with a density-dependence relationship that resulted in maximum net productivity at 50% of carrying capacity. A maximum population growth rate of 4% per year was the default value used for cetaceans in the original development of the PBR procedure and this value was considered conservative for harbour porpoise by a joint IWC/ASCOBANS working group (International Whaling Commission, 2000). The maximum rate at which common dolphin populations can grow is not well understood. Reilly and Barlow (1986) suggested that the maximum growth rate of dolphin populations was probably <9% per year based on general Leslie matrix models. Other Leslie matrix and life table modelling studies have suggested probable maximum population growth rates for common dolphins ≤4% (Woodley, 1993; Murphy *et al.*, 2007). Gerrodette *et al*. (2008) reported trends in dolphin abundance in the eastern tropical Pacific as high as 11% per year with an estimate of almost 5% for common dolphins between 1986 and 2006. Given the results of these studies we chose 4% per year as a conservative maximum population growth rate for common dolphins. A maximum net productivity level of 50% of carrying capacity is conservative in that it results in a lower absolute maximum sustainable removal than would a higher maximum net productivity level. For the third tuning we considered the worst-case scenario to be systematic overestimation of abundance by 50%, systematic underestimation of bycatch by 50% and initial population status as low as 5% of carrying capacity.

The three tunings of the PBR and CLA procedures were used to calculate preliminary bycatch limits for common dolphins in the Northeast Atlantic. Based on available information about population structure in this region and a lack of current information about distribution and abundance further offshore, we considered the combined

SCANS II and CODA survey region (Fig. 1) as a default management area (Murphy *et al.*, 2009). Thus, we calculated preliminary bycatch limits for common dolphins in this area using the two procedures and the combined SCANS-II/CODA abundance estimate, 180,075 (CV=0.272). As with the assessment, we treated this combined abundance estimate as applying to the summer of 2006—halfway between the SCANS-II and CODA surveys. The CLA procedure can also make use of estimates of previous bycatch so we calculated a second set of bycatch limits using the CLA procedure, the abundance estimate and the time-series of previous bycatch estimates used in the assessment.

RESULTS AND DISCUSSION

Assessment

The main result of the assessment was that the combination of data and model used was not informative about the main population parameters of interest: population growth rate, maximum population growth rate and carrying capacity. In the density-dependent Scenarios 1-3 the posterior probability distributions for maximum birth rate were wide and uninformative and the posterior for carrying capacity was similarly wide and uninformative unless it was assumed that the population was at carrying capacity in 1990 (Scenarios 1 and 2). The posterior probability distribution for initial population size in the density-independent model was also wide and uninformative. The model fitted the single estimate of abundance reasonably well, but there were large uncertainties in estimated population size during the study period (Fig. 2). As a result of these uninformative posterior distributions the posterior distributions for maximum population growth rate (Scenarios 1-3) and population growth rate (Scenario 4) were also uninformative.

The model fitted the data on pregnancy rate and age at sexual maturity reasonably well, but the estimation of natural survival rates was problematic. It was difficult to obtain convergent estimates for some of the survival parameters with both the Siler survivorship model and discrete survival rate parameters. The posterior samples for several of the parameters of the Siler model (Scenario 1) exhibited substantial autocorrelation probably due to correlation in the estimates of these parameters and slow mixing in the McMC algorithm. Estimates of age-class-specific survival rates appeared to converge better with the density-dependent model (Scenarios 2 and 3), but the density-independent model revealed a bimodal posterior distribution for the annual survival rate of animals ≥20 years of age (Scenario 4). Despite the convergence issues, all model scenarios suggested a senescent decrease in survival for the oldest ages in the model. The model underestimated the proportion of very young animals in the sample of bycaught animals in all scenarios.

The assessment could be most improved in the future by including one or more historical estimates of abundance and more data on the age structure of natural mortality. Historical estimates of abundance may improve the estimation of population growth rate during the study period, although it is unlikely that there would be sufficient data to estimate maximum population growth rate or carrying capacity. Furthermore, differences in survey areas and methodologies (e.g., not accounting for animals missed on the trackline or responsive movement) will complicate and possibly limit the usefulness of existing historical estimates of abundance in an assessment framework. More data on the age structure of natural mortality should improve the estimation of natural survival rates and may allow the estimation of age-specific vulnerabilities to bycatch. A different model for age-specific natural survival may also help improve parameter estimation.

Given the shortcomings of the assessment, a preferable approach to calculating appropriate bycatch limits for this common dolphin population is a fully-tested procedure, such as the PBR or CLA procedure, that can be expected to achieve conservation objectives in the face of the large uncertainties.

Bycatch limits

Preliminary bycatch limits ranged from 227-1909 animals per year, or 0.1-1.1% of the abundance point estimate, depending on the procedure and tuning to the specific conservation objective (Table 2). It is important to recognise that these bycatch limits are entirely dependent on the stated conservation objective, on the tunings that were used to achieve it under different interpretations, and on the data that were used to initiate the procedure. For example, bycatch limits under the CLA procedure were lower when historical bycatch was incorporated. As discussed above the historical bycatch time-series is likely an underestimate. Incomplete historical bycatch time-series can result in unsatisfactory performance of the first and second tunings of the CLA management procedure (Winship, 2009). These bycatch limits are therefore indicative and should not be used for management purposes. Before that can happen a series of steps must be taken, initiated by agreeing conservation objective(s) at the policy level. Scientists must evaluate whether or not the available information on common dolphins (especially population distribution and structure, seasonal movements, historical abundance and bycatch, and age- and sex-selectivity of bycatch) warrants further simulation testing to examine uncertainties that might not have been fully explored.

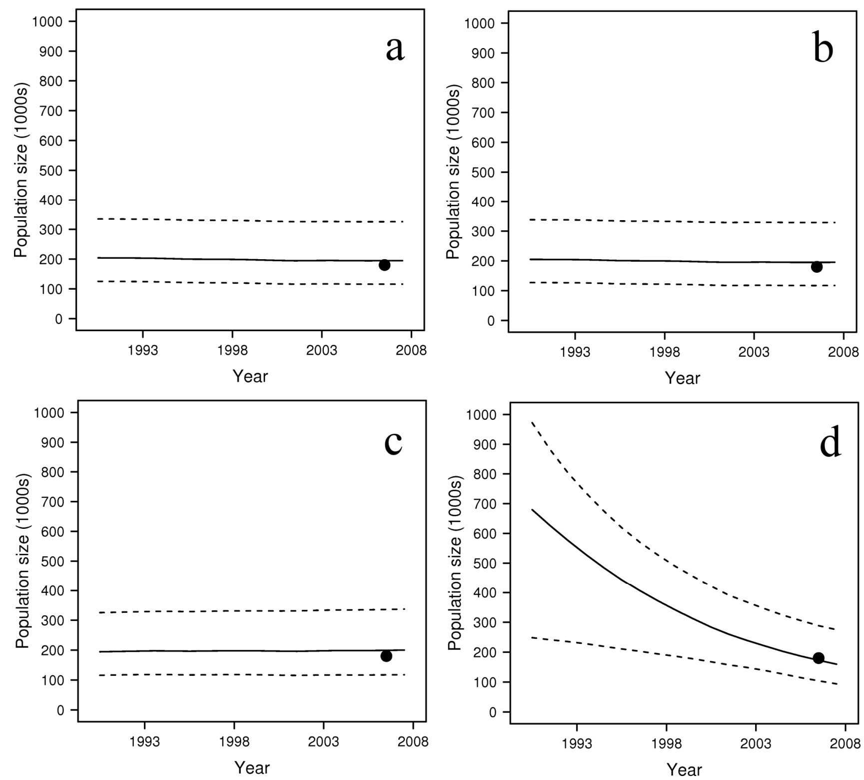

Figure 2. Observed (points) and predicted (lines) total number of males and females during the study period for all model scenarios (panels a-d represent Scenarios 1-4, respectively). The solid line represents median values from the posterior sample and the dashed lines represent the 95% interval of values from the posterior sample.

Table 2. Preliminary bycatch limits for common dolphins in the combined SCANS-II/CODA survey area. Bycatch limits were calculated using three tunings each of the PBR and CLA management procedures. The PBR procedure operated solely on the abundance estimate, while two sets of limits are presented for the CLA procedure: one based solely on the abundance estimate and one based on the abundance estimate and the time-series of historical bycatch up to mid-2006.

Historical bycatch time-series	PBR tuning			CLA tuning		
	1	2	3	1	2	3
no	1524	1092	345	1909	1061	280
yes	-	-	-	1547	860	227

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LITERATURE CITED

Cañadas, A., Donovan, G., Desportes, G. and Borchers, D. In press. A short review of the distribution of short-beaked common dolphins (*Delphinus delphis*) in the central and eastern North Atlantic with an abundance estimate for part of this area. *NAMMCO Special Publications*.

CODA. 2009. Cetacean Offshore Distribution and Abundance in the European Atlantic. Report available from Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, Fife KY16 8LB, UK. Paper SC/61/FI27 available to this meeting.

Cooke, J.G. 1999. Improvement of fishery-management advice through simulation testing of harvest algorithms. *ICES J. Mar. Sci.* 56:797-810.

Gerrodette, T., Watters, G., Perryman, W. and Ballance, L. 2008. Estimates of 2006 dolphin abundance in the eastern tropical Pacific, with revised estimates from 1986-2003. NOAA Technical Memorandum NMFS-SWFSC-422, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California. 39 pp.

International Whaling Commission. 2000. Report of the IWC-ASCOBANS Working Group on harbour porpoises. *J. Cet. Res. Manage. (Suppl.)* 2:297-305.

Murphy, S., Dabin, W., Ridoux, V., Morizur, Y., Larsen, F. and Rogan, E. 2007. Estimation of R_{MAX} for the common dolphin in the Northeast Atlantic. EC NECESSITY Contract 501605 Periodic Activity Report No. 2 Annex 8.4. Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK. 11 pp.

Murphy, S., Natoli, A., Amaral, A.R., Mirimin, L., Viricel, A., Caurant, F., Hoelzel, R. and Evans, P. 2009. Short-beaked common dolphin *Delphinus delphis*. pp. 111-130 *In*: P. G. H. Evans and J. Teilmann (eds.) *Report of ASCOBANS/HELCOM small cetacean population structure workshop*. ASCOBANS, Bonn, Germany. 141 pp.

Murphy, S., Winship, A., Dabin, W., Jepson, P.D., Deaville, R., Reid, R.J., Spurrier, C., Rogan, E., López, A., González, A., Read, F., Addink, M., Silva, M., Ridoux, V., Learmonth, J.A., Pierce, G.J. and Northridge, S.P. In review. The importance of biological parameters in assessing the current status of the short-beaked common dolphin *Delphinus delphis* in the eastern North Atlantic. *Mar. Ecol. Prog. Ser.*

Northridge, S. 2006. Dolphin bycatch: observations and mitigation work in the UK bass pair trawl fishery 2005-2006 season. Occasional report to DEFRA. Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK. 7 pp.

Northridge, S., Kingston, A., Thomas, L. and Mackay, A. 2007. Second annual report on the UK cetacean bycatch monitoring scheme. Contract report to DEFRA (on the work conducted 2005-2006). Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK. 27 pp.

Northridge, S., Morizur, Y., Souami, Y. and van Canneyt, O. 2006. PETRACET project EC/FISH/2003/09. Final report to the European Commission 1735R07D. Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK. 29 pp.

Reilly, S.B. and Barlow, J. 1986. Rates of increase in dolphin population size. *Fish. Bull.* 84:527-533.

Rogan, E. and Mackey, M. 2007. Megafauna bycatch in drift nets for albacore tuna (*Thunnus alalunga*) in the NE Atlantic. *Fish. Res.* 86:6-14.

SCANS-II. 2008. Small cetaceans in the European Atlantic and North Sea. Final Report submitted to the European Commission under project LIFE04NAT/GB/000245. Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews, UK.

Siler, W. 1979. A competing-risk model for animal mortality. *Ecology* 6:750-757.

Skaug, H.J., Øien, N., Schweder, T. and Bøthun, G. 2004. Abundance of minke whales (*Balaenoptera acutorostrata*) in the Northeast Atlantic: variability in time and space. *Can. J. Fish. Aquat. Sci.* 61:870-886.

Tregenza, N.J.C., Berrow, S.D., Hammond, P.S. and Leaper, R. 1997. Common dolphin, *Delphinus delphis* L., bycatch in bottom set gillnets in the Celtic Sea. *Rep. int. Whal. Commn.* 47:835-839.

Tregenza, N.J.C. and Collet, A. 1998. Common dolphin *Delphinus delphis* bycatch in pelagic trawl and other fisheries in the Northeast Atlantic. *Rep. int. Whal. Commn.* 48:453-459.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Mar. Mamm. Sci.* 14:1-37.

Winship, A.J. 2009. Estimating the impact of bycatch and calculating bycatch limits to achieve conservation objectives as applied to harbour porpoise in the North Sea. PhD Thesis, University of St Andrews, UK. 243pp.

Woodley, T.H. 1993. Potential effects of driftnet fisheries for albacore tuna (*Thunnus alalunga*) on populations of striped (*Stenella coeruleoalba*) and common (*Delphinus delphis*) dolphins from the northeast Atlantic. Technical Report 93-02, International Marine Mammal Association, Inc., Guelph, Ontario. 13 pp.