ATLAS OF THE MARINE MAMMALS OF WALES

M.E. Baines and P.G.H. Evans

CCW Marine Monitoring Report No. 68. 2nd edition

with contributions from:

Cardigan Bay Marine Wildlife Centre
Ceredigion County Council
Countryside Council for Wales
JNCC/European Seabirds at Sea
E.ON UK
Eurydice
Friends of Cardigan Bay
Gower Marine Mammal Project
Irish Whale & Dolphin Group
Manx Whale & Dolphin Watch
Marine Awareness North Wales
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This report has been the subject of detailed peer review by international scientific experts under the supervision of CCW and JNCC.

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Plate 1. TL: Long-finned Pilot Whale (C. Swann); TC: Short-beaked Common Dolphin (P. Anderwald); TR: Fin Whale (P.G.H. Evans); ML: Bottlenose Dolphin (P. Anderwald); MC: Atlantic Grey Seal (P. Anderwald); MR: Harbour Porpoise (M.E. Baines); BL: Risso's Dolphin (P.G.H. Evans); BC: Minke Whale (P.G.H. Evans), BR: Killer Whale (F. Ugarte)

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Mae un deg chwech grŵp / prosiect arolwg wedi cyfrannu at y gronfa ddata prosiect sy'n sail i'r Atlas hwn o Famaliaid Morol Cymru. Dadansoddir gwaith arolwg a gynhaliwyd dros y cyfnod 20 mlynedd rhwng 1990-2009; mae'r gwaith hwn yn cynnwys cyfanswm o 216,031 km o ymdrech arolwg a gynhaliwyd mewn cychod ac o'r awyr, ynghyd â 13,399 awr o ymdrech arolwg o'r lan. Mae'r gwaith arolwg yn ymdrin â 373 o'r 414 o gelloedd gofodol yn y rhanbarth yr ymchwilir iddo (Môr Iwerddon, Sianel San Siôr a'r rhan fwyaf o Fôr Hafren). Ar hyn o bryd mae'r gronfa ddata prosiect yn cynnwys 32,986 arsylwad o greaduriaid morfilaidd, a chyfanswm yr unigolion a gofnodwyd yn ystod y troeon hyn oedd 99,085. Roedd y rhain i gyd yn cynrychioli 12 rhywogaeth wahanol o greaduriaid morfilaidd. Hefyd adolygwyd cronfa ddata tiriadau ('strandings') Cymru, a reolir gan Marine Environmental Monitoring: ar ddyddiad y dadansoddiad gwreiddiol, roedd hon yn cynnwys cofnodion o 1,724 creadur morfilaidd ungiol, ac roedd y cyfanswm hwn yn cynrychioli 15 rhywogaeth wahanol. Cafwyd data am forloi llwyd oddi wrth CCGC, yn ychwanegol at y 2,586 o arsylwadau ar y môr (oedd yn cynnwys 3,424 o unigolion) a oedd wedi eu cynnwys yng nghronfa ddata'r prosiect.

Defnyddiwyd grid gyda chydraniad o 10' lledred a 10' hydred, a rhannwyd yr ymdrech arolwg i segmentau y gellid eu neilltuo i gell benodol ar y grid. Casglwyd gwybodaeth am ymdrech arolwg, ynghyd â'r arsylwadau cysylltiedig, mewn tri thabl gwahanol – un yr un ar gyfer y data a gasglwyd o gychod, o'r awyr ac o'r lan. Cafodd rhain eu cyplysu wedyn â thabl pellach a oedd yn cynnwys gwybodaeth ar leoliad ac arwynebedd môr pob cell. Ar gyfer pob un o'r pum rhywogaeth a welwyd yn rheolaidd (llamhidydd, dolffin trwyn potel, dolffin cyffredin, dolffin Risso a morfil pigfain) amcangyfrifwyd cyfradd cyfrif anifeiliaid ar yr wyneb (a fynegwyd yn nhermau nifer unigolion a nodwyd fesul km a deithiwyd yn achos arolygon ar y môr ac o'r awyr, a fesul awr yn achos arolygon o'r lan).

Gwnaethpwyd ymchwiliadau, gan ddefnyddio modelau adiol cyffredinol ('GAM's'), i weld a oedd ffactorau amgylcheddol megis cyflwr y môr, yn ogystal â'r math o arolwg/platfform a'i gyflymder, yn debygol o wyro canlyniadau oherwydd eu hefffaith ar rwyddineb arsylwi. Daethpwyd i'r casgliad mai dim ond ar gyfer cyflwr y môr a chyflymder cwch yr oedd hi'n bosib, yn realistig, i ddefnyddio ffactorau cywiro (a gwnaethpwyd hynny fesul rhywogaeth). Cyflwynwyd canlyniadau'r arolygon o'r awyr, o gychod ac o'r lan ar wahan. Ystyriwyd mai'r canlyniadau'r arolygon a wnaed o gychod a oedd yn cynnig y disgrifiad gorau o ddosbarthiad o bob rhywogaeth am mai'r arolygon hyn oedd yn gorchuddio'r ardal fwyaf. Plotiwyd y canlyniadau terfynol ar fapiau gan ddefnyddio system gwybodaeth ddaearyddol Arc View. Cynhyrchwyd cyfanswm o 236 map ar gyfer yr ail argraffiad hwn ac mae'r rhain i'w gweld mewn Atodiad electronig.

Mae deunaw rhywogaeth forfilaidd wedi cael eu cofnodi yn nyfroedd Cymru ers 1990. Mae pum rhywogaeth (y llamhidydd, y dolffin trwyn potel, y dolffin cyffredin pig fer, dolffin Risso a'r morfil pigfain) yn gymharol gyffredin ac mae dosbarthiad pob un wedi ei fapio yma, yn cynnwys amrywiadau tymhorol a rhai dros y tymor hir. Mae'r rhywogaethau a gofnodwyd yn anfynych iawn yn cynnwys y morfil asgellog llwyd, y lleiddiad a'r morfil pengrwn, ac roedd ymwelwyr achlysurol â'r rhanbarth yn cynnwys y morfil cefngrwm, morfil asgellog sei, y morfil sberm lleiaf, y morfil trwyn potel, morfilod gylfinog Cuvier, Sowerby a Blainville, y dolffin rhesog, y dolffin ystlyswyn a’r dolffin pigwyn. Ceir mapiau o’r rhywogaethau mwy prin yn yr Atodiad eletronig.

Y **llamhidydd** yw’r rhywogaeth fwyaf cyffredin a’r un a geir dros yr ardal ehangaf yn nyfroedd Cymru. Mae llamidyddion yma drwy gydol y flwyddyn, er mae’n debyg nad ydynt wedi cael eu cofnodi ddigon yn y gaeaf. Nid yw dosbarthiad y rhywogaeth yn wastad ar draws Môr Iwerddon. Gellir nodi mannau da oddi ar arfordir Gogledd a Gorllewin Ynys Môn (yn enwedig o gwmpas Trwyn Eilian ac Ynys Lawd, Caergybi), cornel dde-orllewinol Pen Llŷn, rhan ddeheuol Bae Ceredigion, yng nghyffiniau Pen Strwmbwl ac ynysoedd gorllewin Sir Benfro (Sgomer ac Ynys Dewi), ac ym Môr Hafren oddi ar arfordir deheuol Cymru (o gwmpas Penrhyn Gŵyr ac ym Mae Abertawe). Mae’r ardaloedd hyn sydd â dwysedd cymharol uchel o lamidyddion yn aros felly dros amser. Ceir lloi llamhidyddion drwy’r rhanbarth i gyd. Nid oedd yn bosib adnabod ardaoledd gyda chyfran uwch o anifeiliaid ifanc oherwydd nad oedd pob arsyllwr wedi cofnodi presenoldeb anifeiliaid ifanc yn systematig. Dyma’r rhywogaeth sy’n tirio amlaf, a’r achos marwolaeth yn bennaf yw ymosodiadau gan ddolffiniaid trwyn potel.

Y **dolffin trwyn potel** yw’r rhywogaeth a gofnodir amlaf ar ôl y llamhidydd. Arfordirol yw ei ddosbarthiad yn bennaf, er bod dwyseddau isel wedi cael eu cofnodi ar y môr mawr, ymhellach oddi ar y lan, yn arbennig yn Sianel San Siôr a rhan dde-orllewinol ardal yr astudiaeth. Yn rhan ddeheuol Bae Ceredigion y gwelwyd y crynoadau mwyaf o ddolffiniaid trwyn potel ond roedd cyfraddau arsylwi gweddol uchel yn ymestyn i’r gogledd i mewn i Fae Tremadog. Mae’r rhywogaeth hefyd i’w chael oddi ar arfordir gogleddol Cymru, yn arbennig i’r gogledd a’r dwyrain o Ynys Môn. Nodir gwahaniaethau tymhorol ym maint a gwasgariad grwpiau; yn yr haf mae’r dolffiniaid yn bennaf i’w gweld mewn grwpiau bach ger yr lan, â’u prif ganolbwynt yw Bae Ceredigion, ac yna maen nhw’n gwasgaru’n dros ardal ehangach ac yn gyffredinol tua’r gogledd, lle gallant ffurfio grwpiau mawr iawn yn y gaeaf. Fodd bynnag, gellir gweld y rhywogaeth ar unrhyw adeg o’r flwyddyn ar hyd a lled dyfroedd arfordirol Cymru. Ni welwyd unrhyw newid sylfaenol i’w dosbarthiad ers 1990. Mae dolffiniaid trwyn potel yn bridio ar hyd a lled eu hardal ddosbarthiad Cymreig, a gwelir lloi ym mhob mis o’r flwyddyn bron. Dim ond nifer fach sydd wedi cael eu cofnodi’n tirio.

Mae dosbarthiad y **dolffin cyffredin pig fer** gan fwyaf ar y môr mawr, a’i ganolbwynt yw’r Cafn Celtaidd ym mhen deheuol Môr Iwerddon, lle mae dyfnder y dŵr yn amrywio o 50 i 150 o fetrau. Mae’r ardal hon, sy’n cynnal dwysedd uchel o ddolffiniaid cyffredin, yn ymestyn i’r dwyrain tuag arfordir ac ynysoedd gorllewin Sir Benfro. Mewn mannau eraill ym Môr Iwerddon, ceir y rhywogaeth ar ddwyseddau isel, ar y môr mawr yn bennaf, mewn band canolog sy’n ymestyn i’r gogledd tuag Ynys Manaw. Cafwyd patrymau dosbarthiad tebyg dros y pedwar cyfnod o amser a archwiliwyd. Ymwelydd haf yw’r dolffin hwn gan fwyaf, er ei fod yn aros yn y Cafn Celtaidd hyd fis Tachwedd o leiaf. Gall grwpiau o anifeiliaid ifanc heidio i’n dyfroedd yn hwyr yn yr haf. Mae’r rhan fwyaf o’r tiriadau’n digwydd ar hyd glannau de-orllewin Cymru.

Mae dosbarthiad **dolffiniaid Risso** yn gymharol leol, gan ffurfio band llydan sy’n rhedeg o’r de-orllewin i’r gogledd-ddwyrain ar hyd ardal sy’n cwmpasu gorllewin Sir Benfro, pen gorllewinol Pen Llŷn ac Ynys Môn yng Nghymru, arfordir de-ddwyreiniol Iwerddon yn y gorllewin, a dyfroedd o gwmpas Ynys Manaw yn y gogledd. Ymddengys fod y dosbarthiad cyffredinol hwn wedi parhau dros y tymor hir, er y gall y nifer sy’n ymweld â glannau Cymru amrywio’n fawr iawn o flwyddyn i flwyddyn. Mae'n ymwelydd haf a hydref yn bennaf, a cheir y cyfraddau arsylwi uchaf yn ystod y cyfnod rhwng mis Gorffennaf a mis Medi. Mae dolffiniaid Risso yn bridio yn y rhanbarth, a gwelwyd anifeiliaid ifanc lle bynnag y gwelwyd grwpiau. Ychydig o diriadau a gafwyd, yn bennaf ar draws gorllewin Cymru.

Dosbarthiad alldraeth (h.y. ar y môr mawr) sydd gan y **morfil pigfain** yn bennaf, a chasglwyd y dwysedd uchaf o arsylwadau yn ardal y Cafn Celtaidd, er y gwelir y rhywogaeth hefyd mewn mannau gyda dŵr dwfn (fel arfer >50 m) tua'r gogledd, yn enwedig rhwng arfordir Dulyn ac Ynys Môn ac o gwmpas Ynys Manaw. Gwelir y patrwm dosbarthiad hwn ar draws y cyfnodau amser a archwiliwyd. Ymddengys mai yn yr haf yn bennaf mae'r rhywogaeth yn ymweld â'r rhanbarth, a dim ond ychydig o arsylwadau a gafwyd yn y gaeaf, er gallai hyn fod yn rhannol oherwydd mai ychydig o ymdrech a wnaed yn y cyfnod hwnnw. Nid oes unrhyw dystiolaeth eto bod y rhywogaeth yn bridio yn nyfroedd Cymru.

O gwmpas y Cafn Celtaidd, ac yng nghyffiniau Ynys Manaw, y ceir yr amrywiaeth orau o rywogaethau morfilaidd. Yr ardaloedd sydd â'r amrywiaeth orau o rywogaethau ar hyd glannau Cymru yw gorllewin Sir Benfro, pen gorllewinol Pen Llŷn, a gorllewin Ynys Môn – y mannau sydd agosaf at ddyfroedd dyfnach a dylanwad posibl y ddwy brif system ffryntiau ym Môr Iwerddon, ffryntiau'r Môr Celtaidd a ffryntiau gorllewinol Môr Iwerddon.

Y **morlo llwyd** yw'r unig rywogaeth adeindroed ('pinniped') sy'n bridio yng Nghymru. Mae ei ddosbarthiad yn eang, ac mae'n bridio mewn ogofau ac ar gildraethau bach ar ynysoedd alldraeth a mannau llai poblog ar hyd glannau'r tir mawr. Genir y nifer fwyaf o loi bach yng ngogledd-orllewin Sir Benfro, yn arbennig ar Ynys Dewi, ond hefyd tua'r de at Ynys Sgomer ac i'r gogledd i ran ddeheuol Ceredigion. Ceir crynoadau llai o gwmpas Pen Llŷn a glannau Ynys Môn. Gall morloi ddefnyddio'r un mannau i halio'u hunain o'r dŵr i dreulio bwyd ac i fwrw crwyn y tu allan i'r tymor bridio. Mae hyn yn ychwanegol at safleoedd eraill a ddefnyddir ganddynt yn unswydd i fwrw crwyn ac yn ystod teithiau bwydo – enghraifft o hyn yw Banc Tywod West Hoyle yn aber y Ddyfrdwy lle mae dros 800 o forloi llwyd wedi cael eu cyfrif. Mae astudiaethau telemetreg yn awgrymu y gall morloi fod yn gwneud teithiau lleol iawn i ganfod bwyd, a bod anifeiliaid o fan penodol yn tueddu i aros yn yr ardal honno. Mae'r arsylwadau a wnaed o forloi llwyd ar y môr yn dangos bod yna ardal oddi ar arfordir gogledd Cymru a ddefnyddir yn helaeth ganddynt, ac mae hyn hefyd i'w weld yn y data telemetreg. Ond oherwydd nad oes gennym wybodaeth gyson gyflawn dros yr ardal gyfan, am nad oedd pob arsyllwyr yn cofnodi arsylwadau morloi llwyd yn systematig, nid oes modd dod i gasgliadau pendant ar gyfer yr holl ardal.

Er bod 90% o'r celloedd yn ardal yr astudiaeth wedi bod yn destun rhywfaint o ymdrech arolwg, mae'r ymdriniaeth yn annigonol o hyd ym mhob un ond ychydig o ardaloedd bach. Dim ond mewn 177 (43%) o gelloedd yr oedd yr ymdrech arolwg o gwch yn fwy na 100km. Bu'r ymdrech fwyaf yn yr ardaloedd arfordirol, yn bennaf yn rhan ddeheuol Bae Ceredigion o Gei Newydd i Benrhyn Dewi, ac o gwmpas Ynys Enlli. Hefyd cafwyd tuedd dymhorol yn nosbarthiad yr ymdrech, gyda 78% o'r holl ymdrech arolwg o gwch yn digwydd yn ystod cyfnodau chwe mis o fis Ebrill i fis Medi. Byddai'n fuddiol cael mwy o ymdrech arolwg yn yr holl ardaloedd, ond mae yna fylchau penodol ym Mae Caernarfon, de Sir Benfro, ac arfordir Gwent yn ne-ddwyrain Cymru, yn ogystal â nifer o ardaloedd alldraeth ar y môr mawr.

Er bod y mwyafrif o'r grwpiau bellach yn casglu data mewn fformat safonol tebyg, mae'n dal i fod yn anodd cyfuno setiau data o safleoedd ar y tir, arolygon o longau neu gychod ar y môr mawr, ac arolygon o'r awyr. Nid yw'n hawdd integreiddio platfformau sy'n digwydd cynnig cyfle wrth deithio ar hyd bandiau cul ar y môr neu sydd wedi'u cyfeirio at ganfod crynoadau o famaliaid morol, gydag arolygon sy'n gweithio ar draws ardaloedd ehangach yn fwy systematig. Lle bynnag y bo modd, dylid amcangyfrif y pellter rhwng y mamal neu'r mamaliaid a welir a'r platfform, er mwyn galluogi rhywun i ffitio ffwythiannau canfod, ac felly deillio amcangyfrifon dwysedd absoliwt, ond wedyn dylai'r arsyllwyr gael yr hyfforddiant priodol ar amcangyfrif pellter yn gywir.

Executive Summary

Sixteen groups / survey projects have contributed to the project database that forms the basis for this Atlas of the Marine Mammals of Wales. A total of 216,031 km of effort from vessel and aerial surveys and 13,399 hours of land-based effort are analysed, spanning the 20-year period 1990-2009. Spatial coverage amounted to 373 of the 414 cells that encompass the region under investigation (the Irish Sea, St George's Channel and greater part of the Bristol Channel). The project database currently comprises 32,986 cetacean sightings totalling 99,085 individuals of 12 species. In addition, the Welsh stranding database, managed by Marine Environmental Monitoring, was reviewed: at the date of the original analysis, this contained records of 1,724 individual cetaceans of 15 species. Grey seal data were sourced from CCW, besides 2,586 at-sea sightings (comprising 3,424 individuals) in the project database.

A grid with resolution of 10' latitude and 10' longitude was used, and effort partitioned into segments that could be assigned to a particular grid cell. Effort, together with associated sightings, were compiled in three separate tables, one each for vessel, aerial and land-based data, and these were then linked to a further table holding data on position and sea area of each cell. Count rates of animals at the surface (expressed in terms of numbers of individuals counted per km travelled in the case of vessel & aerial surveys, and per hour in the case of land watches) were calculated for all five of the regular species (harbour porpoise, bottlenose, common and Risso's dolphin, and minke whale). Examinations were made for potential bias in sightability due to environmental factors such as sea state, as well as survey/platform type and speed, using generalised additive models (GAMs). It was concluded that correction factors could only realistically be applied for sea state (and this was done on a species by species basis) and vessel speed. Results from aerial surveys, vessel surveys, and land-based watches were presented separately. The results from the vessel surveys were considered to best describe the distributions of each species since they had the greatest spatial coverage. The final results were then plotted onto maps using Arc View GIS. A total of 236 maps were produced for this second edition, and these are contained in an electronic Appendix.

Eighteen species of cetacean have been recorded in Welsh waters since 1990. Five species (harbour porpoise, bottlenose dolphin, short-beaked common dolphin, Risso's dolphin and minke whale) are relatively common and their distributions are mapped here, including variations both seasonally and over the long term. Species recorded rarely include fin whale, killer whale, and long-finned pilot whale, and as casual visitors to the region: humpback whale, sei whale, pygmy sperm whale, northern bottlenose whale, Cuvier's, Sowerby's and Blainville's beaked whales, striped dolphin, Atlantic white-sided dolphin, and white-beaked dolphin. Maps of the rarer species are contained in the electronic Appendix.

The **harbour porpoise** is the commonest and most widespread species in Welsh waters. It is present year round, although probably under-recorded in winter. The species is not evenly distributed within the Irish Sea. Hot spots can be identified off North and West Anglesey (particularly around Point Lynas & South Stack, Holyhead), the southwest coast of the Lleyn Peninsula, southern Cardigan Bay, in the vicinity of Strumble Head and the west Pembrokeshire islands (Skomer & Ramsey), and in the Bristol Channel off the south coast of Wales (around the Gower Peninsula and in Swansea Bay). These areas of relative high density largely persist

across time periods. Porpoise calves occur throughout the region. Identifying areas with higher proportions of juveniles was not possible, due to the fact that the presence of young animals had not been recorded systematically by all observers. The species is the commonest to strand, with cause of death primarily bottlenose dolphin attack.

The **bottlenose dolphin** is the next most frequently recorded species, with a predominantly coastal distribution, although low densities have been recorded offshore, particularly in St George's Channel and the southwest sector of the study area. The main concentrations of sightings were southern Cardigan Bay but with moderately high sighting rates extending north into Tremadog Bay, although the species also occurs off the north coast of Wales, particularly north and east of Anglesey. Seasonal differences in group size and dispersion are noted, with dolphins in summer occurring mainly in small groups near the coast, centred upon Cardigan Bay, dispersing more widely and generally northwards, where they may form very large groups in winter. However, the species can be seen at any time of the year throughout Welsh coastal waters. No fundamental change in distribution has been observed since 1990. Bottlenose dolphins breed throughout their Welsh range, with calves observed in most months of the year. Only small numbers have been recorded stranding.

The **short-beaked common dolphin** has a largely offshore distribution centred upon the Celtic Deep at the southern end of the Irish Sea, where water depths range from 50-150 metres. This high-density area extends eastwards towards the coast and islands of west Pembrokeshire. Elsewhere in the Irish Sea, the species occurs at low densities mainly offshore, in a central band that extends northwards towards the Isle of Man. Similar patterns of distribution have occurred across the four time periods examined. It is mainly a summer visitor although persisting in the Celtic Deep at least to November. An influx of juvenile groups may occur in late summer. Most strandings take place along the coasts of Southwest Wales.

Risso's dolphins have a relatively localised distribution, forming a wide band running SW-NE that encompasses west Pembrokeshire, the western end of the Lleyn Peninsula and Anglesey in Wales, the south-east coast of Ireland in the west, and waters around the Isle of Man in the north. This general distribution appears to have persisted over the long-term although numbers visiting the coasts of Wales can vary a great deal between years. The species is mainly a summer and autumn visitor, with the highest sighting rates in the period July to September. Risso's dolphins breed in the region, and young have been observed wherever groups have been sighted. There have been only a few stranding, mainly across west Wales.

The **minke whale** has a largely offshore distribution, with highest densities of sightings occurring in the area of the Celtic Deep, although the species is found also in deeper areas (generally >50 m) northwards particularly between the coast of Co. Dublin and Anglesey, and around the Isle of Man. This distribution pattern is observed across the time periods under examination. The species appears to be a mainly summer visitor to the region, with few sightings in winter, although this may partly be due to low effort at that period. There is no evidence as yet that the species breeds in Welsh waters.

Cetacean species diversity is highest around the Celtic Deep and close to the Isle of Man. The areas of coastal Wales with highest species diversity are west Pembrokeshire, the western end of the Lleyn Peninsula, and west of Anglesey – the regions that are closest to deeper waters and the possible influence of the two major frontal systems in the Irish Sea, the Celtic Sea and western Irish Sea Fronts.

The **grey seal** is the only pinniped species breeding in Wales. It is widely distributed, breeding in caves and small coves on offshore islands and less populated parts of the mainland coast. Pup production is greatest in Northwest Pembrokeshire, particularly on Ramsey Island, but extending southwards to Skomer Island and northwards to southern Ceredigion. Smaller breeding concentrations occur around the Lleyn Peninsula and the coast of Anglesey. These same areas may also be used as moulting and feeding haul-out sites during the non-breeding season. This is in addition to other sites used solely for moulting and during feeding trips, an example being the West Hoyle Sandbank in the Dee Estuary, where over 800 seals have been counted. Telemetry studies indicate that seals may make foraging trips to very localised areas, with animals from a particular locality tending to remain in that region. Sightings at sea indicate an area of high usage off the North Wales coast that is also shown in the telemetry data, but as there is not even coverage, due to many observers not recording seal sightings systematically, conclusions cannot be drawn across the whole area.

Although 90% of cells in the study area have received some survey effort, coverage remains inadequate in all but a few small areas. In only 177 (43%) of cells has vessel effort exceeded 100km. Effort has been highest in coastal areas, mainly in southern Cardigan Bay from New Quay to St David's Head, and around Bardsey Island. There has also been a temporal bias to the distribution of effort, with 78% of all vessel effort in the six months, April to September. All areas would benefit from greater survey effort, but particular gaps occur in Caernarfon Bay, south Pembrokeshire, and the coast of Gwent in South-east Wales, as well as several offshore areas.

Although the majority of groups are now collecting data in a similar, standardised format, it remains difficult to merge data sets from land based sites, offshore vessel surveys and aerial surveys. Platforms of opportunity that ply narrow bands of sea or are directed to finding concentrations of marine mammals are not easily integrated with surveys covering wider areas more systematically. Wherever possible, the distance of a sighting to the platform should be estimated to enable one to fit detection functions, and hence derive absolute density estimates, but observers should then receive the appropriate training for accurate distance estimation.

INTRODUCTION

There is a requirement for information on marine mammal distribution and abundance in Welsh waters to support environmental stewardship and help to determine appropriate mitigation measures in order to avoid or minimise impacts for future sustainable management. CCW is committed to working with DECC (Department of Energy & Climate Change), developers and others to ensure that impacts upon features of nature conservation interest are avoided, and that development proceeds in an environmentally sustainable way.

The collation of this information is essential to meet our obligations under the EU Habitats and Species Directive: to advise on potential oil and gas exploitation and other marine activities including fisheries and renewable energy exploitation; and to undertake surveillance of the Favourable Conservation Status (FCS) of marine mammals in order to report on natural range, population size and habitat area.

Amendments to the Conservation (Natural Habitats &c.) Regulations 1994 and the new Offshore Marine Regulations (Natural Habitats, &c.) Regulations 2007 have a revised definition of disturbance and the Offshore Marine Regulations extend the offence to areas of UK jurisdiction beyond 12 nm. It is now an offence under both Directives to deliberately disturb wild animals of a European Protected Species (this includes all cetaceans) in such a way as to be likely significantly to affect: a) the ability of any significant group of animals of that species to survive, breed, rear or nurture their young; or b) the local distribution or abundance of that species. A consequence of this is that guidance is being developed by JNCC and the other UK nature conservation agencies, for those carrying out activities in the marine environment that is species-specific and includes best-practice guidelines. Interim guidance can be found on the JNCC website: http://www.jncc.gov.uk/page-4145

A recent collaborative exercise to produce an Atlas of Cetacean Distribution in North-west European Waters (Reid *et al*., 2003) has also resulted in a standard for managing cetacean data, currently termed the Joint Cetacean Protocol. That Atlas is a summary of the 28 species of cetacean that have been recorded in North-west European waters from the latter half of the 20th century. The data sources used to compile a Joint Cetacean Database (JCD) and the annual distribution maps were the European Seabirds at Sea (ESAS) database, the Sea Watch Foundation database, and the SCANS (I) Survey database. The maps in that Atlas depict data at a resolution of one-quarter International Council for the Exploration of the Sea (ICES) rectangles (15' latitude x 30' longitude – somewhat less than 1000 square kilometres (at this latitude). This resolution is very useful for making general statements about relative animal densities at a regional level. However, higher resolution data (as used here for the Atlas of Marine Mammals of Wales, at 10' latitude x 10' longitude) are required at a local level for cetaceans living in Welsh seas in order to meet both the amendments to the Habitats Regulations and FCS reporting.

Data on marine mammal occurrence in Wales and the southern Irish Sea, have been collected by a wide range of organisations each of which may have used different survey methods and protocols for the recording of data in the field, reflecting their various interests, expertise and resources. The aim of this project is to collate as much as possible of these data, compiling a single unified database from which maps of marine mammal distribution at a resolution of 10' latitude x 10' longitude can be produced.

1.1 Objectives and scope

The principal objective is to describe the temporal and spatial distribution and relative abundance of all marine mammal species sighted, detected or stranded in Welsh waters but concentrating on species regularly sighted. Marine mammal distribution and abundance are determined based on occurrence data, and include sighting effort.

This report (including maps), the accompanying database and Geographic Information System (GIS) data layers aims to provide the most-up-to date and relevant information on distribution, abundance, and seasonality of marine mammals found in Welsh Seas. As the most common and widely distributed species, the harbour porpoise analysis will be treated as a priority.

An initiative exists to develop a Joint Cetacean Protocol (JCP) with all holders of cetacean sightings and effort data in the UK and Ireland, and a project was set-up to analyse a sub-set of the JCP data for the Irish Sea to determine what questions the data could address and whether the quality and applicability of future datasets can be improved (Thomas, 2009). This project aimed to meet the data structures and standards of the Joint Cetacean Protocol. A primary function of the JCP is to collate and analyse standardised cetacean datasets, and to demonstrate whether such data can be used to produce indices of range and abundance for both SAC management and Habitats Directive reporting, and ultimately to support habitat modelling and sensitivity mapping.

METHODS

2.1 Spatial and temporal extent of the study area

The study area is located in the southern Irish Sea and encompasses the entire territorial seas of Wales, as well as adjacent areas off Eire, England, Northern Ireland and the Isle of Man, bound by the extents listed in Table 1. Figure 1 shows the study area overlaid with a grid of 10’ x 10’ cells, together with the Wales and England 12 nm territorial limit, the international median line, and the 100 m depth contour. The temporal extent of the sightings data used in this Atlas is from 1990 to 2009.

Table 1 – Limits of the study area

North	54.5° North
South	51.0° North
East	2.25° West
West	7.0° West

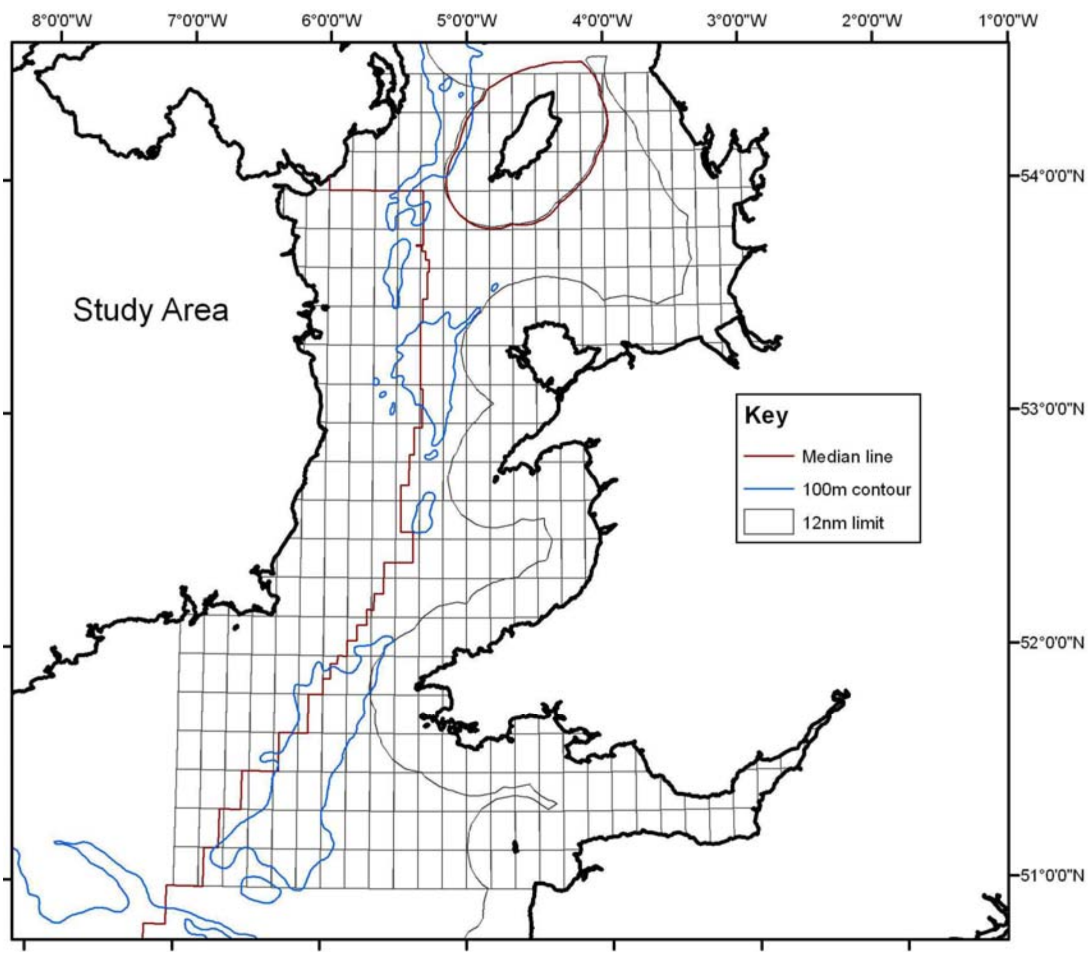


Figure 1a – The Study Area, showing the international median line, the 12 nm UK territorial limit and the 100 m depth contour. The study area itself is overlain by a 10-minute grid of cells

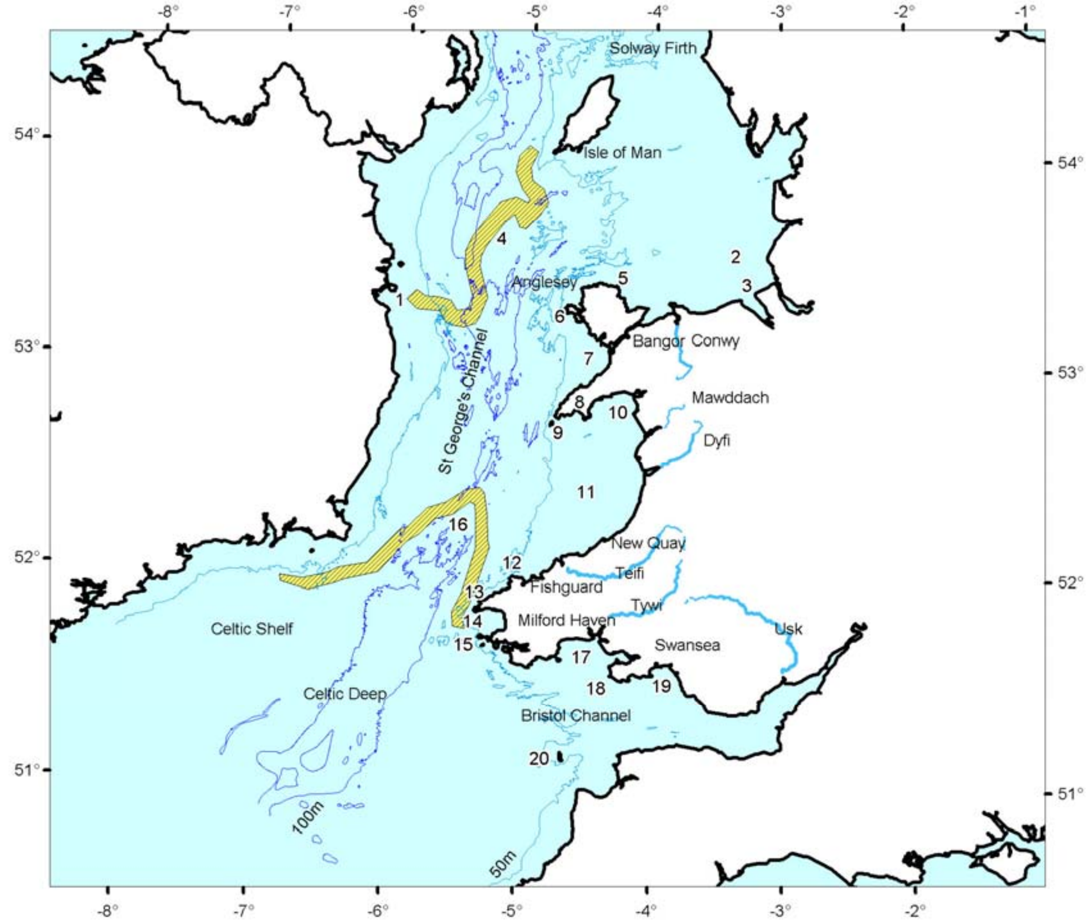


Figure 1b – The Study Area showing the main locations mentioned in the text
[1 = Dublin Bay; 2 = Liverpool Bay; 3 = Hilbre Island; 4 = Western Irish Sea Front; 5 = Point Lynas; 6 = South Stack, Holyhead; 7 = Caernarfon Bay; 8 = Lleyn Peninsula; 9 = Bardsey Island; 10 = Tremadog Bay; 11 = Cardigan Bay; 12 = Strumble Head; 13 = St David's Head; 14 = Ramsey Island; 15 = Skomer Island; 16 = Celtic Sea Front; 17 = Carmarthen Bay; 18 = Gower Peninsula; 19 = Swansea Bay; 20 = Lundy Island]

2.2 Data sources

2.2.1 Vessel Data

Vessel data were received from ten sources. Each data set was first checked to weed out erroneous records. This was achieved by plotting effort legs in GIS, to identify errors such as track lines crossing land. Effort leg distances were calculated from start and end positions and the average speed for each leg was then calculated from the leg duration. Effort records with unrealistically high apparent speeds (> 50 kph), probably caused by errors in entering position data, were removed.

The quantity of useable effort in km travelled is shown in Table 2 for each data contributor, broken down into five-year periods. The overall total amounted to a little over 100,000 km of vessel effort. Further details of the spatial and seasonal distribution of effort and a brief summary of field methods are given below for each data set. All involved dedicated search effort in good viewing conditions by 1-3 observers (usually 2), although for some contributors (notably ESAS), the target group was seabirds and not cetaceans. Eighty-seven percent of all vessel surveys were conducted in sea states of 3 or less. Data from sea states greater than 4 were excluded from all analyses; however, this amounted to only 4% of the available data.

Table 2 – The quantity of vessel effort in km travelled for each contributor [SWF = Sea Watch Foundation database, JNCC = Joint Nature Conservation Committee, IWDG = Irish Whale and Dolphin Group, CBMWC = Cardigan Bay Marine Wildlife Centre, PPS = Pembrokeshire Porpoise Survey, WDCS = Whale and Dolphin Conservation Society, SCAR = Scarweather Sands Survey, MANW = Marine Awareness North Wales, GOWER = Gower Marine Mammal Project; SCANS = Small Cetacean Abundance in the North and Adjacent Seas (July 2005)]

Source	1990-94	1995-99	2000-04	2005-09	Total
SWF	2786	9708	13517	12827	38838
JNCC	16569	12688	349		29606
IWDG			5338	14537	19875
CBMWC				6110	6110
PPS				2735	2735
WDCS		90	831	173	1095
SCAR				866	866
MANW			454	93	548
GOWER				461	461
SCANS	146			125	271
Total	19501	22486	20489	37929	100405

Sea Watch Foundation – SWF

This data set comprised 39% of the total vessel data used and was the only set to cover the entire time period 1990-2009. The SWF database from which this data set was extracted, includes both data collected during surveys carried out by the SWF and data contributed by other organisations and individuals from vessel surveys (including

Eurydice, Friends of Cardigan Bay, Gower Marine Mammal Project, Manx Whale and Dolphin Watch, and West Wales Chartering/Cardigan Bay Marine Wildlife Centre; data sets since 2005 from any of those groups have been separated – see Table 2).

SWF have carried out systematic transect surveys, mainly in Cardigan Bay (Baines *et al*., 2002; Ugarte & Evans, 2006; Pesante *et al*., 2008b) and to the west of Pembrokeshire in the vicinity of the Celtic Deep (Evans *et al*., 2007), as well as photo-identification surveys targeting bottlenose dolphins in which pre-determined transect lines were not necessarily followed (Pesante & Evans, 2008; Pesante *et al*., 2008a). 20% of the SWF data was collected using line transect survey protocols. Approximately 95% of effort was from small vessels with a viewing platform eye-height of 3-4m. The spatial distribution of effort (Figure 2) shows the main concentrations of effort to have been in Cardigan Bay, west and south-west of Pembrokeshire, west and north of Anglesey, and around the Isle of Man, although there is some coverage throughout the study area. The monthly distribution of effort (Figure 3) shows a seasonal bias with the bulk of effort carried out in the five months May to September.

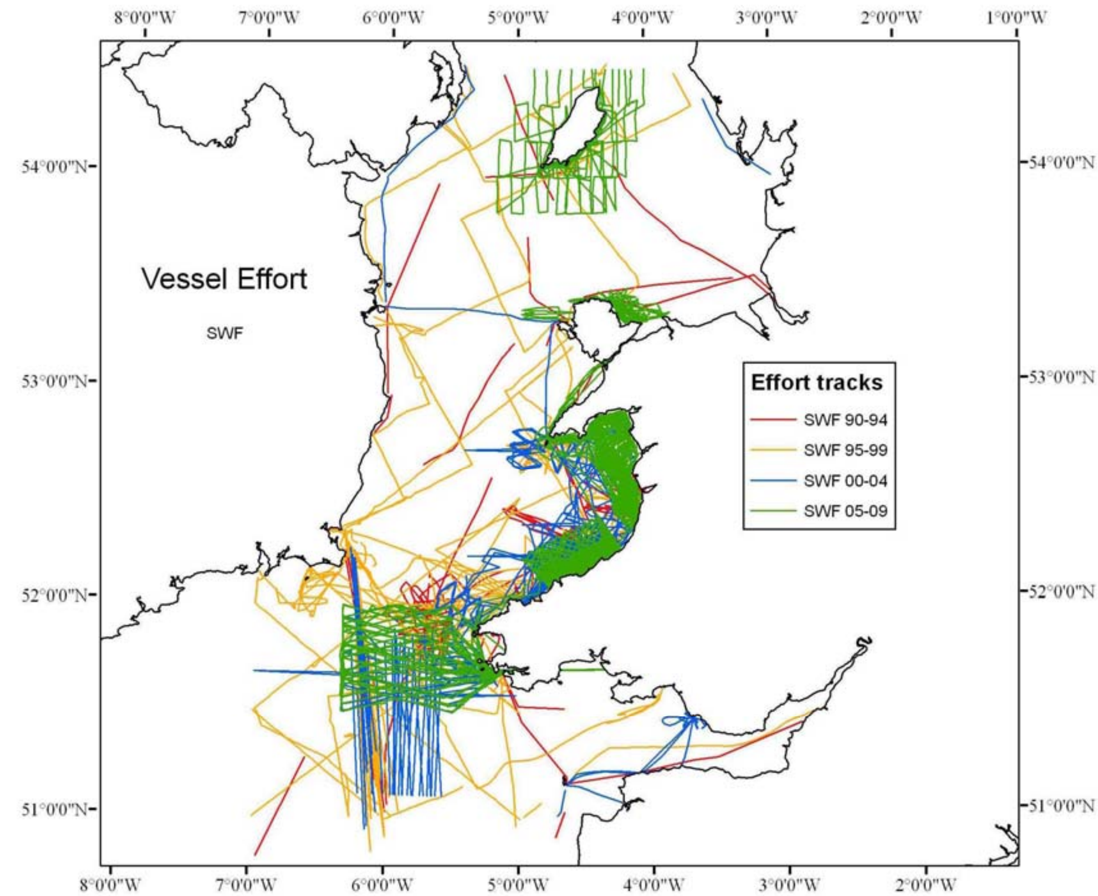


Figure 2 – Spatial distribution of vessel effort contributed by the Sea Watch Foundation database

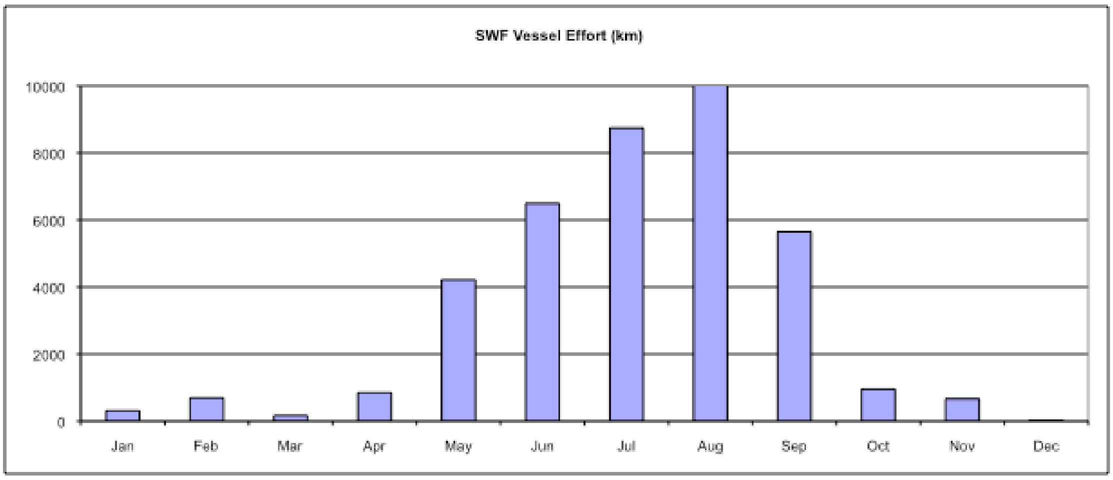


Figure 3 – Seasonal distribution of vessel effort contributed by the Sea Watch Foundation database

Joint Nature Conservation Committee – JNCC

This data set comprised 29% of the total vessel data used. The data were collected on larger vessels with a viewing platform eye-height >5m, following the European Seabirds at Sea (ESAS) protocol (Tasker *et al*., 1984; Webb & Durinck, 1992; Camphuysen *et al*., 2004). This differs from the field methods used by the other data contributors in being a strip transect method, with the main target taxa being seabirds. Some 99% of effort dated from before 2000. In the period 1990-94 most effort was on the Welsh side of the median line with Ireland, the reverse being true in the period 1995-99 (Figure 4). The seasonal distribution of effort (Figure 5) shows a clear summer peak, but moderate levels of effort were maintained throughout the year.

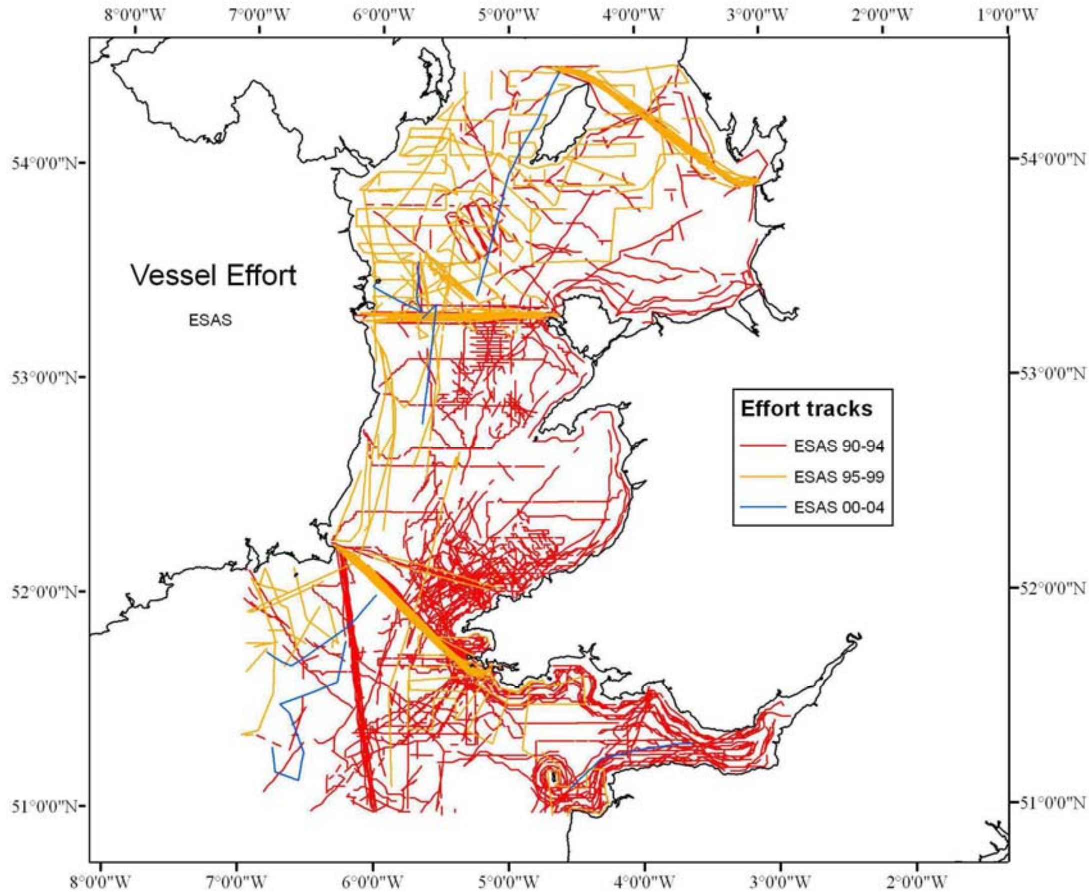


Figure 4 – Spatial distribution of vessel effort contributed by JNCC (ESAS)

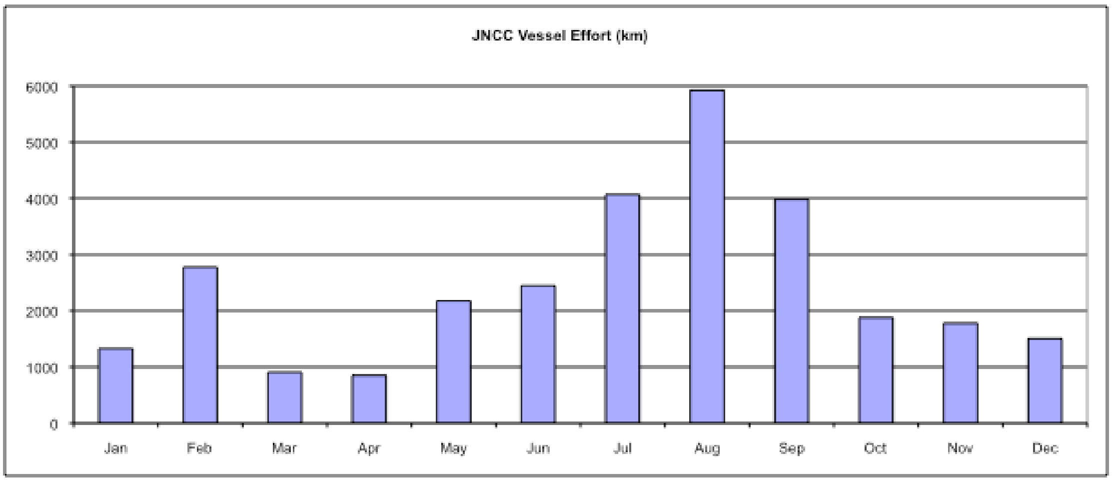


Figure 5 – Seasonal distribution of vessel effort contributed by JNCC (ESAS)

Irish Whale and Dolphin Group – IWDG

This data set comprised 20% of the total vessel effort. Approximately 75% of this effort was collected by observers on ferries (15-20m eye-height), with 25% from transects carried out on research vessels. The spatial distribution of effort (Figure 6) shows concentrations of effort along ferry routes and a tendency for research surveys to be located predominantly in the northern part of the study area. The seasonal distribution of effort (Figure 7) does have a summer bias, but with relatively high levels of effort maintained throughout the year.

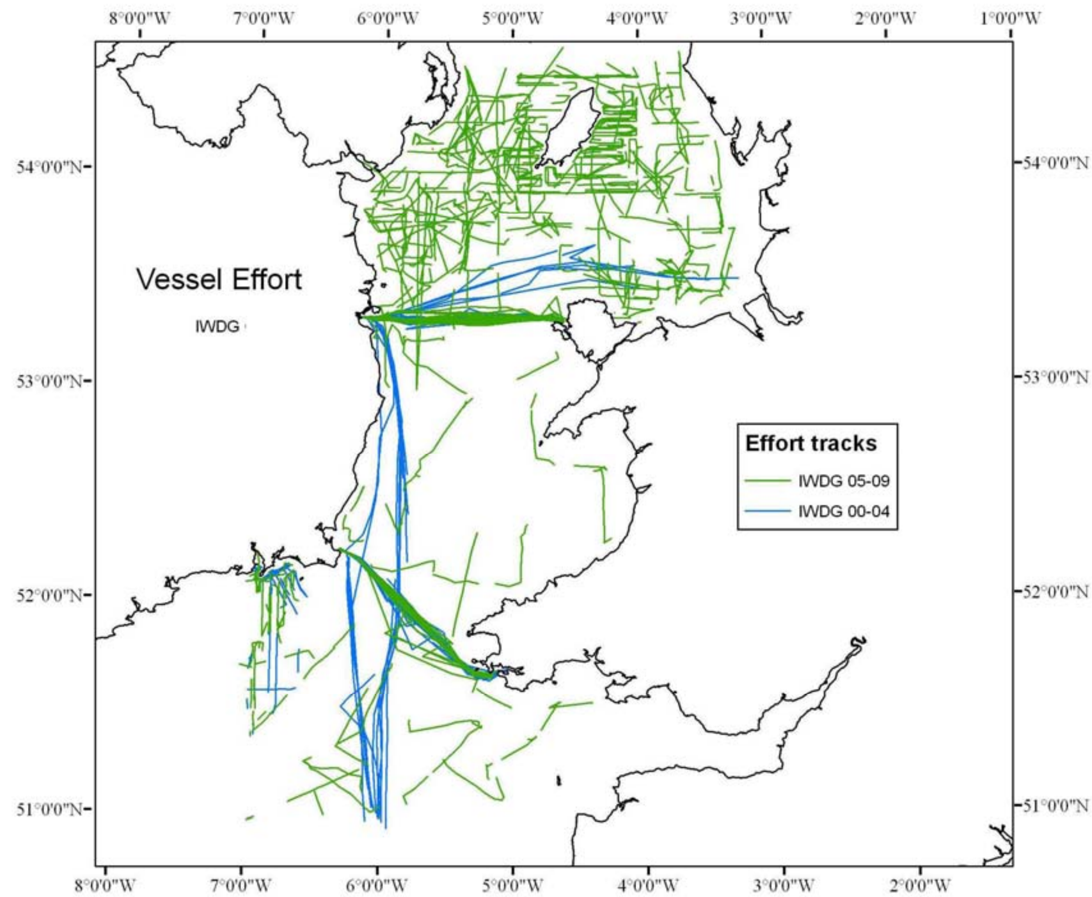


Figure 6 – Spatial distribution of vessel effort contributed by IWDG

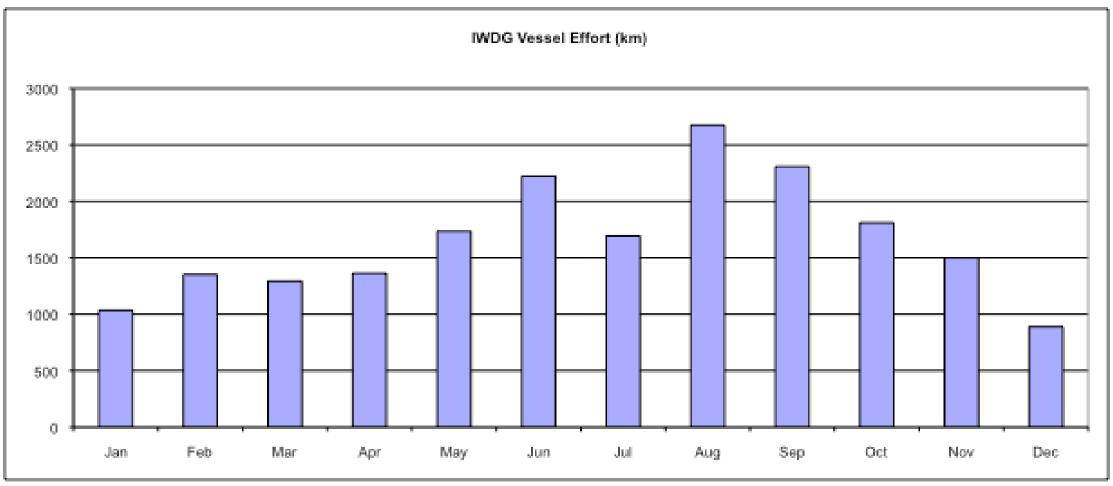


Figure 7 – Seasonal distribution of vessel effort contributed by IWDG

Cardigan Bay Marine Wildlife Centre – CBMWC

Cardigan Bay Marine Wildlife Centre operates a small boat (3m eye-height) service based in New Quay, taking tourists to view the scenery and wildlife of the immediate area, although some research surveys are also undertaken. Nearly all effort was from within the Cardigan Bay SAC (Figure 8). Some 59% of effort was during tourist trips, with 14% from line transect surveys, and 26% from other dedicated surveys, including photo-identification surveys of bottlenose dolphins. The seasonal distribution of effort (Figure 9) shows a strong seasonal bias coinciding with the summer tourist season.

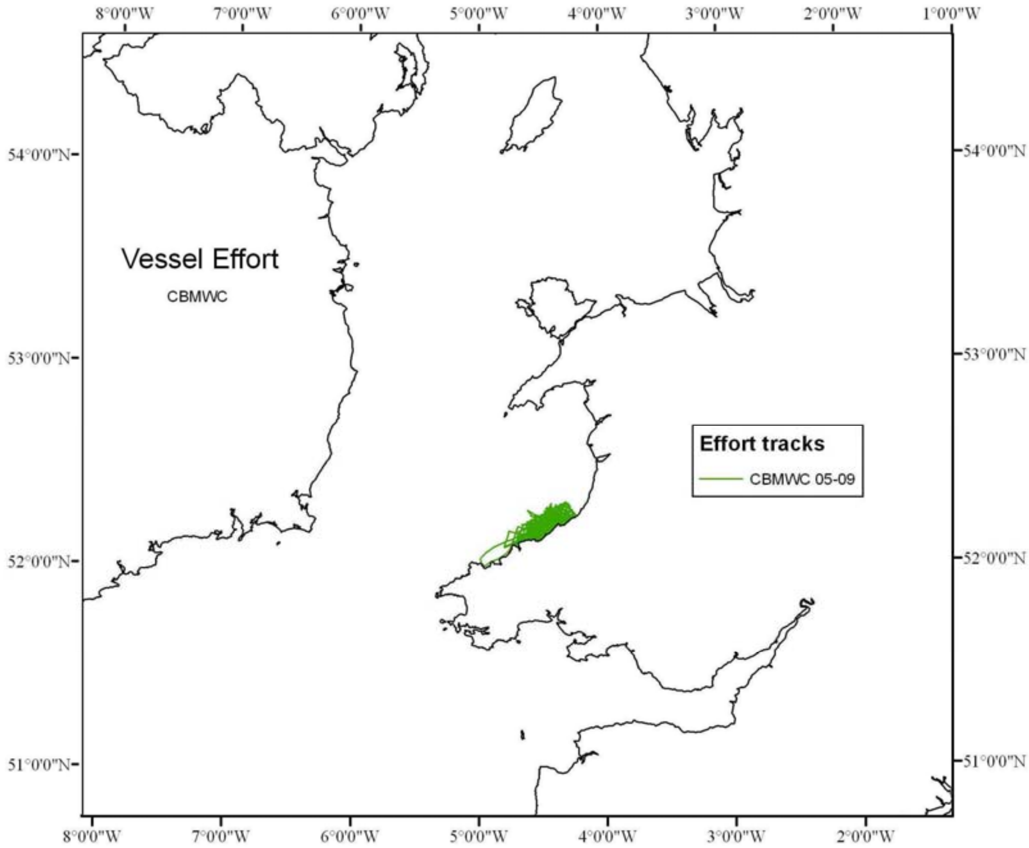


Figure 8 – Spatial distribution of vessel effort contributed by CBMWC

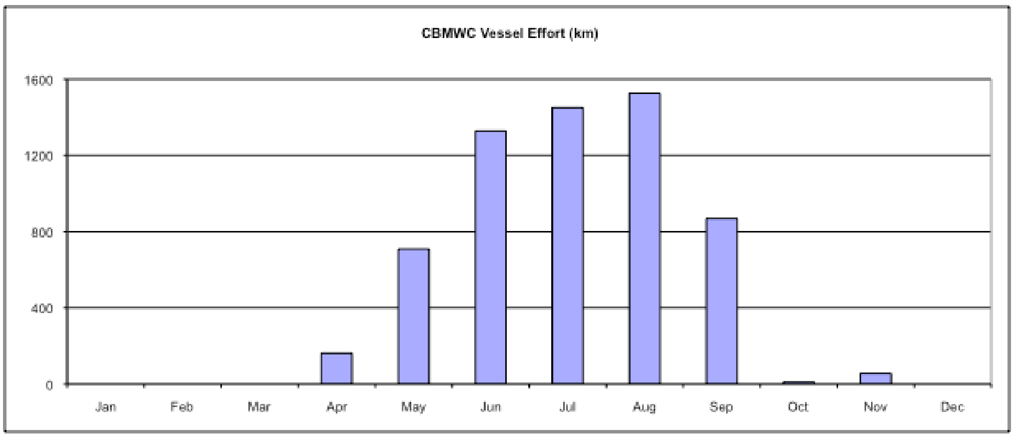


Figure 9 – Seasonal distribution of vessel effort contributed by CBMWC

SWF Pembrokeshire Porpoise Survey – PPS

This was a small-boat (RIB, 2m eye-height) transect survey carried out by Sea Watch Foundation off west Pembrokeshire in the years 2007 and 2008 with all effort in the vicinity of the Pembrokeshire islands to the west of Milford Haven (Isojunno & Evans, 2008; Isojunno *et al*., 2012; Figure 10). The surveys were carried out within a short season between July and September (Figure 11).

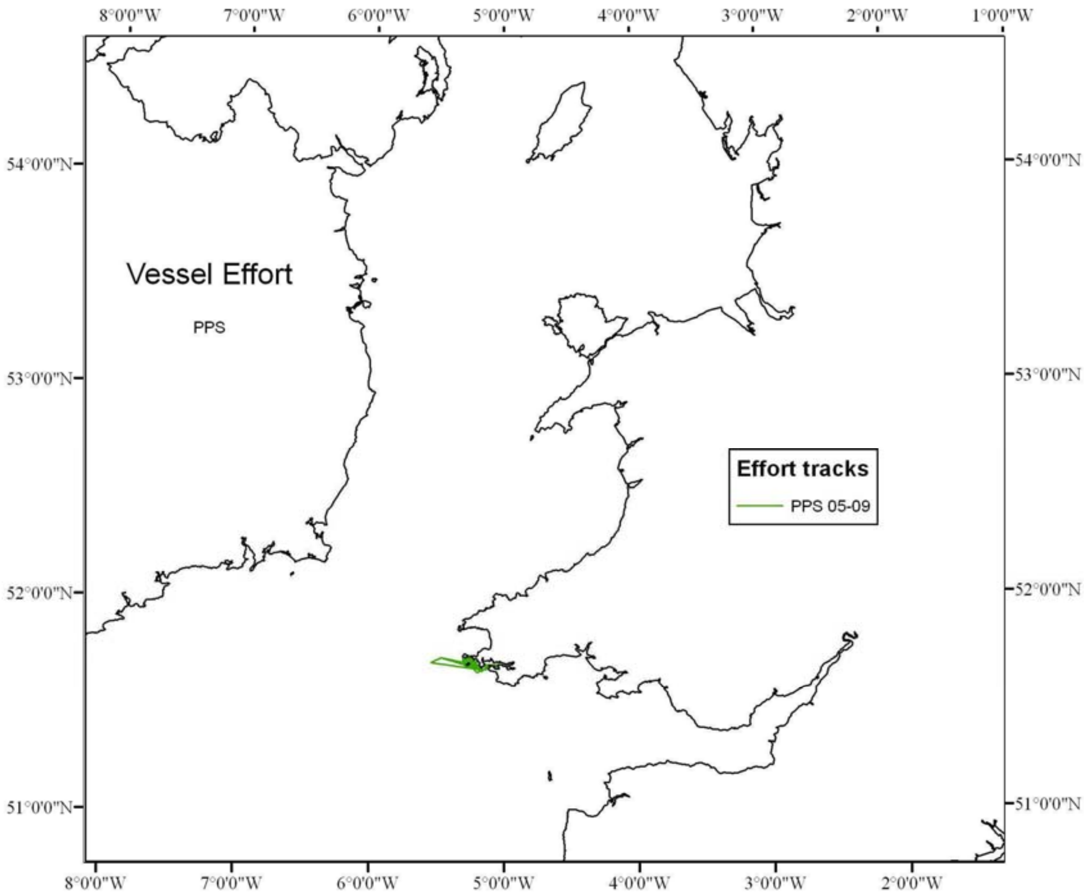


Figure 10 – Spatial distribution of vessel effort contributed by PPS

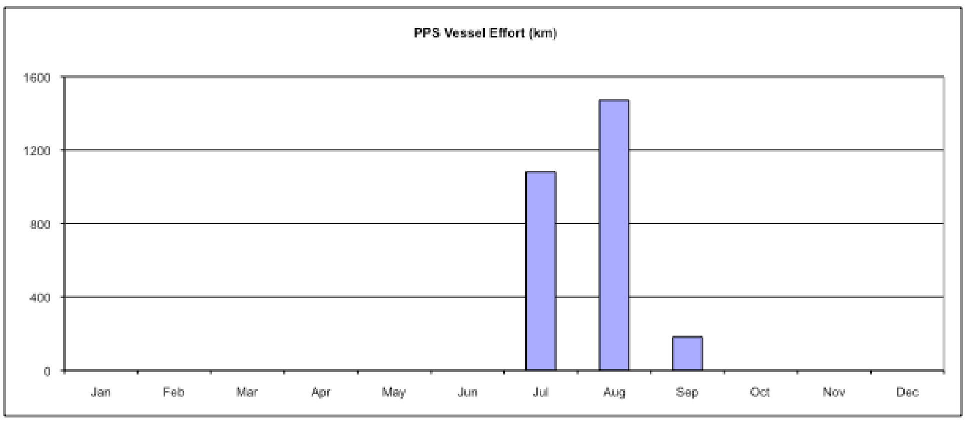


Figure 11 – Seasonal distribution of vessel effort contributed by PPS

Whale and Dolphin Conservation Society – WDCS

The WDCS data were recorded during small boat (2.5-3m eye-height) surveys carried out in the vicinity of Bardsey Island and the Lleyn Peninsula in the period 1999-2007 (WDCS Science Team, 2002, 2005, 2006; Figure 12). The majority of effort was confined to a short field season between July and September, with some further effort in April (Figure 13).

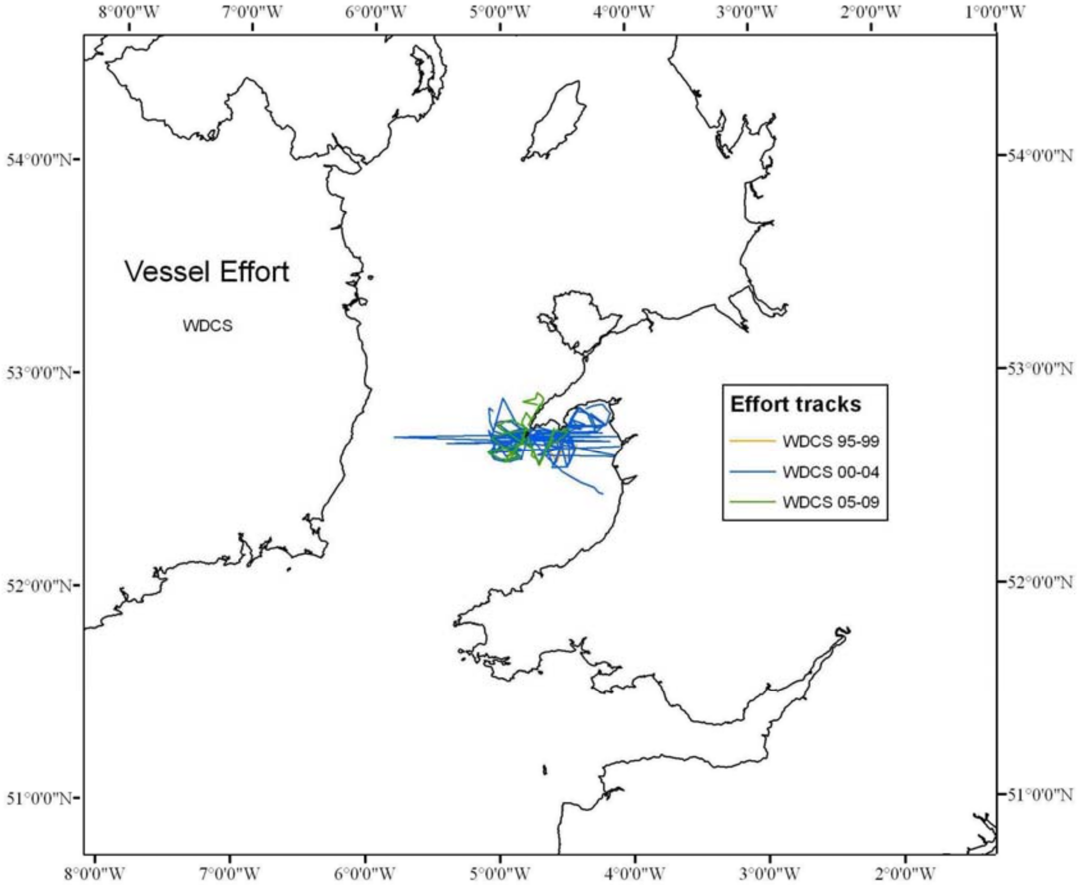


Figure 12 – Spatial distribution of vessel effort contributed by WDCS

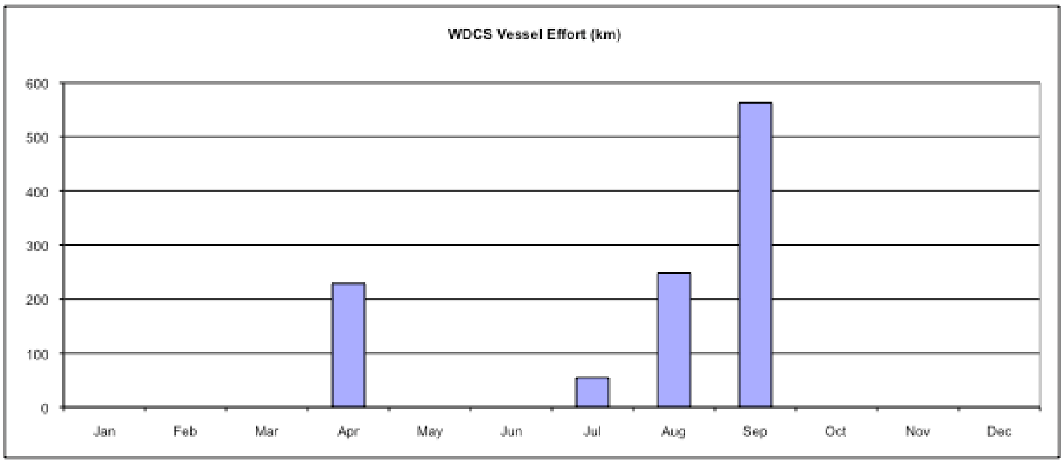


Figure 13 – Seasonal distribution of vessel effort contributed by WDCS

Scarweather Sands Surveys – SCAR

This data set supplied by E-ON UK was collected by Eurydice (Chris Pierpoint) during combined visual and acoustic transect surveys from a small boat (3m eye-height) at the site of a proposed wind farm. The surveys were confined to a relatively small area off the south coast of the Gower Peninsula (Figure 14) in 2005-07. The seasonal distribution of effort (Figure 15) shows an attempt to maintain consistent levels of effort in each month, although this was not possible in January, March and November.

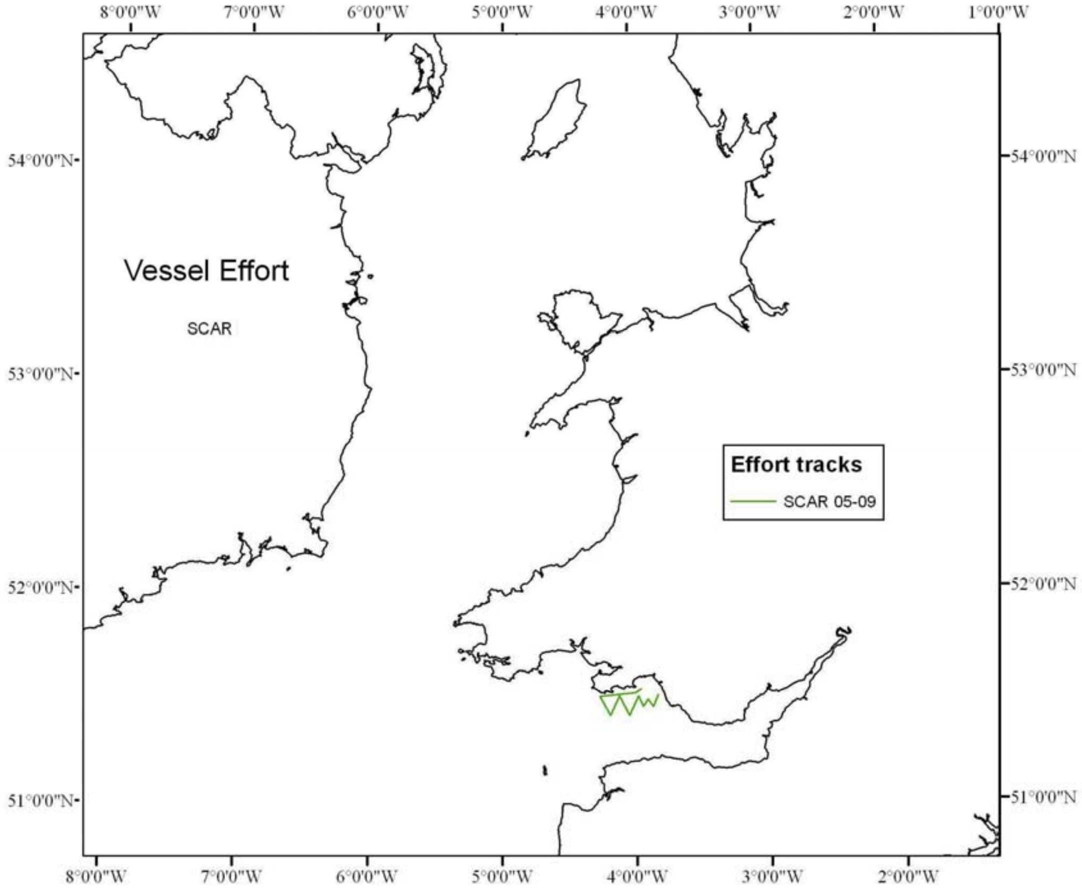


Figure 14 – Spatial distribution of vessel effort contributed by E-ON UK (SCAR)

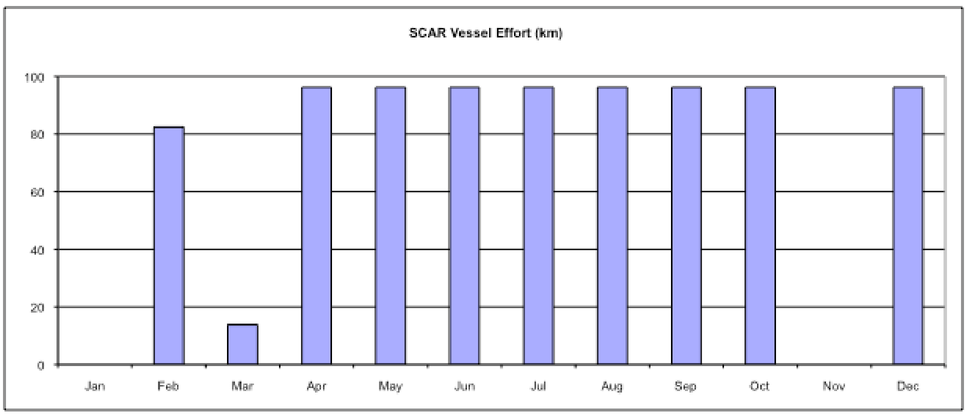


Figure 15 – Seasonal distribution of vessel effort contributed by E-ON UK (SCAR)

Marine Awareness North Wales - MANW

MANW provided data from small boat (2.5m eye-height) transects carried out off the north coast of Anglesey over the period 2002-08 (Jones *et al*., 2005; Shucksmith *et al*., 2009; Figure 16). The seasonal distribution of effort (Figure 17) shows that effort was confined to two periods of the year, from April to May, and from July to September.

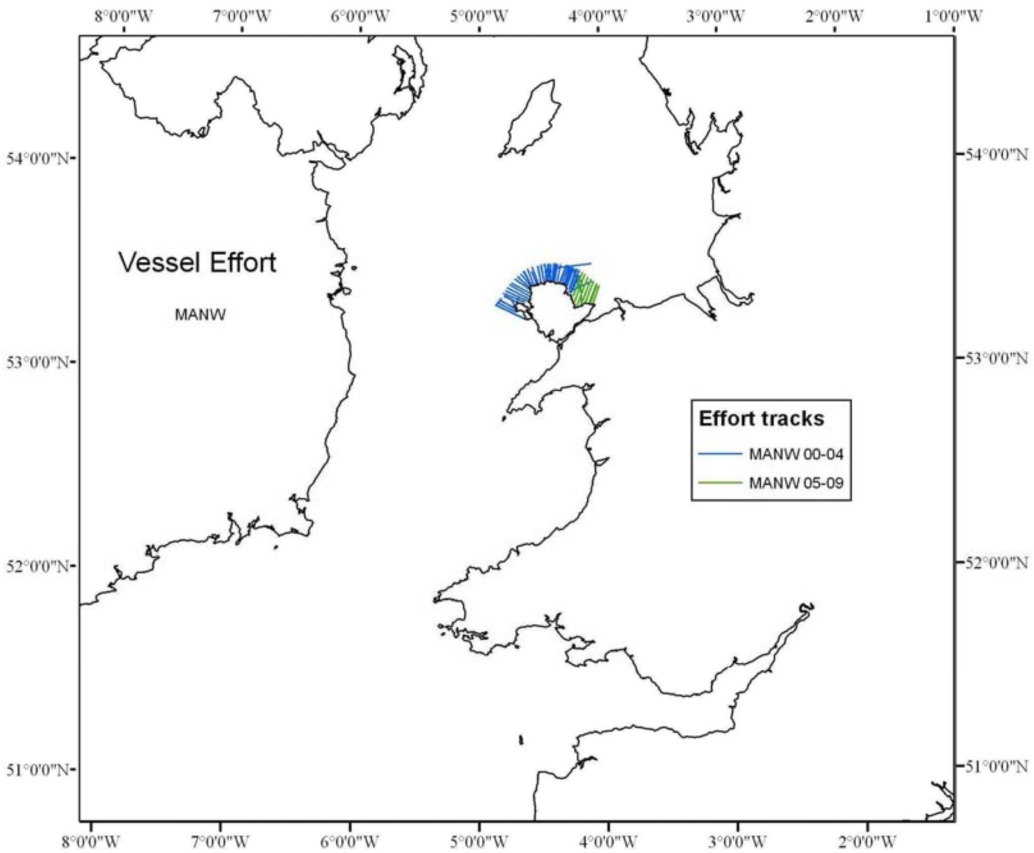


Figure 16 – Spatial distribution of vessel effort contributed by MANW

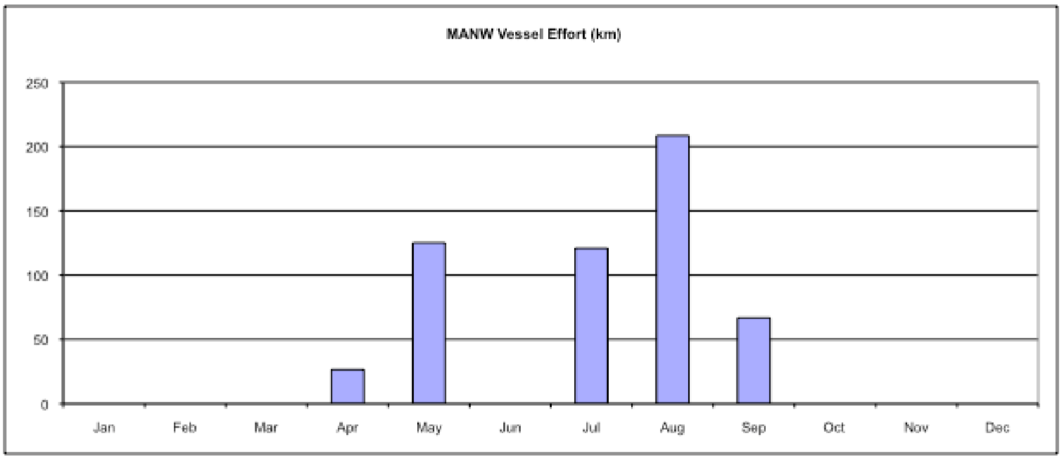


Figure 17 – Seasonal distribution of vessel effort contributed by MANW

Gower Marine Mammal Project – GOWER

The Gower Marine Mammal Project provided small vessel (3m eye-height) data collected from an area off the mouth of the Bristol Channel, between the Gower Peninsula and Lundy Island (Figure 18). The seasonal distribution of effort (Figure 19) was between April and September, with a small amount of effort in December.

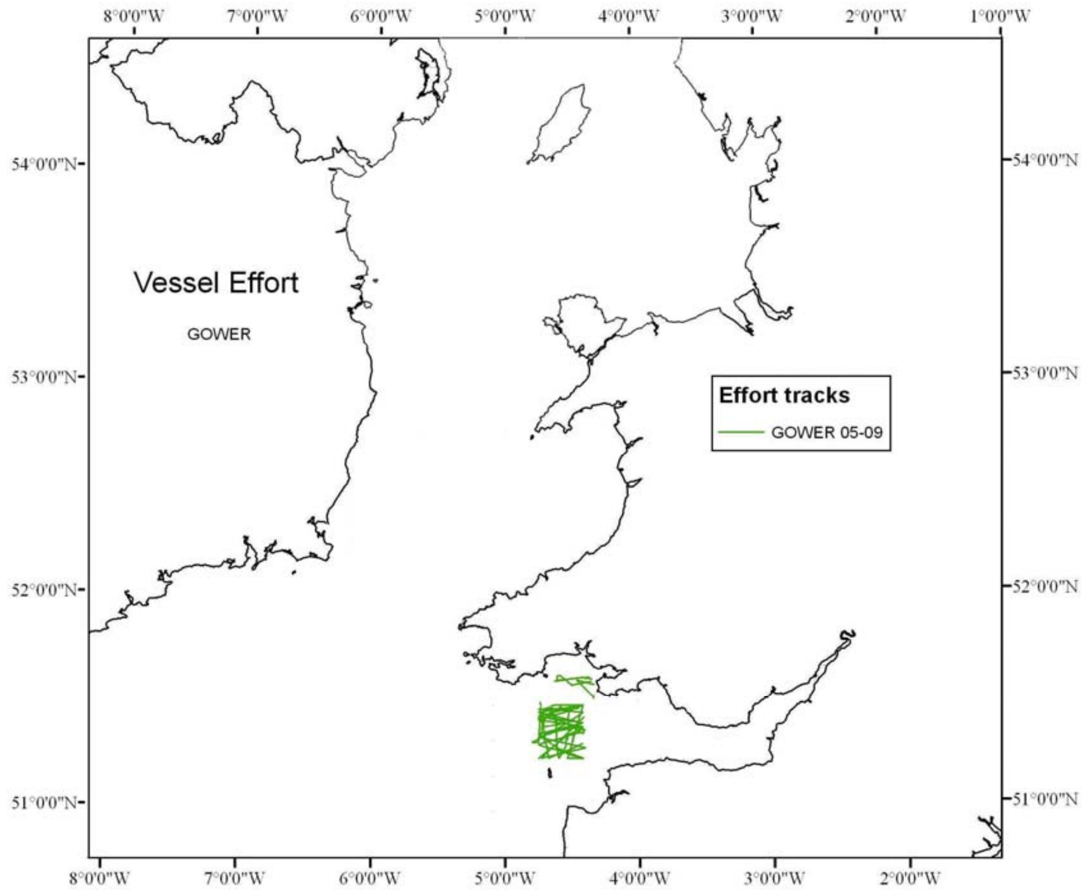


Figure 18 – Spatial distribution of vessel effort contributed by GOWER

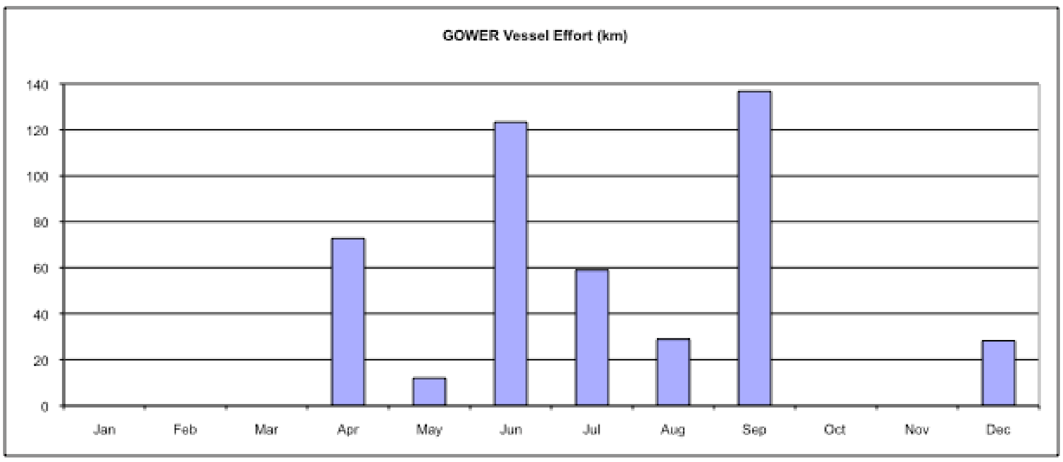


Figure 19 – Seasonal distribution of vessel effort contributed by GOWER

Small Cetacean Abundance in the North Sea - SCANS

The SCANS survey took place in 1994 (Hammond *et al*., 1995, 2002). These were line transect surveys in larger vessels (>5m eye-height) using dual platforms: a primary platform and an independent tracker platform. However, in order to maintain compatibility with other line transect data sets used in this Atlas, only the primary platform data have been used here. Although these were large-scale surveys, a total of only 271 km of vessel transects passed through the study area (southern edge), collected entirely within the month of July (Figure 21).

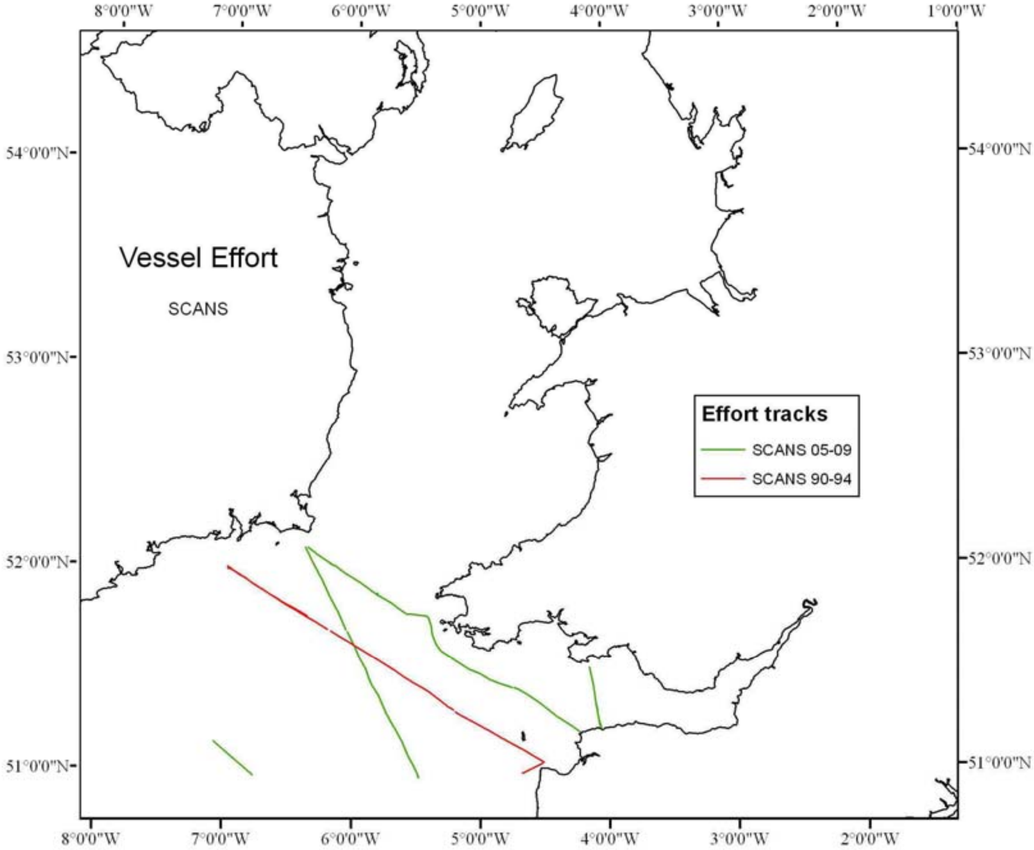


Figure 20 – Spatial distribution of vessel effort contributed by SCANS

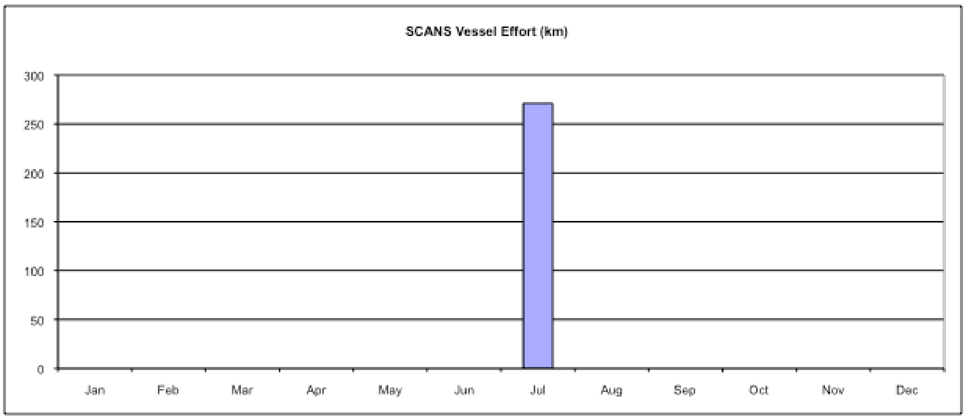


Figure 21 – Seasonal distribution of vessel effort contributed by SCANS

2.2.2 Aerial Data

Aerial data were received from three sources, spanning the period 2001-09. In each case the data sets extended beyond the boundaries of the Atlas study area, so the extra-limital data were removed and the same checks applied for errors as with vessel data. The resulting quantities of effort from each source are listed in Table 3, with further summary information, including the spatial distribution of effort for each source below. Note that in Table 3, the Wildfowl and Wetlands Trust (WWT) data have been split into two sets, corresponding to the starboard and port viewing platforms, which operated independently.

Table 3 – The quantity of aerial effort in km travelled for each contributor [WWT = Wildfowl and Wetlands Trust, S = starboard, P = port platform. JELLY = Swansea University jellyfish and megafauna surveys. SCANS = Small Cetacean Abundance in the North and Adjacent Seas]

Source	1990-94	1995-99	2000-04	2005-09	Total
WWT (S)			15198	40419	55616
WWT (P)			15631	39808	55439
JELLY			2003	616	2619
SCANS				1952	1952
Total	0	0	32831	82795	115626

Wildfowl and Wetlands Trust – WWT

The WWT aerial surveys were flown primarily to count marine waterbirds and seabirds at sea in UK waters, where coverage was systematic and comprehensive WWT Consulting, 2009; Figure 22). Both effort and cetacean sightings data were recorded independently by port and starboard observers, and so these data sets have been analysed separately, giving an overall total of 111,055 km of effort, or 96% of the total aerial effort contributed. The seasonal distribution of effort (Figure 23) was spread throughout the year, with peaks in both summer and winter, although effort was low in April, September and October.

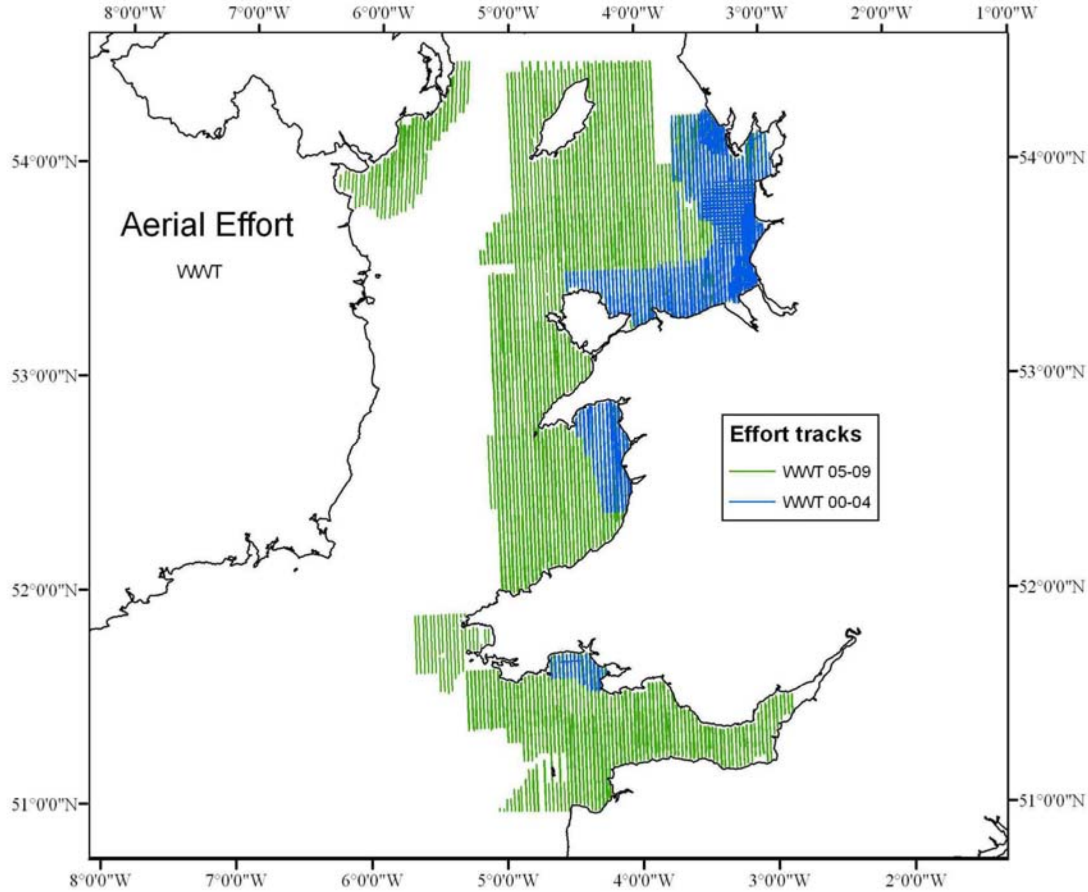


Figure 22 – Spatial distribution of aerial effort contributed by WWT

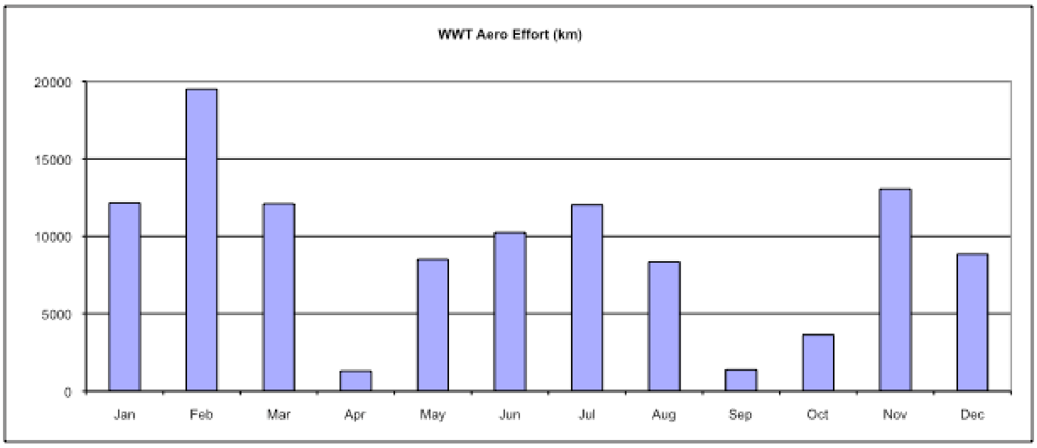


Figure 23 – Seasonal distribution of aerial effort contributed by WWT

University of Swansea Jellyfish and Marine Megafauna Surveys – JELLY

These aerial surveys were flown primarily to investigate the distribution of the jellyfish prey of leatherback turtles (Houghton & Hays, 2006; Houghton *et al*., 2006a, b). Coverage included the coast of Wales as well as offshore areas between Wales and Ireland (Figure 24). The surveys were carried out in 2004 and 2005 (Table 3). The seasonal distribution of effort (Figure 25) showed a pronounced bias with all data collected in the period June to September.

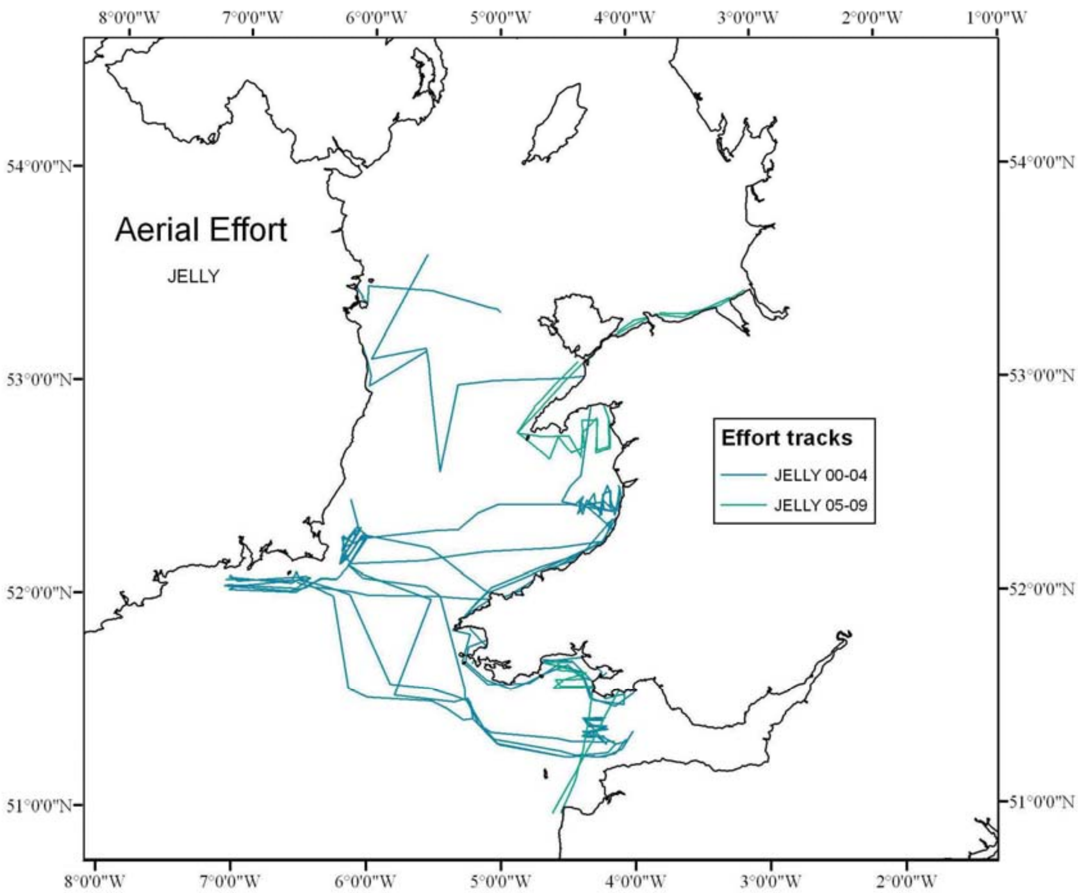


Figure 24 – Spatial distribution of aerial effort contributed by the University of Swansea

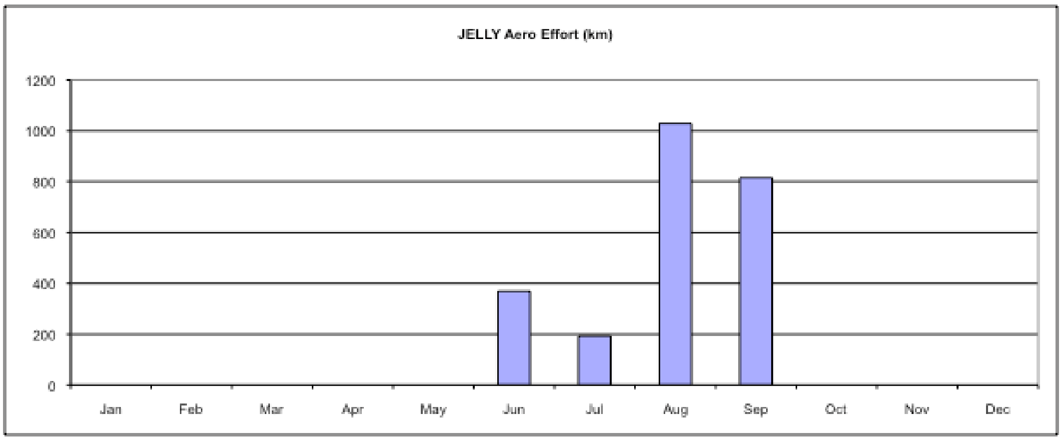


Figure 25 – Seasonal distribution of aerial effort contributed by the University of Swansea

Small Cetacean Abundance in the North Sea – SCANS II

The SCANS II survey in July 2005 included aerial coverage of the Irish Sea (Hammond, 2008; Figure 26); there was no overlap between this and SCANS vessel effort. A systematic line transect design was implemented that gave even coverage across the area to the north of St David's Head with a total track distance of 1952 km. The SCANS surveys were all carried out in July (Figure 27).

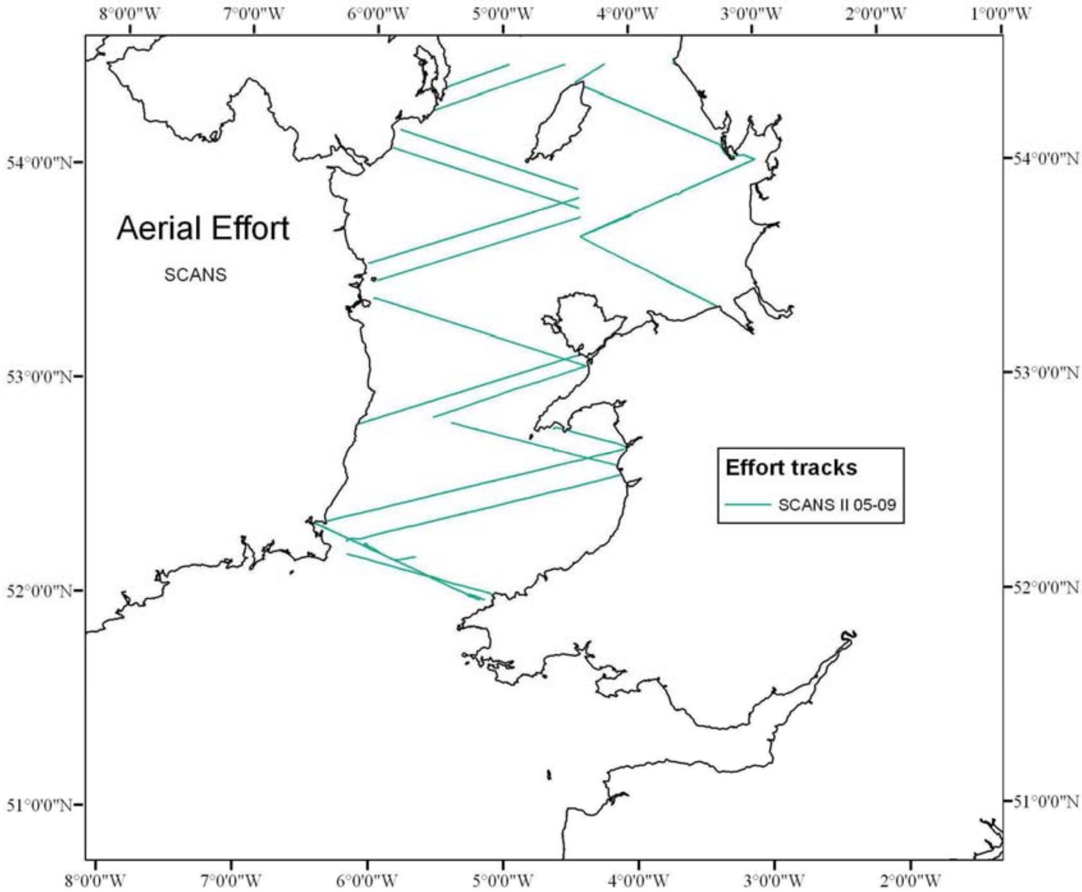


Figure 26 – Spatial distribution of aerial effort contributed by SCANS II

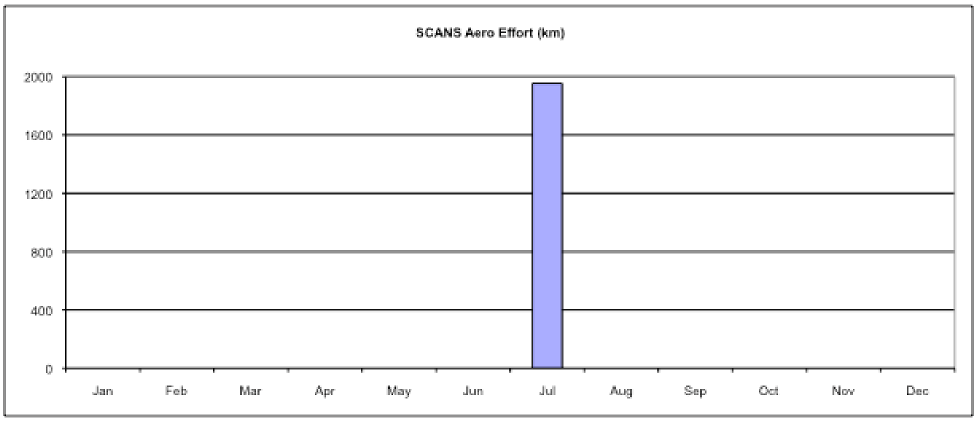


Figure 27 – Seasonal distribution of aerial effort contributed by SCANS II

2.2.3 Land-based Data

Land-based data were received from six sources, although one of these, the SWF database, includes data from a number of other individuals and organisations. Summary information on the temporal distribution of these data sets is given in Table 4 and the location and seasonal distribution of effort is summarised for each contributor below.

Table 4 – The amount of land-based effort in observation hours, for each contributor [SWF = Sea Watch Foundation database, CCC = Ceredigion County Council, MANW = Marine Awareness North Wales, WDCS = Whale and Dolphin Conservation Society, GOWER = Gower Marine Mammal Project, NWP = RWE nPower]

Source	1990-94	1995-99	2000-04	2005-09	Total
SWF	1365	598	782	795	3540
CCC		2010	1487	1071	4568
MANW			977	1330	2307
WDCS			1359	1048	2407
GOWER		312	195		506
NWP			71		71
Total	1365	2920	4871	4244	13399

Sea Watch Foundation – SWF

This was the only land-based data set to span the entire period from 1990-2009, with a total of 3,540 hours of effort (Table 4). It includes data from a relatively large number of individual observers with a spatial distribution covering the entire coastline of Wales, England and the Isle of Man within the study area (Figure 28). The seasonal distribution of effort shows a strong bias towards the summer months, with a peak in August and relatively few data between November and March (Figure 29).

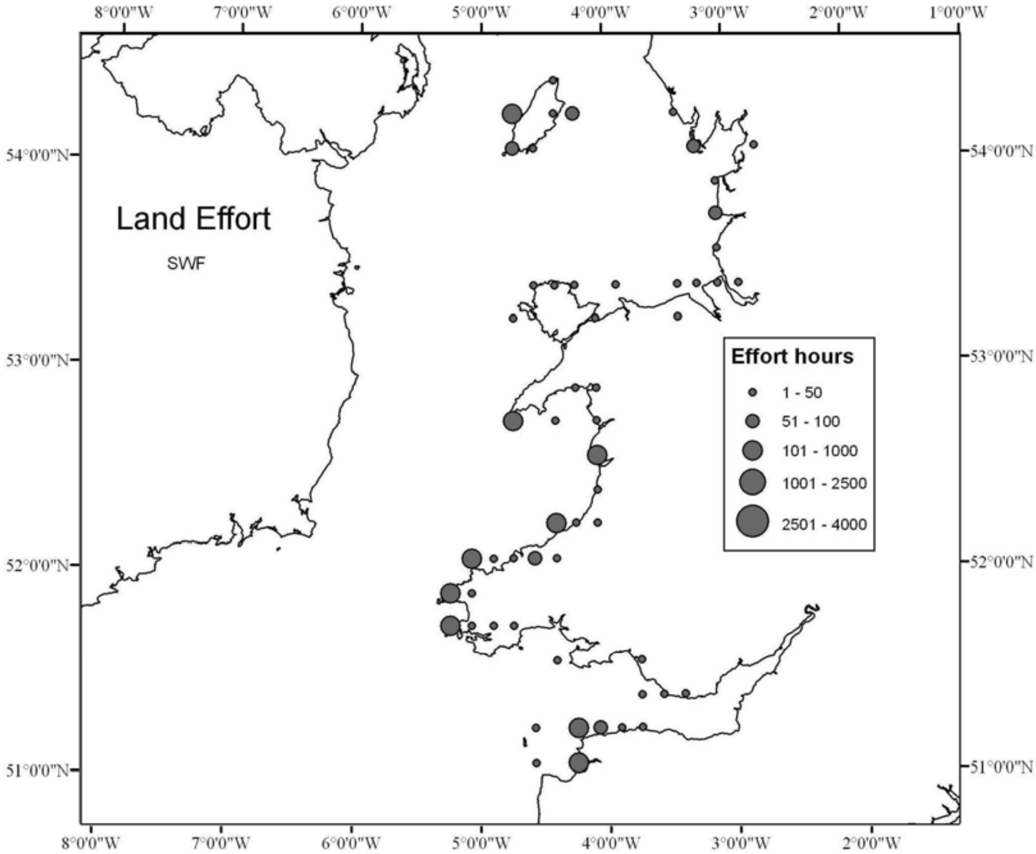


Figure 28 – Spatial distribution of land-based effort contributed by the Sea Watch Foundation database

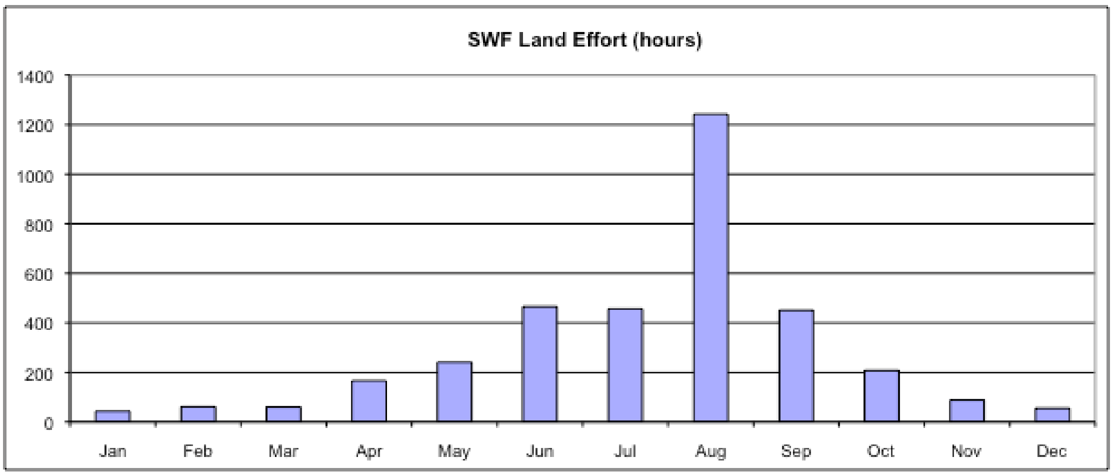


Figure 29 – Seasonal distribution of land-based effort contributed by the Sea Watch Foundation database

Ceredigion County Council – CCC

This is the largest land-based data set with over 4500 hours of observation (Pierpoint *et al*., 2009; Table 4) from a series of locations between Aberystwyth and Cardigan

(Figure 30). The watches carried out under the auspices of the Ceredigion County Council (CCC) had the aim of monitoring bottlenose dolphins in the Ceredigion Heritage Coastal zone and investigating potential anthropogenic impacts on the dolphins, especially from boats.

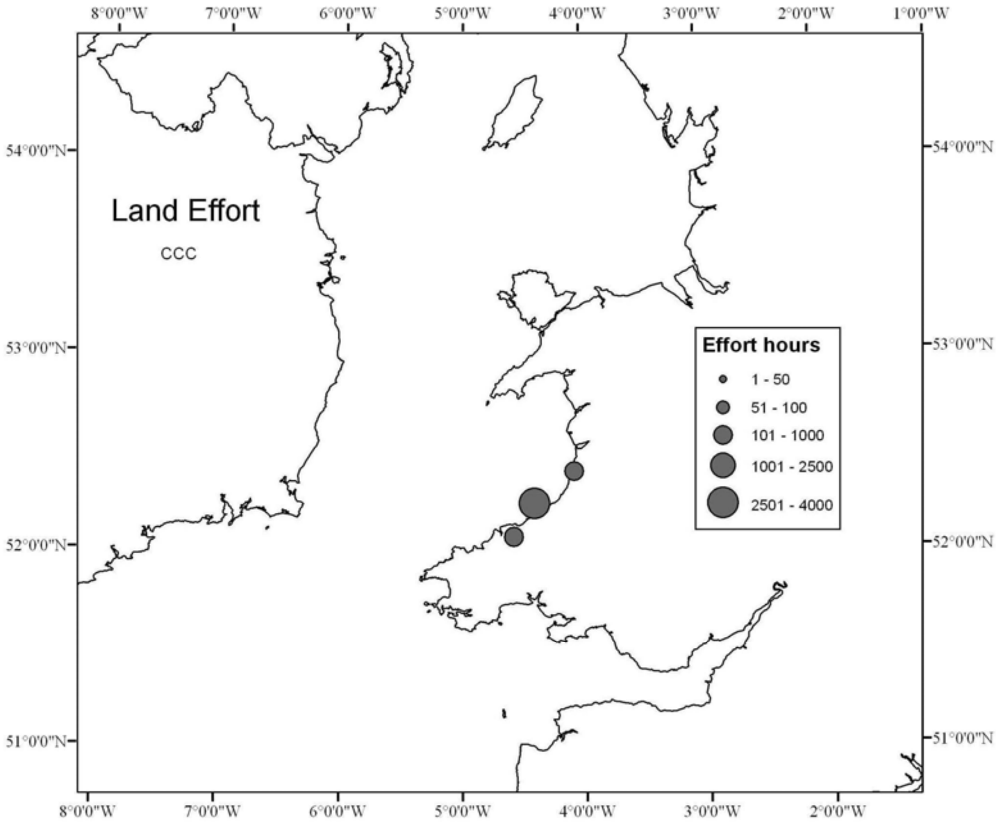


Figure 30 – Spatial distribution of land-based effort contributed by CCC

Other species were recorded, but not with the same rigour, so that group size information was collected only for bottlenose dolphins. Hence these data have been used in this Atlas only for the calculation of land based sighting rates for bottlenose dolphins and have been excluded from analyses of harbour porpoise sighting rates. Surveys were carried out exclusively between May and September (Figure 31).

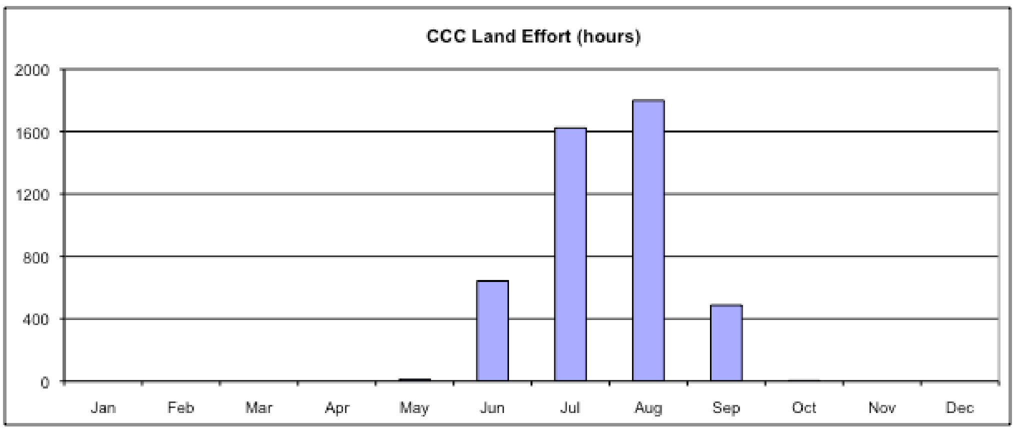


Figure 31 – Seasonal distribution of land-based effort contributed by CCC

Marine Awareness North Wales – MANW

Marine Awareness North Wales (MANW) provided both timed watch and scan sampling data amounting to 2,307 effort hours (Table 4) from the coast of Anglesey (Figure 32) during the period 2001-08. The seasonal distribution of data (Figure 33) shows effort spread throughout the year with a peak in August.

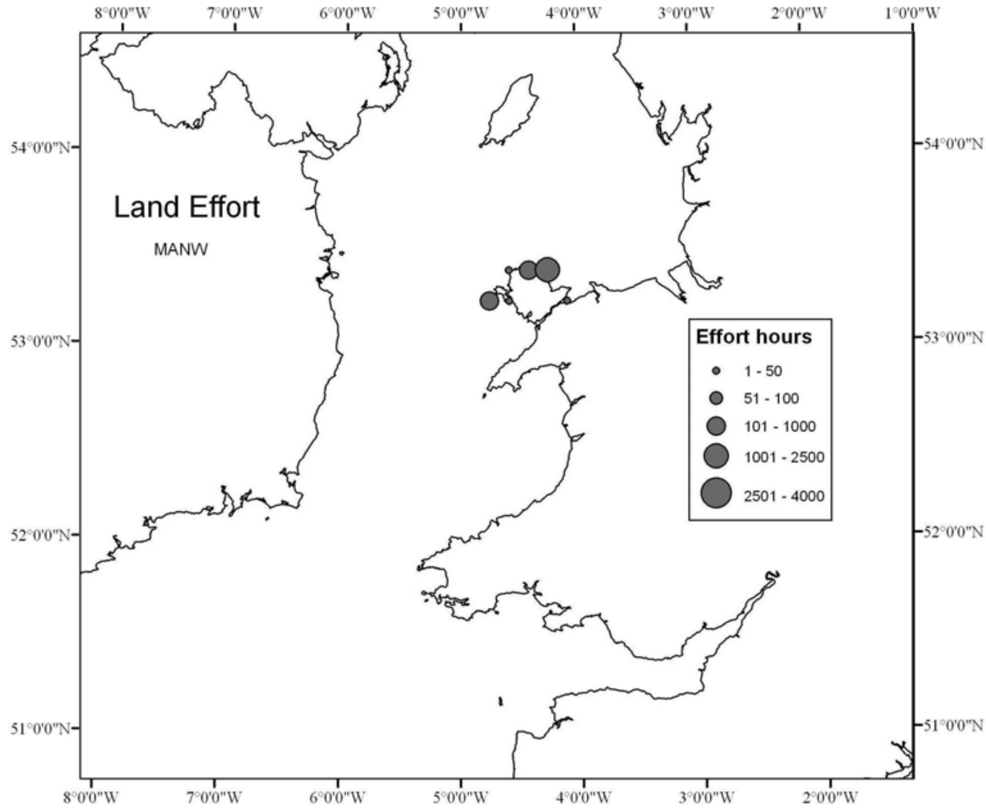


Figure 32 – Spatial distribution of land-based effort contributed by MANW

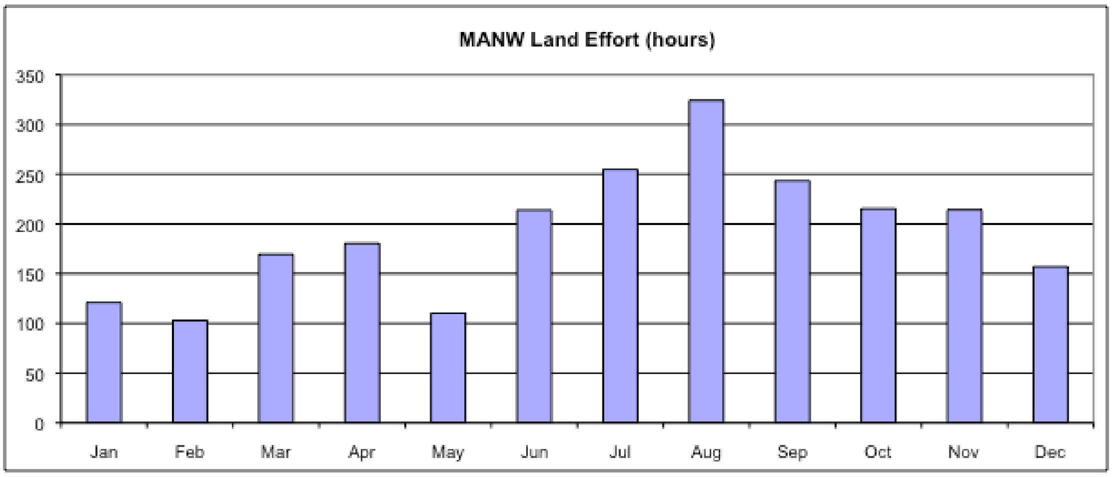


Figure 33 – Seasonal distribution of land-based effort contributed by MANW

Whale and Dolphin Conservation Society – WDCS

The Whale and Dolphin Conservation Society (WDCS) provided 2407 hours of land-based effort data (Table 4), mainly from Bardsey Island (WDCS Science Team, 2002, 2005, 2006; Figure 34). Their main target species were Risso's dolphin and harbour porpoise, although other species were also recorded. The seasonal distribution of effort (Figure 35) shows some effort in April and May, but the majority in July to September.

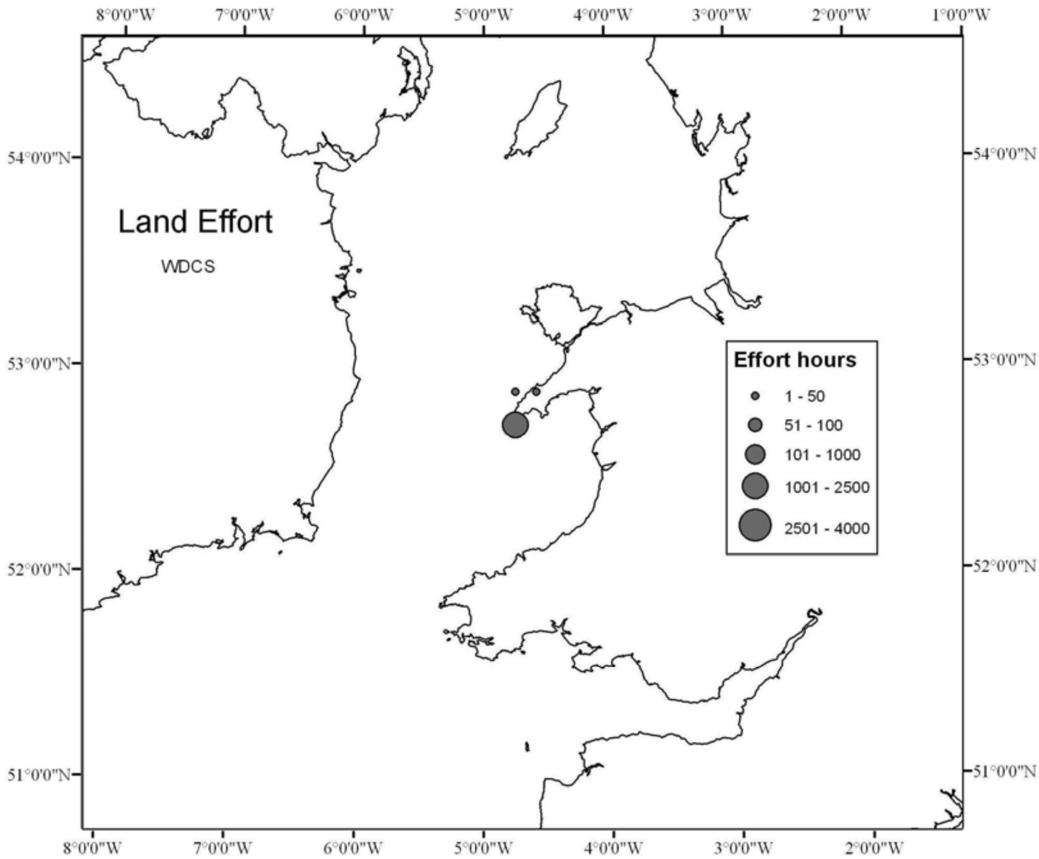


Figure 34 – Spatial distribution of land-based effort contributed by WDCS

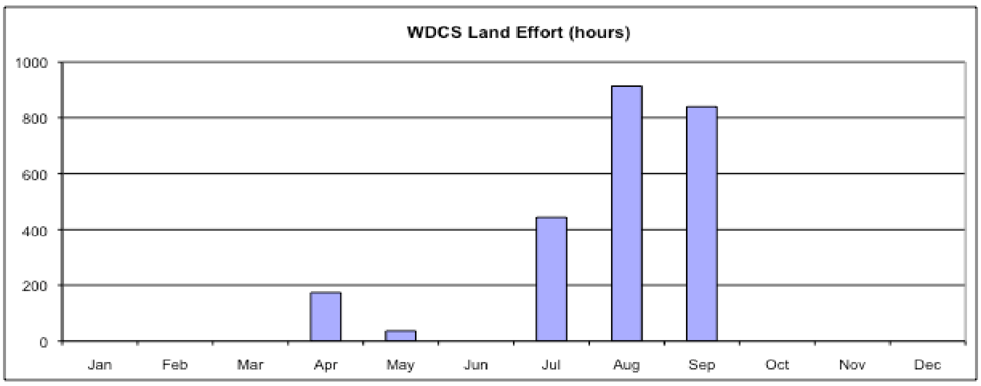


Figure 35 – Seasonal distribution of land-based effort contributed by WDCS

Gower Marine Mammal Project – GOWER

Gower Marine Mammal Project contributed a total of 506 hours of scan sampling data from the Gower Peninsula (Gower Marine Mammal Group; Figure 36). Effort was distributed throughout the year (Figure 37) with a tendency to be higher in the summer months, apart from June.

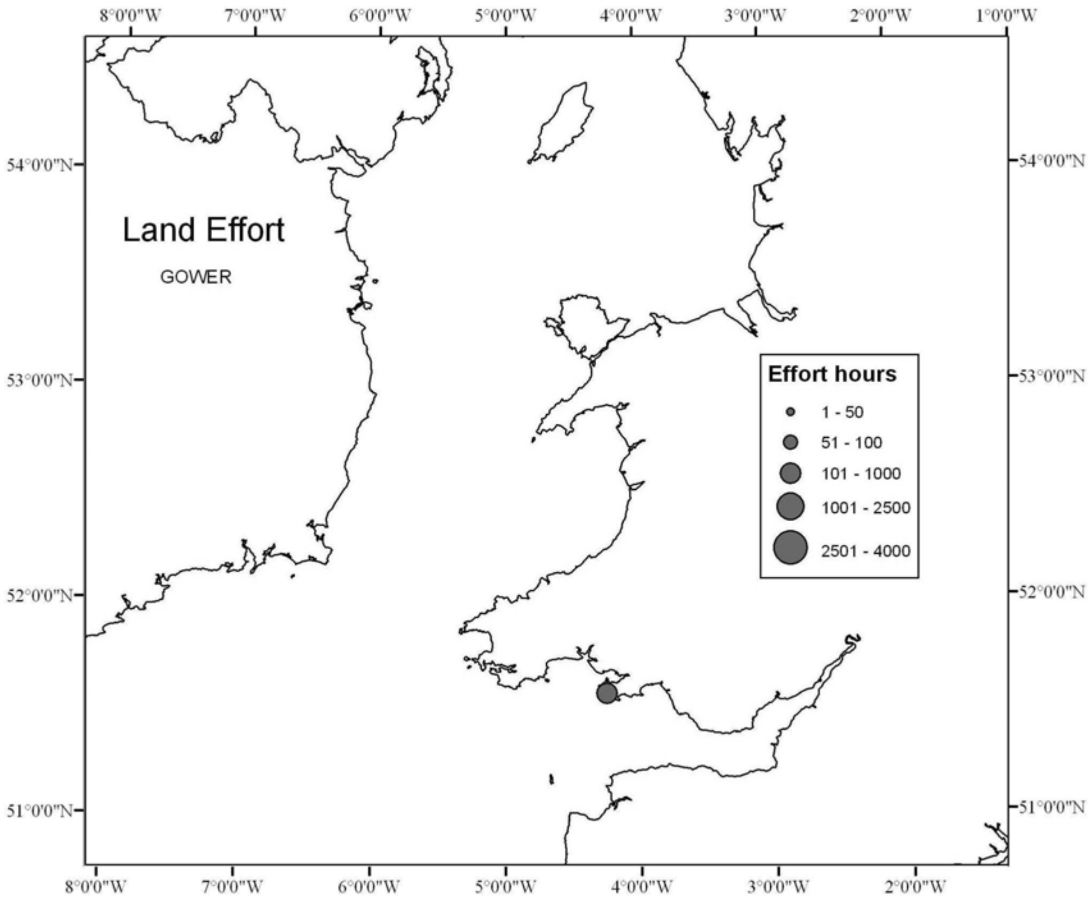


Figure 36 – Spatial distribution of land-based effort contributed by GOWER

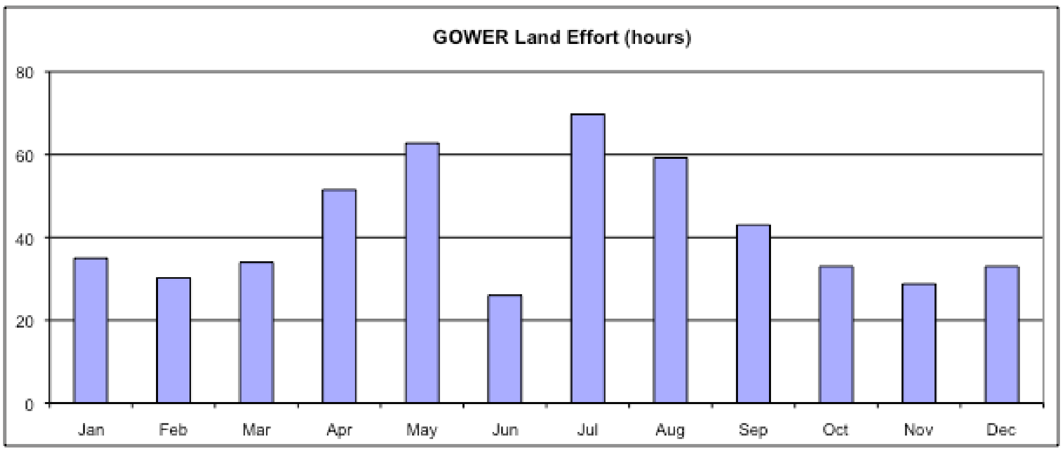


Figure 37 – Seasonal distribution of land-based effort contributed by GOWER

Northern Wind Power – NWP

A set of scan sampling data amounting to 71 hours of observation carried out at the proposed site of a wind farm off the North Wales coast (Figure 38) was contributed by Dr John Goold (at the time, based at Bangor University). The spatial distribution of effort is depicted in Figure 39.

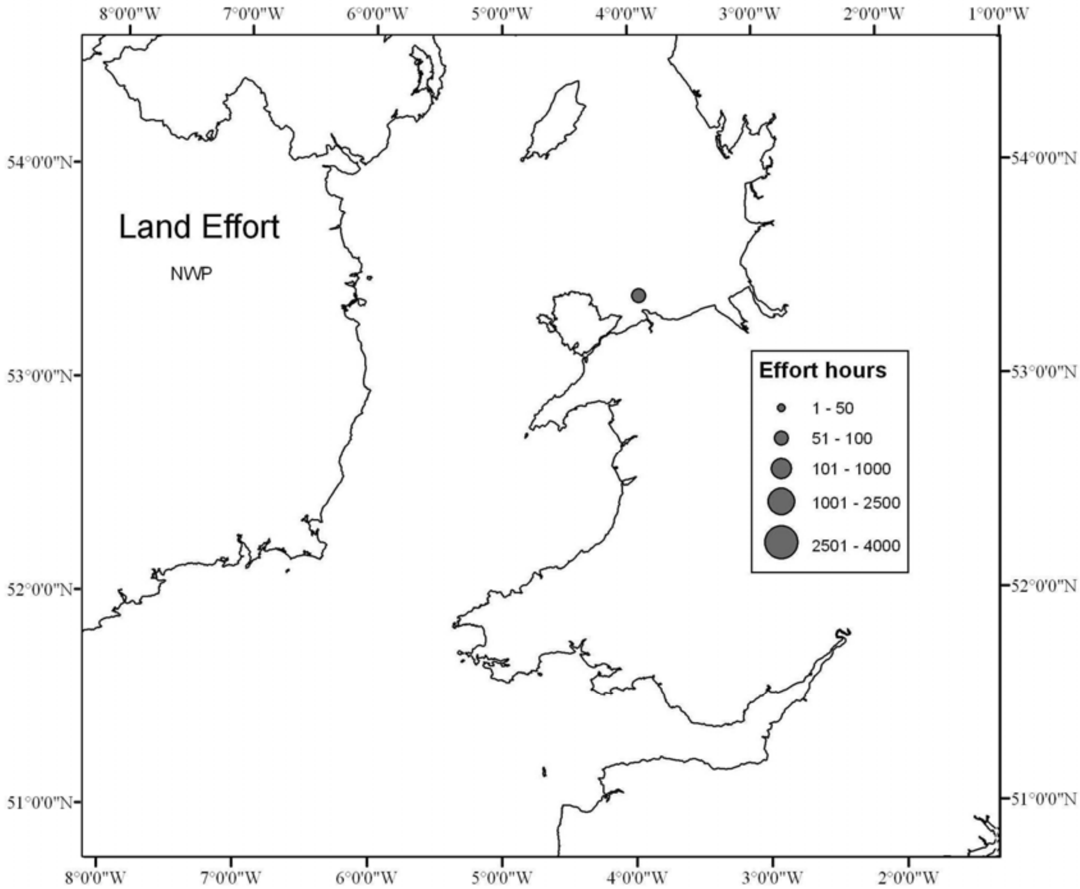


Figure 38 – Spatial distribution of land-based effort contributed by NWP

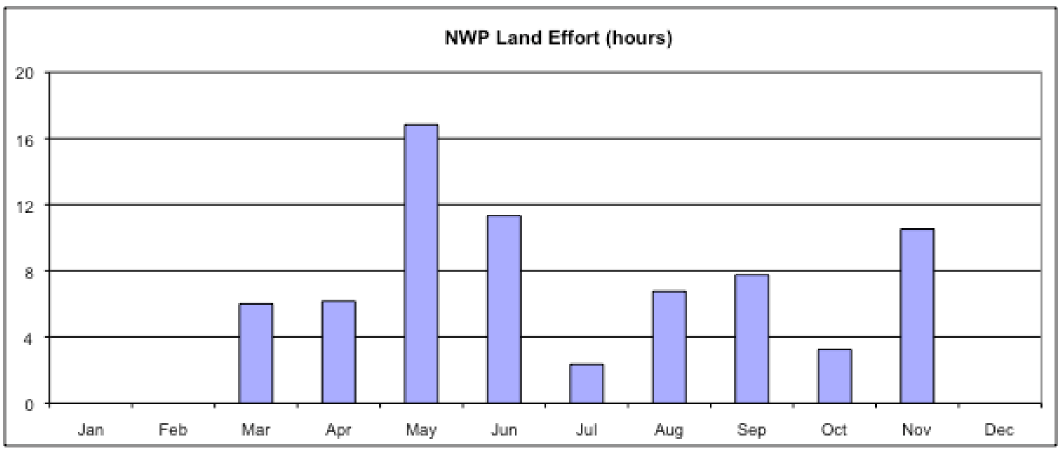


Figure 39 – Seasonal distribution of land-based effort contributed by NWP

2.3 Treatment of Data

All data were partitioned into a grid of cells overlying the study area. Pooling data in larger spatial units increases sample sizes and reduces the number of cells with low or no data levels. A grid of cells measuring 10 minutes latitude by 10 minutes longitude was chosen to achieve a useful resolution of detail, while minimising the number of cells without data.

The data were compiled in three database tables, one each for vessel, aerial and land-based data. Vessel and aerial data were treated similarly, with effort expressed as distance travelled (km), while land-based data were treated differently, the metric of effort in this case being the duration of watches (hours).

2.3.1 Vessel Data

Organisation of data

In order to partition the data, effort legs were first split into short sections of approximately 1 km, and each section was then assigned to a grid cell on the basis of the position of its mid point. Consecutive sections in the same cells with the same sea state were then summed to create effort segments. Each effort segment was associated with the following data fields:

Source
A code corresponding to the data contributing organisation, e.g. JNCC.

Type
Survey type was classed as: LINE – line transect; BOAT – ad hoc surveys; ESAS – European Seabirds at Sea data; TOUR – data from tour boat operators; FERY – data collected by observers on ferries; or SAIL - data from sailing vessels under sail.

Length
Segment length in km.

Speed
Segment speed in kph.

Platform height
Observer eye-height for each vessel was assigned to one of three classes: <5 m = Low; 5 – 10 m = Medium; > 10 m = High.

Cell
Cell ID code providing a link to latitude, longitude and potentially other environmental parameters associated with each cell.

Year

Month

Sp Sightings
A field duplicated for each of the five main cetacean species occurring in the study area, holding the number of sightings of each species made in that segment.

Sp Count
A field duplicated for each of the five main cetacean species occurring in the study area, holding the count of animals of each species made in that segment.

Effort correction factors

Sighting rates are affected by two sets of variables: environmental variables such as prey availability that determine the distribution of animals; and survey specific variables such as platform characteristics, field methods and viewing conditions at the time of the survey. The possibility of deriving correction factors for survey variables was investigated by the application of generalised additive models (GAM) to the data. Models were run in R v. 2.12.2 for Mac OS X using package mgcv 1.7-3 (Wood, 2000, 2006).

In order to correct for sea state and survey variables, a presence or absence model was developed in which species presence was modelled as a function of sea state, source, speed, platform height and type of survey. Platform height was found to be correlated with platform speed, and so was rejected as a potential variable. A binomial family with logit link function was used, with an offset for effort segment length. Model selection was based on a stepwise procedure in which explanatory variables were removed to achieve the best fit. Vessel speed, sea state and data source were found to be the most significant explanatory variables for each species, in the case of harbour porpoise, accounting for 36% of deviance (Table 5).

Data source was in many cases confounded with season or localised areas in which the data had been collected and, given this potential spatio-temporal bias, it was not considered appropriate to derive correction factors for this variable, so this term was dropped. Resulting parametric coefficients for sea state and vessel speed for each species are listed in Table 6. The GAM predict function was applied to the original data set, such that the response obtained represented a probability of making a sighting for each effort segment given its combination of predictor variables. The distance travelled was then multiplied by this value in order to apply a correction factor for sea state and vessel speed.

Table 5 – Summary of GAM applied to harbour porpoise presence/absence data

Family: binomial
Link function: logit

Formula:
HP_presence ~ Sea + s(Speed) + Source

Parametric coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-6.64999	0.15537	-42.800	<2e-16 ***
Sea	-1.11867	0.03474	-32.205	<2e-16 ***
GOWER	0.41517	0.43363	0.957	0.3384
IWDG	2.80498	0.18101	15.496	<2e-16 ***
JNCC	-7.55999	0.25456	-29.698	<2e-16 ***
MANW	3.17692	0.31878	9.966	<2e-16 ***
PPS	2.84811	0.22481	12.669	<2e-16 ***
SCANS	1.26285	0.57252	2.206	0.0274 *
SCAR	2.03947	0.23945	8.517	<2e-16 ***
SWF	-0.22315	0.14718	-1.516	0.1295
WDCS	2.04289	0.23670	8.631	<2e-16 ***

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:

	edf	Ref.df	Chi.sq	p-value
s(Speed)	8.821	8.991	733.3	<2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) = -0.197   Deviance explained =   36%
UBRE score = -0.053216 Scale est. = 1   n = 23728

Table 6 – Summary of parametric coefficients for sea state and platform speed for each species. NS denotes no significant coefficient was obtained for this species – variable combination

Species	HP	BND	SBCD	RD	MW
Sea state	-1.124	-0.290	NS	-0.911	-0.447
Speed	-0.119	-0.106	NS	NS	-0.089

Calculation of sighting rates

Sighting rates for each species were calculated for each effort segment by dividing the count of animals by the corrected effort to give a count per km. For each time period to be plotted, a mean sighting rate was calculated for each cell. In many cases this resulted in very low mean rates, so in order to plot these in ArcGIS the rates were multiplied by 10 to give mean counts per 10 km.

Interpolation

Interpolation was carried out using the overall vessel data for each species. The data that had been binned into cells was unsuitable for interpolation as only a single point location was associated with data that had been pooled from across the entire area of each cell. So each effort segment with the position of its mid point, together with its associated sighting rate for each species, corrected for sea state and vessel speed, were input to the interpolation process. This amounted to a total of 20,798 data points. The interpolation method used was ordinary kriging with a circular variogram model (for a comparison of the two main interpolation methods examined, see section 2.4.3).

2.3.2 Aerial data

Aerial data were treated in the same way as vessel data with the following exceptions. Sea state was not available for the WWT data, which comprised 96% of all aerial data. However, all WWT data were collected in sea states <4, so any data with sea states >3 were rejected from the other sources of aerial data. No further sea state correction was applied. Sighting rates were typically much lower than for vessel data and it was necessary to express rates as counts per 100 km in order to display all the resulting values in ArcGIS.

2.3.3 Land-based data

The land data were organised in a similar way to the vessel data, except the unit of effort was the duration of each record and this replaced the length and speed fields used in vessel data. Sighting rates were calculated as counts per hour of observation.

Types of land-based data

Land-based data fall into two methodological types: conventional timed watches and scan samples. In the former case, start and end times of watches are recorded, together with environmental variables such as sea state. When a sighting is made, then as a minimum the time of first sighting is recorded, with species and group size. Repeat sightings of the same animals may be recorded, but if so, the status of such sightings as repeats is noted so that these can be excluded from analyses, if appropriate. This approach is adequate in low animal density situations, but it may become difficult to keep track of animals already recorded where densities are higher. Consequently, at a number of sites in Wales, a scan sampling method has been adopted for land-based watches in order to cope with situations in which there may be a flux of animals entering and leaving the observer’s field of view.

In land-based watches using a scan sampling method, the field of view is scanned for a fixed period of time, e.g. 15 minutes, and the number of animals of each species present during that period is recorded, together with environmental data such as sea state. This is then repeated in successive (usually contiguous) periods until the end of the watch.

Treatment of scan-sampling data

In order to make scan sampling data directly comparable to conventional land-watch data, the following treatment was carried out. When animals were first recorded in a scan, a sighting event was considered to have started. That sighting then continued through each successive scan, until a scan sample occurred in which no animals of the same species were recorded. The sighting was then considered to have ended and the maximum count in any scan sample during the sighting event was taken as the best estimate of group size (see example in Table 7). This conservative approach ensures that group sizes are not over-estimated, although some under-estimation of actual numbers present may result.

Table 7 – Example showing treatment of scan sampling data. A sighting of harbour porpoises was considered to start at 9:45 with a best estimate of group size of 5 animals. The first sighting had ended by 11:00 and a second sighting started at 11:45 with a group size of 3.

Time	09:30	09:45	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00
HP count	0	2	4	5	5	1	0	0	0	2	3	1	2	0	0
Sighting		Sighting 1								Sighting 2					
Group size		5								3					

Sea state correction for land surveys

GAMs were applied to the land-based data to investigate the possibility of deriving correction factors for sea state. The data were first filtered to remove all records where sea state >3. However, the data were found to be zero-inflated, skewed and despite attempts to transform the data it was not possible to fit a model in which sea state was a significant variable. Therefore no further correction was applied to the data, other than to exclude data where sea state >3.

2.3.4 Seasonal Sub-division of Data

The data were sub-divided into three-month periods in order to plot seasonal variation. Monthly mean sea surface temperatures collected at the Wylfa Nuclear Power Station on the north coast of Anglesey (53° 25' N, 4° 29' W) as part of a long-term monitoring programme co-ordinated by CEFAS are shown in Figure 40. Minimum sea temperatures occur in February, with a maximum in August. Therefore the year can conveniently be divided with the first quarter from January to March representing winter with the coldest sea temperatures; in the spring second quarter from April to June, temperatures rise; maximum temperatures are reached in the summer third quarter from July to September; and in the autumnal fourth quarter from October to December temperatures fall.

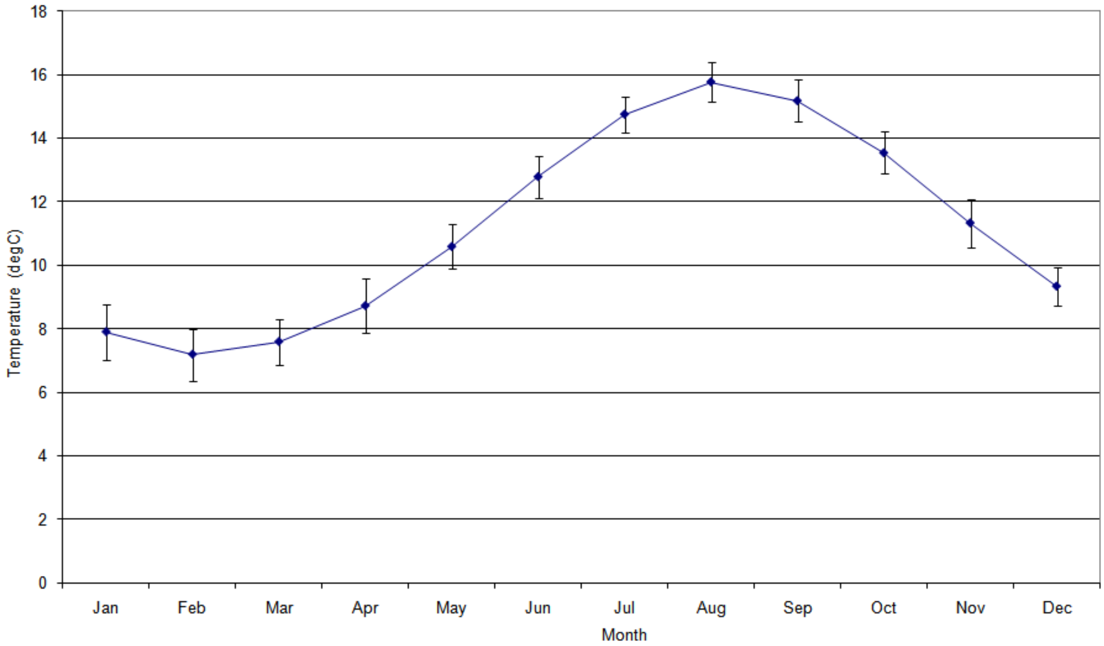


Figure 40 – Mean monthly sea surface temperatures collected at Wylfa Power Station on the north coast of Anglesey (53° 25' N, 4° 29' W) with error bars representing standard deviation (source: CEFAS)

2.4 Plotting the Results on Maps

Vessel and aerial effort maps were plotted using grey-scale shading in each cell. Sighting rates were then superimposed on the corresponding effort layer using red dots with a diameter proportional to sighting rate categories placed over the centre of each cell. Scales were set for each species by using the maximum rate for that species to determine the range of the scale and selecting sub-divisions for each category to maximise the detail displayed in the map. Thus scales differ between species and between vessel and aerial survey maps within each species.

Land-based effort was plotted using dots of scaled size placed on the centre points of each coastal cell. Sighting rates were displayed using a colour ramp scale applied to a 3 nm wide band around the coastline.

2.4.1 Projection

A Transverse Mercator projection was used for all maps, with the following parameters:

False Easting: 200000.0
False Northing: -10000.0
Central Meridian: -5.0
Scale Factor: 0.999601
Latitude of Origin: 51.0

2.4.2 Displaying the Data

A wide range of methods are available for the spatial analysis and display of marine mammal sighting data, ranging from simple plots of sighting locations, through binning data in grids of cells to modelling using environmental features as predictive variables (Matthiopoulos & Aarts, 2010). The selection of appropriate methods depends on both the quality of data and the objective to be achieved. Our objective was to depict the distribution of marine mammals in the study area and identify any persistent hotspots, while being as inclusive as possible in the use of available data. The only constraints we imposed on data quality were that they should always be associated with a measure of observer effort and if possible, environmental factors such as sea state should have been recorded with the effort.

The data made available for this project came from many sources, each tending to use their own field methods and recording protocols, resulting in an extremely heterogeneous data set. Relatively few of the contributors had used field-recording methods sufficiently rigorous to allow the fitting of detection functions. The method chosen for pre-processing the data prior to display was the calculation of sighting rates, as counts per unit effort, corrected for the most significant factors affecting viewing conditions (sea state) and survey methods (platform speed).

The data were binned into a grid of cells overlying the study area and the mean sighting rate for each cell in each time period to be plotted was calculated. As the resulting value for each cell was a mean rate derived from the pooling of data from across the entire area of that cell, the most appropriate representation of such rates is by the use of choropleth maps, in which each cell is shaded according to a colour scale representing rate values. However, for the display of vessel and aerial sighting rates we elected to plot dots of scaled size placed at the centre of each cell, overlying a grey-scale choropleth plot of effort. Thus sighting rates and the level of effort from which the rates were derived are available simultaneously. Land-based sighting rates were plotted as coloured choropleths in a 3 nm wide band around the coastline, as to use whole cells would give the misleading impression that the underlying data were collected cell-wide.

2.4.3 Interpolation

The main objective of interpolation is to fill in gaps within the study area for which there are no or too few data, and produce a continuous surface layer. This differs from predictive modelling in that the continuous layer is produced entirely by a statistical algorithm based on the spatial relationship of points which each have a value. There are two categories of interpolation techniques: deterministic and geostatistical (Childs, 2011). Two methods were considered, both commonly used in spatial analysis (Cressie, 1993): inverse distance weighted (IDW) interpolation, a deterministic method that was applied in the first edition of this Atlas (Baines & Evans, 2009) and kriging, a geostatistical method (Isaaks & Srivastava, 1990; Mathiopoulos & Aarts, 2010).

IDW interpolation may be used when the set of input points is dense enough to capture the extent of variation needed for the analysis. Typically, a grid of sample points with known values is input to the IDW process, which then calculates interpolated points using a linear weighted function, such that the greater the distance, the less influence an input point has on the output value. The result is a continuous layer in which the maximum and minimum values of the input data are retained, with a smoothed gradation between input points. IDW was therefore considered appropriate where the input values were the mean sighting rates for each cell, with a single input point for each grid cell. Several studies of cetacean distribution have used this method (see, for example, Kelper *et al*., 2005; Friedlaender *et al*., 2006; Pittman *et al*., 2006; Redfern *et al*., 2006; Becker *et al*, 2010; Forney *et al*., 2011).

Kriging is a more sophisticated statistical interpolation method in which spatial correlation is used to explain variation in a surface (Dungan *et al*., 2002; Mathiopoulos & Aarts, 2010). The predicted values are derived from the relationship between samples using a weighted average technique. The resulting output values can exceed the input value range and the surface does not necessarily pass through the input samples, i.e. output values differ from input values at the same location. This is therefore not a method that can be applied to a grid of mean sighting rates per grid cell. In order to apply kriging, the data input points were the mid points of the individual effort segments, together with their associated sighting rates, corrected for sea state and platform speed. Over 20,000 data points were input; these included a large number of zero values and a wide range of sighting rates. The method used was ordinary kriging with a circular variogram model.

The two interpolation processes are illustrated here for two key species, harbour porpoise and bottlenose dolphin. Figures 41 & 45 show the data input to the IDW interpolation process for each of the two species. Figures 43 & 47 show the data input to the kriging process. Note that the data input in both cases were actual values, not the categories used to display dots on the maps, and that zero values were included. Figures 42 & 46 show the resulting IDW plots, and Figures 44 & 48 show the kriged plots. Both interpolation methods show broadly the same distribution for both species, but the IDW plots appear smoother while kriging results in greater apparent detail. For completeness, the plotted results of kriging *vs* inverse distance weighting are provided also for the three other regular cetacean species: common dolphin (Figures 49 & 50), Risso’s dolphin (Figures 51 & 52), and minke whale (Figures 53 & 54).

Technically, kriging is the better method for interpolation because IDW assumes that the correlation between data points decays as the inverse of distance, which is probably incorrect. On the other hand, kriging assumes that the data are normally distributed which is rarely the case for count data. For understanding species distributions given that effort is uneven, the maps in which actual sighting rates are displayed overlaid on a shaded effort scale are best to refer to.

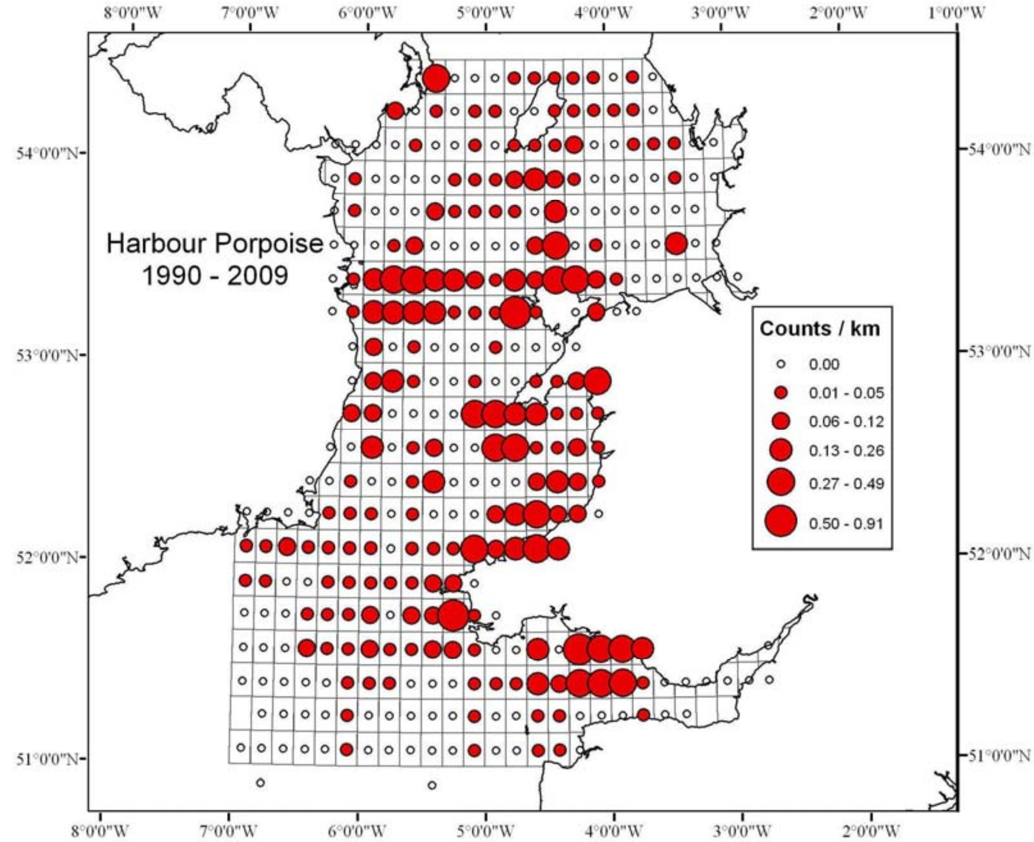


Figure 41 – Harbour porpoise data input to the IDW interpolation process

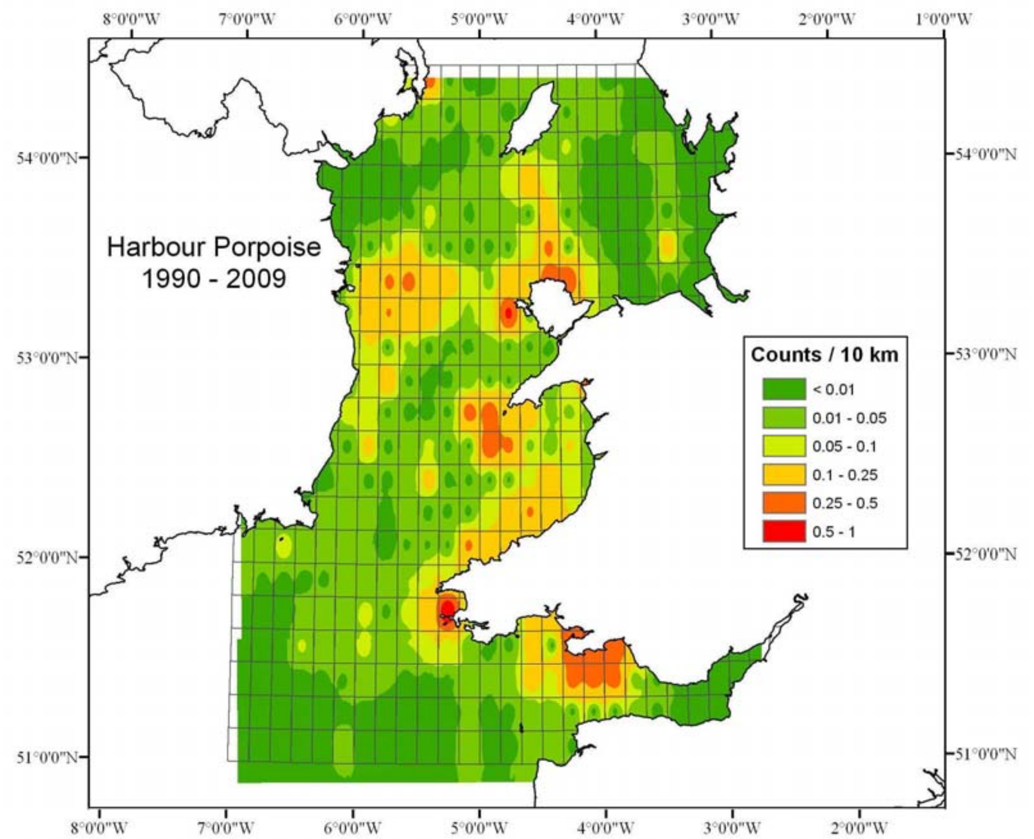


Figure 42 – IDW interpolated map of harbour porpoise distribution

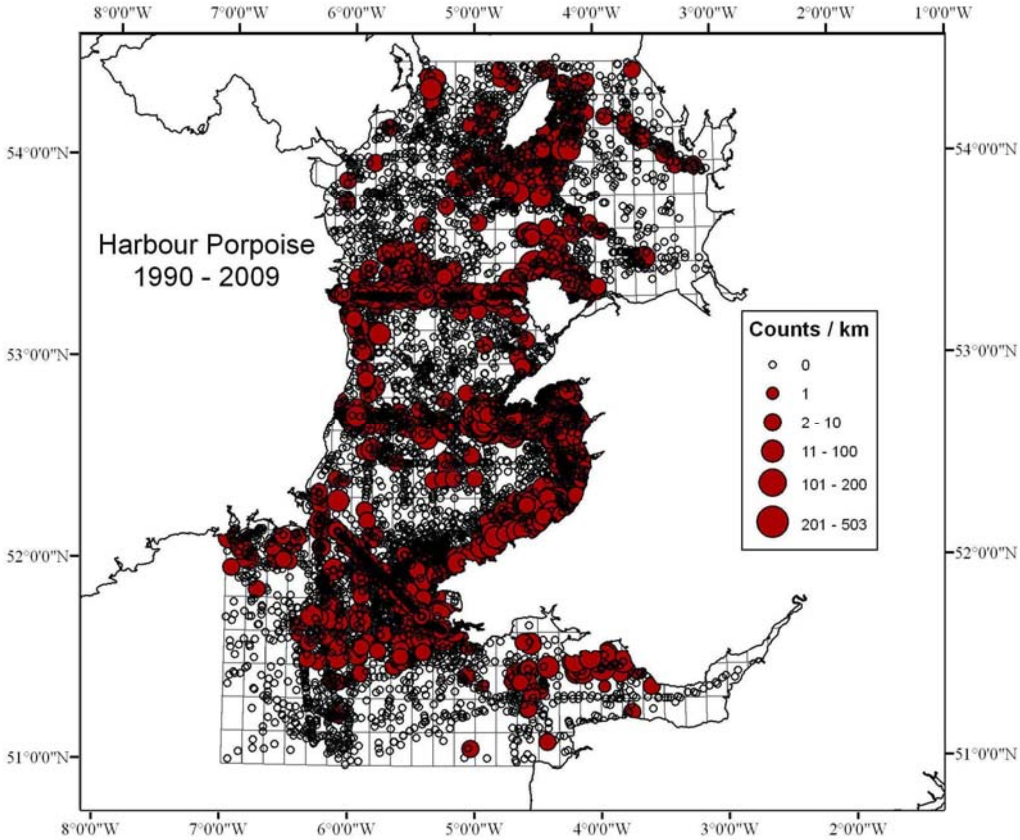


Figure 43 – Harbour porpoise data input to the kriging interpolation process

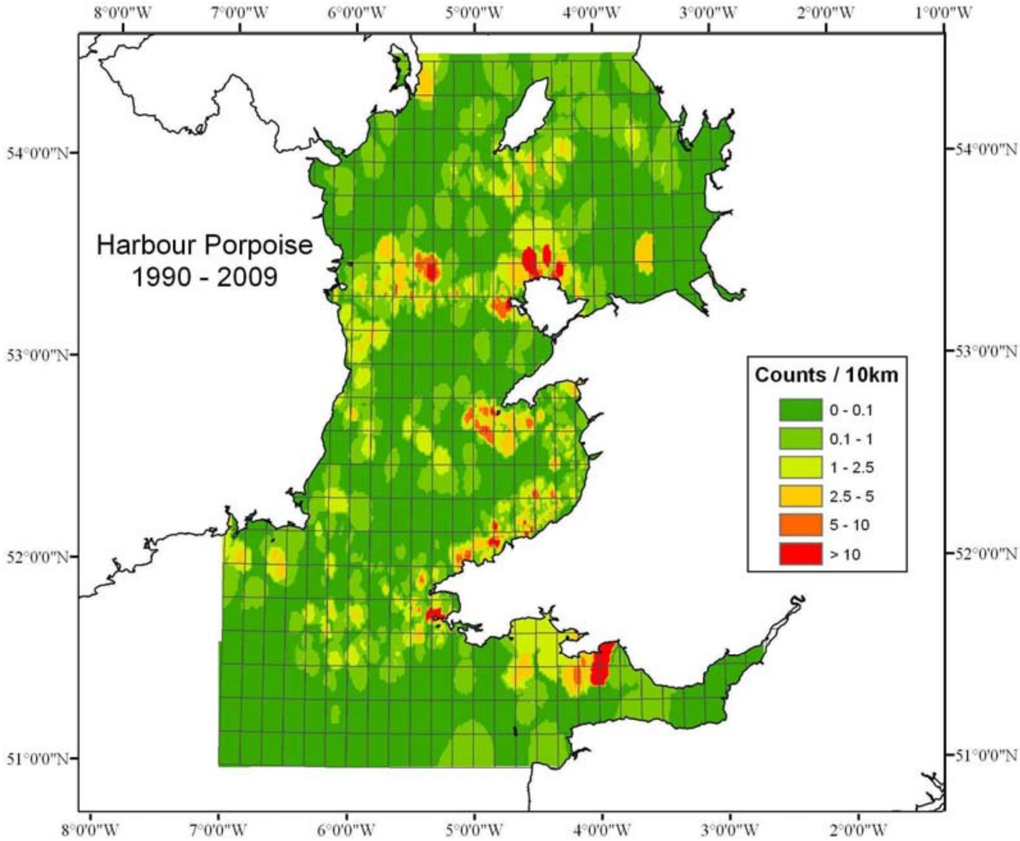


Figure 44 – Kriging interpolated map of harbour porpoise distribution

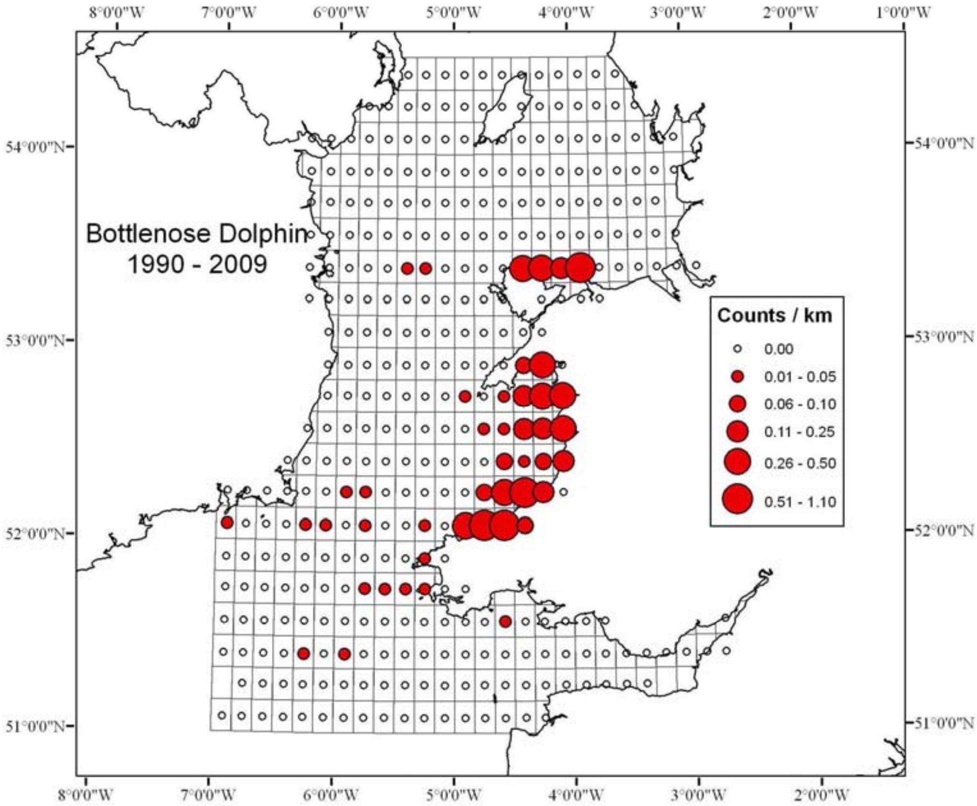


Figure 45 – Bottlenose dolphin data input to the IDW interpolation process

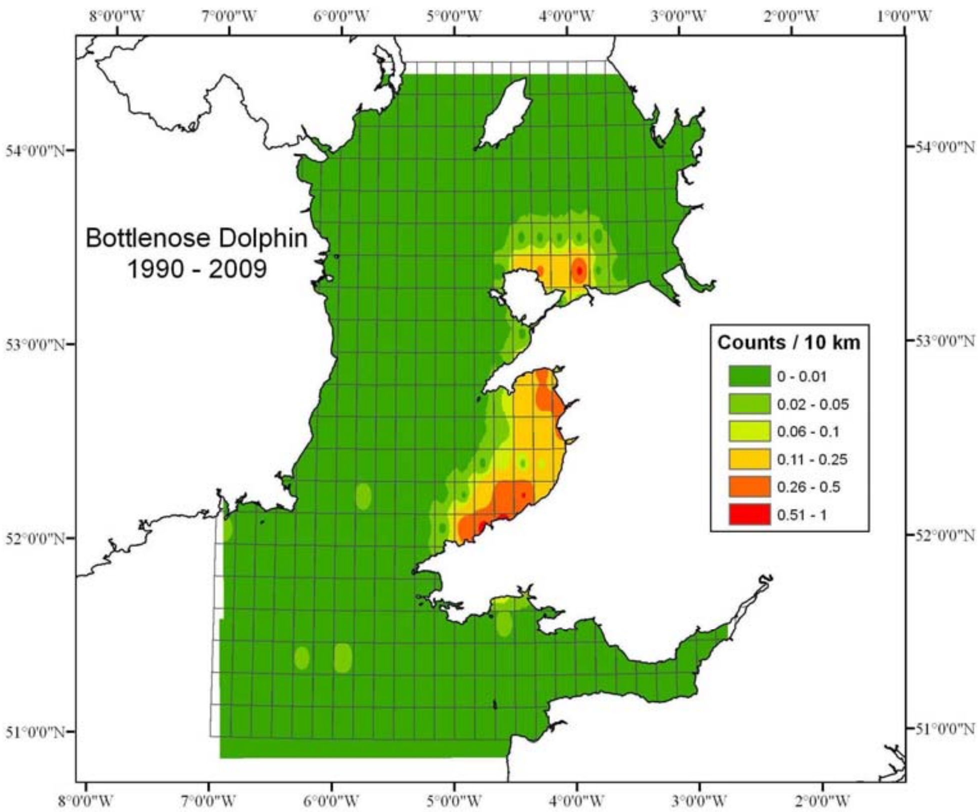


Figure 46 – IDW interpolated map of bottlenose dolphin distribution

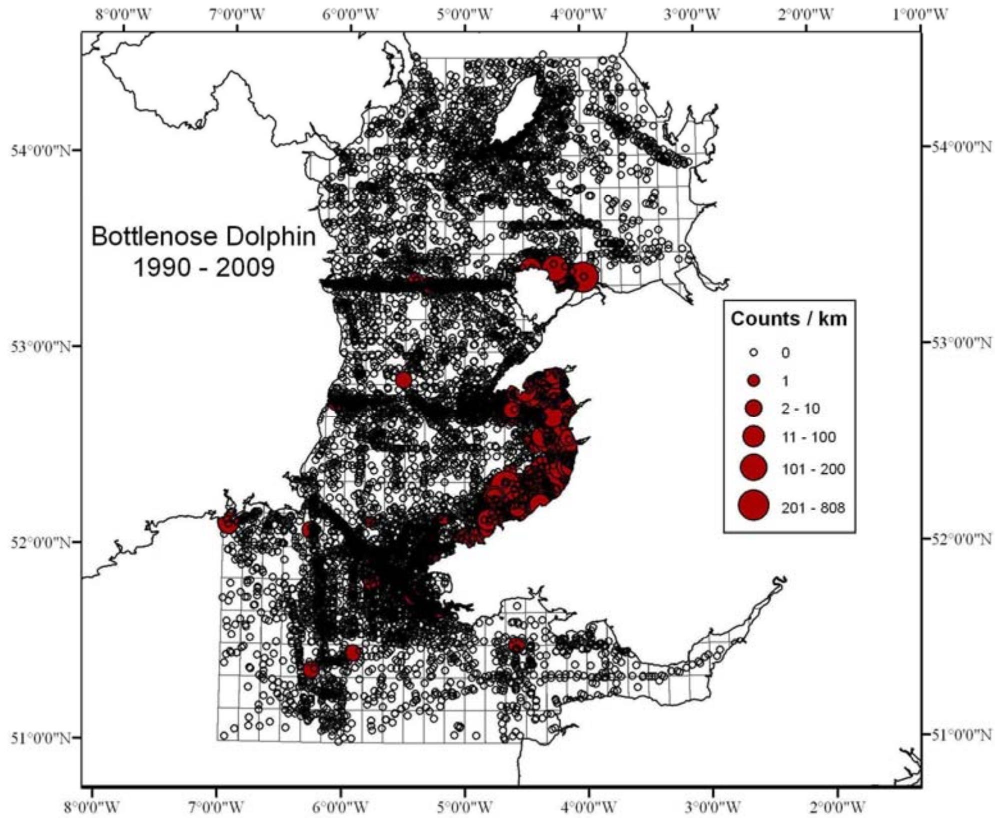


Figure 47 – Bottlenose dolphin data input to the kriging interpolation process

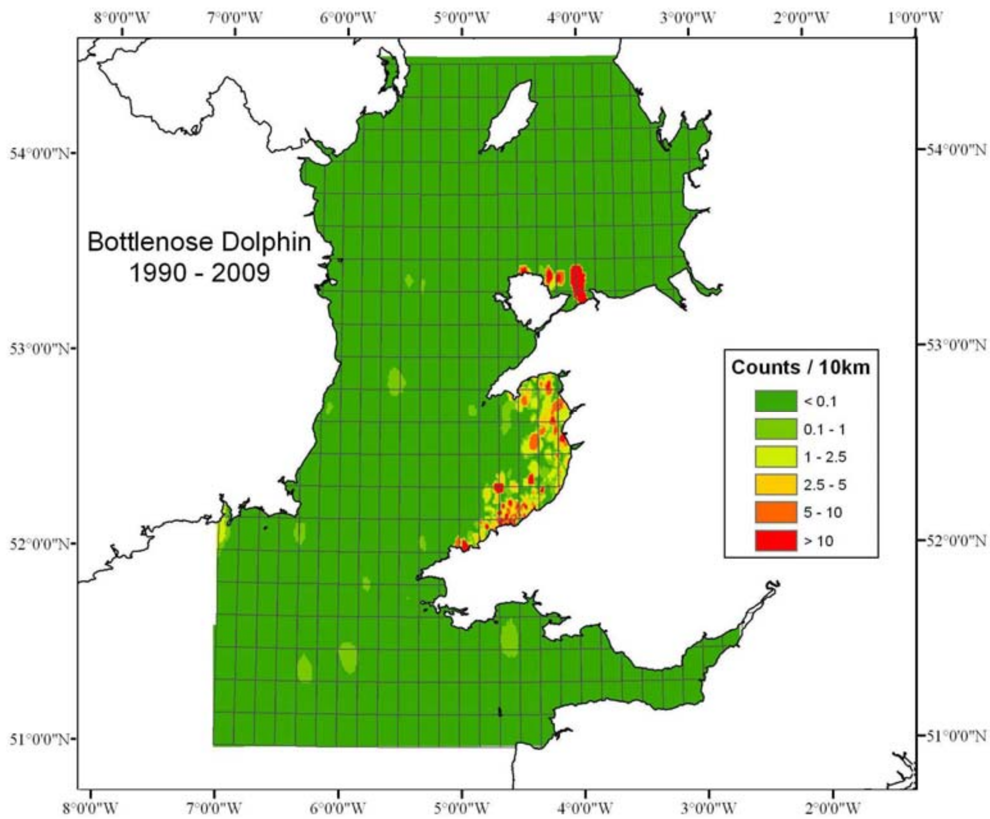


Figure 48 – Kriging interpolated map of bottlenose dolphin distribution

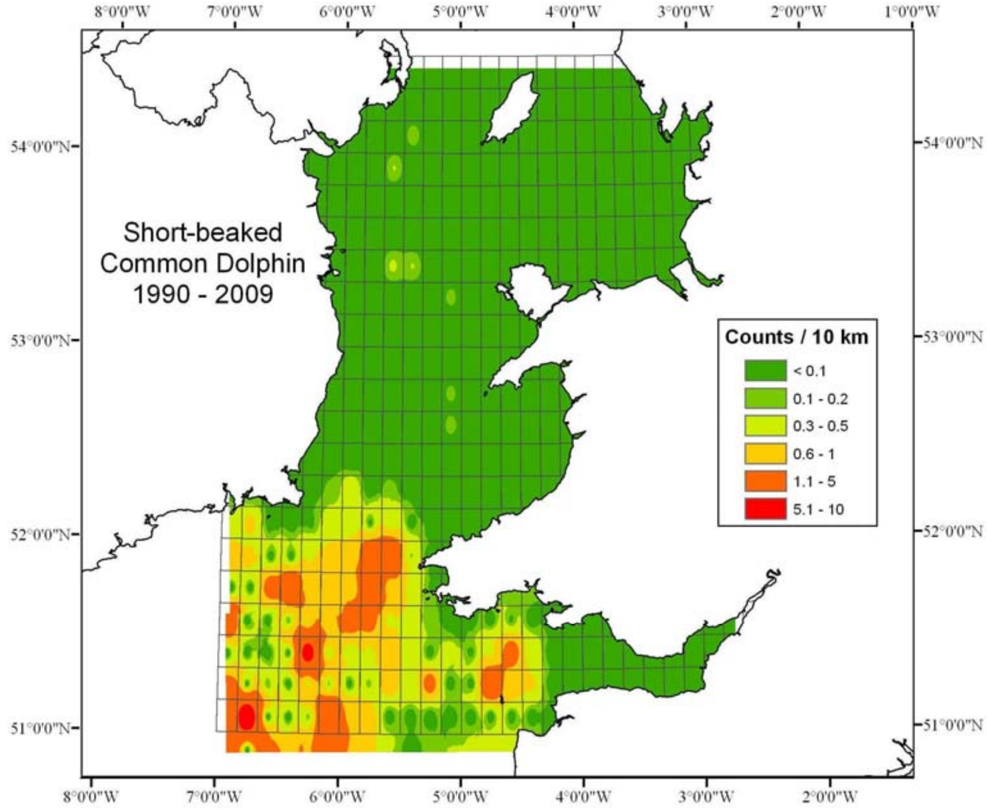


Figure 49 –IDW interpolated map of common dolphin distribution

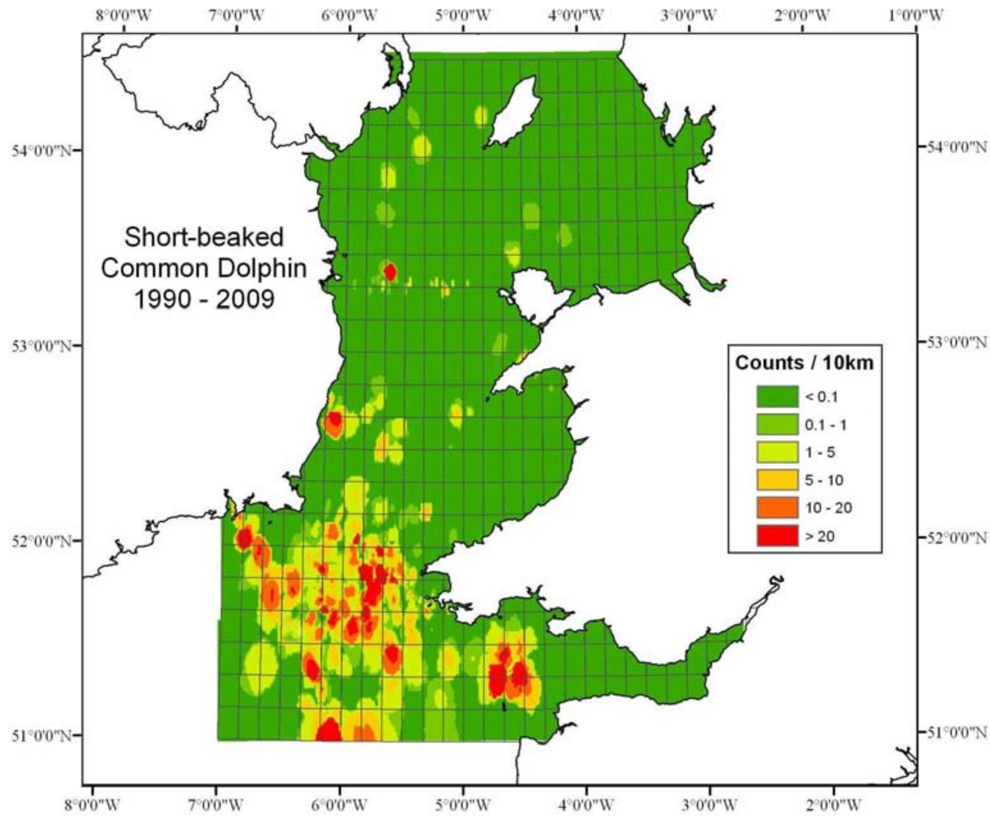


Figure 50 – Kriging interpolated map of common dolphin distribution

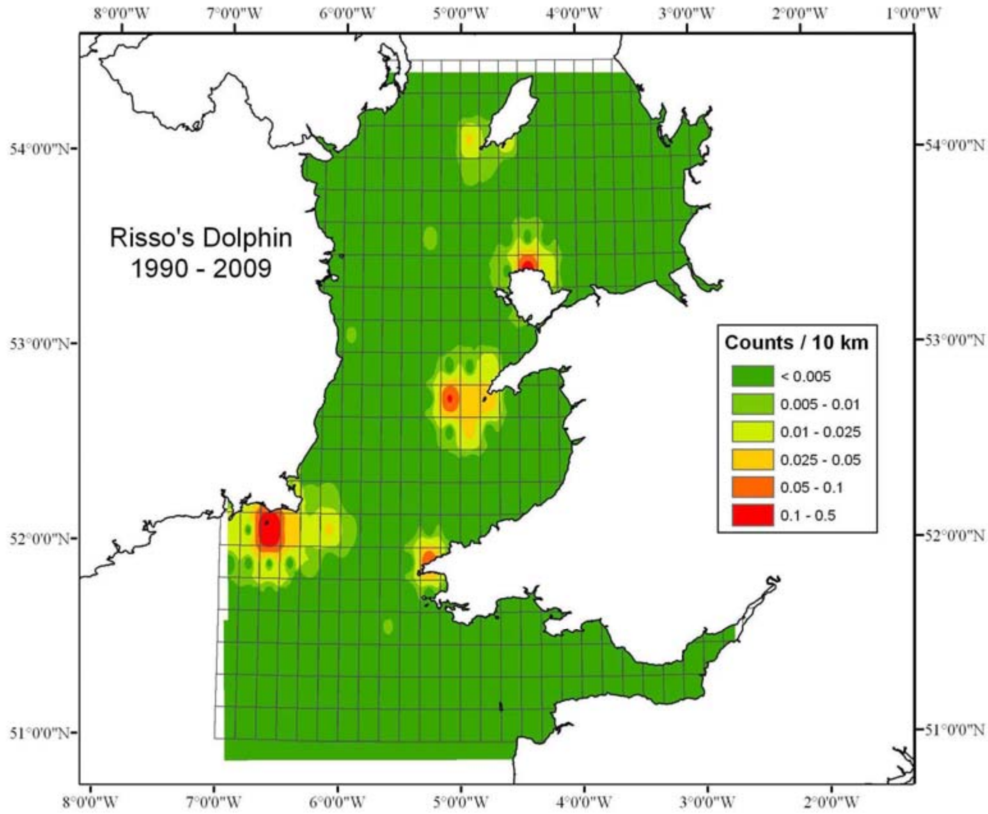


Figure 51 –IDW interpolated map of Risso's dolphin distribution

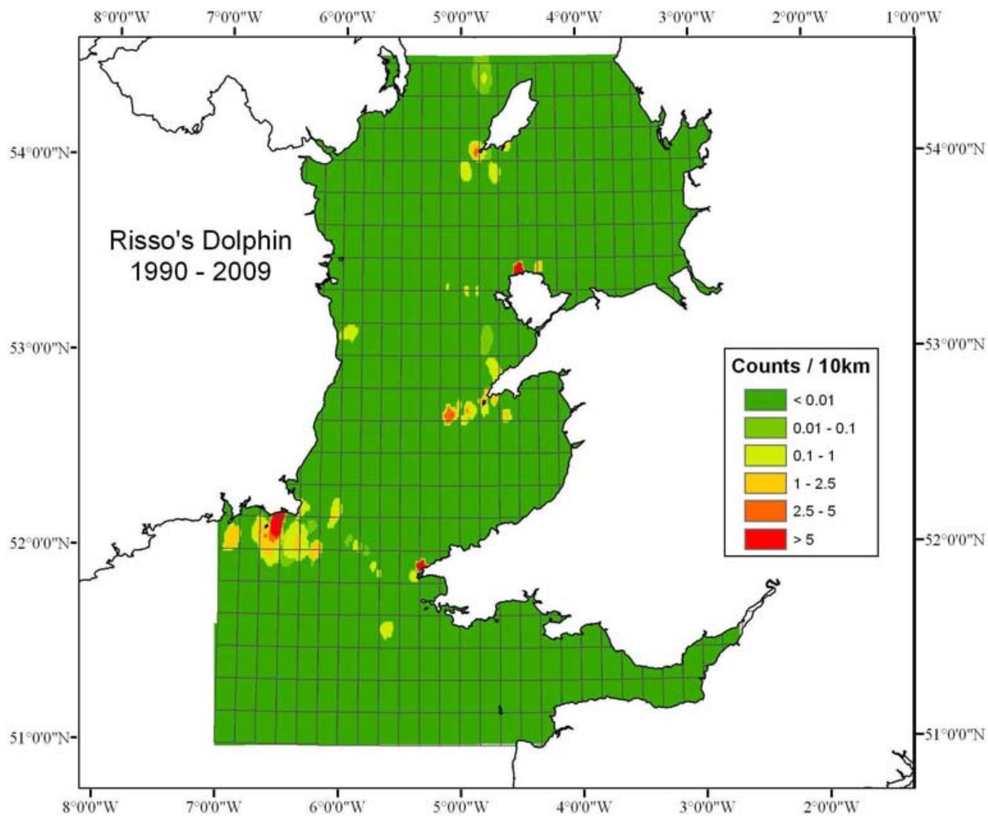


Figure 52 – Kriging interpolated map of Risso's dolphin distribution

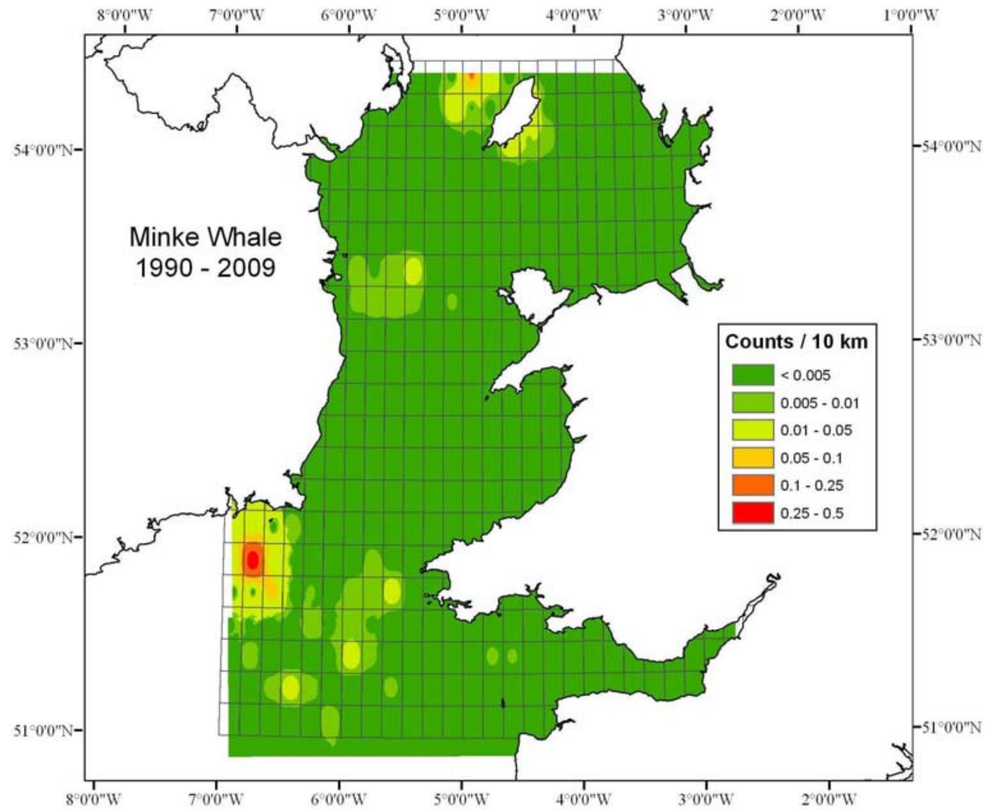


Figure 53 –IDW interpolated map of minke whale distribution

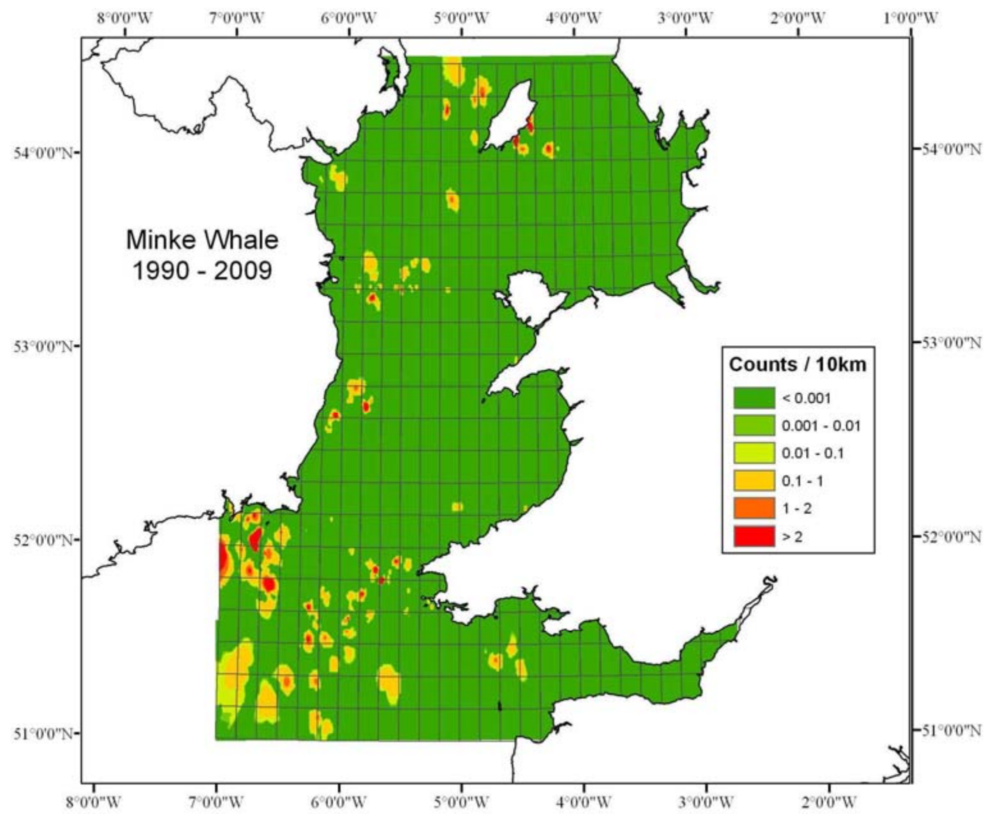


Figure 54 – Kriging interpolated map of minke whale distribution

3. RESULTS

3.1 Effort

Realised vessel effort in the project database amounted to 96,334.47 km in 355 of the 414 cells of which part or all covered areas of sea. However, the spatial distribution of effort (Figure 56) was not evenly spread and 50% (748 km) of the total effort was in only 24 cells, and 95% of the effort fell in approximately half (223) of the cells. However, vessel effort exceeded 100 km in 177 cells and the mean effort of cells (excluding cells with no effort) was 271 km. Effort was highest on ferry routes between Wales and Ireland and in coastal areas, particularly in southern Cardigan Bay from New Quay to St David's Head, and around Bardsey Island (Figure 56), and this was largely the case for all four time periods (Fig. 59). There was also a temporal bias to the distribution of effort, with approximately 75% of all effort in the five months, May to September (Figures 55 & 63).

Realised aerial effort amounted to 115,413.4 km, distributed in 297 cells, with a mean of 389 km in those cells with effort. Again, spatial distribution was not even (Figure 57), with 50% (57,810 km) of effort in 31 cells. Effort was highest in Liverpool Bay, Tremadog Bay (northeast Cardigan Bay), and Carmarthen Bay, for both time periods (Figures 60 & 61). The seasonal distribution of aerial effort showed peaks between November and March and between June and August, with less effort in spring and autumn (Figures 55 & 64).

Land effort amounted to 13,399 hours of observation in 60 coastal cells (Figure 58). 75% of land effort was in just six cells located in southern Cardigan Bay, Bardsey Island and Anglesey. Since 2000, there have also been land watches from the Isle of Man (Figure 62). There was a pronounced seasonal bias with 80% of effort in the four months June to September (Figures 55 & 65).

The confidence that can be placed on sighting rates in any cell increases with the level of effort in that cell. The higher the level of effort in any one cell, the more reliable the sighting rates are likely to be. Some cells with low effort but with just one or two sightings showed disproportionately high sighting rates, so care should be taken not to over-interpret the results where effort levels are low.

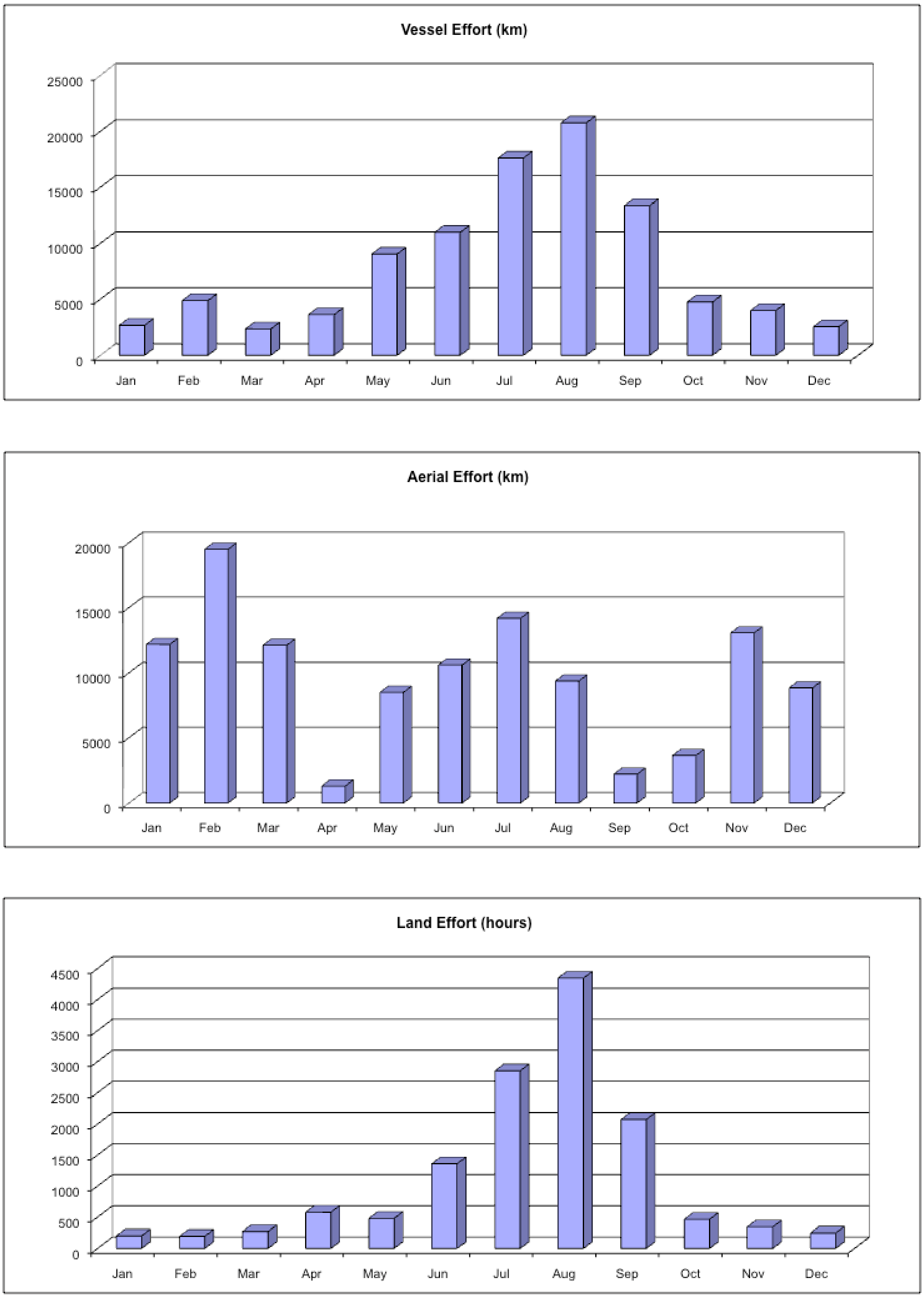


Figure 55 – Monthly levels of effort in the study area from 1990 – 2009

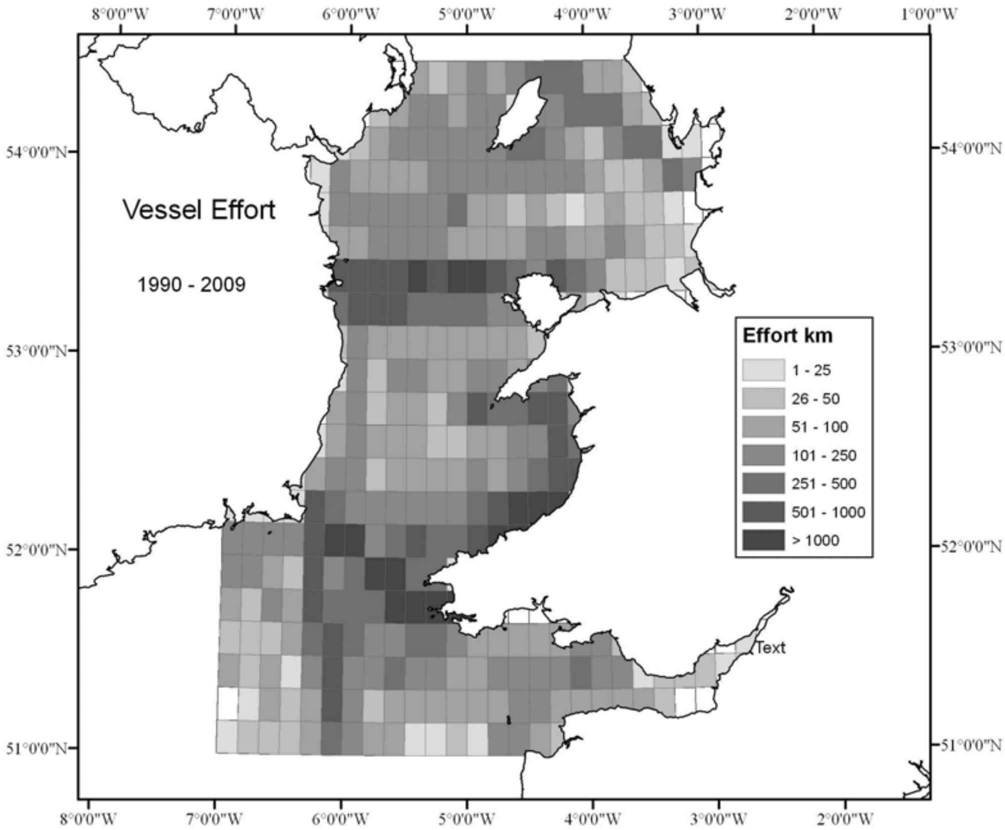


Figure 56 – Overall kilometres of vessel-based effort in the study area from 1990 – 2009

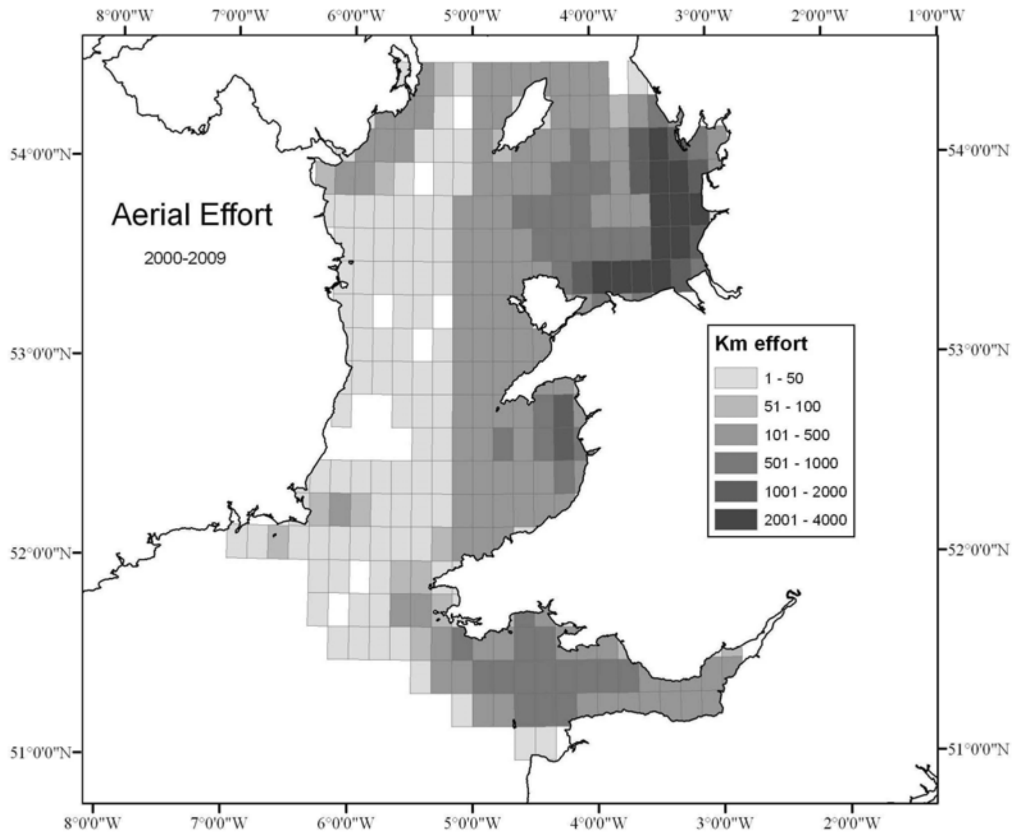


Figure 57 – Overall kilometres of aerial-based effort in the study area from 2000 – 2009

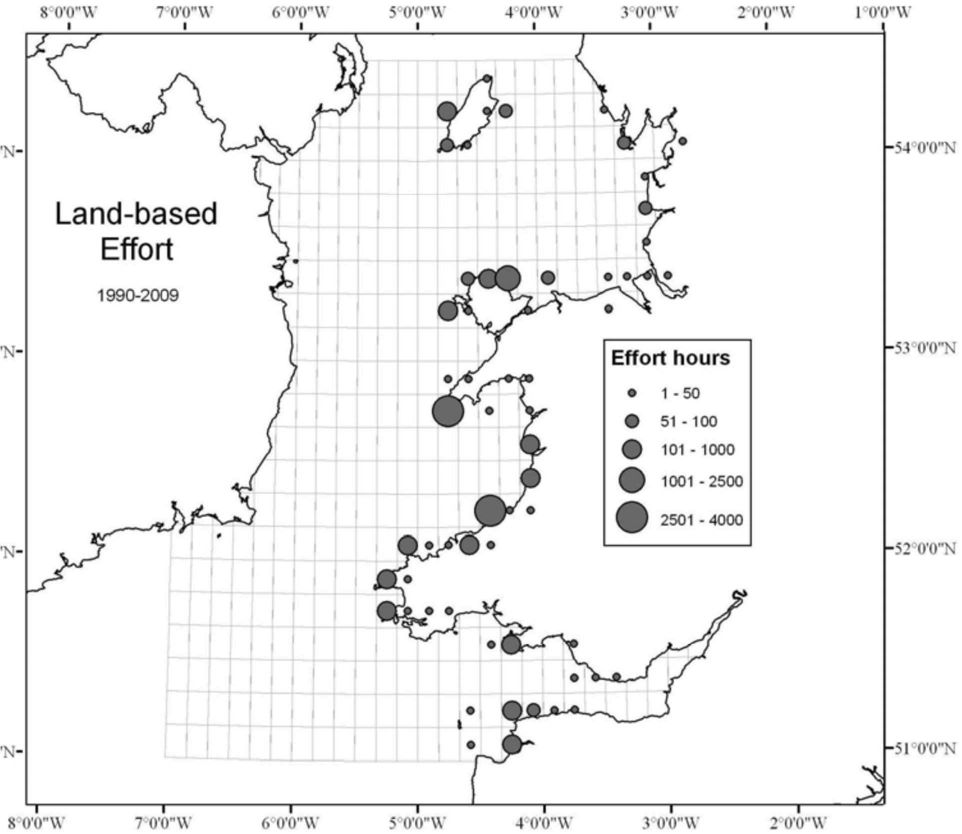


Figure 58 – Overall hours of land-based effort in the study area from 1990 – 2009

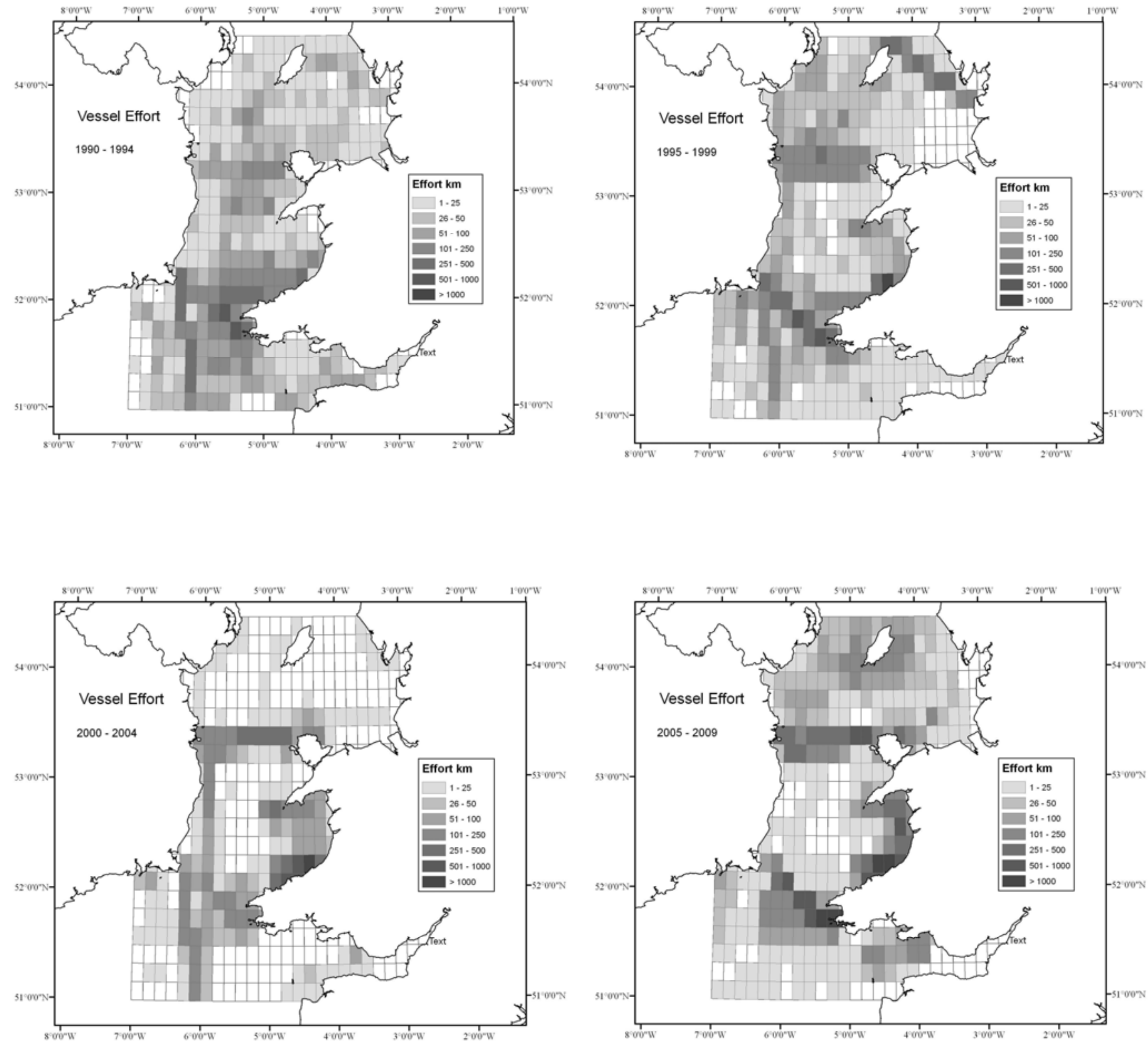


Figure 59 – Kilometres of effort for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

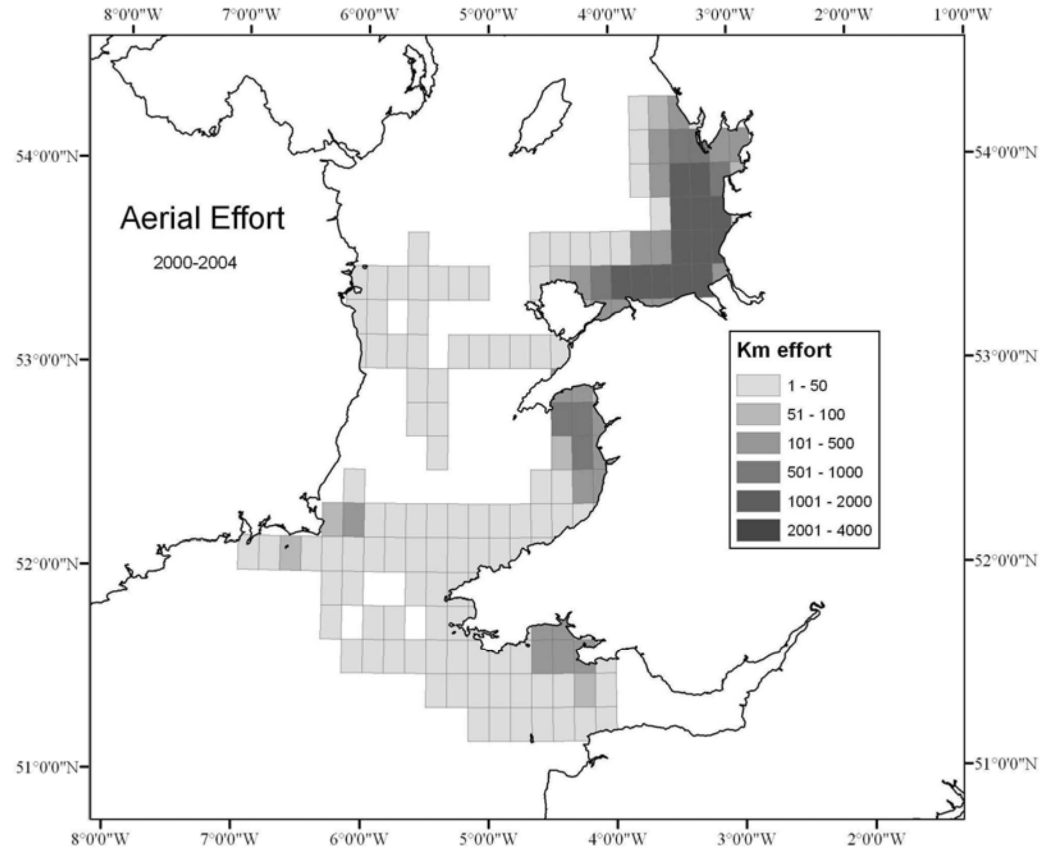


Figure 60 – Overall kilometres of aerial-based effort in the study area from 2000 – 2004

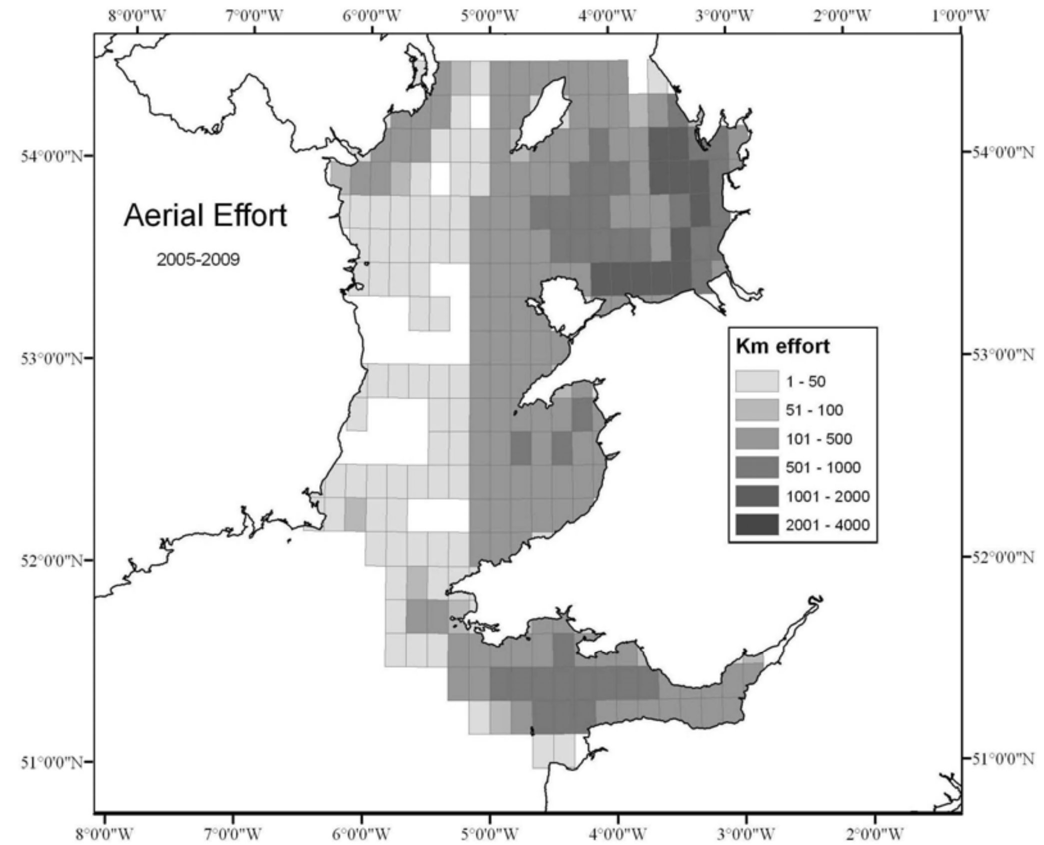


Figure 61 – Overall kilometres of aerial-based effort in the study area from 2005 – 2009

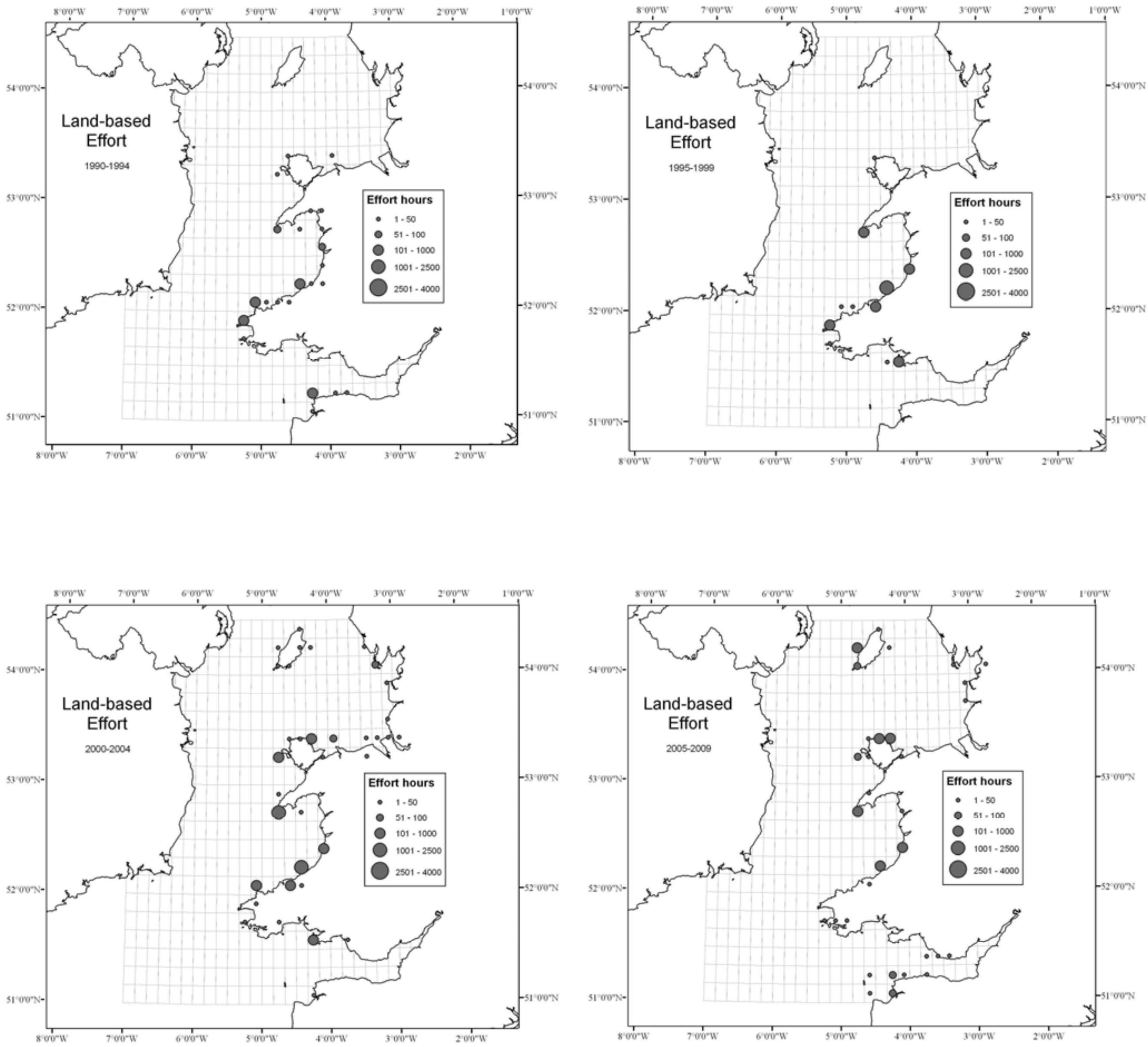


Figure 62 – Hours of effort for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from land surveys

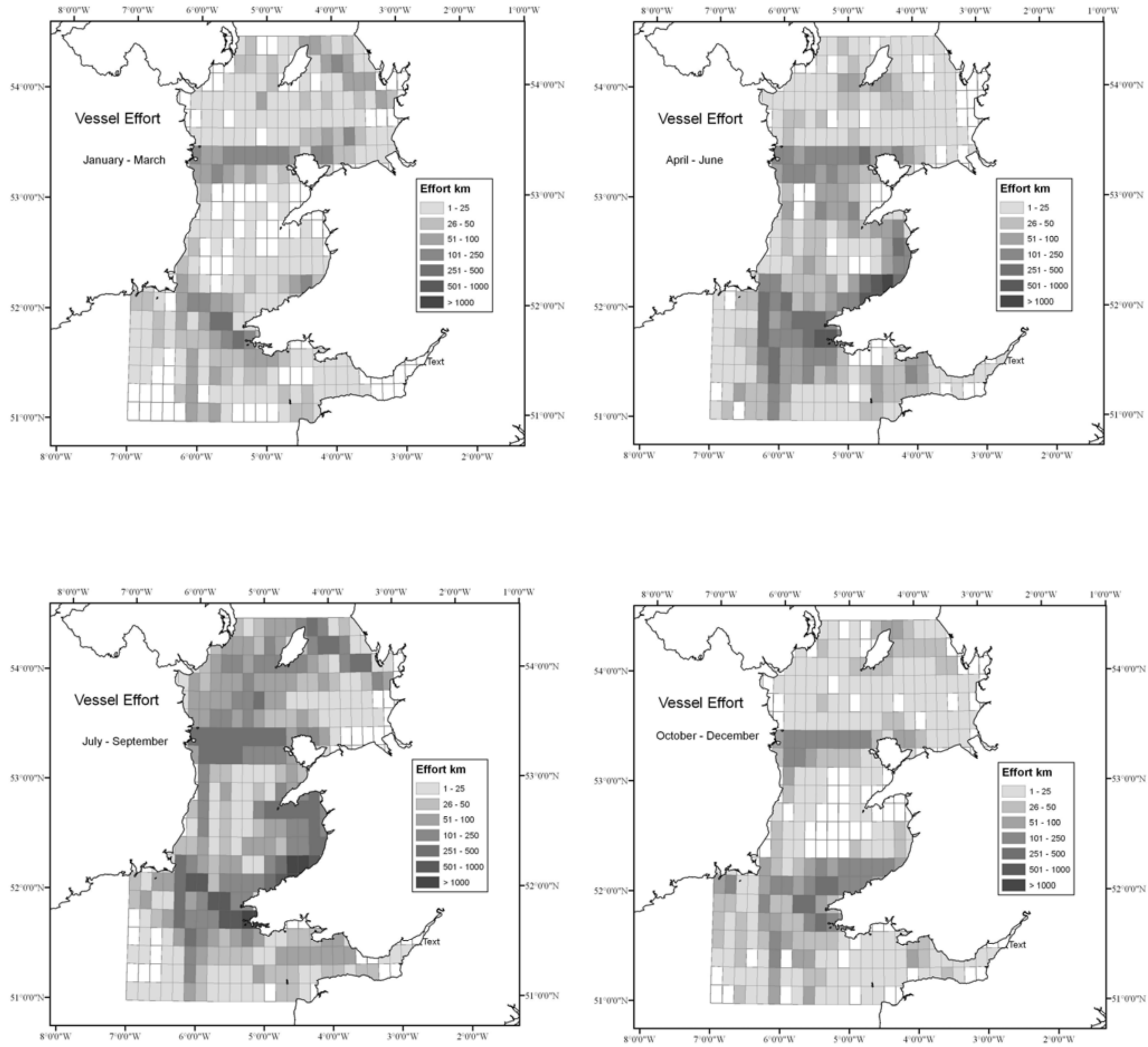


Figure 63 – Quarterly effort (in kilometres) from vessel surveys

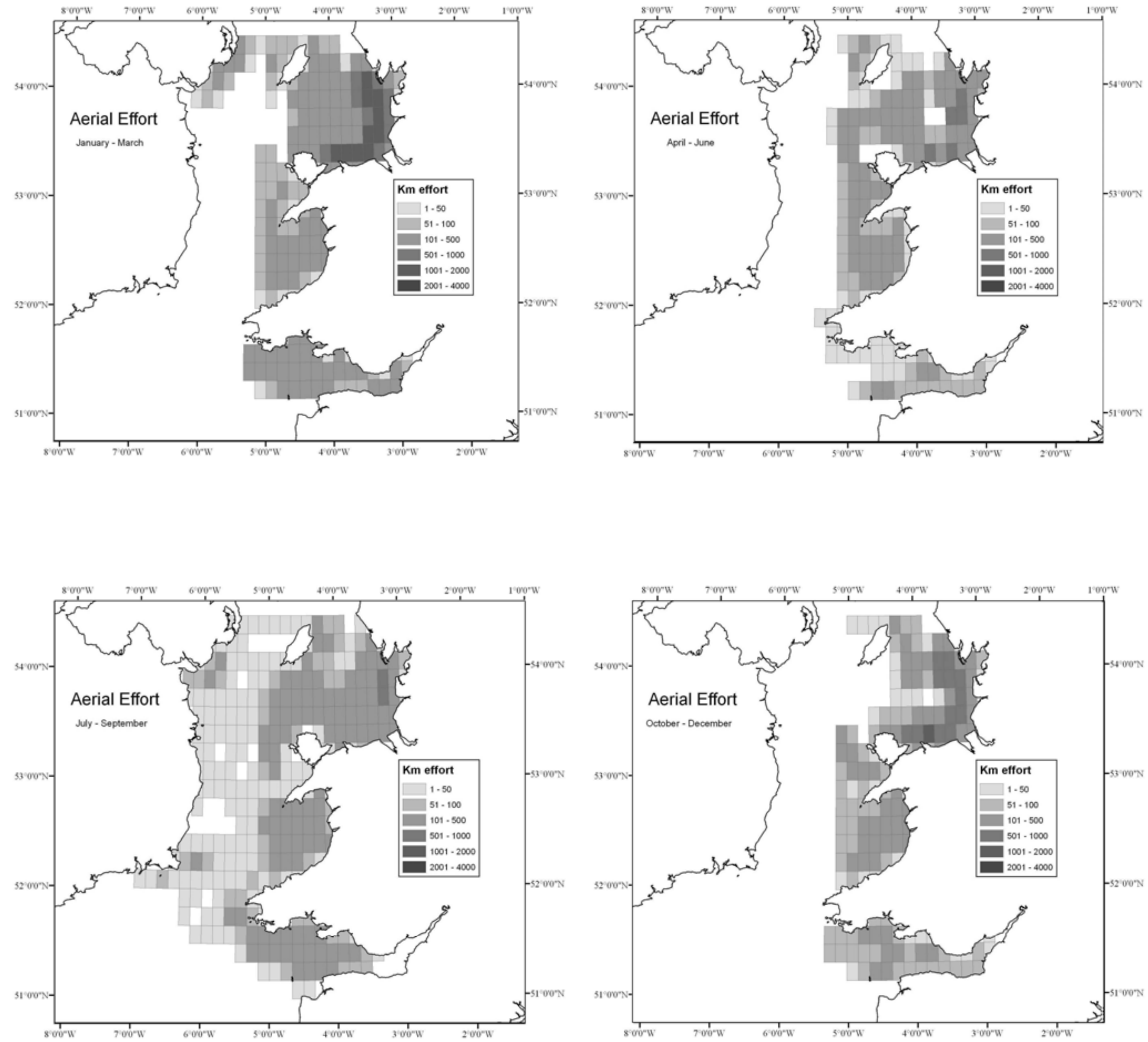


Figure 64 – Quarterly effort (in kilometres) from aerial surveys

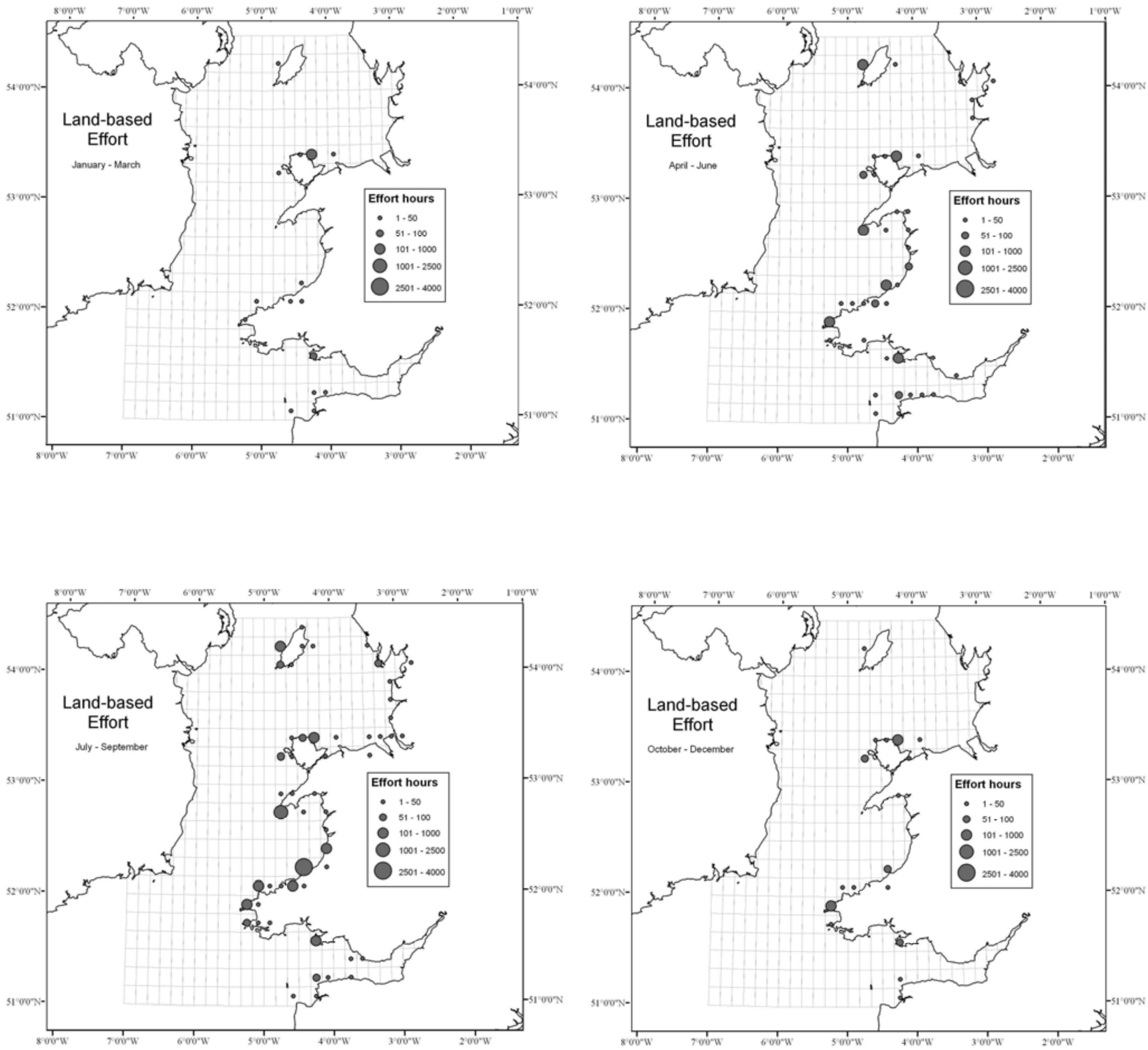


Figure 65 – Quarterly effort (in hours) from land surveys

3.2 Marine Mammal Fauna of Wales

Eighteen cetacean species have been recorded since 1990 in Welsh waters. Five of these are regular (with >100 sightings in the Project Database; see Table 8). These include harbour porpoise, bottlenose dolphin, common dolphin, Risso's dolphin and minke whale. A further thirteen species have been recorded more rarely. These are: fin whale, sei whale, humpback whale, pygmy sperm whale, northern bottlenose whale, Cuvier's beaked whale, Sowerby's beaked whale, Blainville's beaked whale, long-finned pilot whale, killer whale, striped dolphin, white-beaked dolphin, and Atlantic white-sided dolphin. Table 8 lists the number of sightings and individuals contained within the project database (from all the effort-based observations analysed here); Table 9 summarises the total numbers within the Sea Watch database (which includes both effort-related and casual observations, but does not include data submitted for this project from other contributors); and Table 10 lists strandings from the Welsh coast. Maps of the distribution of strandings, and/or sightings of the rarer species from the project database, are included in the electronic Appendix.

Table 8 - Summary of species in the Project Database

Species	Sightings	Count of Individuals
Identified cetaceans		
Harbour porpoise	13,056	35,700
Bottlenose dolphin	10,236	33,683
Short-beaked common dolphin	1,502	19,861
Risso's dolphin	616	1,515
Minke whale	211	274
Fin whale	31	81
Killer whale	6	14
White-beaked dolphin	5	10
Atlantic white-sided dolphin	4	67
Long-finned pilot whale	2	3
Humpback whale	3	5
Northern bottlenose whale	1	1
Unidentified cetaceans		
Dolphin species	406	1,362
Cetacean species	418	503
Large whale	27	39
Unidentified small whale	13	17
Unidentified whale	6	6
Patterned dolphin species	2	8
Common / striped dolphin	2	53
Fin / sei whale	7	27
Seals		
Grey seal	2,580	3,428

Table 9 - Summary of all sightings data (effort + non-effort) in Sea Watch database for study area and time period under review

Species	Sightings	Counts of Individuals
Harbour porpoise	10,385	42,615
Bottlenose dolphin	6,836	33,552
Short-beaked common dolphin	1,606	23,442
Risso's dolphin	614	2,813
Minke whale	495	710
Killer whale	54	104
Fin whale	29	67
Long-finned pilot whale	21	120
Atlantic white-sided dolphin	6	67
Humpback whale	23	30
Striped dolphin	4	11
Northern bottlenose whale	4	7
White-beaked dolphin	2	9
Sei whale	1	1

Table 10 - Summary of strandings on the coasts of Wales

Species	Number
Identified cetaceans	
Harbour porpoise	1,312
Short-beaked common dolphin	126
Bottlenose dolphin	36
Striped dolphin	33
Long-finned pilot whale	18
Risso's dolphin	16
Minke whale	6
Atlantic white-sided dolphin	4
Fin whale	4
Sowerby's beaked whale	2
Blainville's beaked whale	1
Cuvier's beaked whale	1
Humpback whale	1
Northern bottlenose whale	1
Pygmy sperm whale	1
Unidentified cetaceans	
Cetacean species	122
Common / striped dolphin	29
Dolphin species	10
Beaked whale species	1

It should be noted that strandings data for cetaceans and land counts of grey seals presented here are confined to the coasts of Wales.

3.3 Map Outputs

A full set of 236 maps is provided as an electronic Appendix, comprising the following:

Effort

Overall kilometres of vessel-based effort in the study area from 1990 – 2009
Overall kilometres of aerial-based effort in the study area from 2000 – 2009
Overall hours of land-based effort in the study area from 1990 – 2009
Kilometres of effort for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys (4 maps)
Overall kilometres of aerial-based effort in the study area from 2000-04 and 2005-09 (2 maps)
Hours of effort for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from land surveys (4 maps)
Quarterly effort (in kilometres) from vessel surveys (4 maps)
Quarterly effort (in kilometres) from aerial surveys (4 maps)
Quarterly effort (in hours) from land surveys (4 maps)

Cetacean species distribution maps (Harbour porpoise, Bottlenose dolphin, Short-beaked Common dolphin, Risso's dolphin & Minke whale)

Long-term mean sighting rates (vessel counts per 10km) plotted over effort (5 maps)
Long-term mean sighting rates (vessel counts per 10km) interpolated (5 maps)
Long-term mean sighting rates (aerial counts per 100km) (5 maps)
Long-term mean sighting rates (land counts per hour) (5 maps)
Mean sighting rates for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys (20 maps)
Mean sighting rates for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from land-based surveys (20 maps)
Long term quarterly mean sighting rates from vessel surveys (20 maps)
Long term quarterly mean sighting rates from aerial surveys (20 maps)
Long term quarterly mean sighting rates from land surveys (20 maps)
Long term mean monthly ratio of juveniles to adults (27 maps)
Distribution of strandings on the coasts of Wales (40 maps)

Grey seal

Grey seal annual pup production in Wales
Counts at grey seal haul-out sites in Wales during non-breeding season
Sighting rates of grey seals 1990 – 2009 plotted over effort
Sighting rates of grey seals 1990 – 2009 interpolated
Long term quarterly mean sightings rates of grey seal from vessel surveys (4 maps)

Rare cetacean species

Total number of sightings per cell 1990 – 2009 (9 maps)

Species diversity

The number of cetacean species recorded in each cell (2 maps)

3.4 Harbour porpoise *Phocoena phocoena*

This is a very widespread species, occurring throughout the study area, although sighting rates tend to be higher in coastal areas than offshore. Within the 12 nm territorial limit around the coast of Wales, count rates from vessel surveys are highest off North and West Anglesey (particularly around Point Lynas & South Stack, Holyhead), the southwest coast of the Lleyn Peninsula, southern Cardigan Bay, in the vicinity of Strumble Head and the west Pembrokeshire islands (Skomer & Ramsey), and south of the Gower Peninsula east into Swansea Bay (Figure 66). Care should be taken not to over-interpret the map of interpolated sighting rates (Figure 66b); refer to section 2.4.3 for an explanation of the interpolation process (and see Figures 41-43). It is also important to note that the interpolated maps are based upon vessel surveys only.

Aerial survey effort has been concentrated in coastal areas (with the exception of west Pembrokeshire where effort was lower). They show highest count rates west of Anglesey, along the south coast of the Lleyn Peninsula, in Carmarthen Bay and Swansea Bay (Figure 67). Interestingly, they do not show the high count rates observed from vessel surveys for southern Cardigan Bay. The same discrepancy applies to the bottlenose dolphin (see section 3.5). It might relate to the fact that the WWT surveys generally end their transects c. 1.5 km from the coast so that a turn can be completed without crashing (G. Bradbury, WWT Consulting, *pers. comm.*). Surveyors keep counting until that end point but beyond that any nearshore animals will not be counted. Land-based surveys were also mainly conducted in the summer months and show highest count rates off North Anglesey, around the western end of the Lleyn Peninsula, off Northwest Pembrokeshire (particularly around Strumble Head and Ramsey Sound), and the eastern end of Swansea Bay (Figure 68).

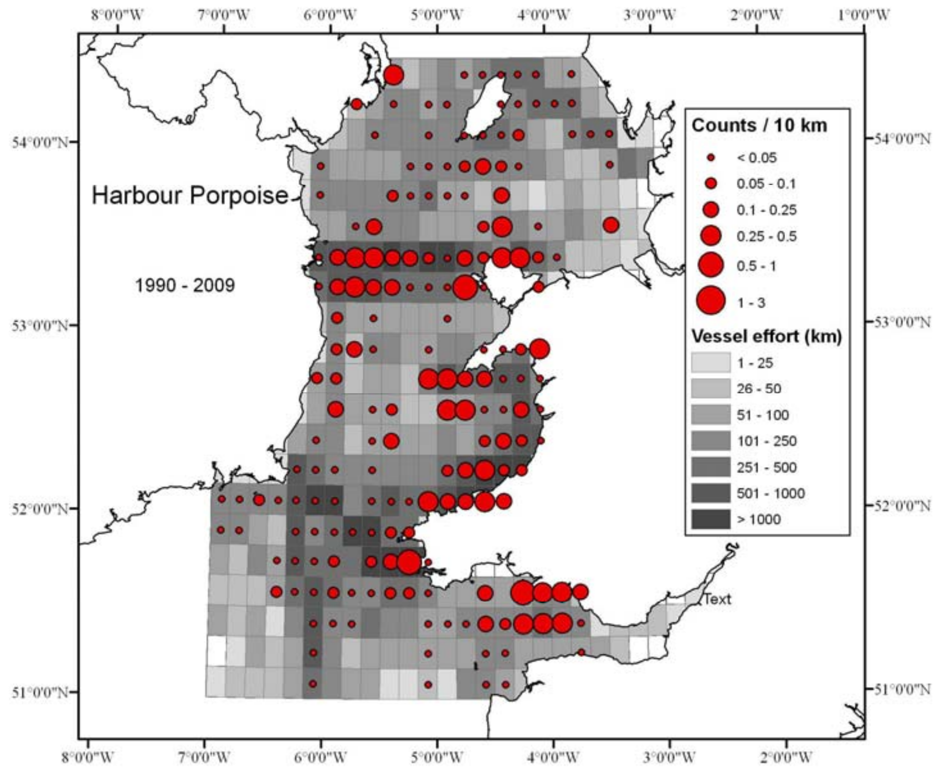
Sighting rates from vessel surveys have increased in most regions within the Irish Sea since the mid 1990s (Figure 69). Effort data from the 1980s also indicate lower numbers in the Irish Sea at that time (Evans *et al*., 2003; Paxton & Thomas, 2010). Interpretation of long-term patterns in land counts is hampered by the variation in observation effort, with much more watches in Anglesey (and the Isle of Man) in the last ten years than previous to that whereas effort in Pembrokeshire has declined over the same time period. Nevertheless, some of the sites in West Pembrokeshire that were watched regularly in the 1990s showed high count rates during the whole of that decade (see also Evans, 1995; Pierpoint *et al*., 1998; Pierpoint, 2008).

Bearing in mind the low levels of effort during the winter months particularly from vessel surveys and land watches, the species is clearly present in Welsh waters throughout the year, as indicated from the maps of long term quarterly mean count rates from vessel and aerial surveys and land watches (Figures 71-73). Although summer peaks in abundance have been widely reported (Evans, 1995; Pierpoint *et al*., 1998; Evans *et al*., 2003; Shucksmith *et al*., 2009), there is some evidence at least from southern Cardigan Bay and north Pembrokeshire that numbers may actually be higher there during winter months (Pierpoint *et al*., 1998, 1999; Pesante *et al*., 2008b).

The maps of the long term monthly mean ratio of juveniles to adults for the months May to September (derived from vessel and land-based observation effort as shown in the plots) indicate higher proportions of juveniles in South and Southwest Wales (Figure 74). These areas were also highlighted as important, from strandings data (Penrose & Pierpoint, 1999). However, spatial patterns indicating high proportions of calves should be interpreted with some caution for this, as for each of the other species. The presence of juveniles has not been recorded systematically by all observers, and some groups have not recorded them at all. Furthermore, young porpoise calves tend to swim close alongside their mothers making them difficult to observe in all but ideal conditions, so their presence is likely to be under-recorded in several data sets. Juvenile porpoises have been recorded wherever numbers are seen in summer (see also Pesante *et al*., 2008; Shucksmith *et al*., 2009; Sea Watch Foundation, unpublished data).

No particular spatial pattern exists for strandings, which occur along all sectors of the Welsh coastline (Figure 75). Note that the symbols are placed over cell centres, so some may appear to be inland. In some cases, carcasses were also found in river estuaries. Given the fact that the original locations of animals on death is not known, and the prevailing currents may take them far from those sites (and generally from SSW to NNE), it is impossible to relate this to actual distribution of living animals. The cause of death for most porpoise strandings in Wales, where known, is currently bottlenose dolphin attack (Jepson, 2005; Deaville & Jepson, 2011; Penrose, 2010, 2011).

a) Long-term mean sighting rates overlying effort



b) Interpolated long-term mean sighting rates

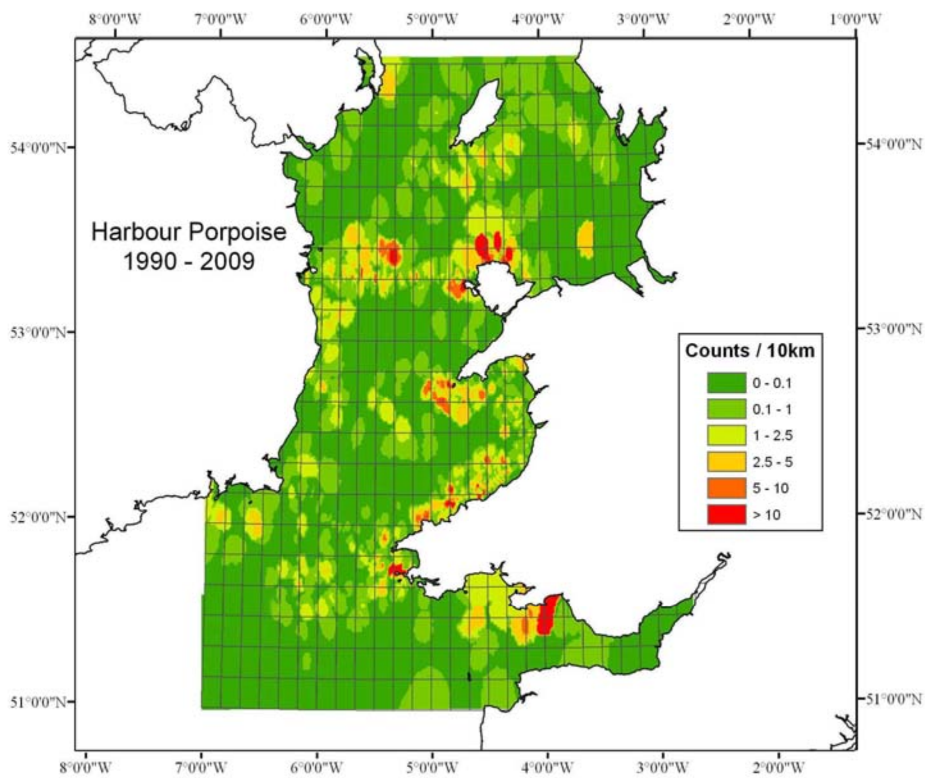


Figure 66 – Long-term mean sighting rates (vessel counts per 10km) of harbour porpoise

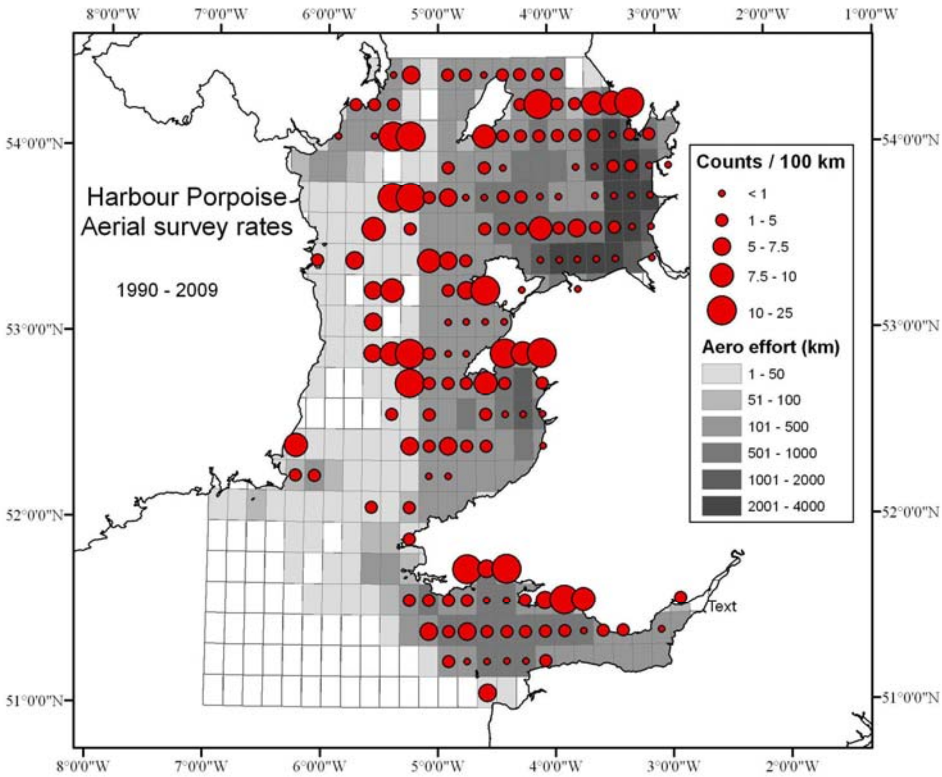


Figure 67 – Long-term mean sighting rates (aerial counts per 100km) of harbour porpoise

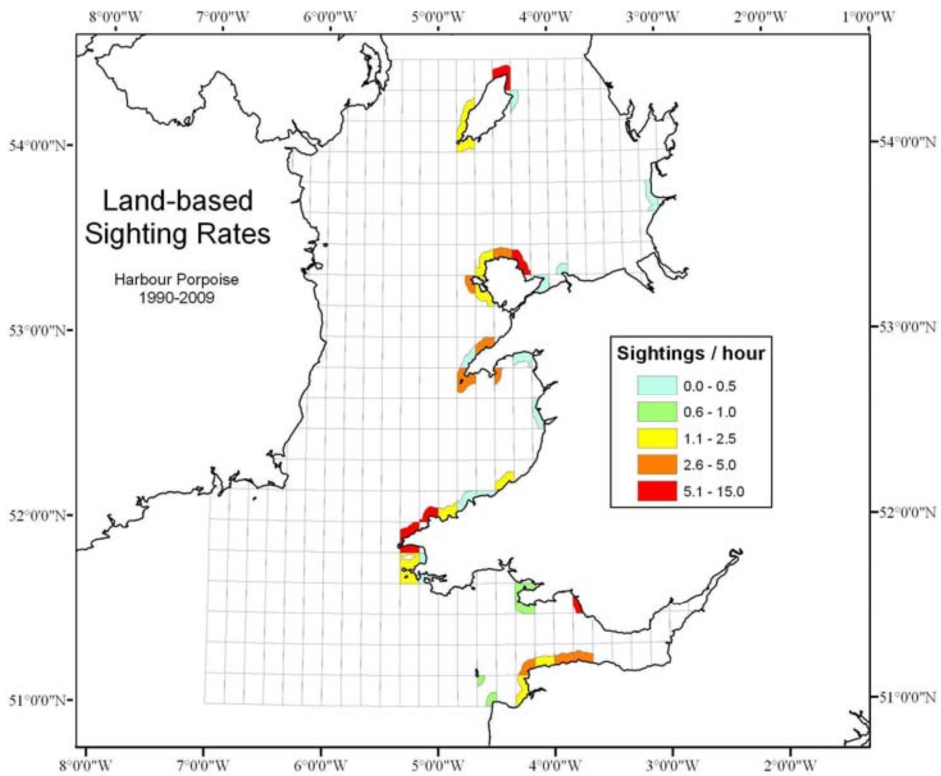


Figure 68 – Long-term mean sighting rates (land counts per hour) of harbour porpoise

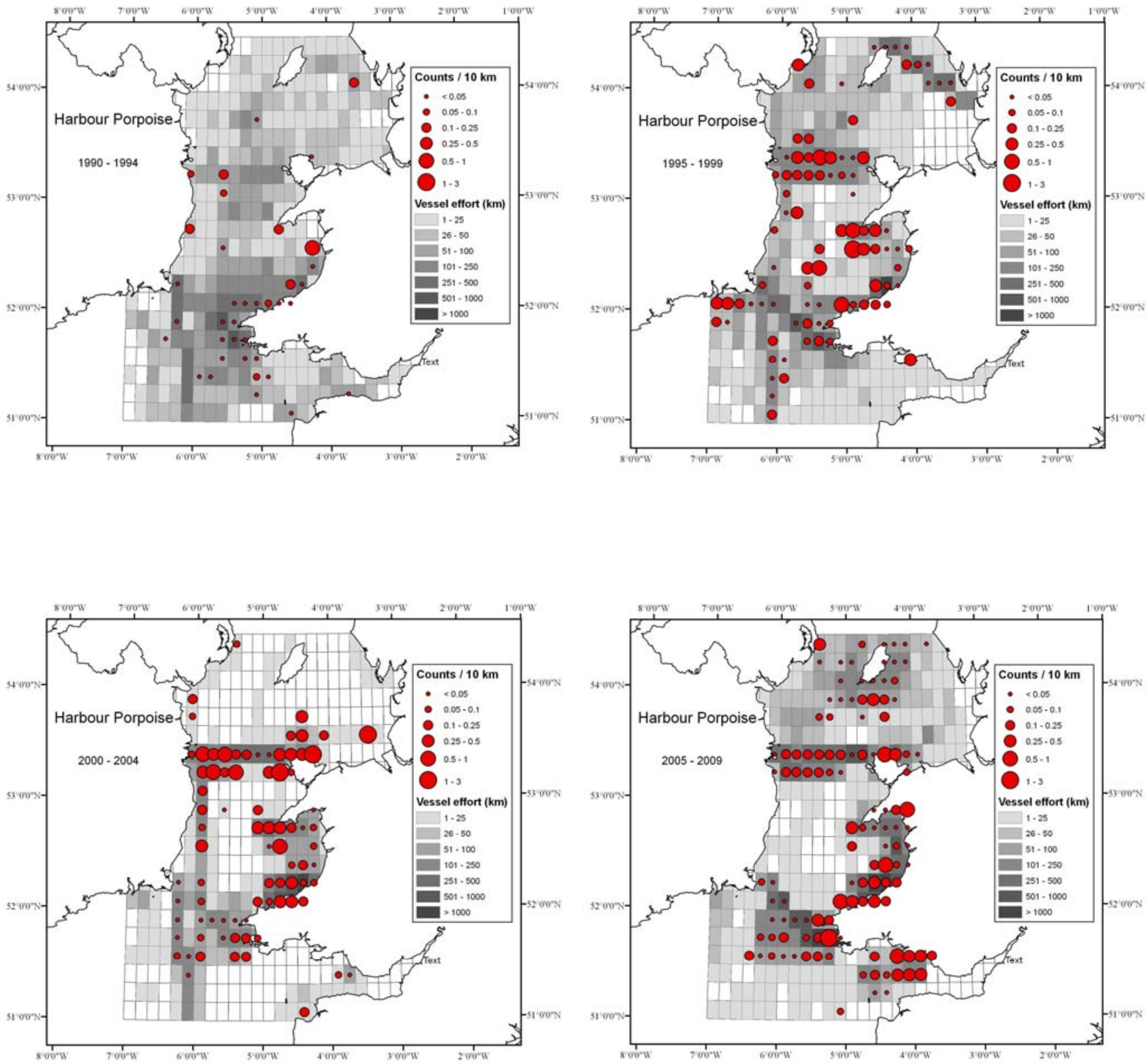


Figure 69 – Mean sighting rates of harbour porpoise for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

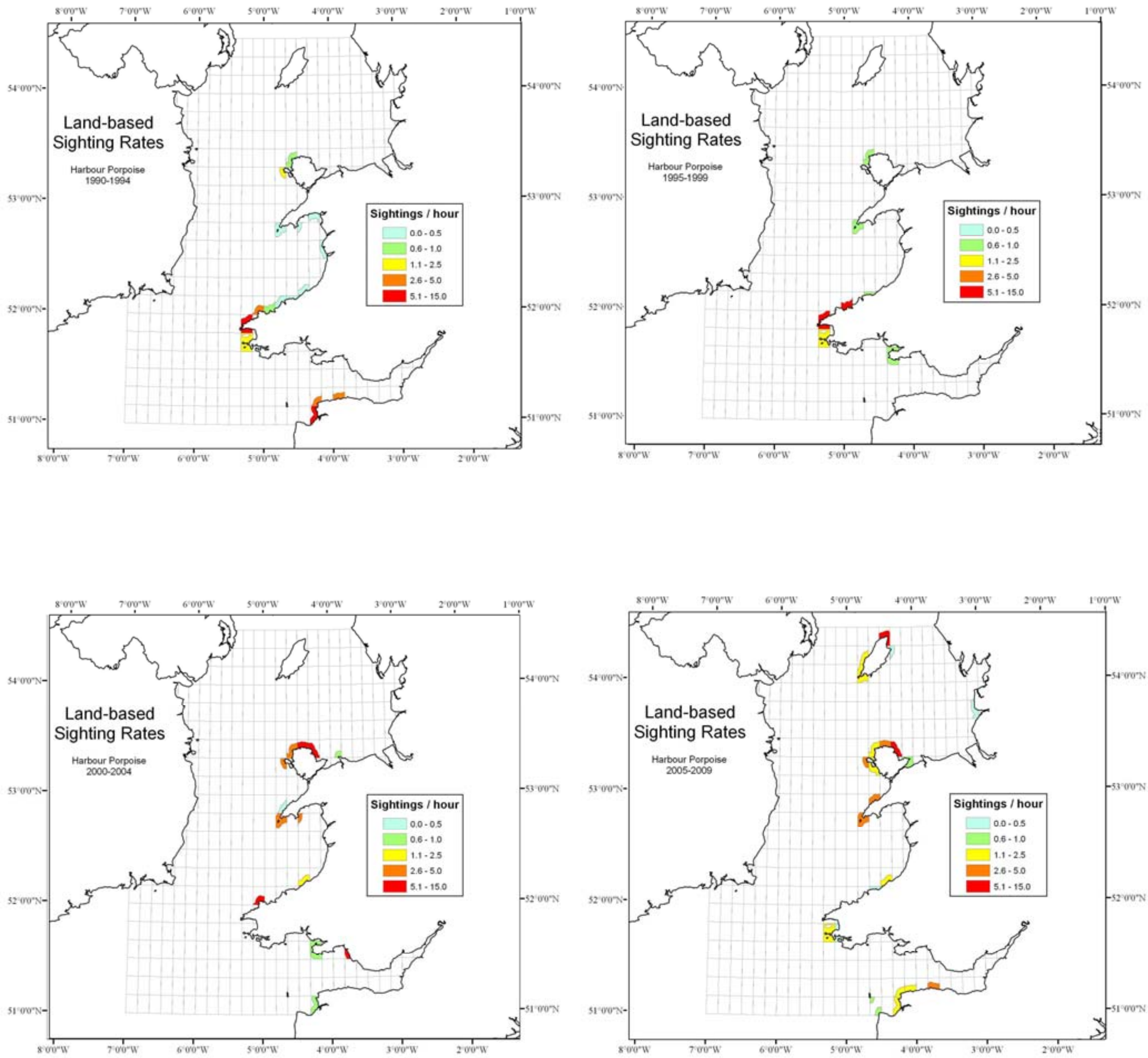


Figure 70 – Mean sighting rates of harbour porpoise for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from land-based surveys

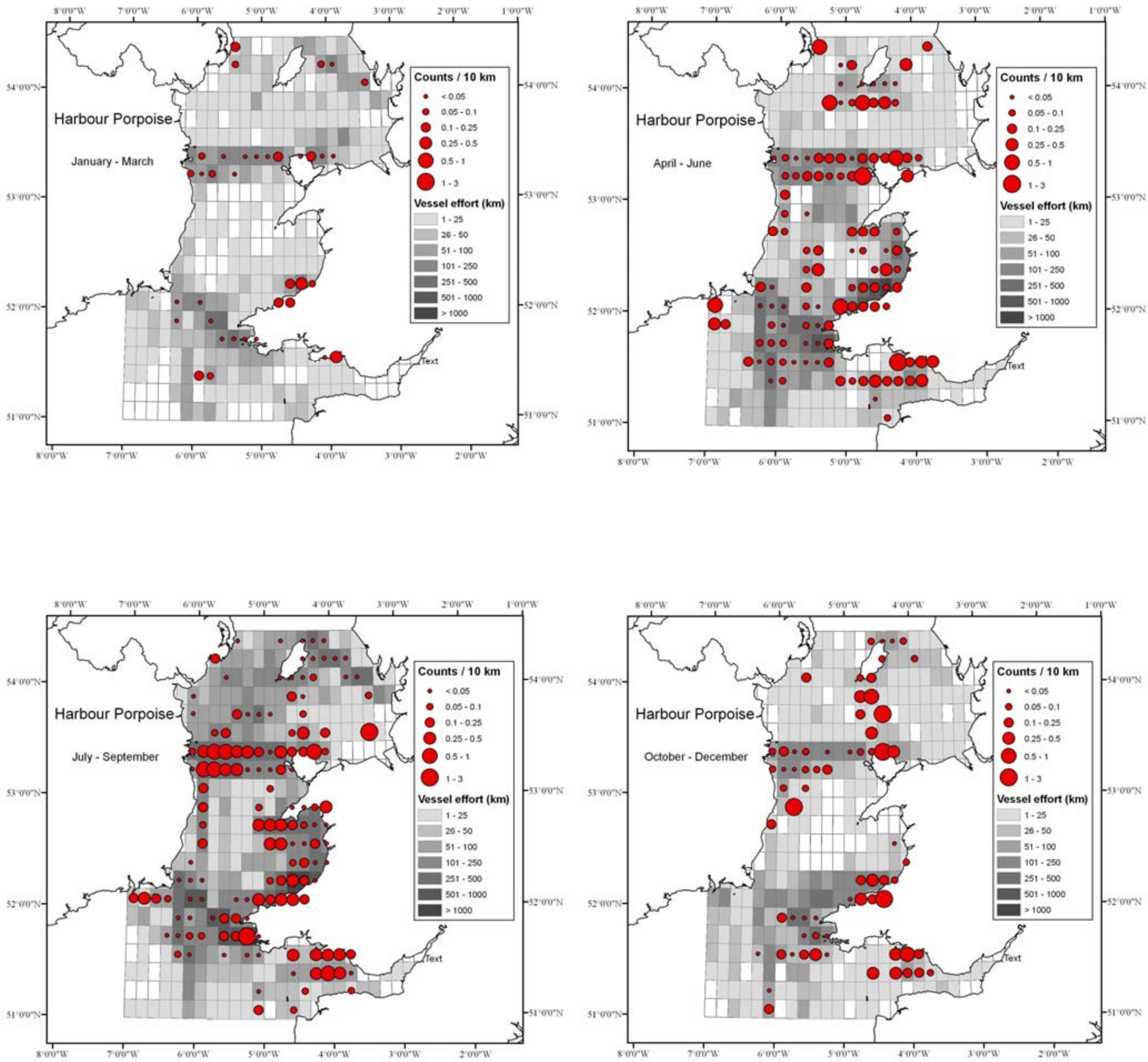


Figure 71 – Long term quarterly mean sighting rates of harbour porpoise from vessel surveys

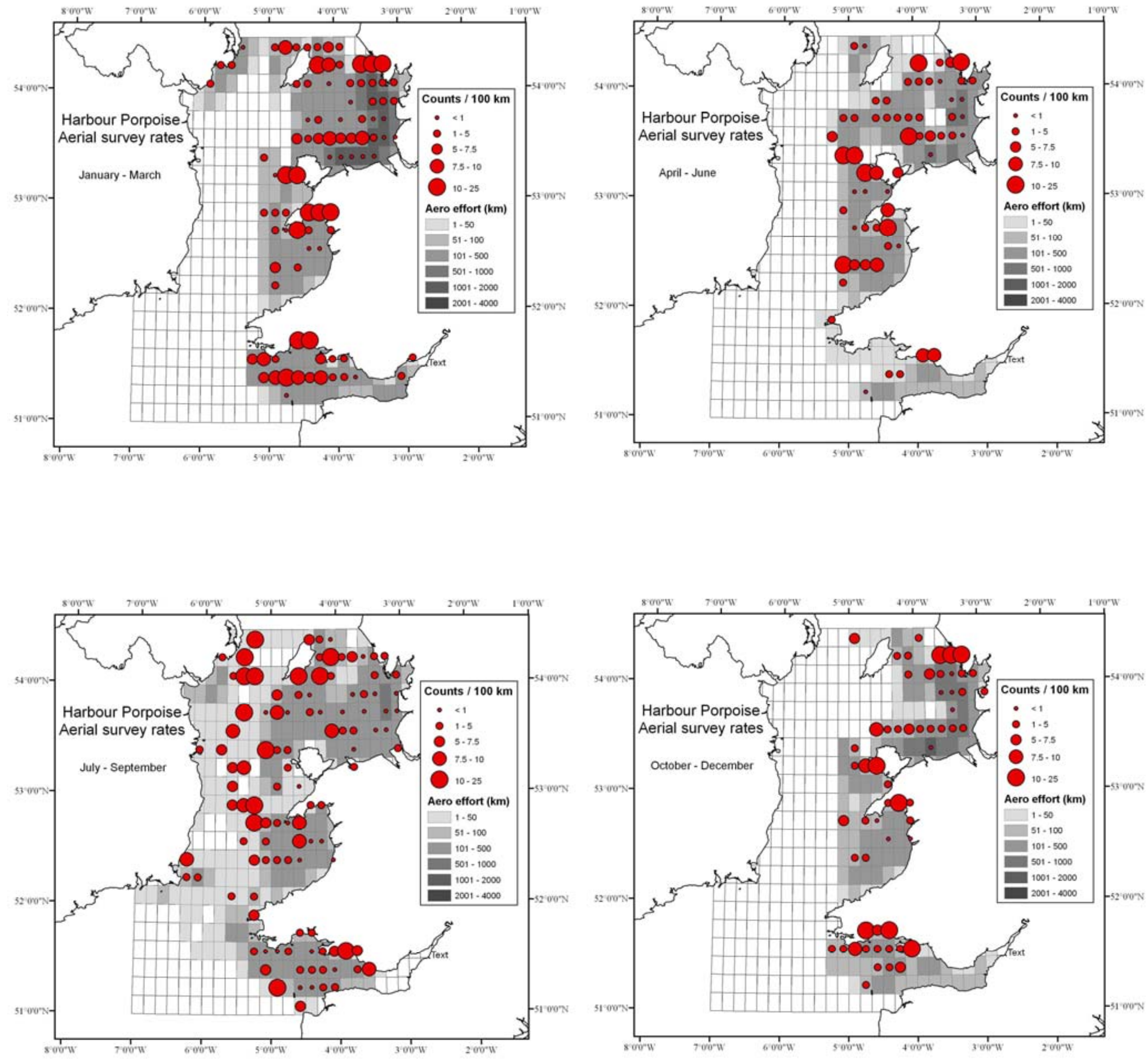


Figure 72 – Long term quarterly mean sighting rates of harbour porpoise from aerial surveys

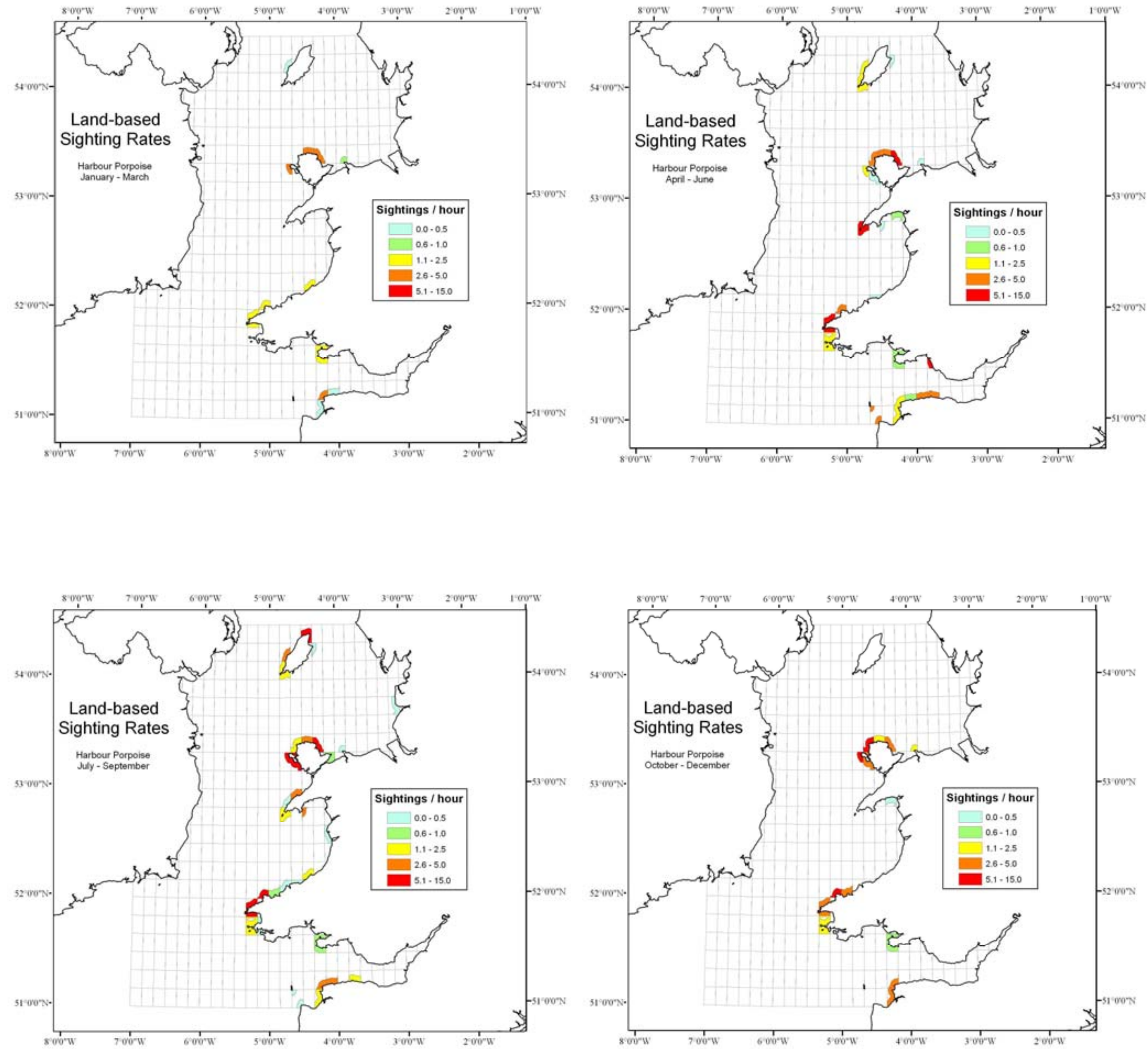


Figure 73 – Long term quarterly mean sighting rates of harbour porpoise from land surveys

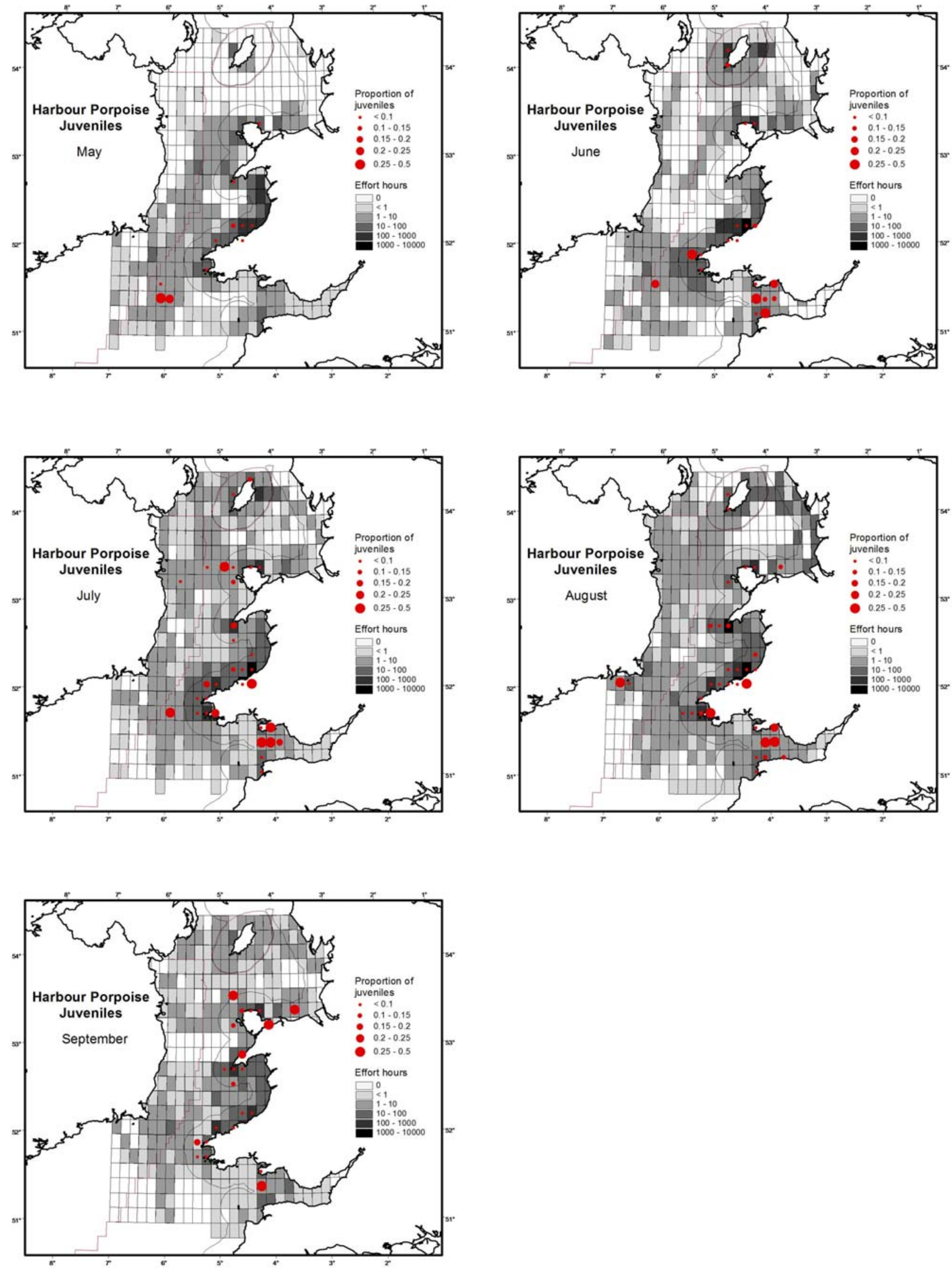


Figure 74 - Long term mean monthly ratio of juveniles to adults of harbour porpoise

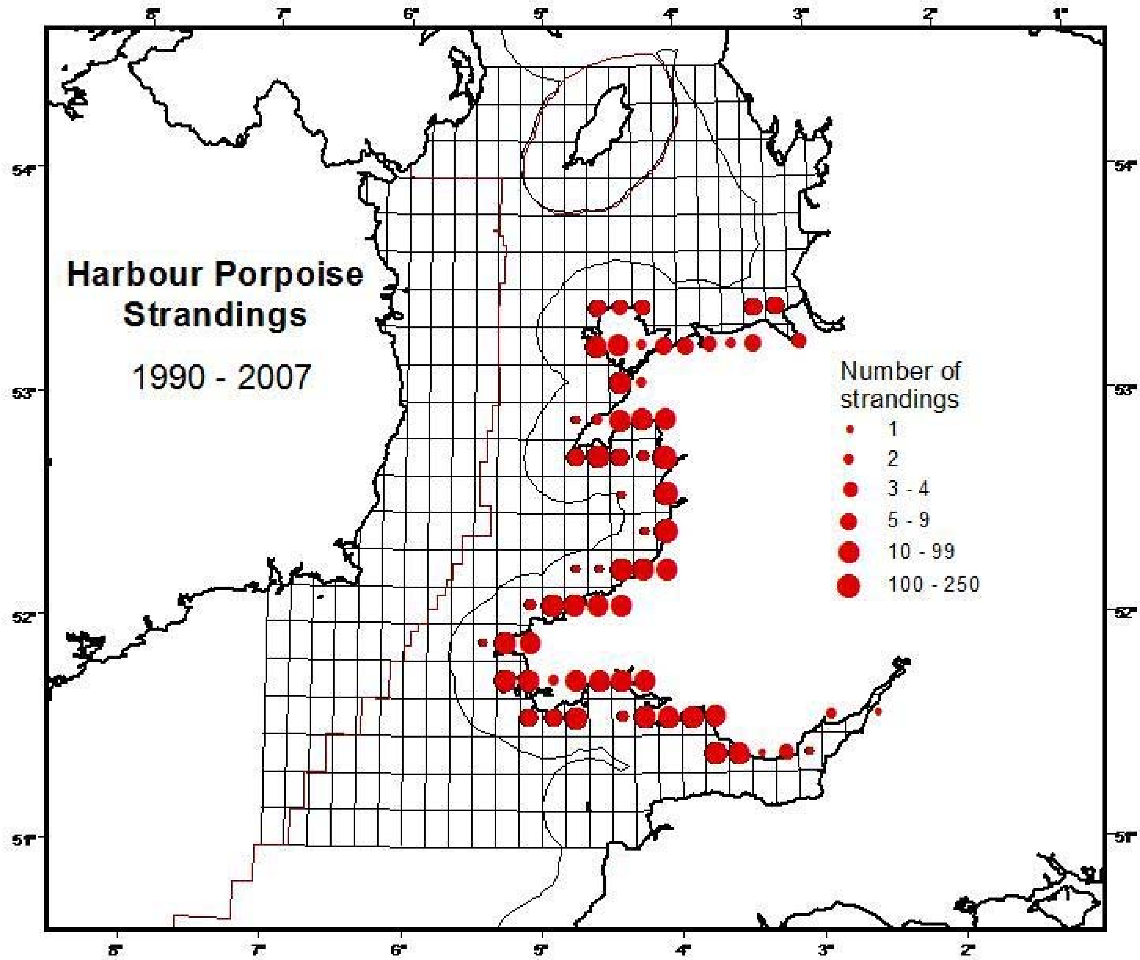


Figure 75 - Distribution of strandings of harbour porpoise on the coasts of Wales

3.5 **Bottlenose dolphin** *Tursiops truncatus*

This is a species with a predominantly coastal distribution within the study area, centred particularly on Cardigan Bay and north & east Anglesey, although its presence in Caernarfon Bay is probably under represented since this area has received little survey effort (Figures 76-78). The species has also been recorded offshore, with low densities in St George's Channel and the southwest sector of the study area (from vessel surveys; Figure 76) and in the northeastern Irish Sea (from aerial surveys; Figure 77). There has been little survey effort in the northeastern Irish Sea for comparison, but interestingly, in southern Cardigan Bay aerial surveys do not reveal the same high densities as do vessel surveys and land counts (Figures 76-78). One possibility is that the dolphins tend to occur very close to the coast in this part of the bay (Baines *et al*., 2002; Ugarte & Evans, 2006; Pesante *et al*., 2008b; Pierpoint *et al*., 2008), and so may be missed if aerial observers go off effort when approaching or leaving land between transect legs, which seems to have been the case 1.5 km from the coast (G. Bradbury, WWT Consulting, *pers. comm.*; see also section 3.4).

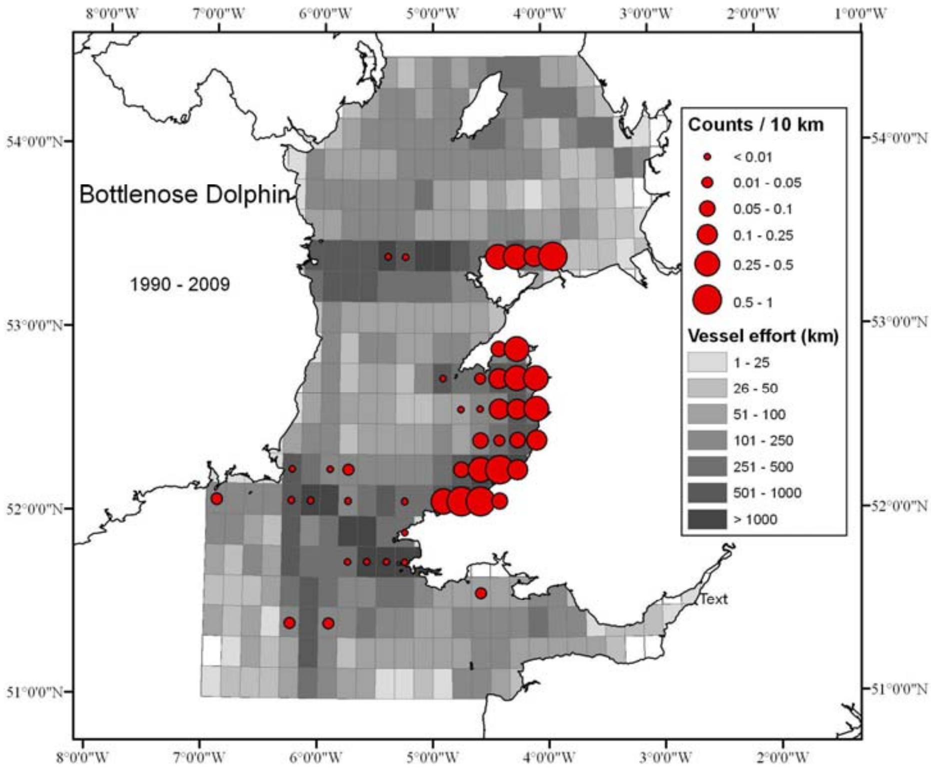
The main concentration of bottlenose dolphin sightings has been in southern Cardigan Bay, with moderately high sighting rates extending throughout Cardigan Bay. However, the species also occurs off the north coast of Wales, particularly north and east of Anglesey (Figure 76). Cardigan Bay has been important for bottlenose dolphins for many years, as reflected in the distribution patterns across time periods (Figures 79-80), although systematic line transect surveys and photo-ID indicate numbers increasing slightly over the last decade (Baines *et al*., 2002; Ugarte & Evans, 2006; Pesante *et al*., 2008b). Recent survey effort off North Wales has also indicated its regular presence there as well (Figure 79). This is not a recent phenomenon, however, as indicated by casual sightings records that have been submitted to Sea Watch over the last 30 years (Evans, 1980, 1992; Evans *et al*., 2003). Casual records also show its presence, albeit erratically, off the Isle of Man and elsewhere in the northeastern Irish Sea (Manx Whale & Dolphin Group unpublished data; Sea Watch Foundation unpublished data).

In Cardigan Bay, there are marked seasonal trends in bottlenose dolphin distribution, with high coastal sighting rates in the summer and autumn, contrasting with low rates in late winter and early spring (Figures 81-82). However, there appears to be a northward shift in distribution in the last quarter of the year that may suggest dispersal into the Irish Sea during the winter, and this is the period when largest group sizes (50-150 individuals) have been recorded in North Wales and in Manx waters (Pesante *et al.*, 2008a, b; Sea Watch Foundation unpublished data). Photo-ID has shown that at least one third of the population from Cardigan Bay (and probably more) move into this region (Pesante *et al*., 2008a; Pesante & Evans, 2008). Generally, smaller groups are observed during summer months, particularly within Cardigan Bay, and these groups are predominantly coastal, whereas in winter they are more dispersed and much larger (Pesante *et al.*, 2008a, b). Although not recorded from vessel or aerial surveys in the first quarter of the year, land-based watches and casual observations indicate that at least some animals remain in Cardigan Bay through the winter (Figure 83; Pesante *et al*., 2008b).

Relatively high proportions of juveniles have been recorded throughout Cardigan Bay, and to a lesser extent in North Wales and in Manx waters (Figure 84). Young have been observed in most months of the year, but particularly between April and October (Figure 84). This corresponds with more detailed observations of newborns from the bottlenose dolphin photo-ID study, which found 60% of births occurred in July and August, and 92% between May and September (Pesante *et al.*, 2008b; Sea Watch Foundation unpublished data). The relatively high sighting rates in Cardigan Bay during summer, with small groups occurring all along the coast, suggests that the Bay is utilised particularly as a calving area for the species.

The spatial pattern of bottlenose dolphin strandings in Wales (Figure 85) agrees largely with the distribution of sightings, occurring mainly within Cardigan Bay and around Anglesey (see also Penrose, 2010).

a) Long-term mean sighting rates



b) Interpolated long-term mean sighting rates

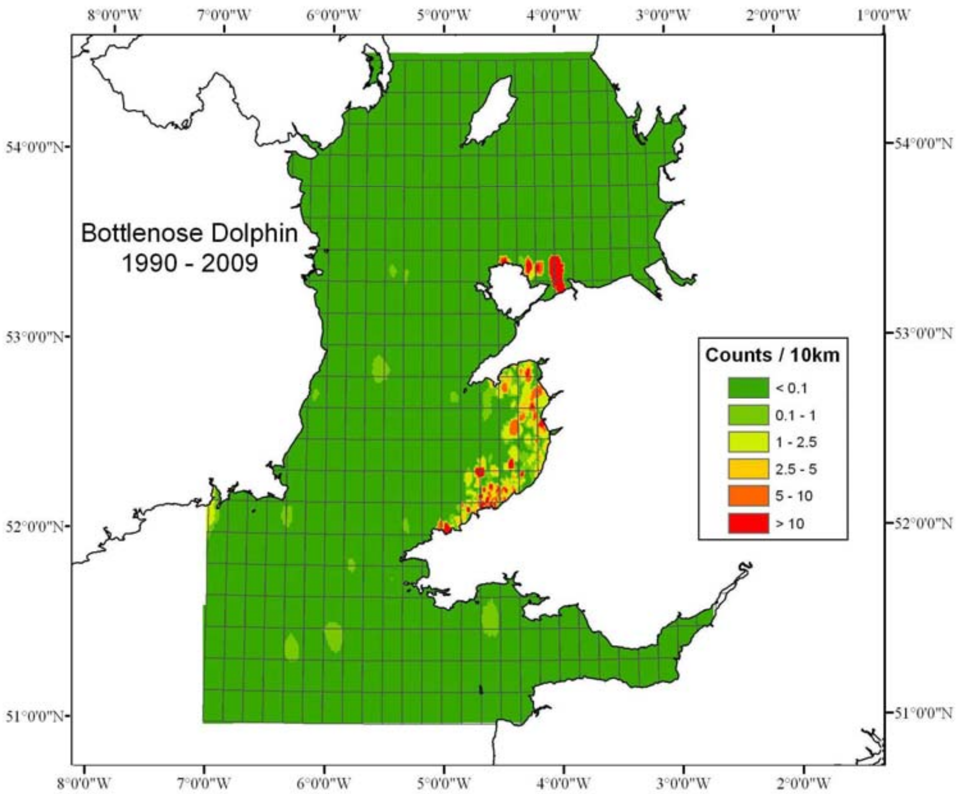


Figure 76 – Long-term mean sighting rates (vessel counts per 10km) of bottlenose dolphin

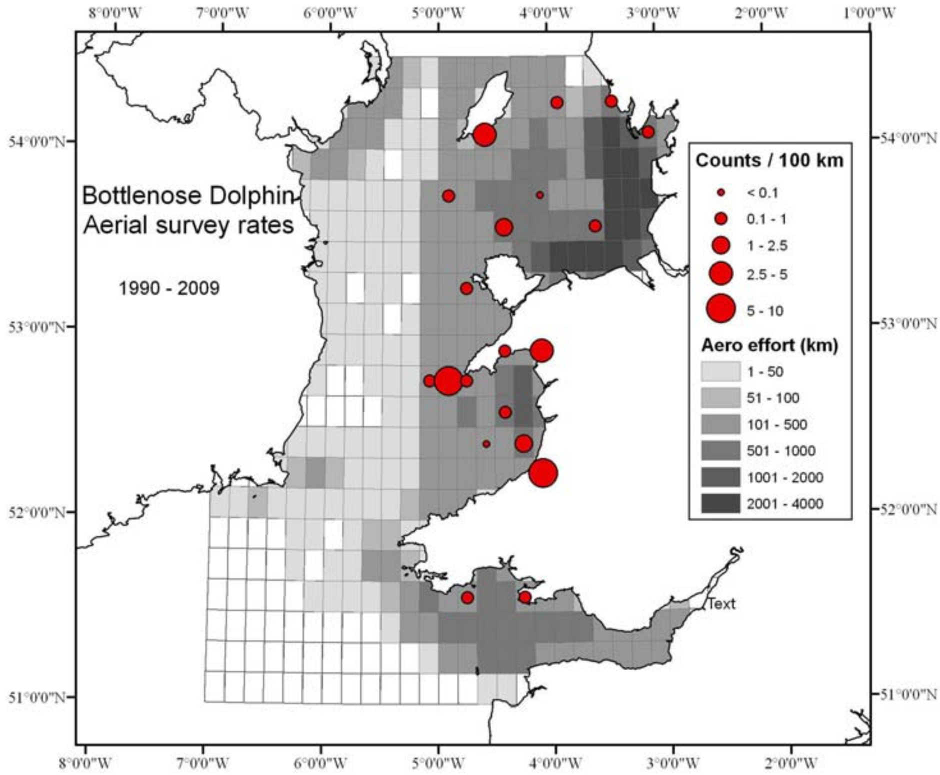


Figure 77 – Long-term mean sighting rates (aerial counts per 100km) of bottlenose dolphin

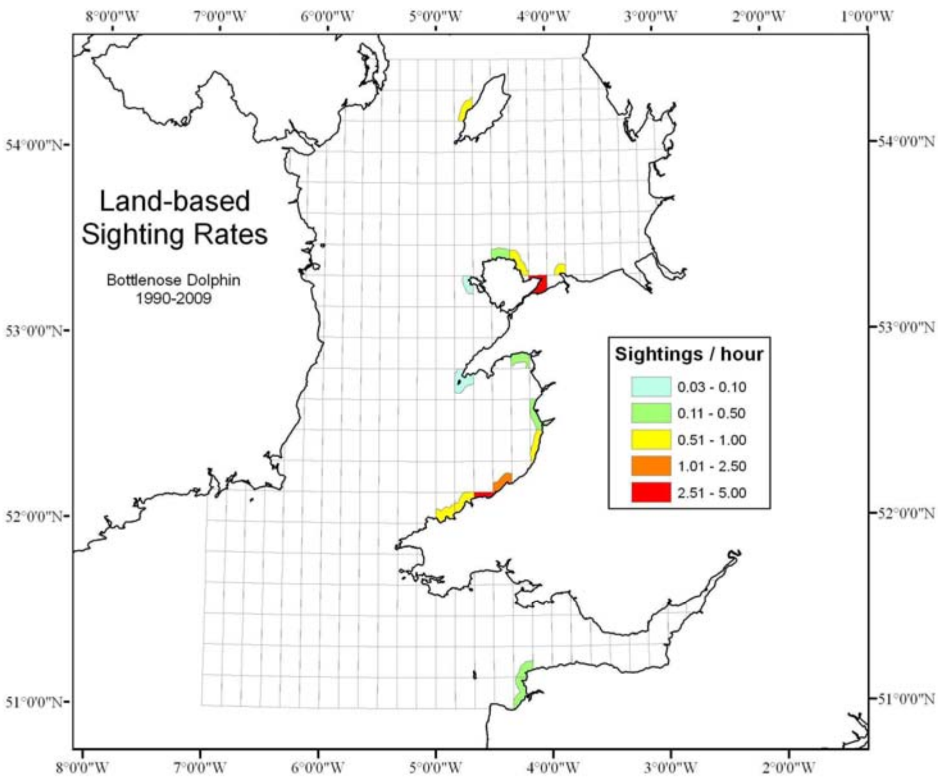


Figure 78 – Long-term sighting rates (land counts per hour) of bottlenose dolphin

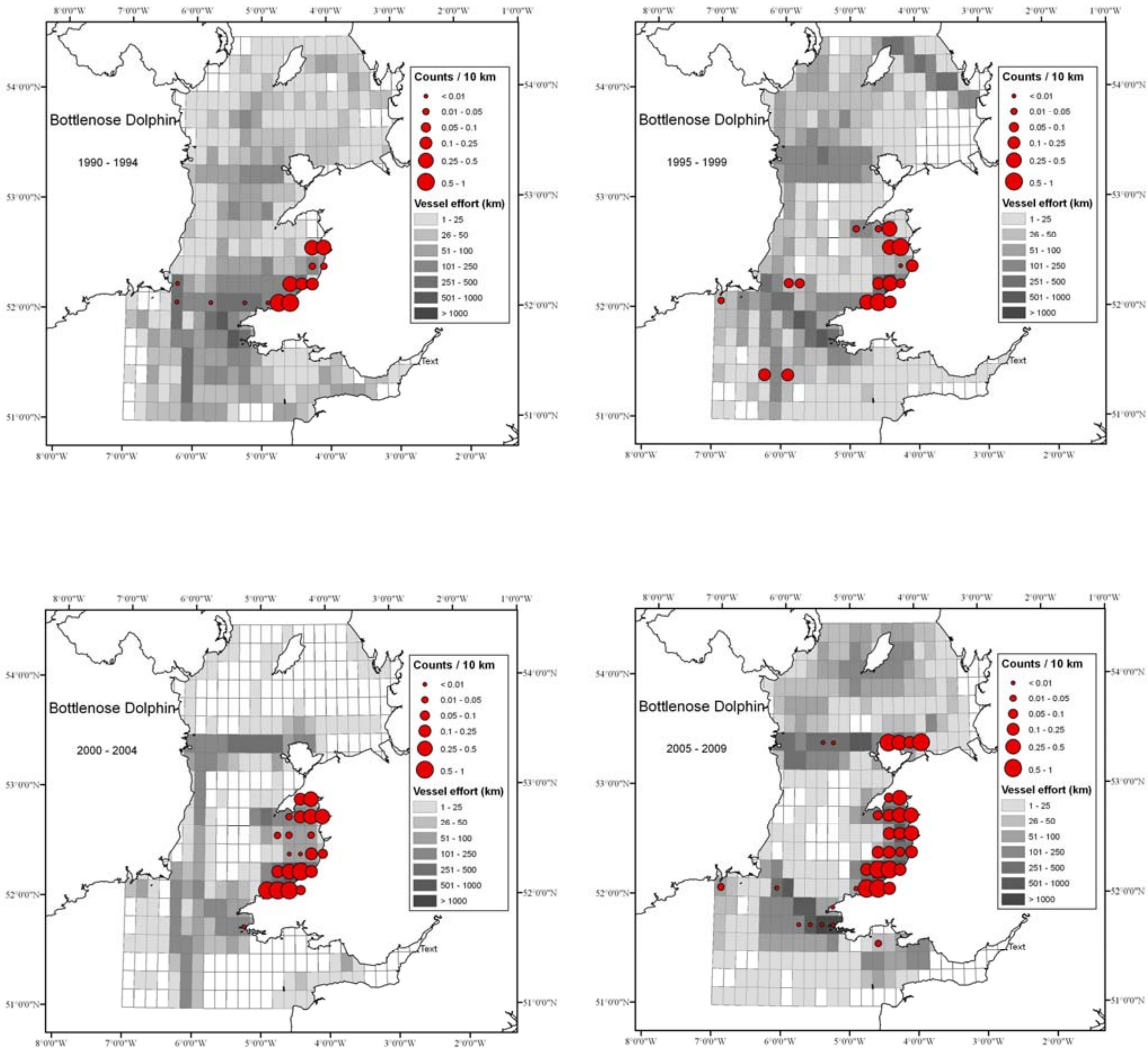


Figure 79 – Mean sighting rates of bottlenose dolphin for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

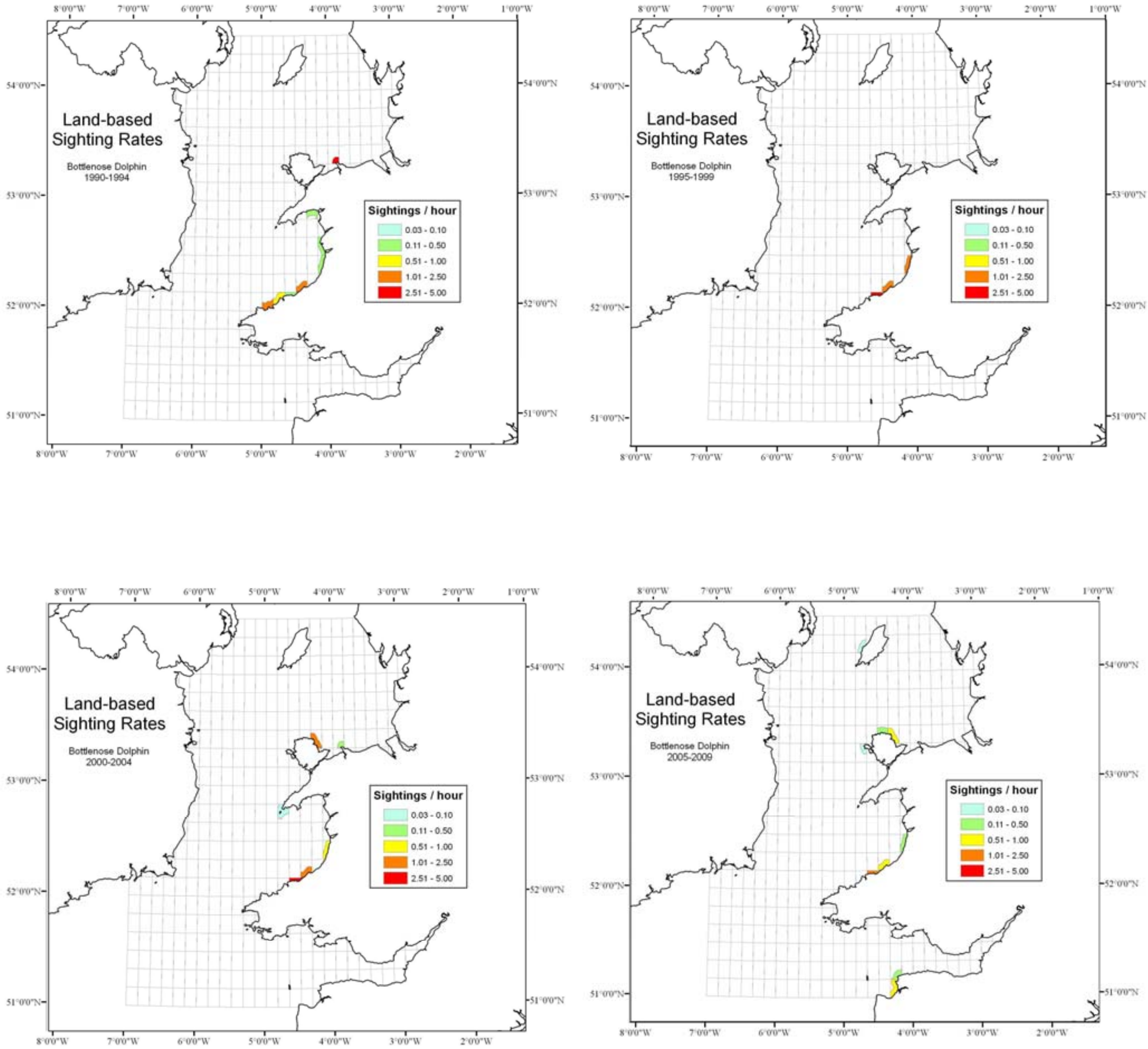


Figure 80 – Mean sighting rates of bottlenose dolphin for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from land surveys

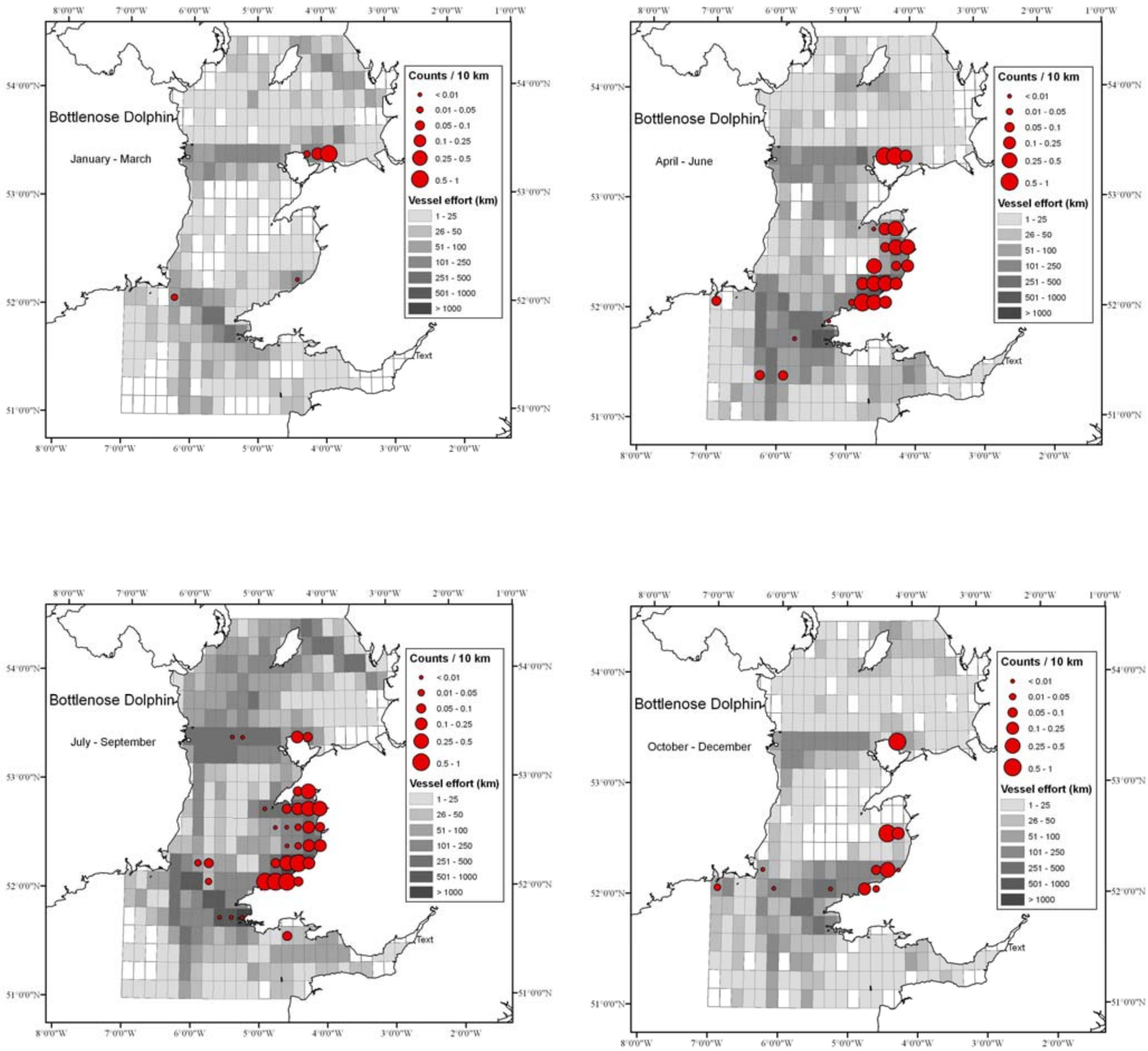


Figure 81 – Long term quarterly mean sighting rates of bottlenose dolphin from vessel surveys

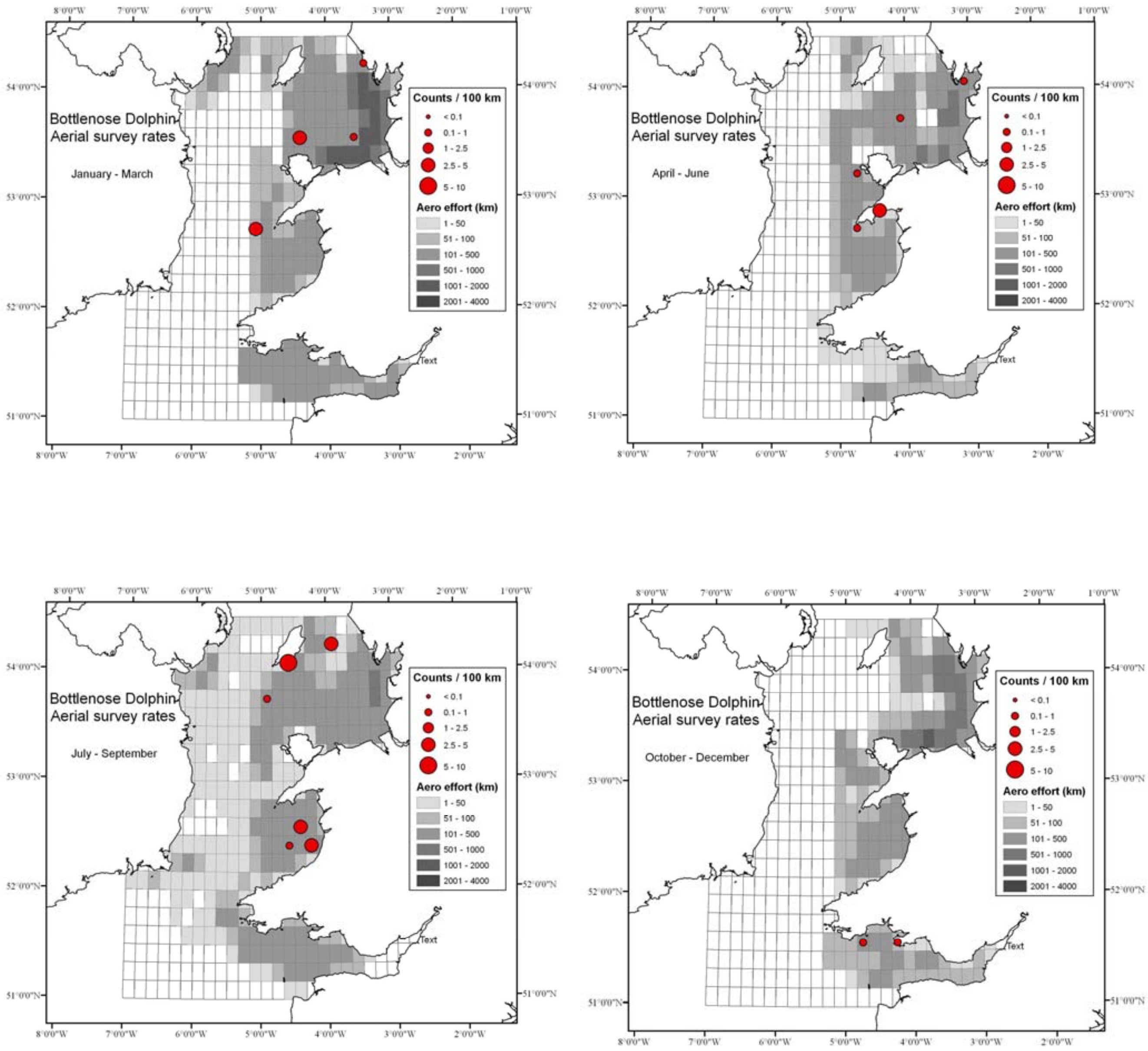


Figure 82 – Long term quarterly mean sighting rates of bottlenose dolphin from aerial surveys

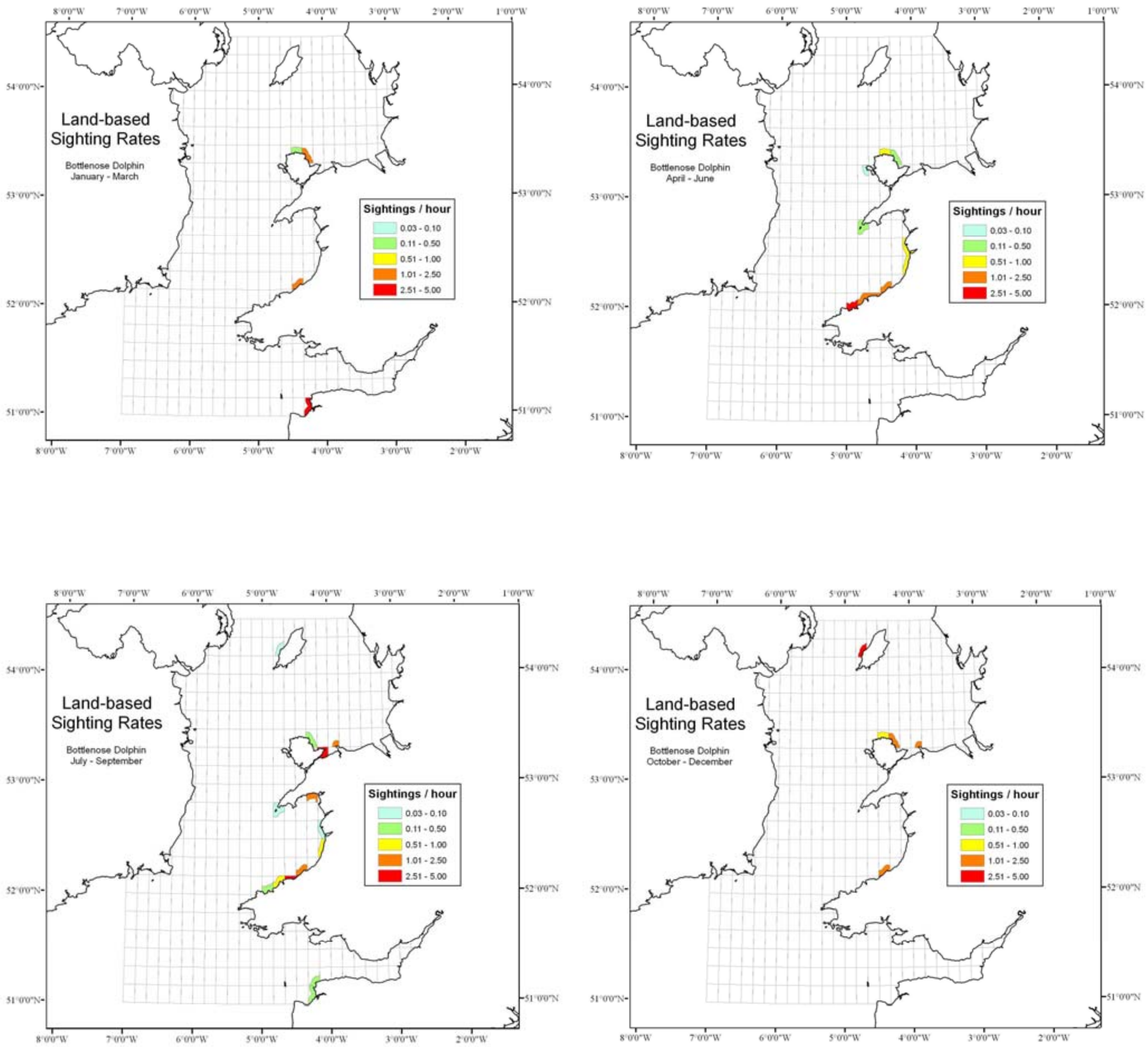


Figure 83 – Long term quarterly mean sighting rates of bottlenose dolphin from land surveys

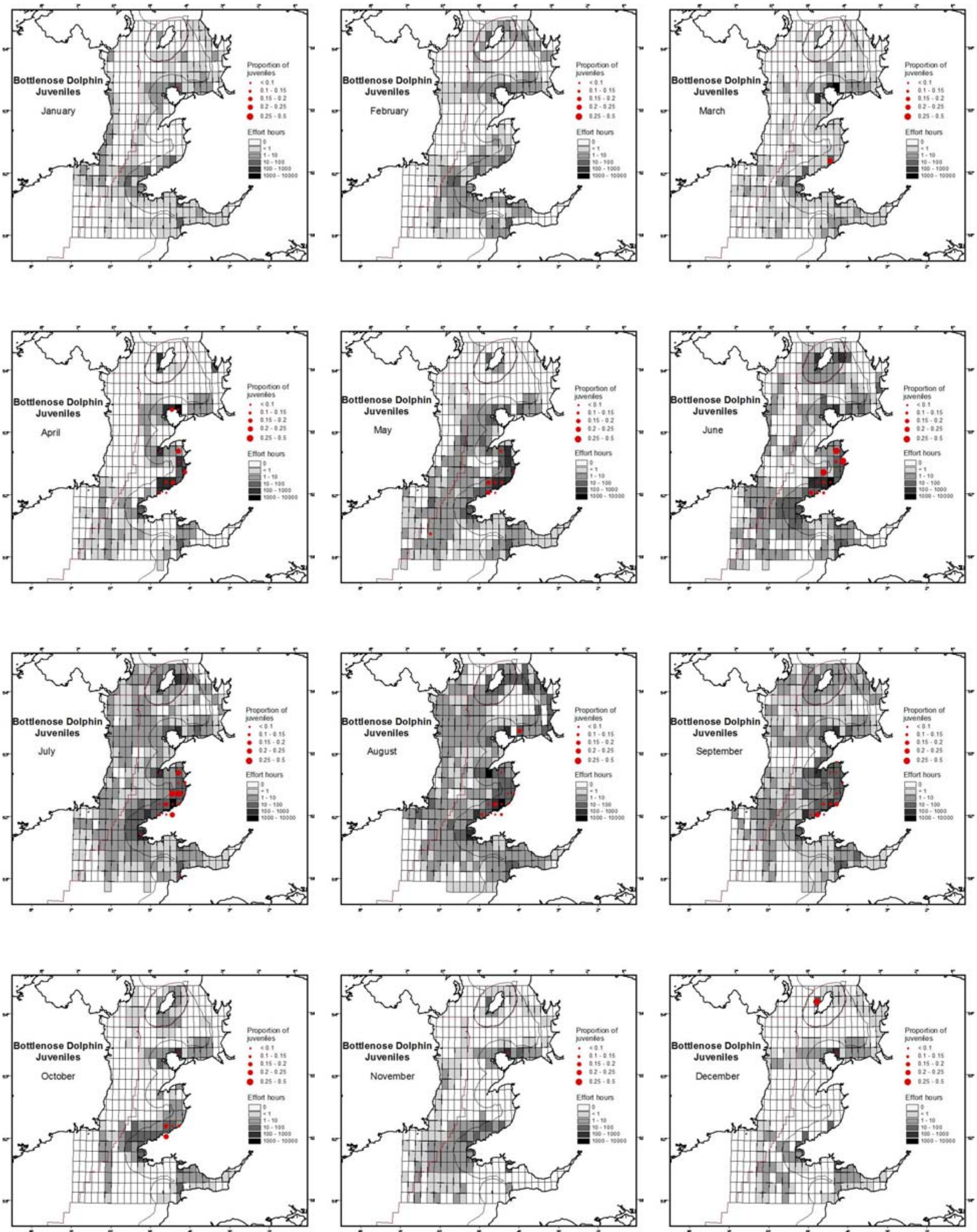


Figure 84 – Long term monthly ratio of juveniles to adults of bottlenose dolphin

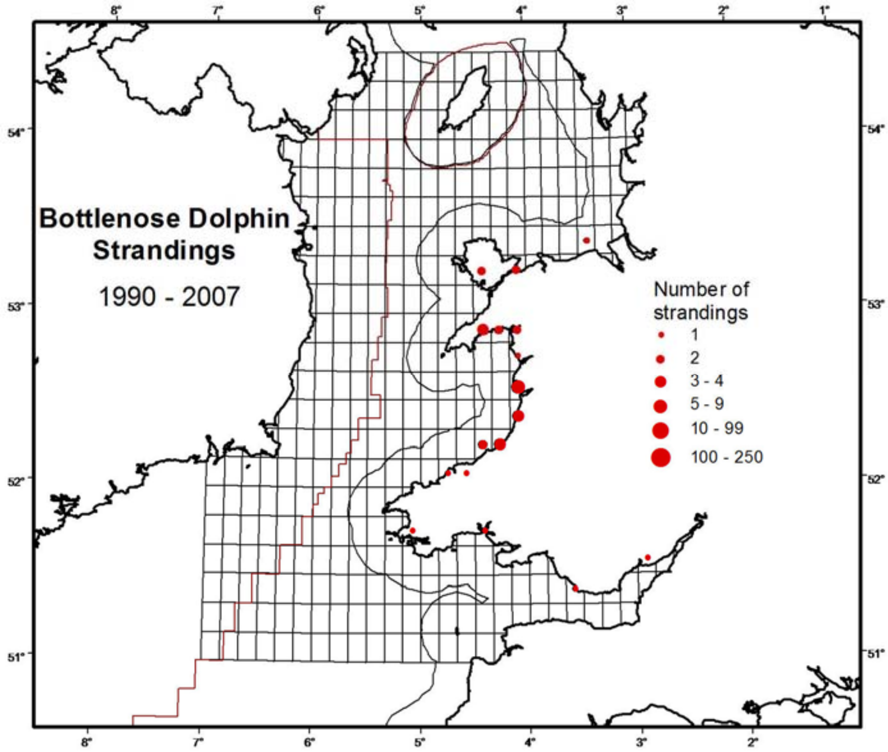


Figure 85 – Distribution of strandings of bottlenose dolphin on the coasts of Wales

3.6 Short-beaked common dolphin *Delphinus delphis*

There is a clearly defined area of high sighting rates of common dolphins over the Celtic Deep, offshore to the west of Pembrokeshire. This high-density area straddles the median line, although it falls largely on the Welsh side and extends partly within the 12 nm territorial limit of Wales. Moderately high densities have been recorded over the Celtic Shelf in the southwest of the study area, whereas relatively low densities occur further north in the Irish Sea (Figures 86-87), although the species is nevertheless seen regularly off the Isle of Man (Figure 88). This southerly concentration for the species within the region has been observed in each of the four time-periods examined, from 1990-2009 (Figure 89).

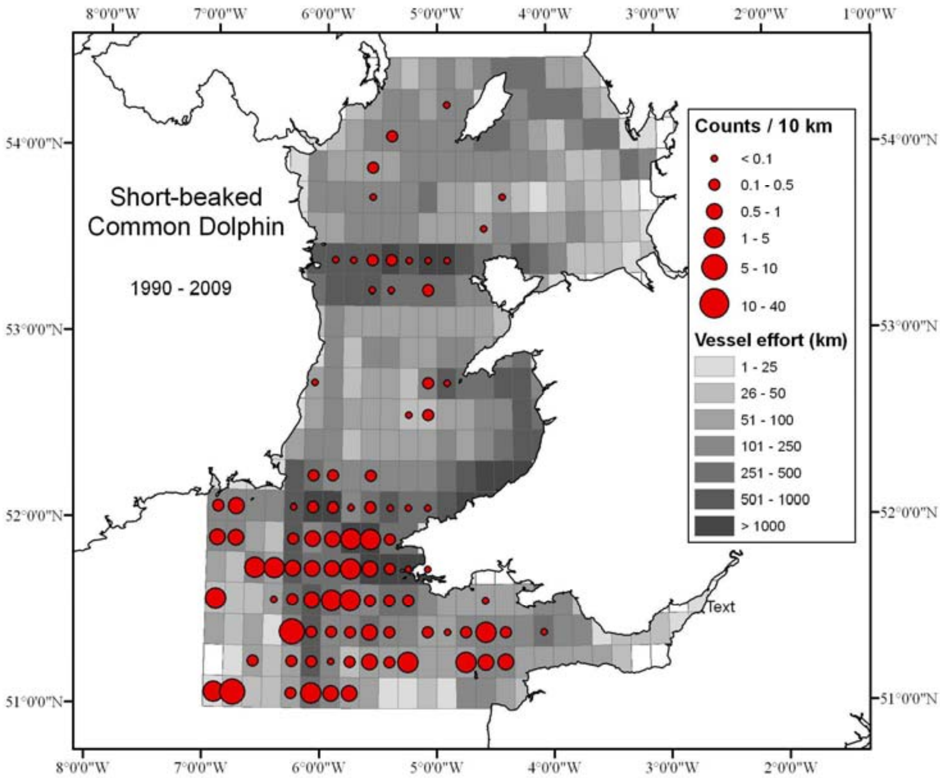
The maps of quarterly mean sighting rates indicate that common dolphins are mainly summer visitors to the study area, largely moving away to the south from December to April, although they have been recorded in the area in every month of the year, and one should note that effort in winter remains low (Figures 90 & 91).

Proportions of juveniles amongst sightings are highest in the months of July and August (Figure 92), which is when group sizes are also greatest, suggesting a post-breeding coalition of family groups (see also Evans *et al*., 2003, 2007).

Second to the harbour porpoise, the common dolphin is the most common cetacean species recorded stranding on the Welsh coasts (Penrose, 2010, 2011). Most strandings occur in Pembrokeshire and along the southern Cardigan Bay coast (Figure 93a), mirroring the overall distribution of sightings, particularly bearing in mind the prevailing currents from the SSW. In most cases where cause of death could be determined, it has been attributed to entanglement in fishing gear, probably reflecting the relatively high bycatch levels recorded in the Celtic Sea (Tregenza *et al*., 1997; Evans & Hintner, 2010).

For a number of stranded specimens, it was not possible to determine with certainty whether the species was *Delphinus delphis* or the similar striped dolphin *Stenella coeruleoalba*. Thus we have also plotted the distribution of strandings of all *Delphinus* and *Stenella* dolphins, including those unidentified specimens (Figure 93b). The results are generally similar, with most strandings in Pembrokeshire and Cardigan Bay, but with slightly more further north and east than for confirmed common dolphin strandings.

a) Long-term mean sightings rate



b) Interpolated long-term mean sightings rate

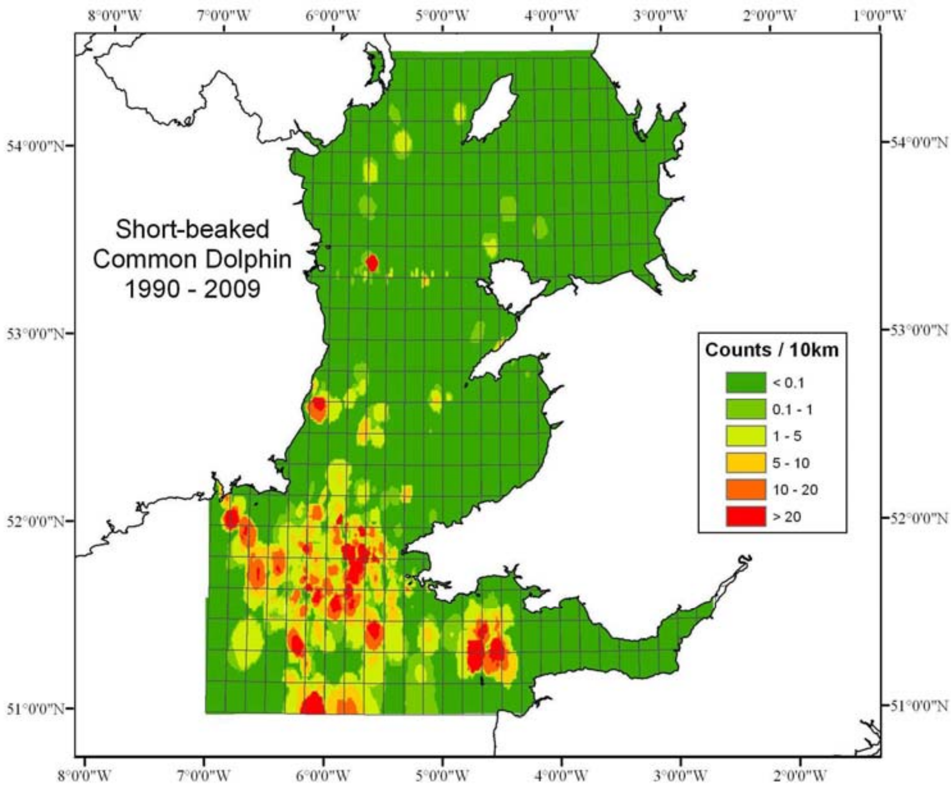


Figure 86 – Long-term sighting rates (vessel counts per 10km) of common dolphin

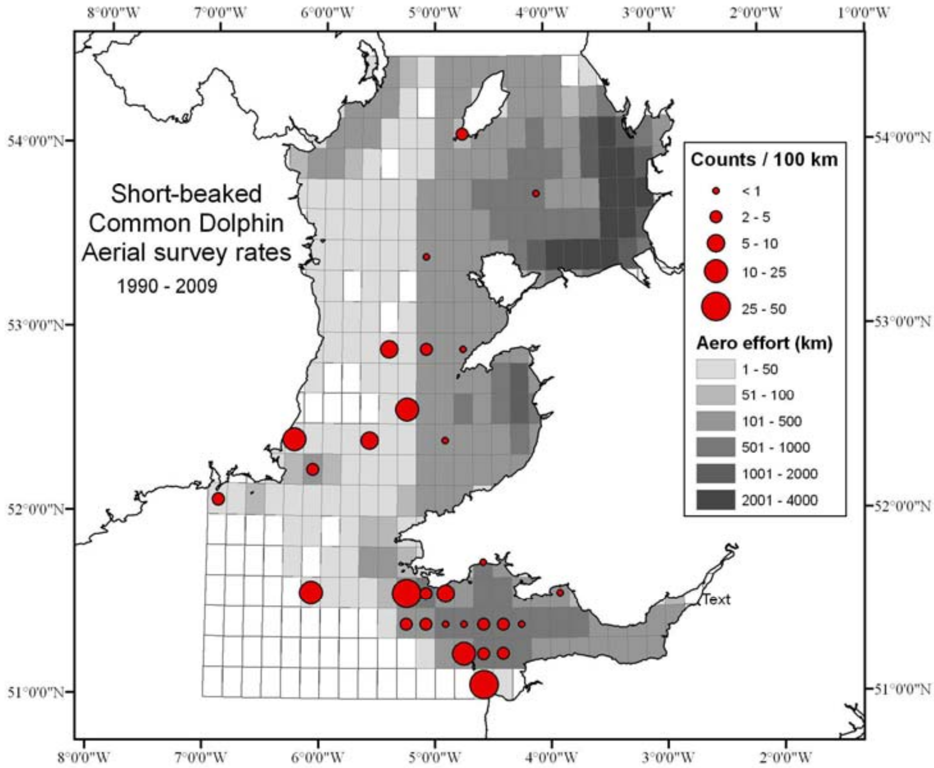


Figure 87 – Long-term mean sighting rates (aerial counts per 100km) of common dolphin

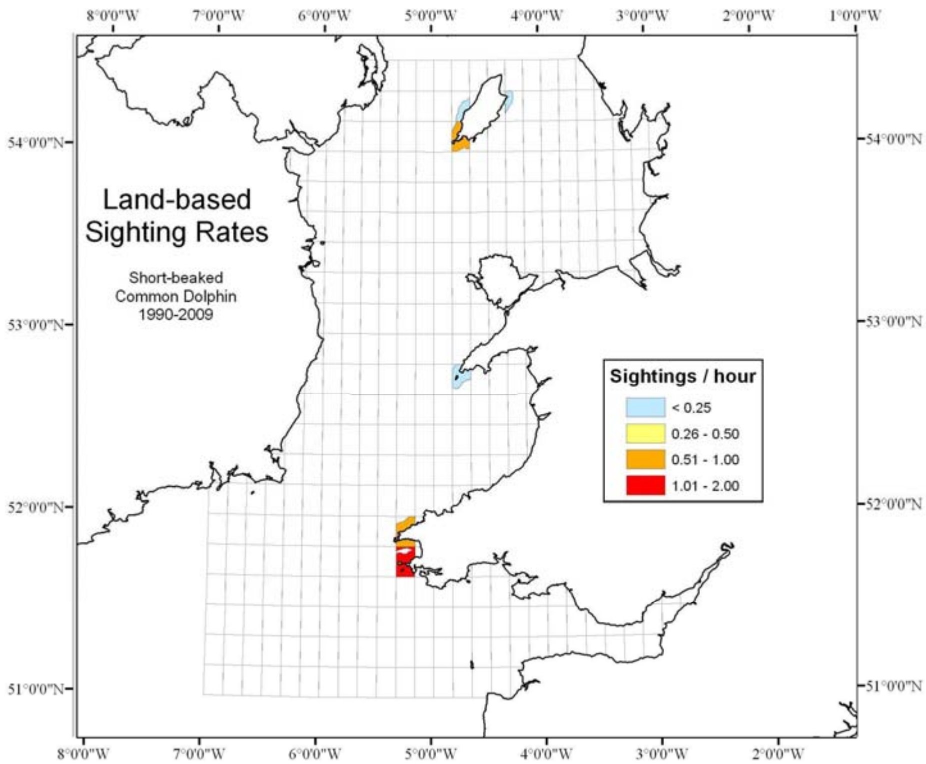


Figure 88 – Long-term sighting rates (land counts per hour) of common dolphin

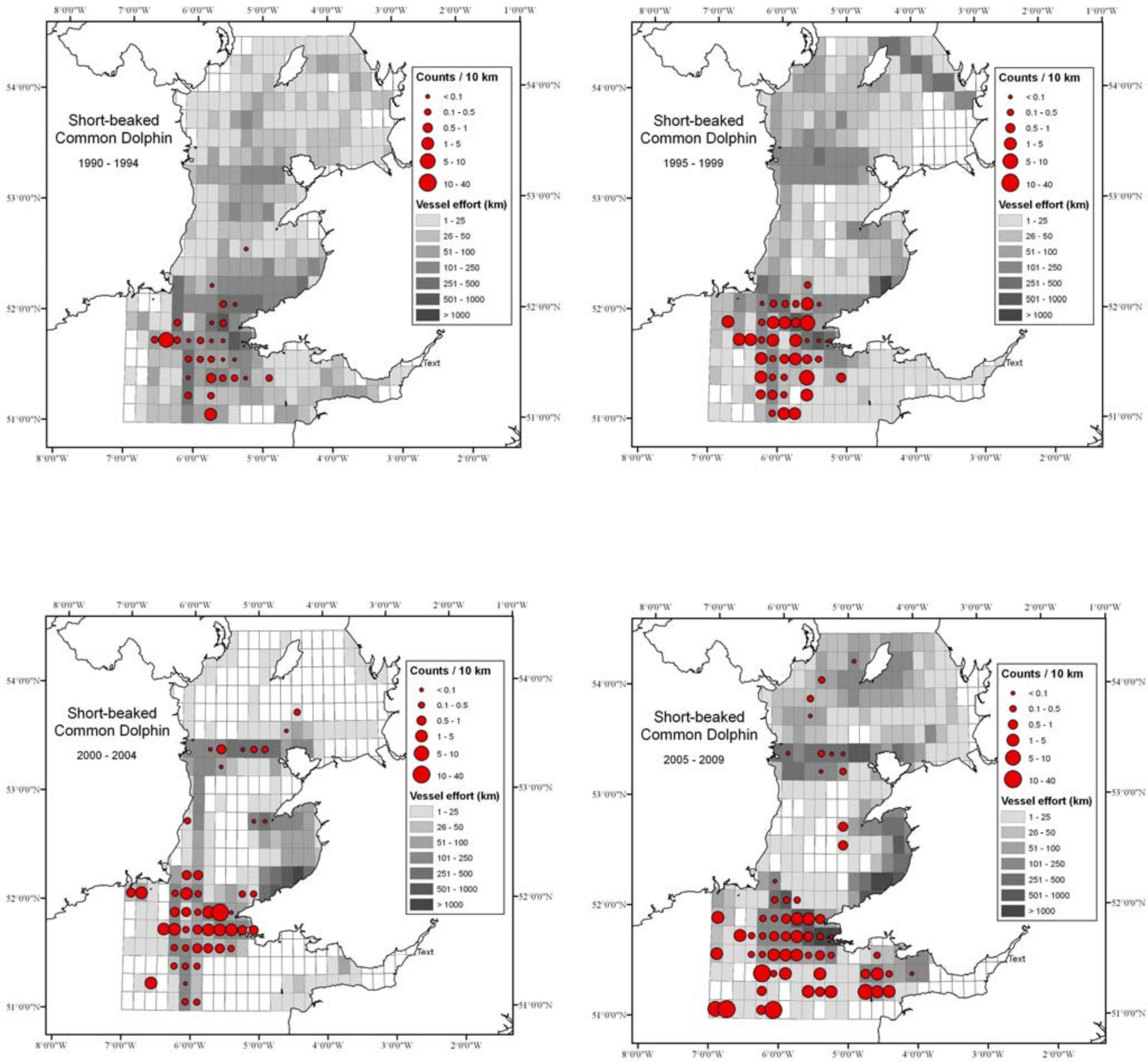


Figure 89 – Mean sighting rates of common dolphin for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

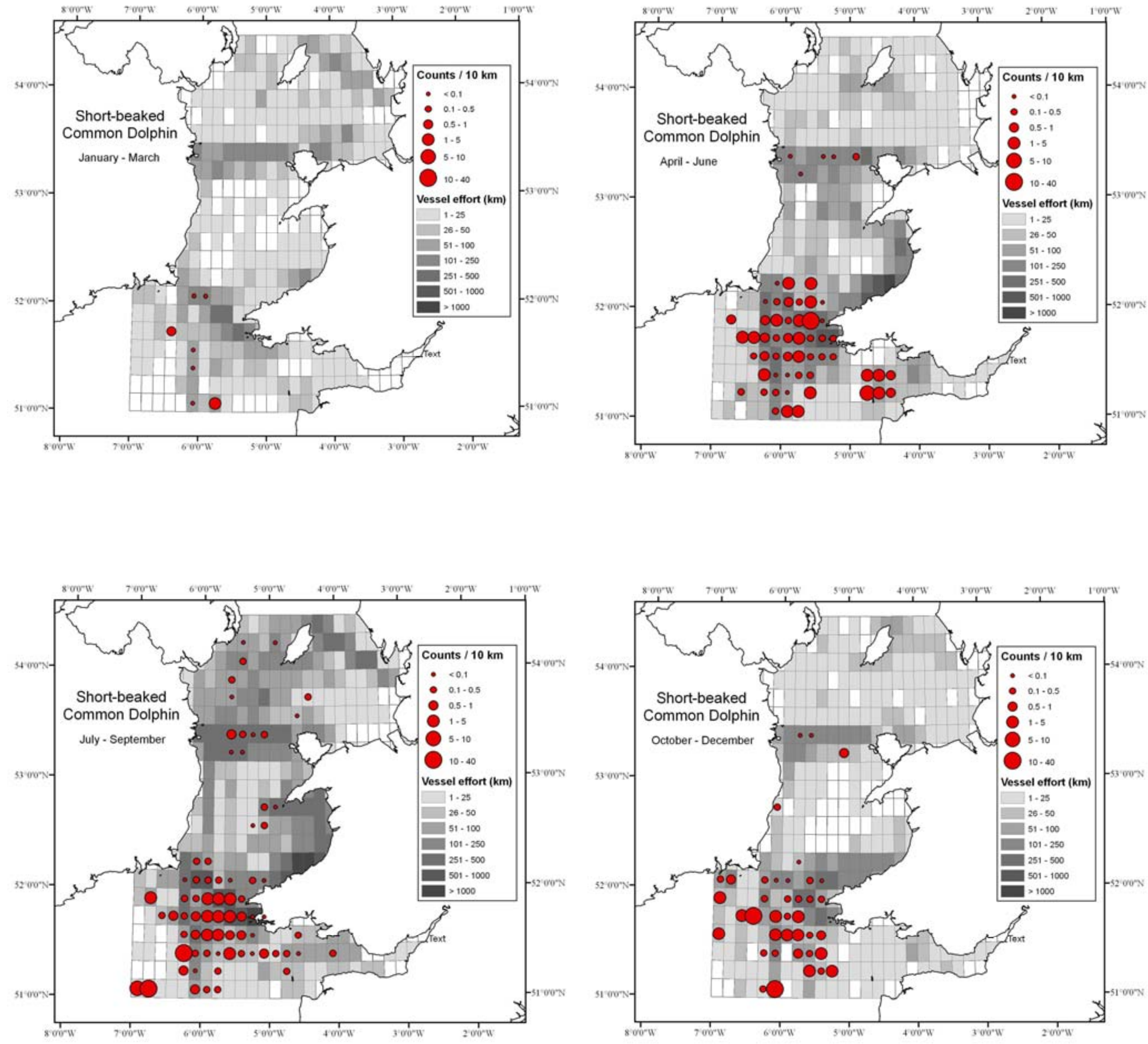


Figure 90 – Long term quarterly mean sighting rates of common dolphin from vessel surveys

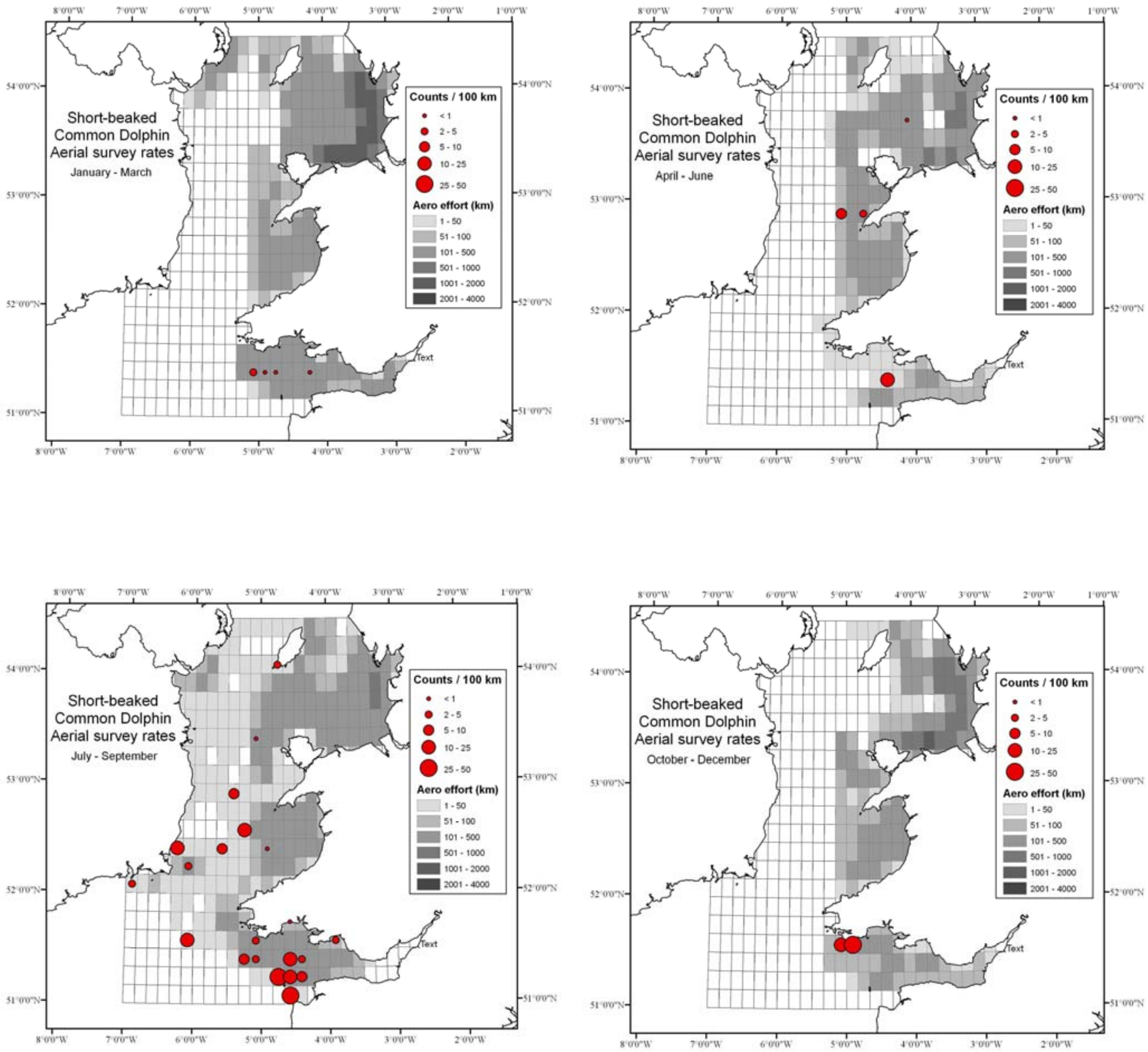


Figure 91 – Long term quarterly mean sighting rates of common dolphin from aerial surveys

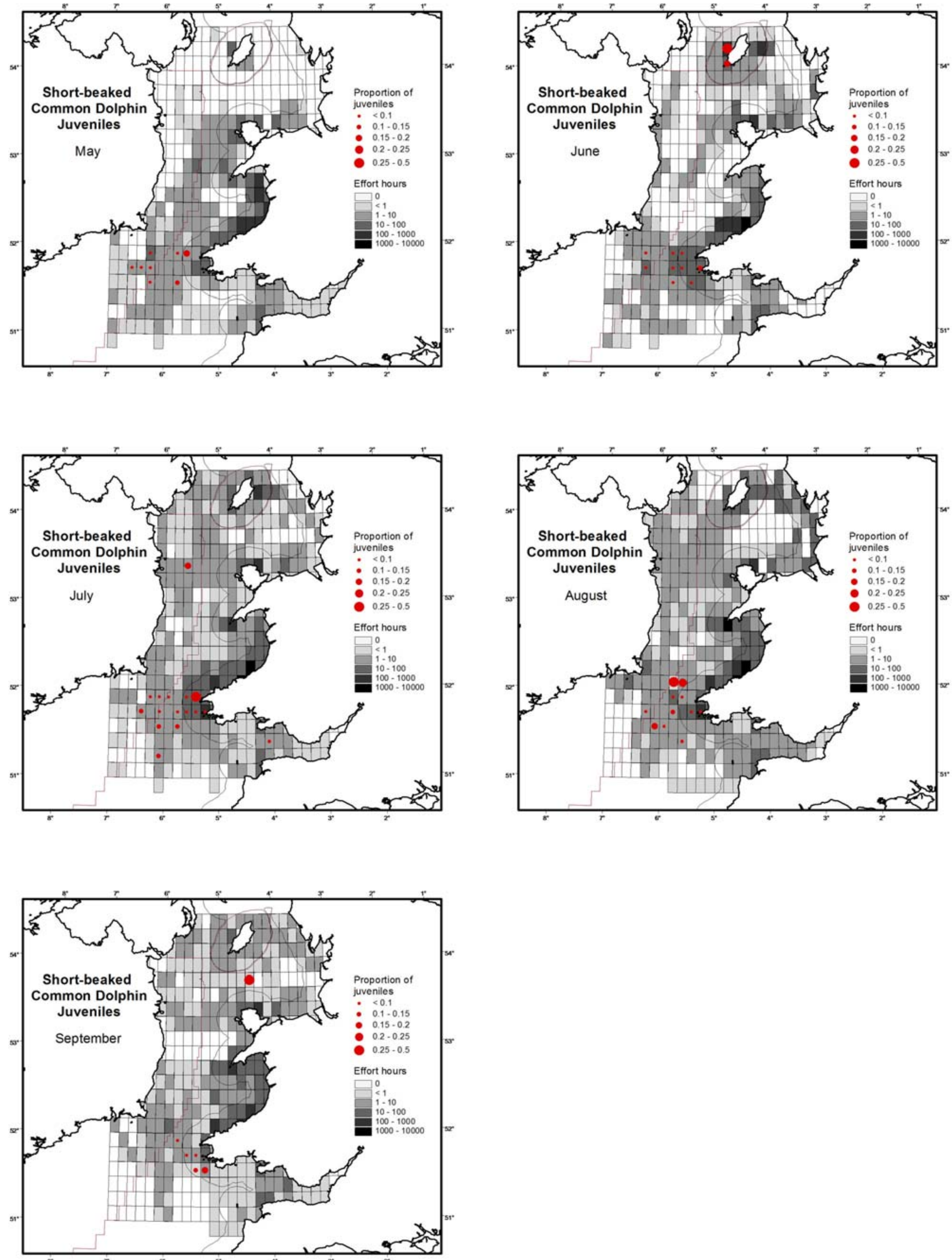
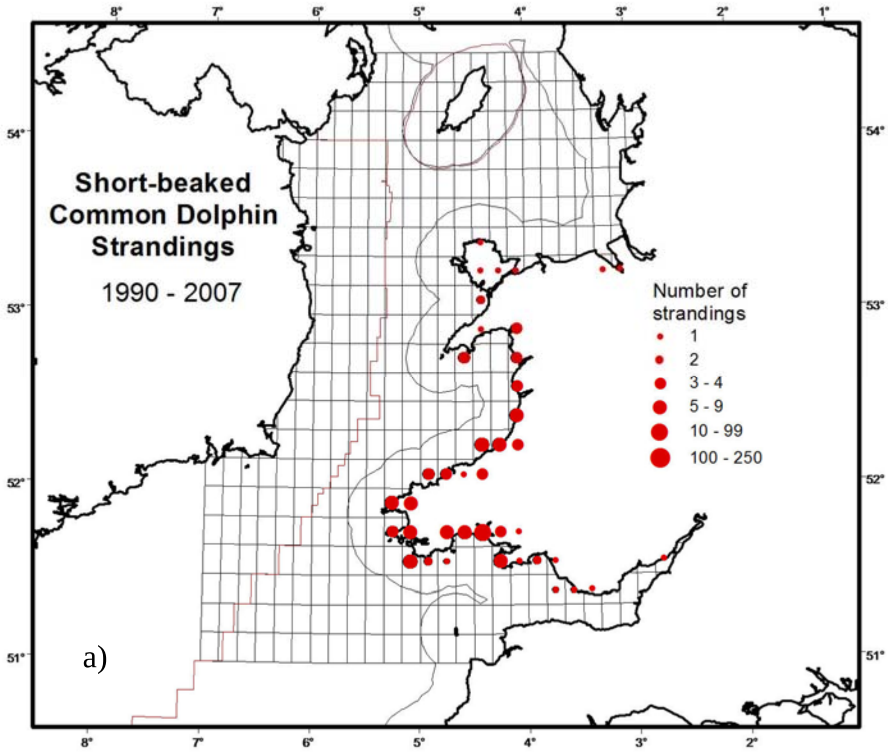


Figure 92 – Long term mean monthly ratio of juveniles to adults of common dolphin



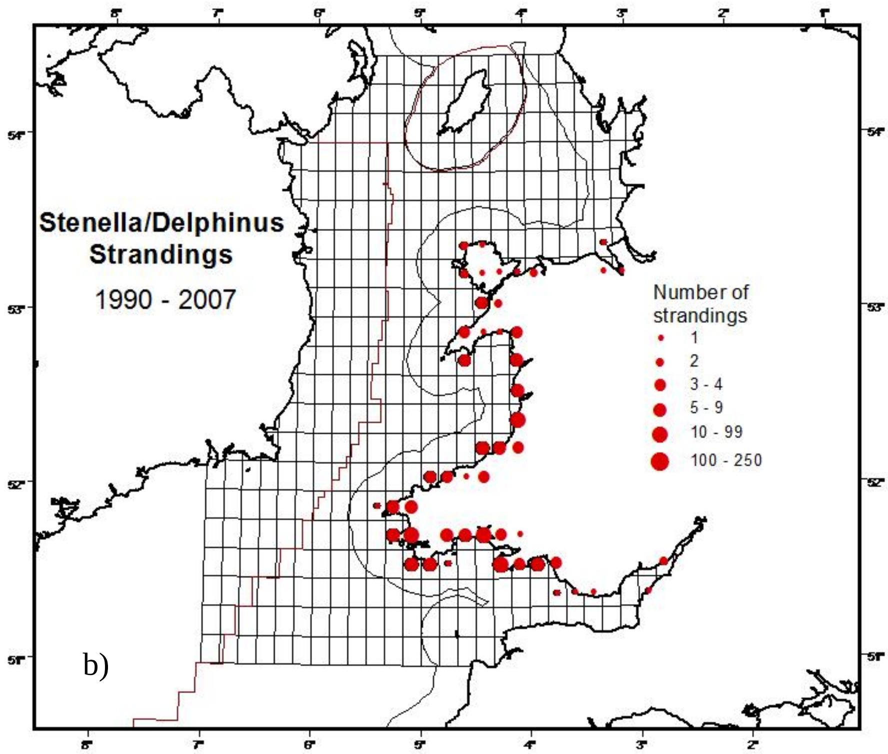


Figure 93 – Distribution of strandings of a) common dolphins and b) all *Stenella* and *Delphinus* dolphins on the coasts of Wales

3.7 Risso's dolphin *Grampus griseus*

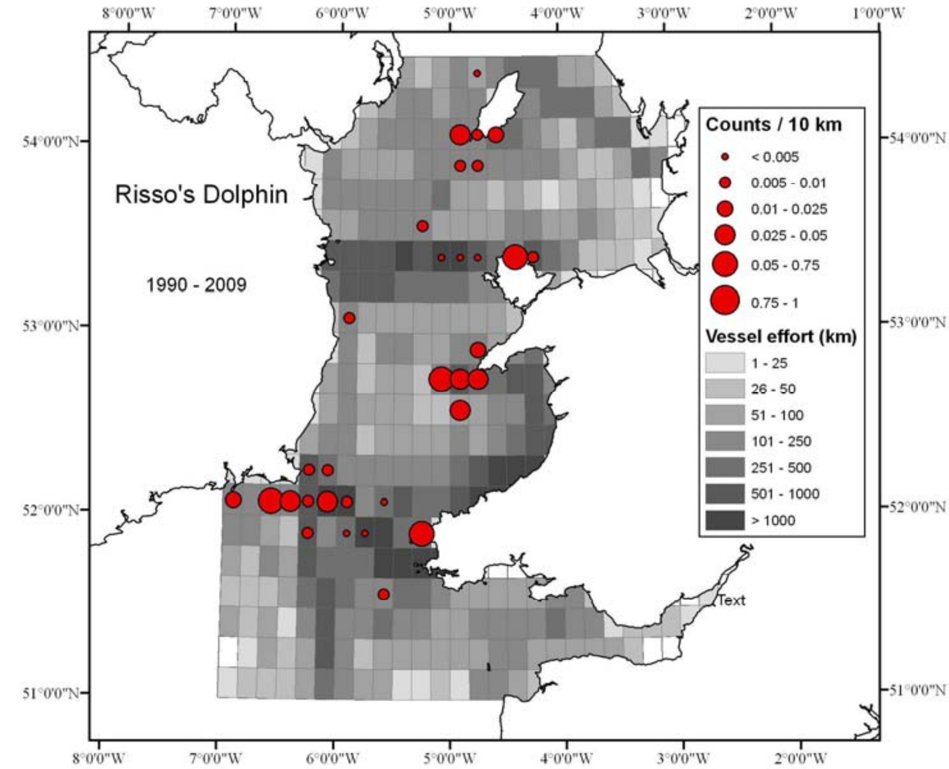
Within the 12 nm territorial limit of Wales, the highest density of sighting rates from both vessel and aerial surveys has been in the area of Bardsey Island off the western end of the Lleyn Peninsula (Figures 94-96). Other coastal areas with lower sighting rates are located to the west and north of Anglesey up to the Isle of Man, in north Pembrokeshire, and particularly off south-east Ireland and St George's Channel (Figures 94-96). Together, these form a broad band of occurrence through the Irish Sea on a SW-NE axis. Bearing in mind variation in effort (e.g. regular surveys around the Isle of Man only started from 2007 onwards – Stone *et al*., 2009), the species otherwise has had similar spatial distributions for each of the four time periods between 1990 and 2009 (Figure 97).

Risso's dolphin is mainly a summer and autumn visitor to the study area, with the highest sighting rates in the period July to October, and no effort related sighting between December and March although survey effort remains low during winter (Figures 98 & 99). Numbers visiting both Welsh and Manx coastal waters can vary a large amount from year to year (WDCS, 2002, 2005, 2006; Stone *et al*., 2009; Sea Watch Foundation unpublished data; Manx Whale & Dolphin Group unpublished data). Photo-ID matches of individuals have been found between Pembrokeshire, Bardsey Island, Anglesey and the Isle of Man, indicating that these form part of the same population, with some individuals seen repeatedly from year to year (Whale & Dolphin Conservation Society, Sea Watch Foundation, and Manx Whale & Dolphin Group Joint Photo-ID Catalogue, 2008-present).

In Welsh waters, young have been recorded between July and September mainly in the vicinity of Bardsey Island, and off the north coasts of Pembrokeshire and Anglesey (Figure 100). Elsewhere, young have been seen in spring and early summer in Manx waters.

Strandings of Risso's dolphins have occurred in small numbers throughout western Wales, from Pembrokeshire in the south to Anglesey in the north (Figure 101; see also Penrose, 2010, 2011).

a) Long-term mean sightings rate



b) Interpolated long-term mean sightings rate

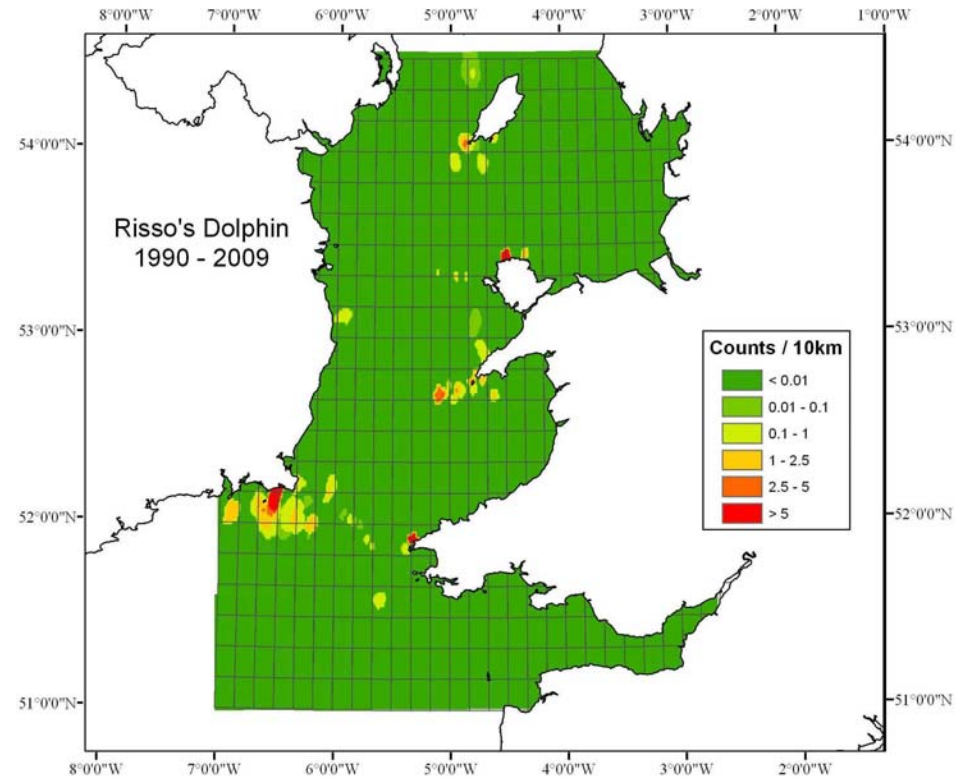


Figure 94 – Long-term sighting rates (vessel counts per 10km) of Risso's dolphin

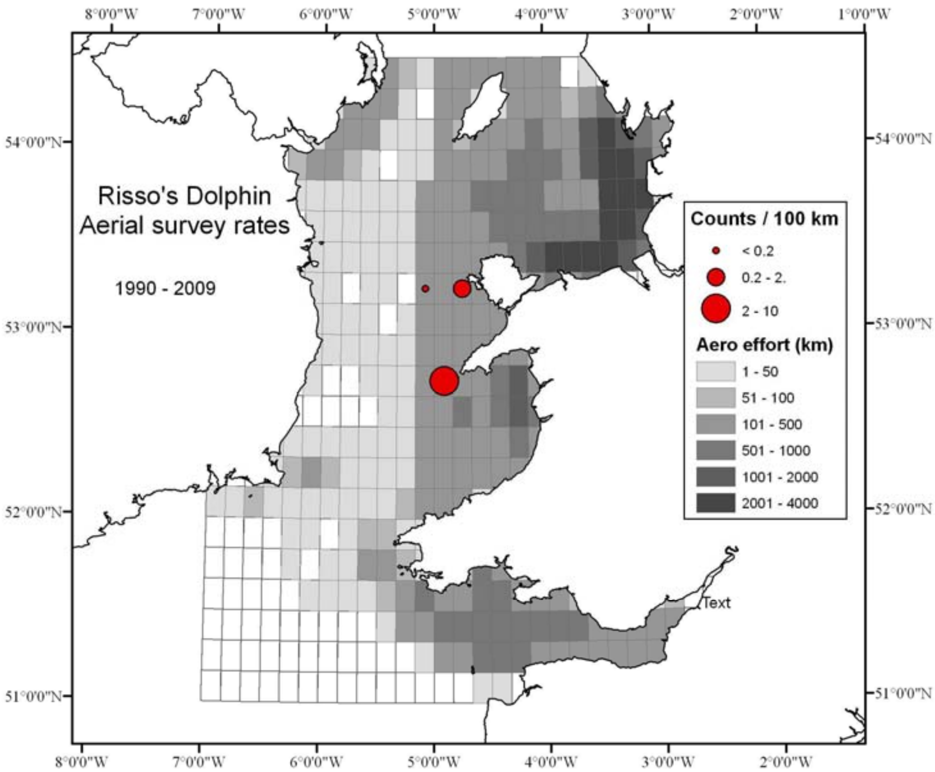


Figure 95 – Long-term mean sighting rates (aerial counts per 100km) of Risso's dolphin

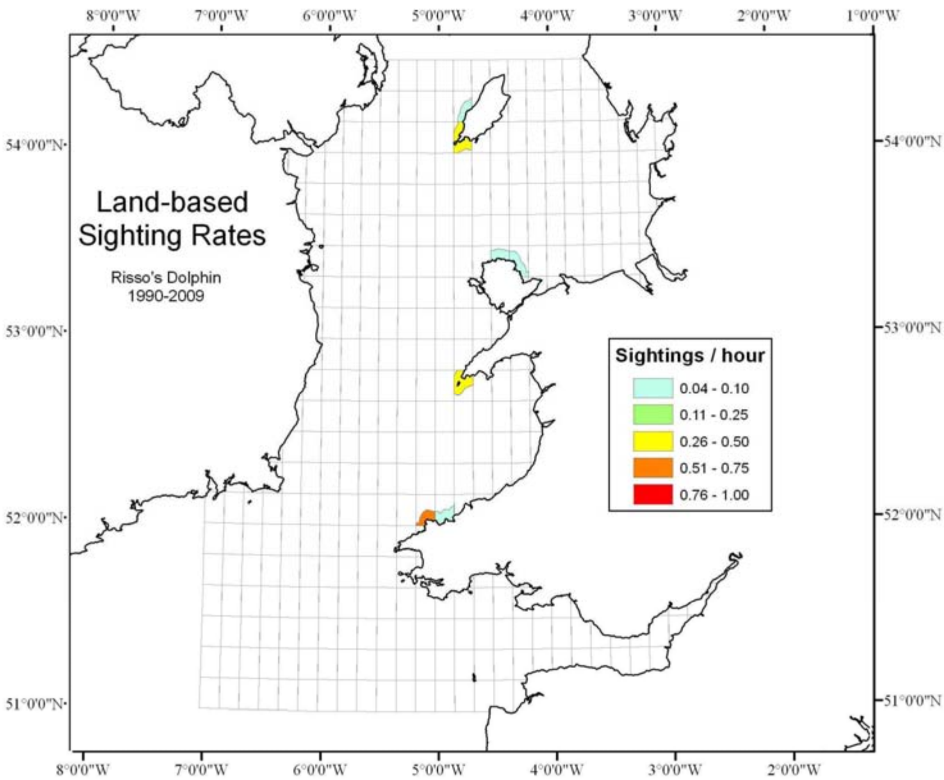


Figure 96 – Long-term sighting rates (land counts per hour) of Risso's dolphin

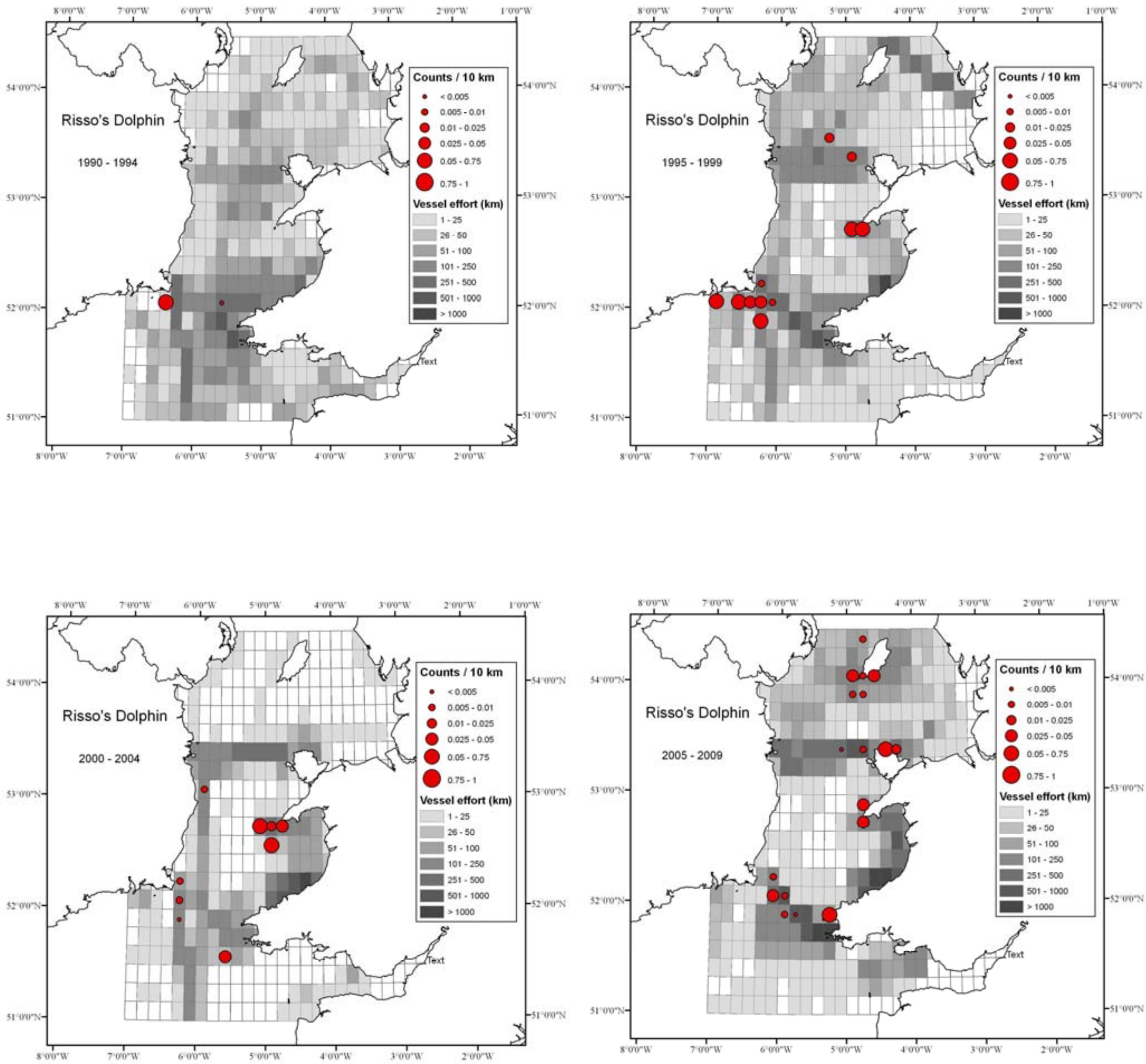


Figure 97 – Mean sighting rates of Risso's dolphin for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

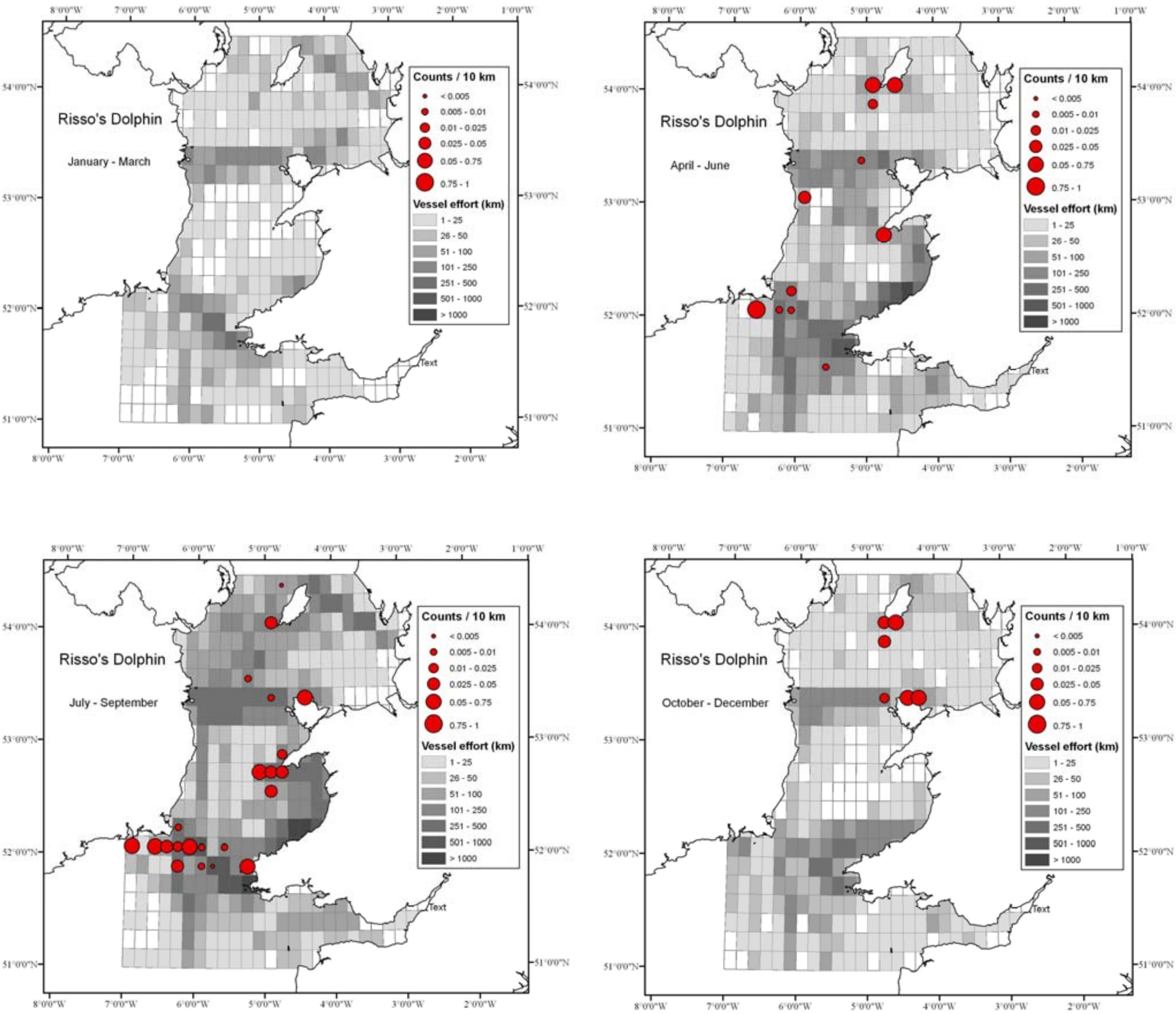


Figure 98 – Long term quarterly mean sighting rates of Risso’s dolphin from vessel surveys

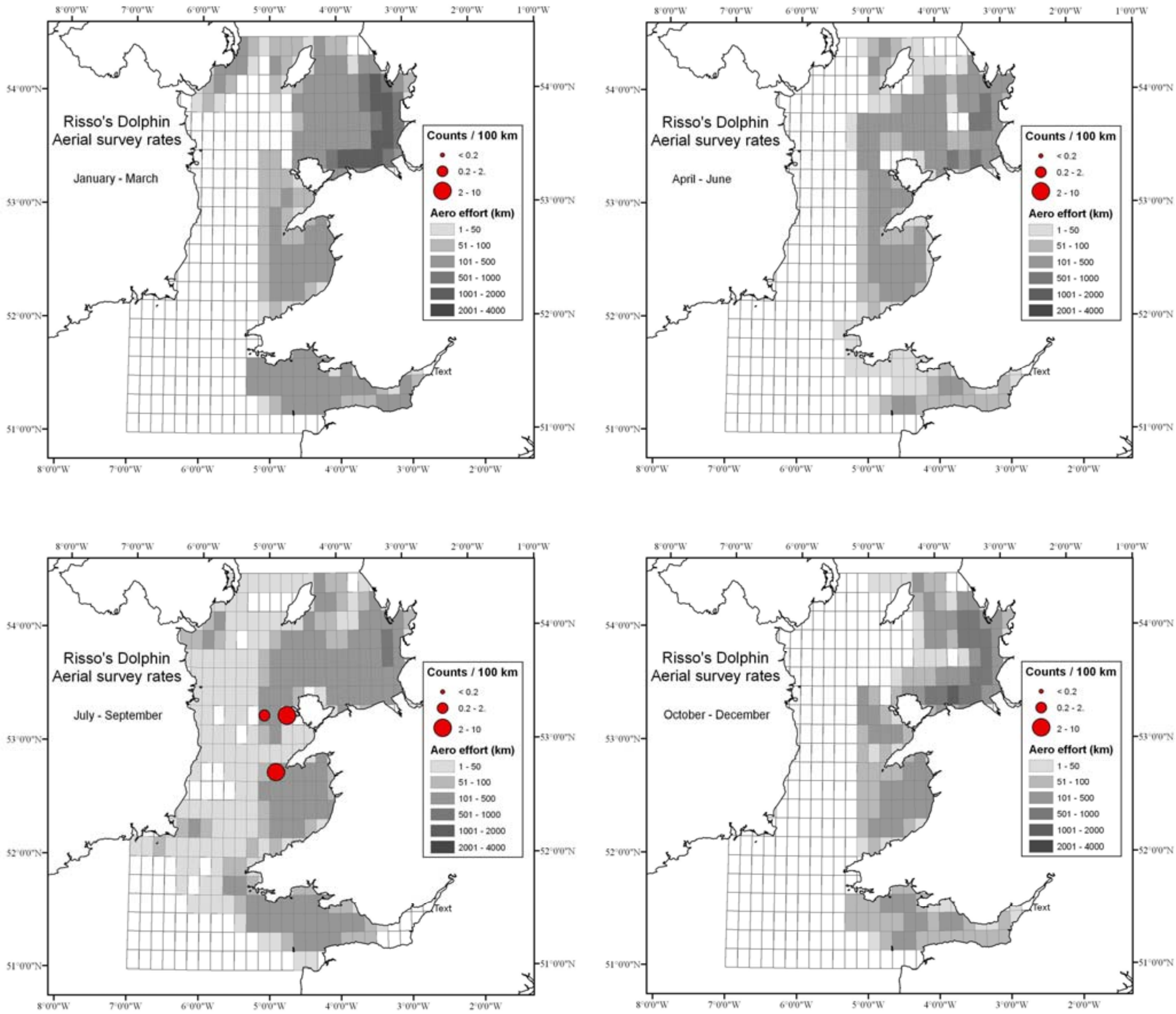
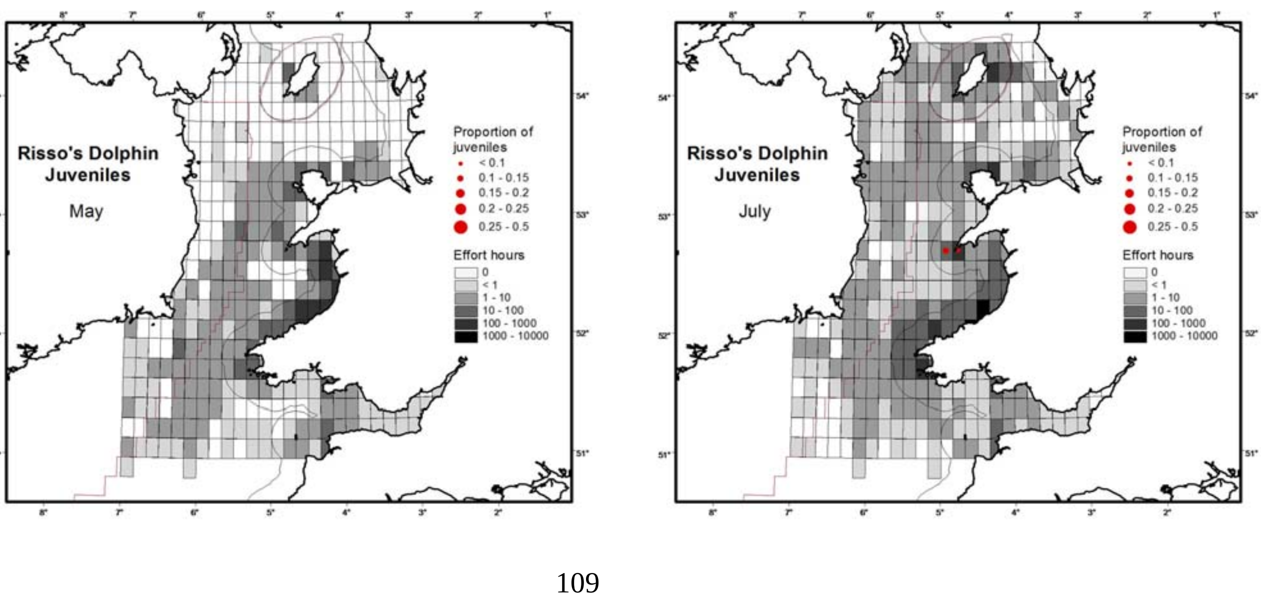


Figure 99 – Long term quarterly mean sighting rates of Risso's dolphin from aerial surveys



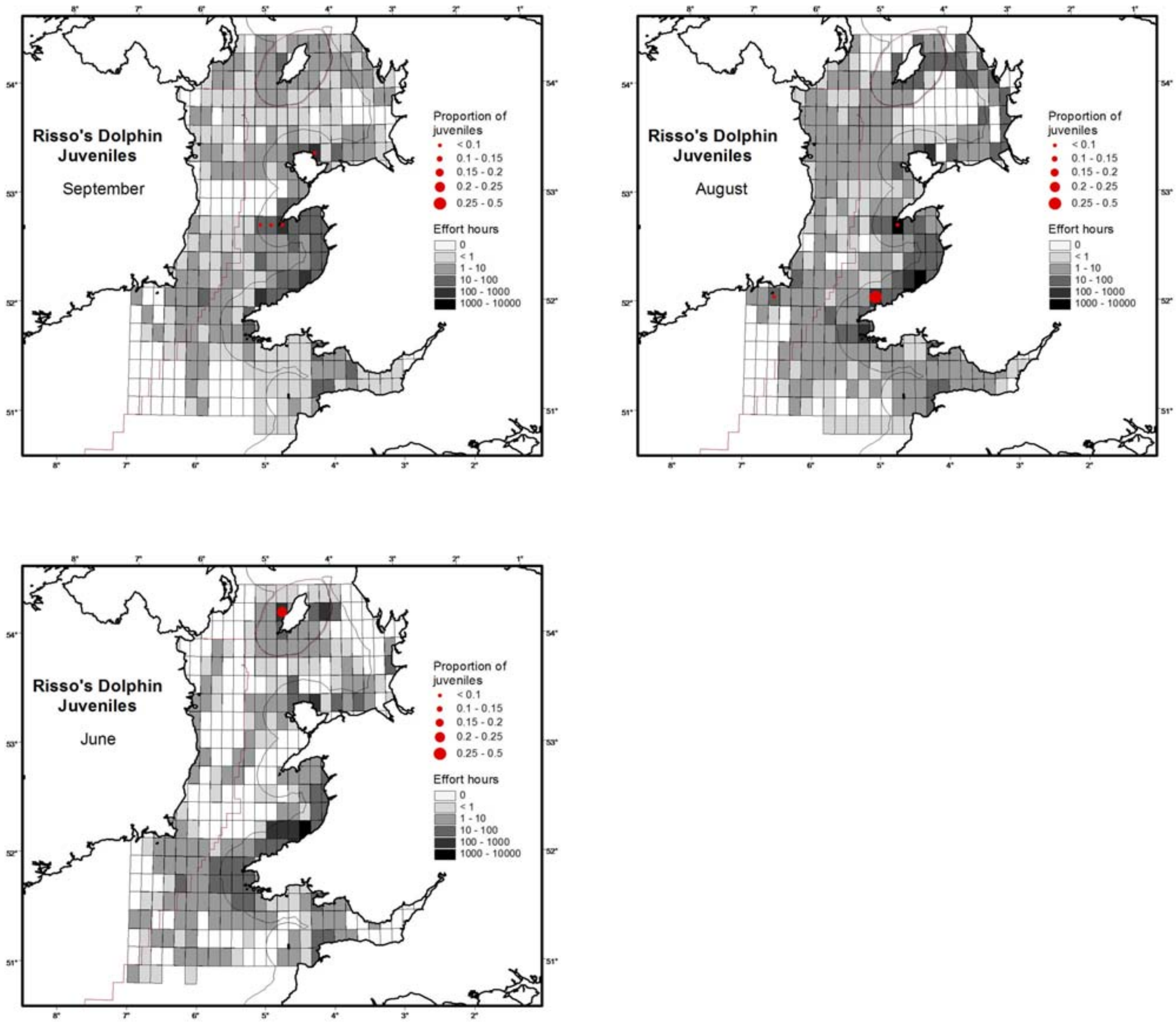


Figure 100 – Long term mean monthly ratio of juveniles to adults of Risso’s dolphin

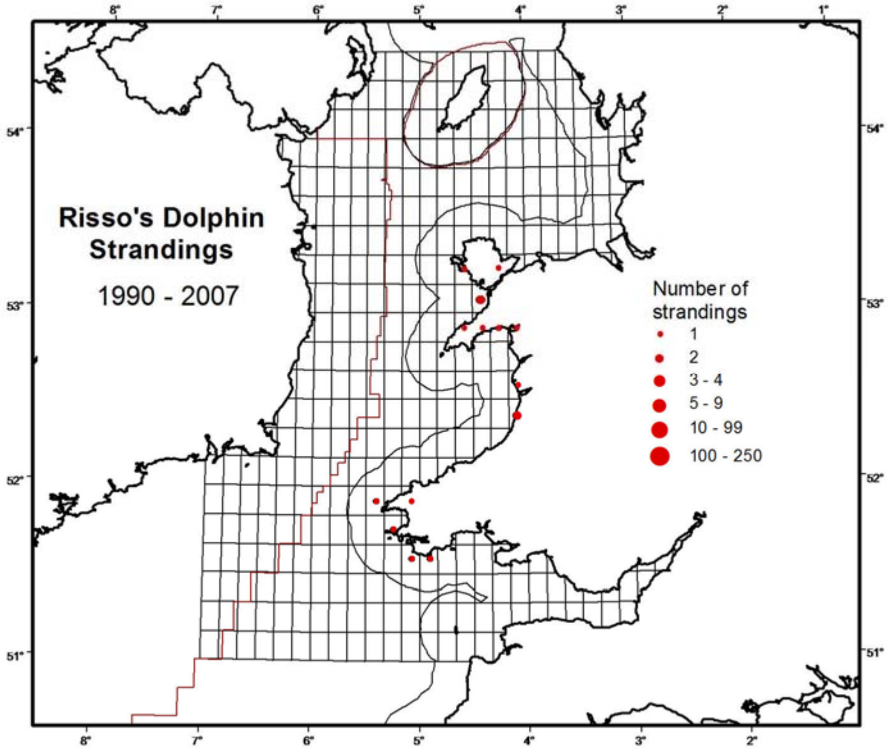


Figure 101 – Distribution of strandings of Risso's dolphin on the coasts of Wales

3.8 Minke whale *Balaenoptera acutorostrata*

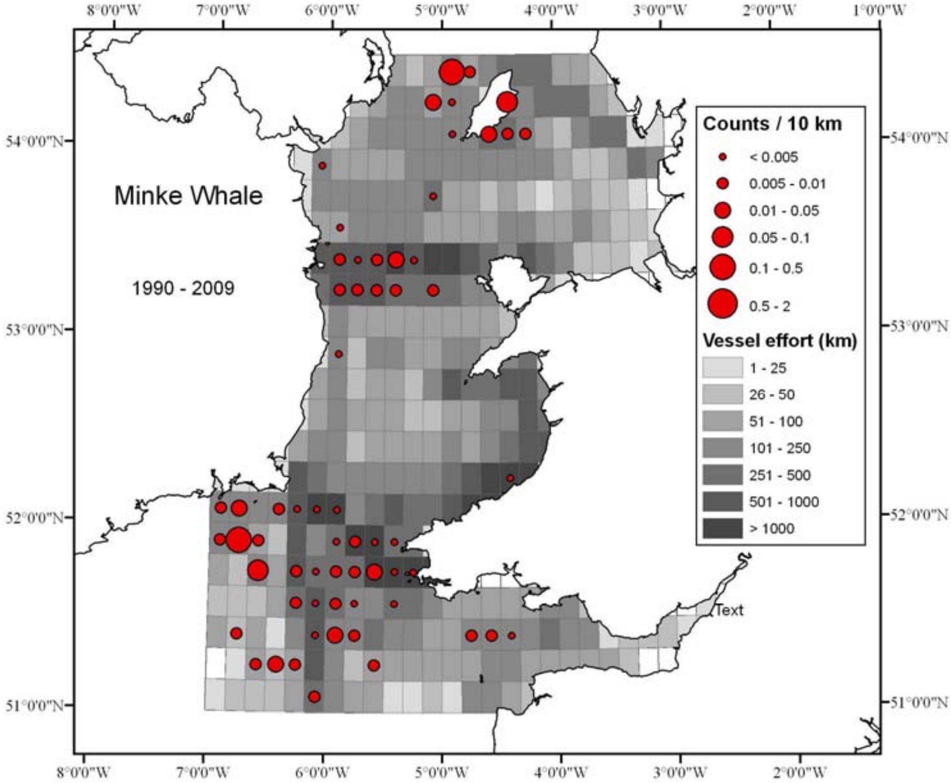
This species has a predominantly offshore distribution with the highest densities of sighting rates in the south-west of the study area over the Celtic Shelf, around the Isle of Man, and east of Co. Dublin (Figures 102-104). Within the 12 nm territorial limit of Wales, minke whales have been recorded predominantly to the west of Pembrokeshire (Figures 102-103), although land watches have recorded minke whales in North Wales off Anglesey and Bardsey Island (Figure 104). However, effort offshore in the central Irish Sea has been relatively low so the species is probably under-recorded there. Distribution patterns for the species are broadly similar for the four time periods under analysis (bearing in mind that effort has varied in some areas, e.g. regular surveys around the Isle of Man started only from 2007), though with an apparent increase in occurrence since the early 1990s (Figure 105).

Sighting rates are highest between April and September; outside this period, sightings are low (particularly for the northern part of the Irish Sea) (Figures 106 & 107). This fits with findings in other parts of the UK where the species becomes rare during winter months, apparently largely moving offshore (Northridge *et al*., 1995; Evans *et al*., 2003; Reid *et al*., 2003; Anderwald and Evans, 2008).

Minke whale calves are born during winter months, presumably mainly outside the region, and so most sightings of juveniles are of uncertain age. It is therefore not meaningful to plot proportions of juveniles to adults.

Only a few strandings of the species have occurred on the Welsh coasts, and these are distributed widely over the region with no particular area of concentration (Figure 108; see also Penrose, 2010, 2011).

a) Long-term mean sightings rate



b) Interpolated long-term mean sightings rate

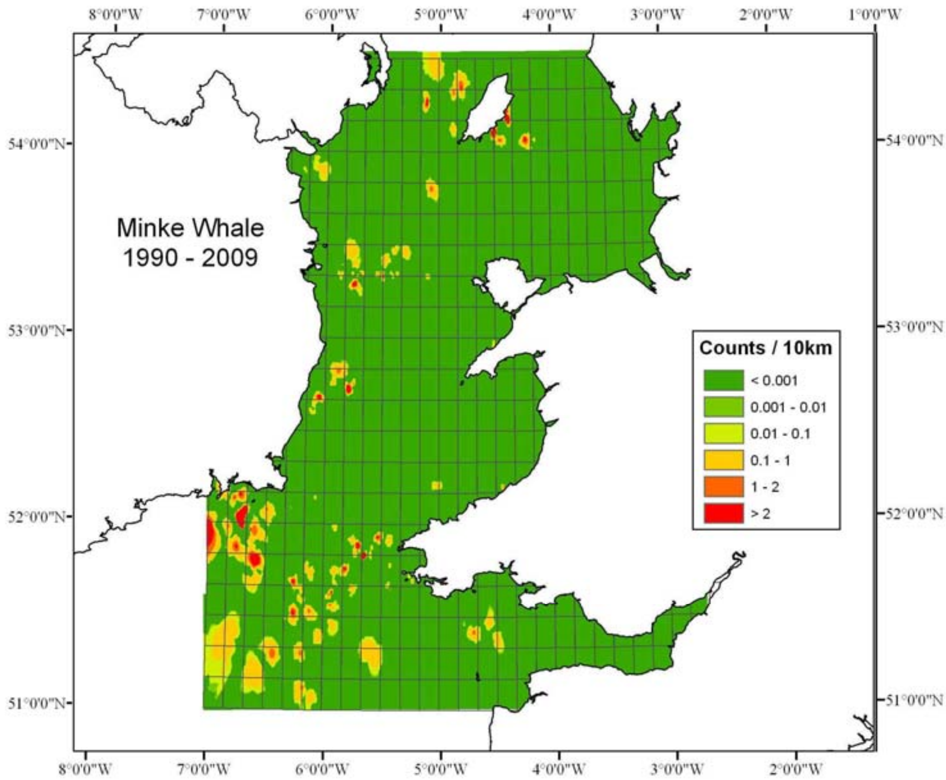


Figure 102 – Long term sighting rates (vessel counts per 10km) of minke whale

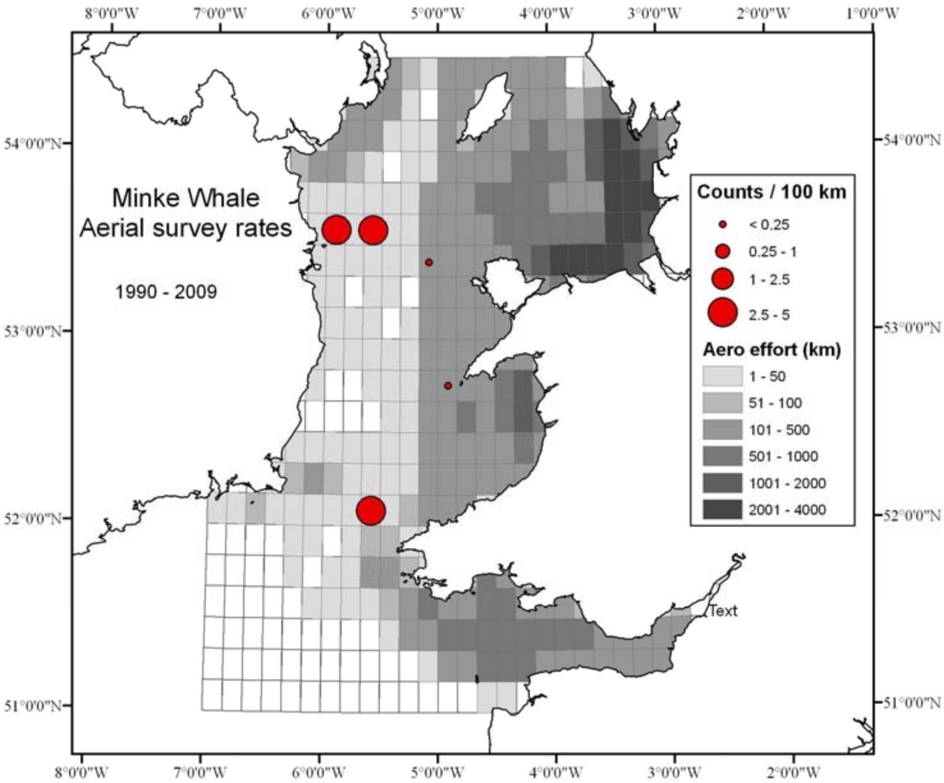


Figure 103 – Long-term mean sighting rates (aerial counts per 100km) of minke whale

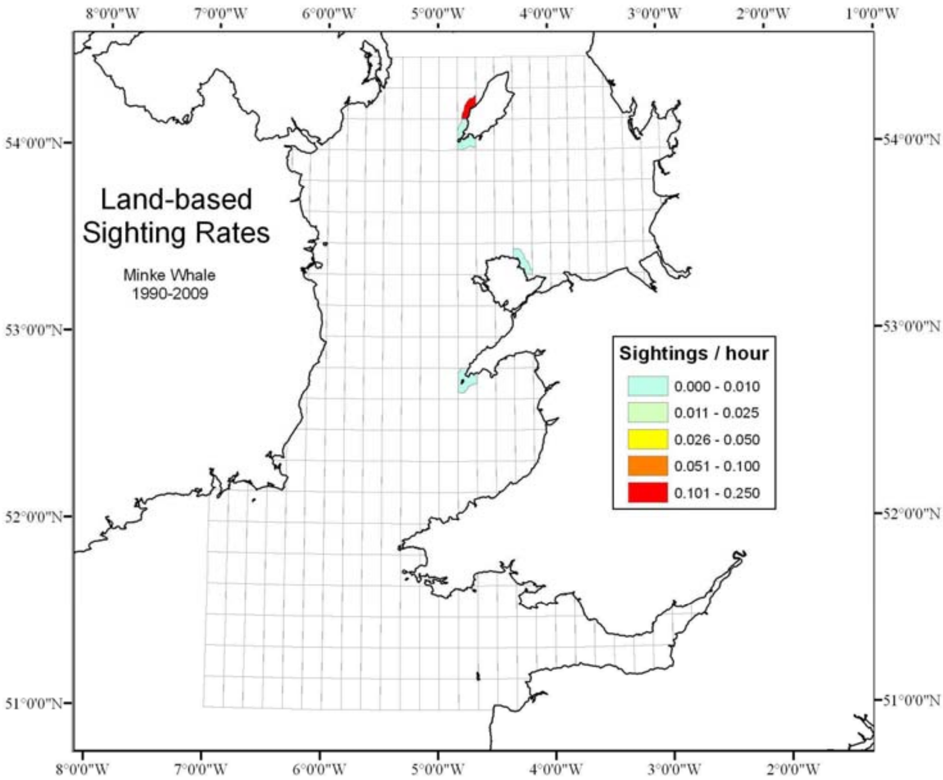


Figure 104 – Long-term sighting rates (land counts per hour) of minke whale

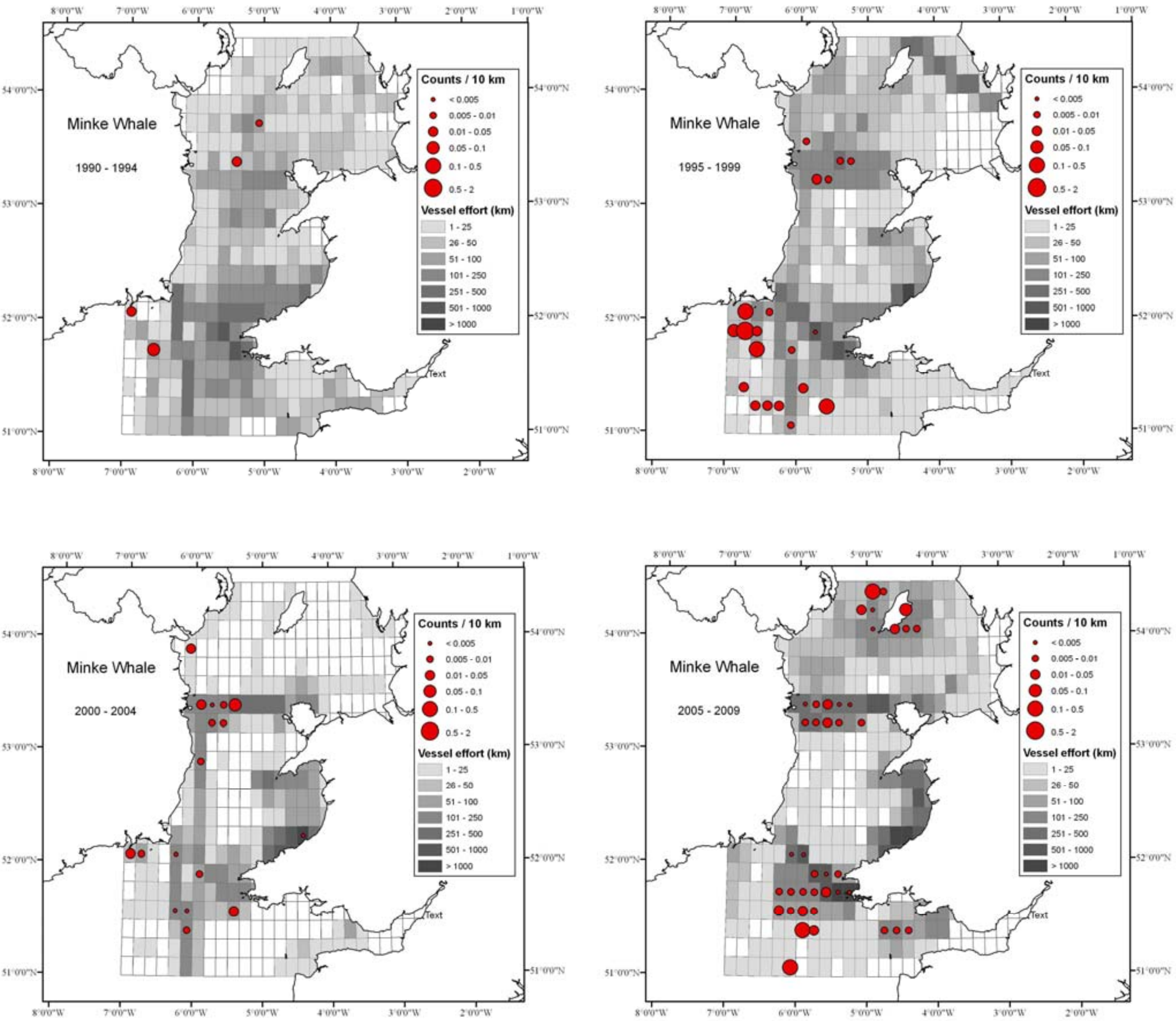


Figure 105 - Mean sighting rates of minke whale for the time periods 1990-94, 1995-99, 2000-04, and 2005-09 from vessel surveys

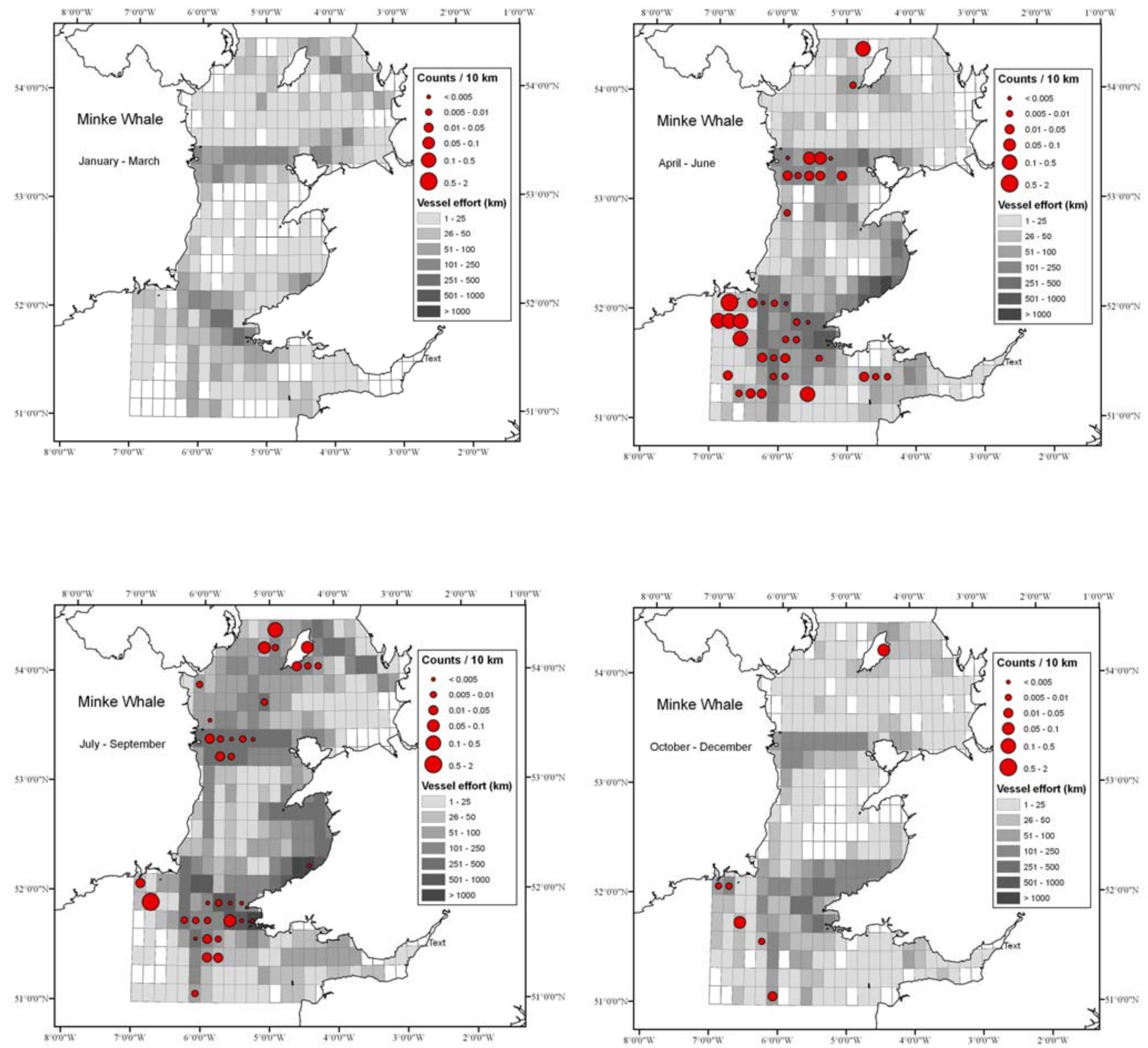


Figure 106 – Long term quarterly mean sighting rates of minke whale from vessel surveys

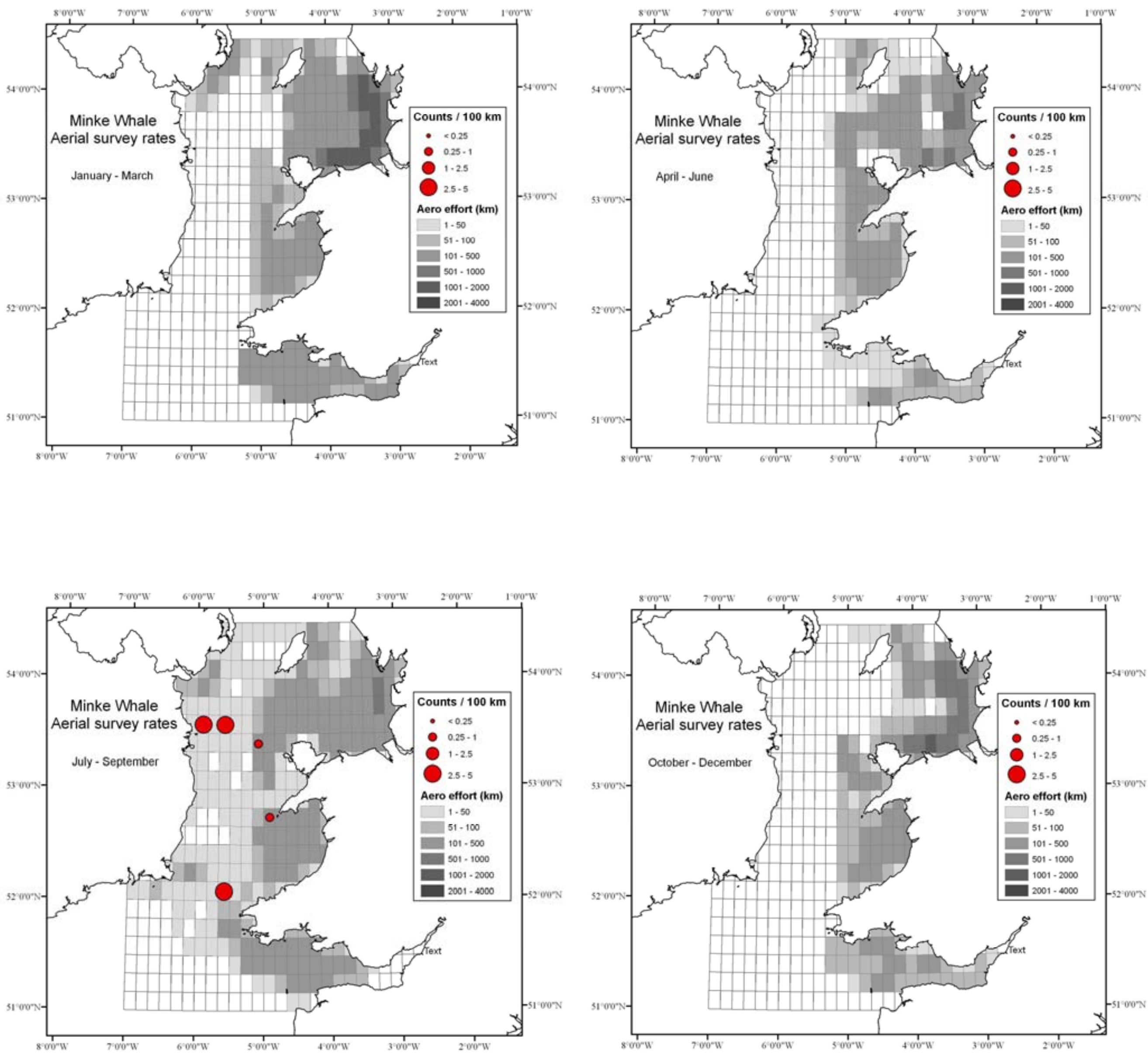


Figure 107 – Long term quarterly mean sighting rates of minke whale from aerial surveys

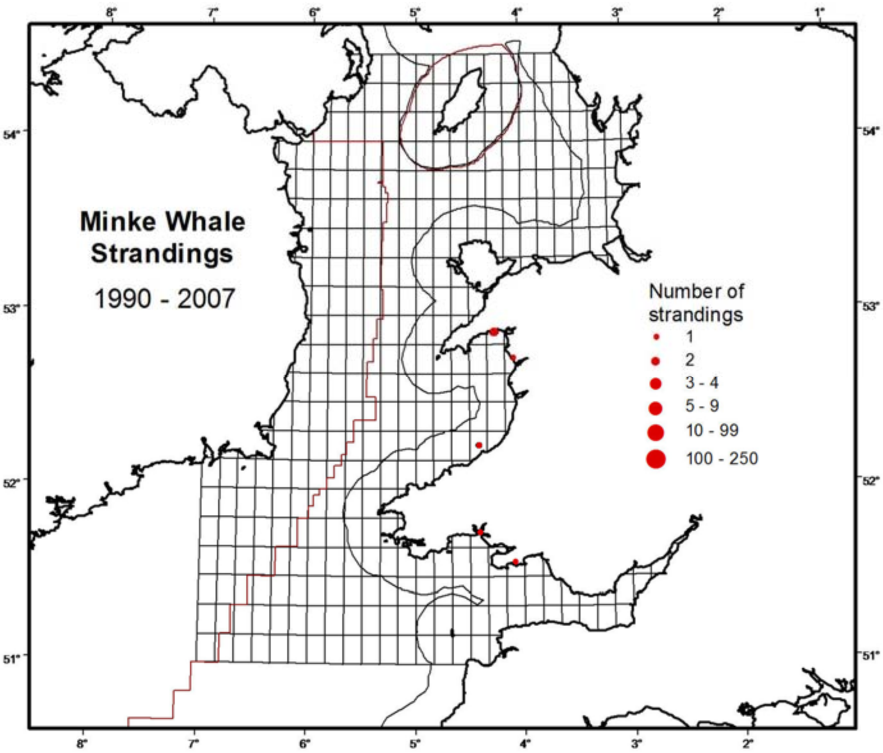


Figure 108 – Distribution of strandings of minke whale on the coasts of Wales

3.9 Cetacean Species Diversity

The project database includes only effort related data and therefore some occasional sightings of rarer species, such as beaked whales are not included. Nevertheless, Figures 109 & 110 indicate those areas in which the highest diversity of cetacean species has been recorded.

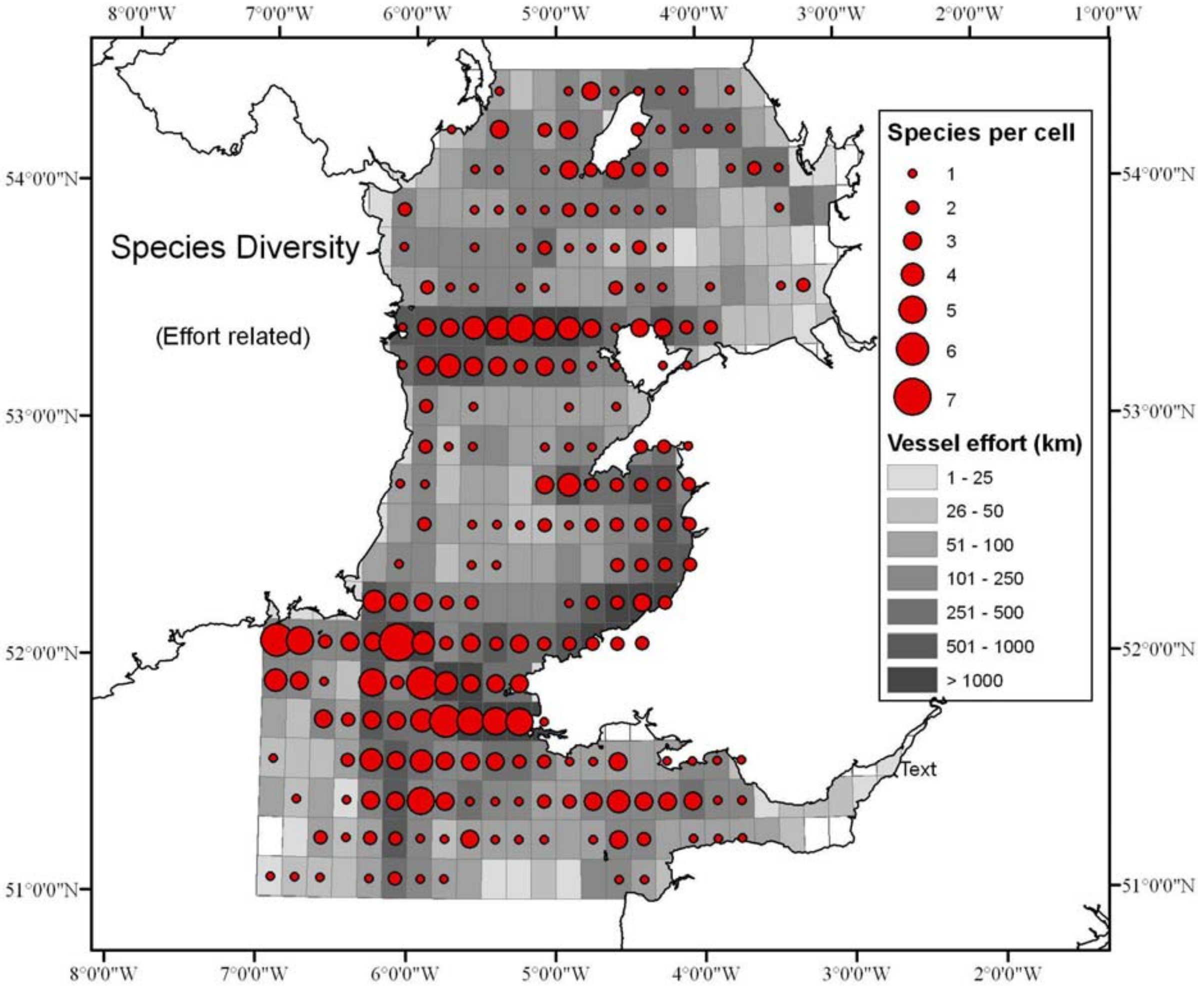


Figure 109 – Map of the number of cetacean species recorded per cell 1990 – 2009 (overlying a plot of effort)

The main area of high diversity stretches in a band across St George's Channel, with the highest levels on the edge of the Celtic Deep. A smaller area of high diversity occurs off Bardsey Island at the western end of the Lleyn Peninsula, and further north, off the west coasts of Anglesey and the Isle of Man. All these areas represent the most central areas of the Irish Sea where land protrudes, and probably reflects the role played by the deeper parts of the Irish Sea through which the North Atlantic current flows, and the influence of the Celtic Sea and Irish Sea Fronts (Weir & O'Brien, 2000; Reid *et al*., 2003; Bush, 2006).

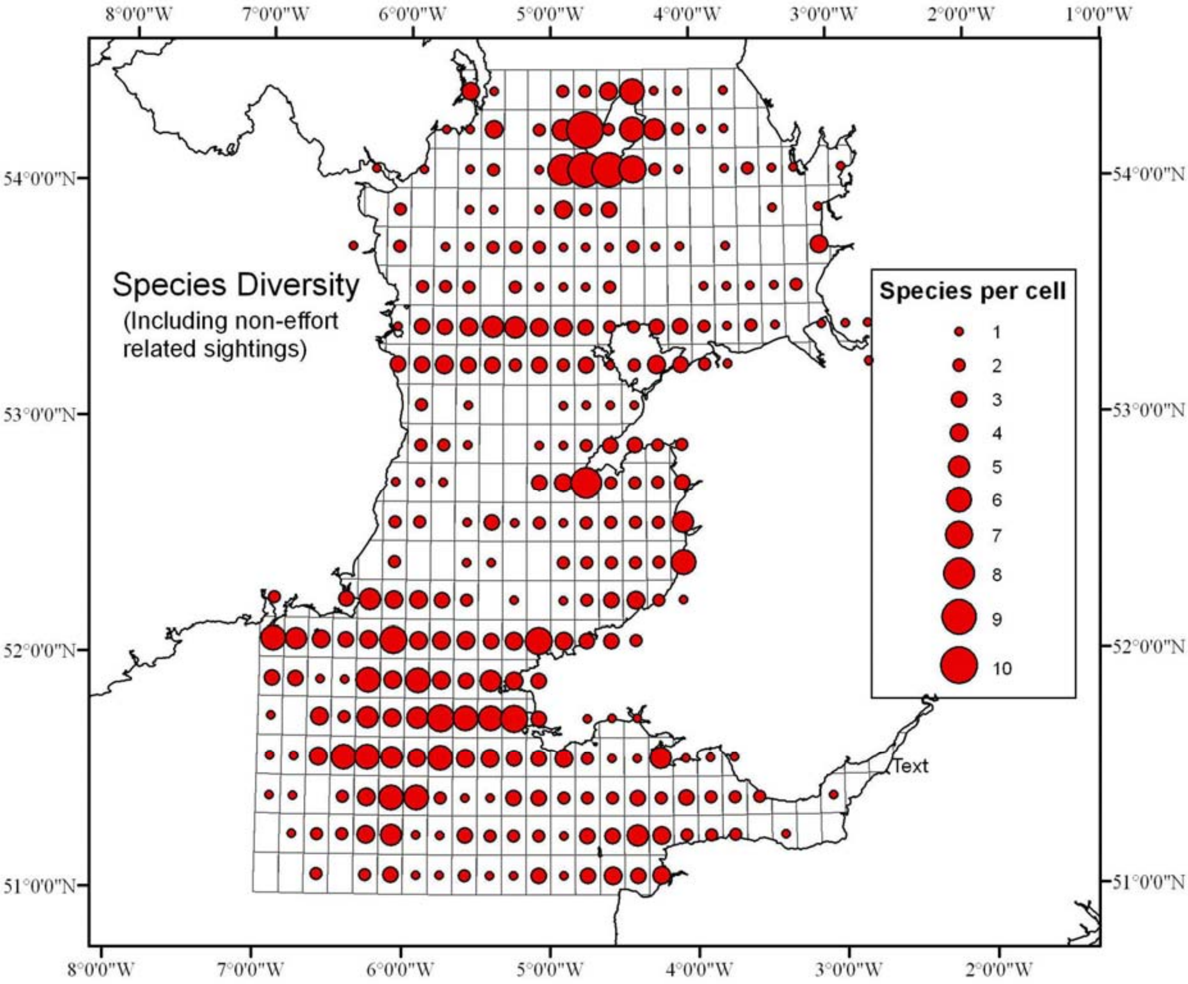


Figure 110 – Map of the number of cetacean species recorded per cell 1990 – 2009 (including both effort-related and casual records)

A plot of the number of species recorded per cell from both effort-related and casual sightings shows a greater spread (Figure 110), but interpretation is hindered by the variation in observation effort. For example, there is a well co-ordinated network of casual observers in the Isle of Man who have been reporting incidental sightings on a regular basis since 2005. This almost certainly at least partly accounts for the greater number of species recorded from that area

3.10 **Grey seal** *Halichoerus grypus*

The annual pup production data in Figure 111 are based on counts carried out in Ceredigion and Pembrokeshire in 1992-94 (Baines *et al.*, 1995) and in North Wales in 2002-03 (Westcott and Stringell, 2003, 2004). Although some counts of pup production have been carried out in Pembrokeshire since the 1992-94 census (Strong *et al.*, 2006), these have been at a relatively small number of selected sites, so the earlier data were used to ensure comprehensive spatial coverage. The highest concentration of pup production is centred on Ramsey Island and north-west Pembrokeshire, extending southwards to Skomer Island and northwards to southern Ceredigion (Figure 111). Smaller breeding concentrations in North Wales are located around the Lleyn Peninsula and the coast of Anglesey (the Skerries).

The maps of grey seal sightings (Figure 112) should be interpreted with some caution, because the recording of seals during sightings surveys has been erratic, many observers simply not recording seals when their main target species have been cetaceans. Nevertheless, they show a wide distribution in Welsh seas. Although pup production in Wales is highest in Pembrokeshire, highest sighting rates occur in the north-east of Wales towards Hilbre Island, Cheshire, reflecting the distribution of moulting and feeding haul-out sites during the non-breeding season (Figure 113). Note that the maps in Figure 113 include both vessel and land-based surveys since much of the monitoring has involved land observations in coastal waters. The dots in Figure 113a do not necessarily fall exactly on the locations of haul-outs. They are located in the centres of cells, as in all other maps. Hence the size of each dot is scaled to represent the sum total of all counted haul-outs in each cell. This ensures that precise locations of sensitive sites are not revealed.

The maps of quarterly mean sighting rates (from vessel and land-based surveys) indicate that the species is present in coastal waters throughout the year (Figure 114). However, probably a better indication of the movements of grey seals comes from the results of radio tagging grey seals at three of the major haul-out sites. In June 2004, the Sea Mammal Research Unit (SMRU) attached Argos satellite (series 7000 SRDL) tags on 19 grey seals: four males and three females on Ramsey Island (Pembrokeshire), three males and two females on Bardsey Island (Gwynedd), and two males and five females on Hilbre Island (Cheshire) (B. McConnell, SMRU, *pers. comm.*). The seals were tracked for an average of 141 days (range 76-183 days). The results indicated foraging trips to often very localised areas (Figures 115 & 116). A relatively regional structure to foraging patterns was observed, although with occasional relocation between Wales and Ireland. However, most movement was contained within the Irish Sea (Hammond *et al.*, 2005), as also indicated from photo-ID at breeding, moult and haul-out sites (Rosas da Costa & McMath, 2011).

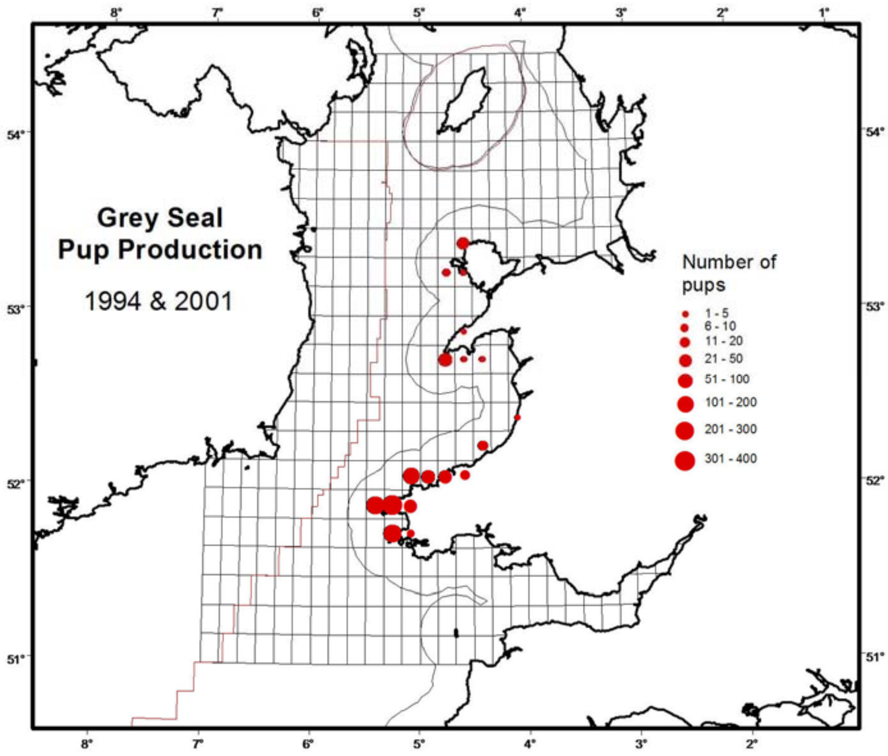


Figure 111 – Grey seal annual pup production in Wales

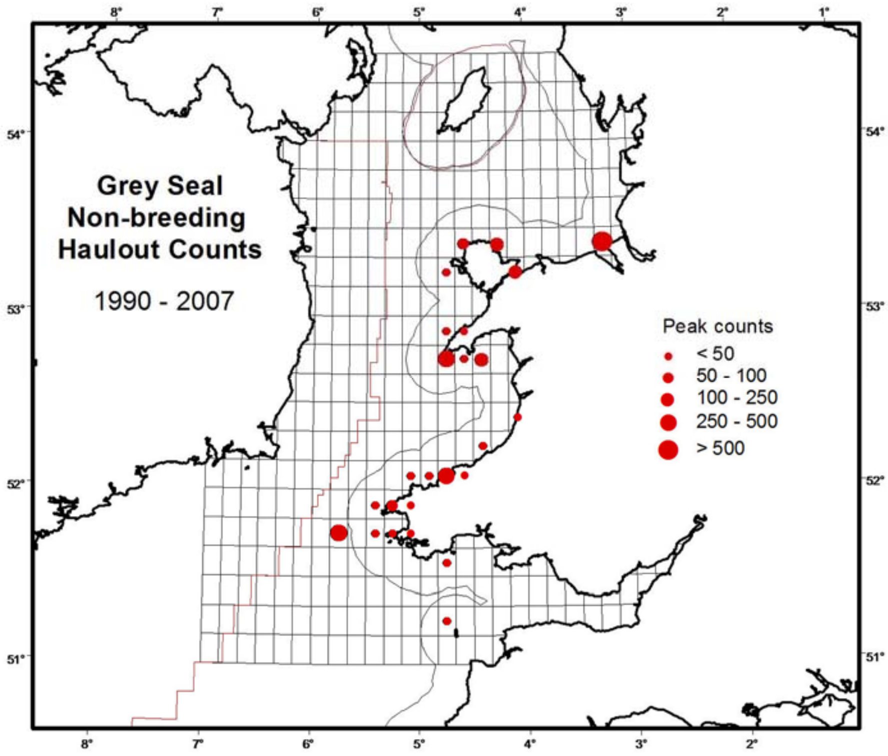
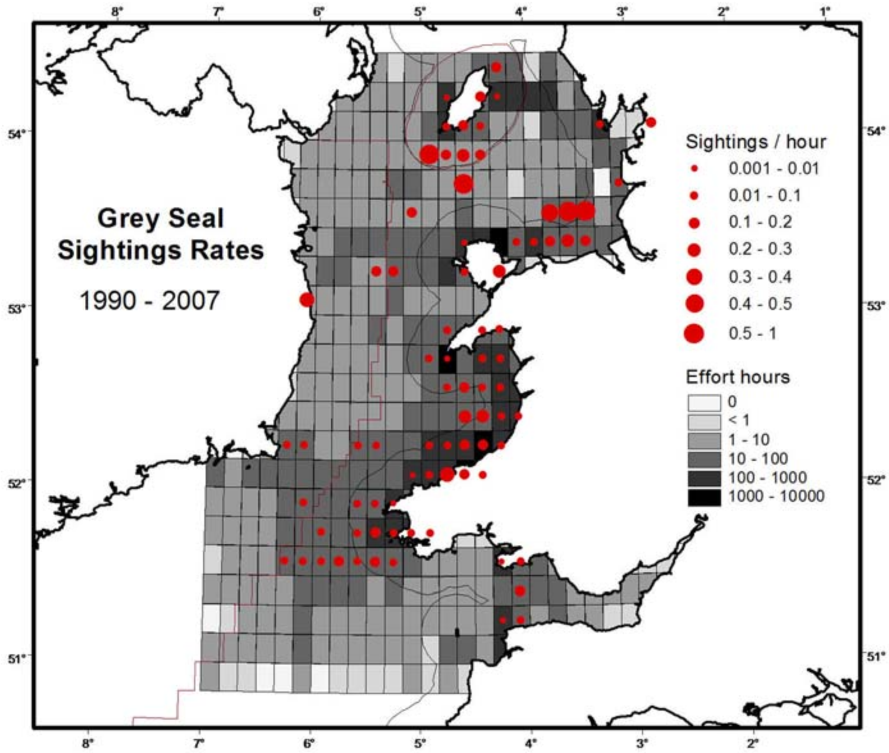


Figure 112 – Counts at grey seal haul-out sites in Wales during non-breeding season

a) Long-term mean sighting rates



b) Interpolated long-term mean sighting rates (vessel & land-based)

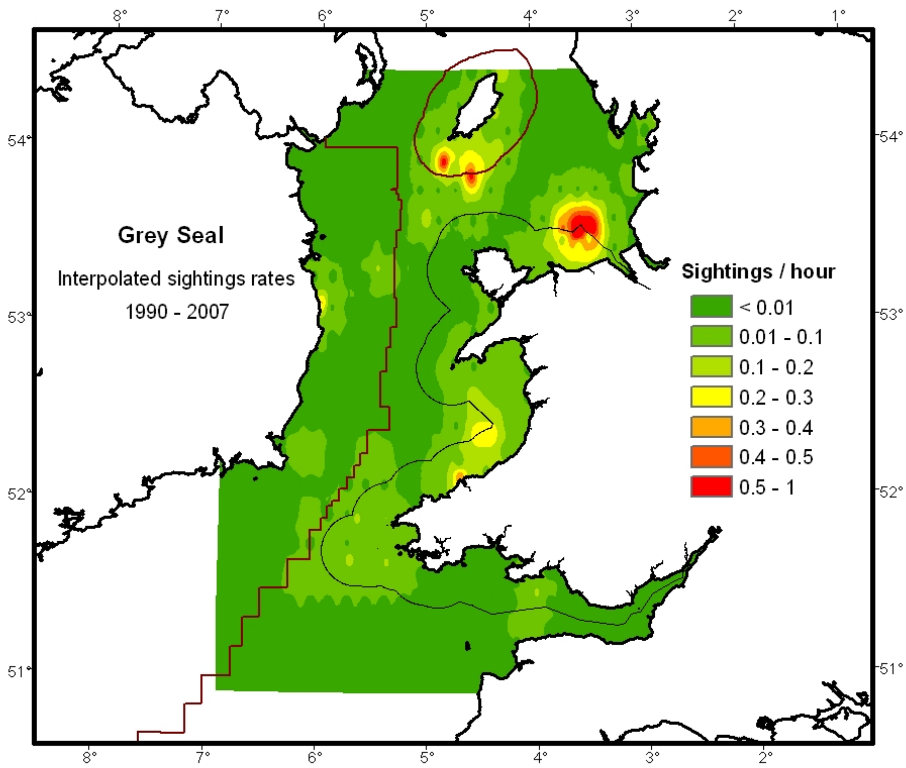


Figure 113 – Sighting rates (from vessel & land-based surveys) of grey seals 1990 – 2009

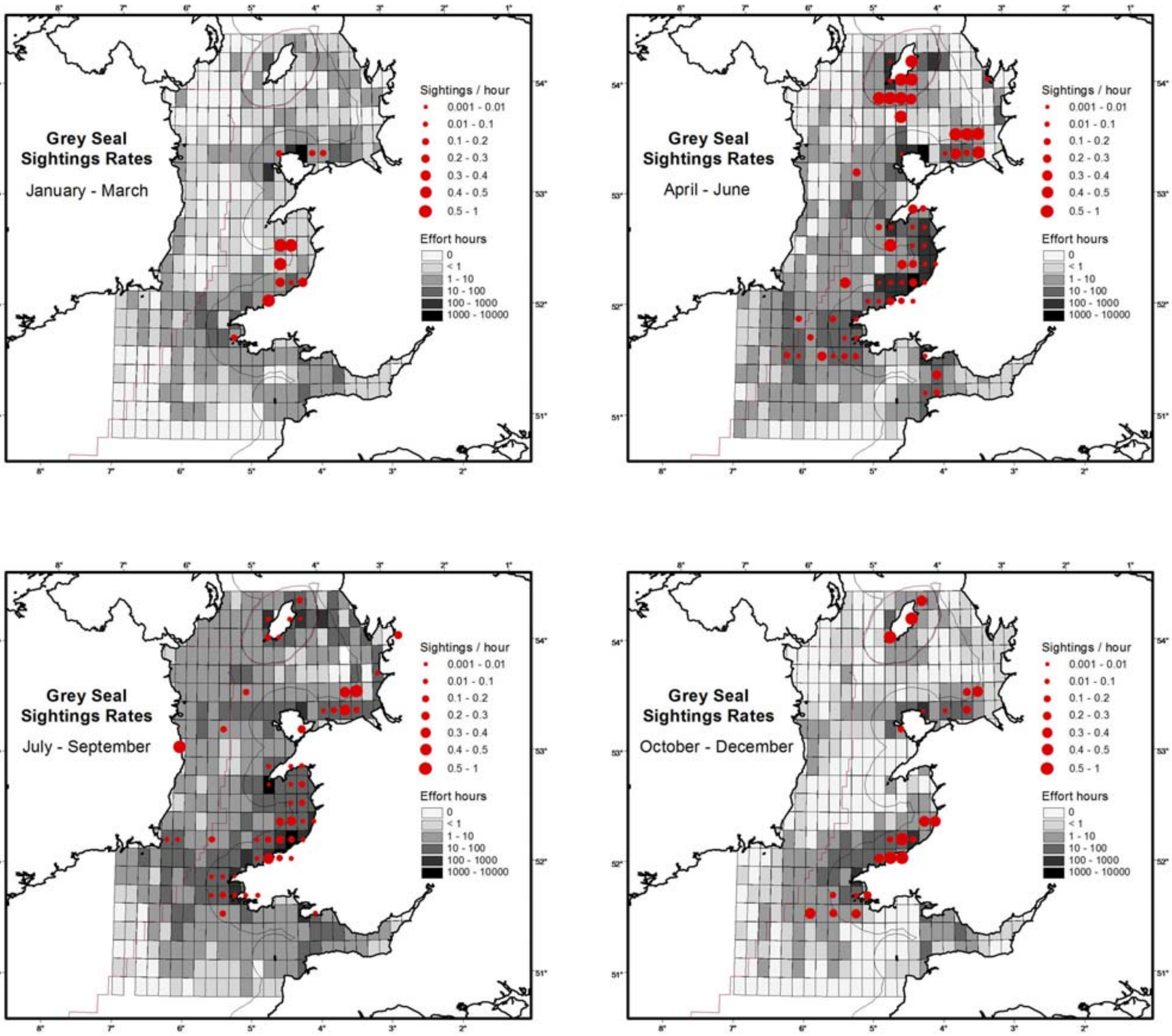


Figure 114 – Long term quarterly mean sightings rates of grey seal from vessel & land-based surveys

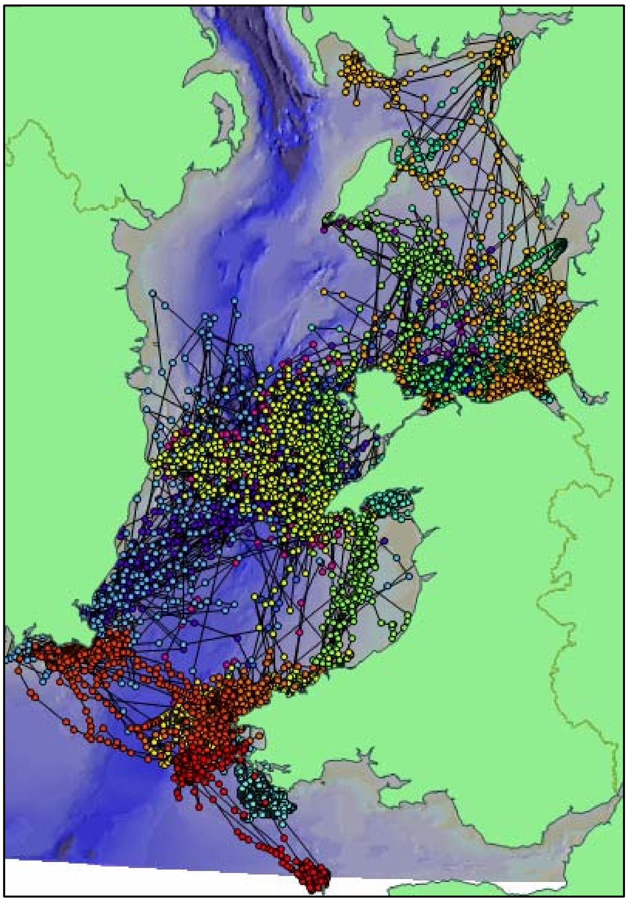


Figure 115 – Distribution of foraging grey seals tagged from Hilbre Island (Cheshire), Bardsey Island (Gwynedd), and Skomer Island (Pembrokeshire) [Hammond *et al*., 2005]

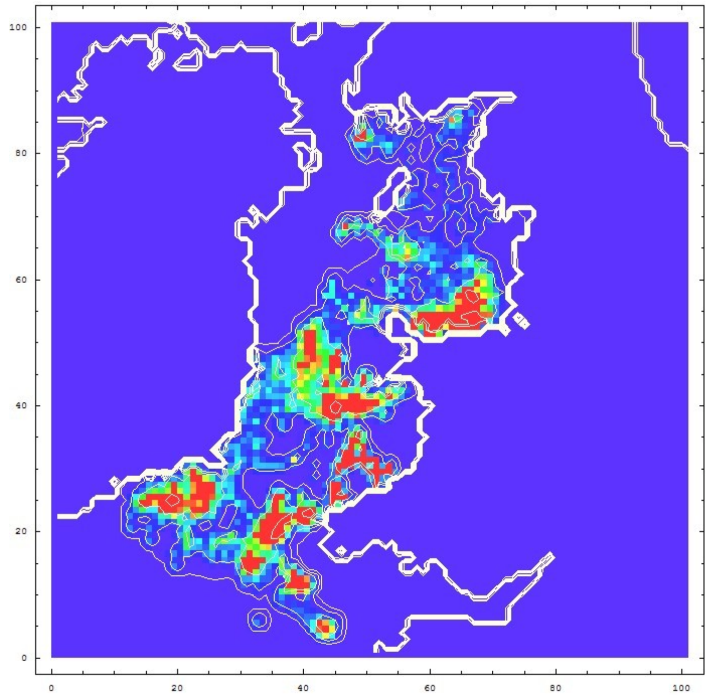


Figure 116 – Interpolated distribution of foraging tagged grey seals [SMRU unpublished data]

4. DISCUSSION

Eighteen species of cetacean have been recorded in Welsh waters since 1990. Five of these show regular occurrence (>100 sightings), and it is possible to map their distributions and how they may vary in time. These are harbour porpoise, bottlenose dolphin, short-beaked common dolphin, Risso’s dolphin and minke whale. Rare species include fin whale, killer whale, and long-finned pilot whale, whereas other species are more or less casual visitors to the region: humpback whale, sei whale, pygmy sperm whale, northern bottlenose whale, Cuvier’s, Sowerby’s and Blainville’s beaked whales, striped dolphin, Atlantic white-sided dolphin, and white-beaked dolphin. The striped dolphin appears more frequently in the stranding record than indicated from sightings. Given that it may associate with groups of common dolphins and is relatively difficult to distinguish, the species may be more regular than the number of sightings records suggest. Fin whales are seen in the Irish Sea mainly in the St George’s Channel between SE Ireland and West Pembrokeshire, whilst humpback whale records have also increased in recent years.

The harbour porpoise is the commonest and most widespread species in Welsh waters. It is present year round, although probably under-recorded in winter. Static acoustic monitoring using T-PODs in Cardigan Bay SAC in fact indicate a higher occurrence of the species in winter than in summer, with higher activity in coastal waters at night-time, possibly to avoid bottlenose dolphin attacks (Pesante *et al*., 2008b). The species is not evenly distributed within the Irish Sea. Hot spots can be identified off North and West Anglesey (particularly around Point Lynas & South Stack, Holyhead), the southwest coast of the Lleyn Peninsula, southern Cardigan Bay, in the vicinity of Strumble Head and the west Pembrokeshire islands (Skomer & Ramsey), and in the Bristol Channel off the south coast of Wales (around the Gower Peninsula and in Swansea Bay), often occurring near headlands or in sounds between islands associated with areas of high tidal energy (Pierpoint, 2008; Shucksmith *et al*., 2009). The species is known elsewhere to use tidal conditions for foraging (Evans, 1997; Marubini *et al*., 2009). These areas of relative high density largely persist across time periods. Outside Welsh waters, there is a clear hotspot east of Dublin Bay in Ireland in the vicinity of the western Irish Sea Front (Weir & O’Brien, 2000), and in the outer parts of the Solway Firth. Porpoise calves occur throughout the region. Although juvenile : adult ratios are highest in southwest and south Wales, these findings should be viewed with some caution since they have not been recorded systematically by all observers.

The bottlenose dolphin has been the next most frequently recorded species. In the region it has a predominantly coastal distribution, although low densities have been recorded offshore, particularly in St George’s Channel and the southwest sector of the study area. The main concentration of sightings appears to be southern Cardigan Bay but with moderately high sighting rates extending north into Tremadog Bay. However, the species also occurs off the north coast of Wales, particularly north and east of Anglesey.

There is some indication that bottlenose dolphins form small groups (generally <10 individuals) in summer centred upon Cardigan Bay, but then disperse more widely in winter, moving mainly northward to North Wales and beyond, where they often form very large groups (numbering 50-150 animals) (Pesante *et al*., 2008a, b). However, some bottlenose dolphin groups remain in coastal areas of Cardigan Bay through the winter, and conversely, the species can be seen at any time of the year at least occasionally in North Wales (Pesante *et al*., 2008a). The importance of Cardigan Bay for bottlenose dolphins has been maintained across the four 5-year time periods, but there is also evidence from casual recording that the same applies to the species in winter along the north Welsh coast.

Bottlenose dolphins have an extended breeding season, and calves have been observed in most months of the year (though with peaks in July & August) throughout Cardigan Bay and, to a lesser extent, east of Anglesey. The attraction of Cardigan Bay may be due to its relatively shallow nature and diverse benthic habitats, as well the proximity to significant populations of migratory salmonids in the rivers draining into the bay (Pesante *et al*., 2008b) Only small numbers of bottlenose dolphins have been recorded stranding (Penrose, 2010, 2011).

The short-beaked common dolphin has a largely offshore distribution centred upon the Celtic Deep at the southern end of the Irish Sea, where water depths may exceed 100 metres (see Figure 1). Common dolphin abundance in this area may be associated with a frontal system of high primary productivity, termed the Celtic Sea Front (Reid *et al*., 2003; Bush, 2006; Evans *et al*., 2007). This common dolphin high-density area extends eastwards towards the coast of west Pembrokeshire and the islands of Skomer, Skokholm, Grassholm and the Smalls. Elsewhere in the Irish Sea, common dolphins occur at low densities, mainly offshore northwards towards the Isle of Man. Similar patterns of distribution have persisted across the four time periods examined. The species appears to be mainly a summer visitor although it persists in the Celtic Deep at least to November. There is some indication of an influx of juvenile groups in late summer. Most strandings occur along the coasts of Southwest Wales (Penrose, 2010, 2011).

Risso's dolphins have a rather localised distribution, forming a wide band running SW-NE that encompasses west Pembrokeshire, the western end of the Lleyn Peninsula and Anglesey in Wales, the south-east coast of Ireland in the west, and Manx waters in the north. There is no indication that this general distribution has changed over the long-term, the same areas of higher density persisting over time. It is unclear what determines the patchy distribution of Risso's dolphin in the Irish Sea. The species feeds upon cephalopods such as octopus, cuttlefish and small squid, and in some areas of the Irish Sea its occurrence can be linked to *Modiolus* beds (Evans, 2008; Evans & Hintner, 2010). The species is mainly a summer and autumn visitor to the Welsh coasts, with the highest sighting rates in the period July to September. At other times of the year, Risso's dolphins may range more widely offshore. In the Isle of Man, the species occurs particularly in late spring and early summer. The species breeds in the region, and young of the year have been seen frequently in groups sighted in Pembrokeshire, around Bardsey Island and Anglesey. There have been only a few strandings, across west Wales (Penrose 2010, 2011).

Like the short-beaked common dolphin, the minke whale has a predominantly offshore distribution, with highest densities of sightings in the area of the Celtic Deep, although the species also occurs in deeper areas (generally >50 m) northwards particularly between the coast of County Dublin and Anglesey, and around the Isle of Man. This distribution pattern is observed across the time periods under examination, and may be linked to the two main frontal systems of high primary productivity, the Celtic Sea Front and western Irish Sea Front. Minke whale associations with high chlorophyll concentrations have been demonstrated elsewhere in UK (e.g. Anderwald *et al*, 2012; Tetley *et al*, in press). Minke whales appear to be mainly summer visitors to the region, with few sightings in winter, although this may partly be due to low effort at that period. There is no evidence as yet that the species breeds in Welsh waters.

Overall, cetacean species diversity is highest around the Celtic Deep. The areas of coastal Wales with highest species diversity are west Pembrokeshire, the western end of the Lleyn Peninsula, and west of Anglesey, and further north, in the vicinity of the Isle of Man – all regions closest to deeper waters and the possible influence of the two major frontal systems in the Irish Sea, the Celtic Sea and western Irish Sea Fronts (Weir & O'Brien, 2000; Reid *et al*., 2003; Bush, 2006).

Of the two native pinniped species occurring in the British Isles, only the grey seal breeds in Wales. This species is widely distributed around the coasts of Wales, breeding in caves and small coves on offshore islands and less accessible parts of the mainland coast. Pup production is greatest in Northwest Pembrokeshire, particularly on Ramsey Island, but extending southwards to Skomer Island and northwards to southern Ceredigion (Baines *et al*., 1995; Strong *et al*., 2006). Smaller breeding concentrations occur around the Lleyn Peninsula and the coast of Anglesey. These same areas are used as moulting and feeding haul-out sites during the non-breeding season (Westcott, 2002; Westcott & Stringell, 2003, 2004). This is in addition to other sites used solely for moulting and during feeding trips, an example being the West Hoyle Sandbank in the Dee Estuary, where over 800 seals have been counted (Hilbre Island Bird Observatory unpublished data). Many observers conducting surveys have not systematically recorded seals and so their distribution at sea is difficult to assess at this stage. However, the species clearly is widely distributed in Welsh coastal waters and throughout the year. Telemetry studies indicate foraging trips to often very localised areas, with animals from a particular area tending to remain in that region (Hammond *et al*., 2005).

Much progress has been made in the last twenty years in terms of surveys for marine mammals in Welsh waters. In this atlas, a total of 216,031 km of effort from vessel and aerial surveys and 13,399 hours of land-based effort were devoted to systematically recording cetaceans in 373 (90%) of the 414 cells within the study area, over a period of twenty years. Nevertheless, coverage remains inadequate in all but a few small areas. For 45 cells (11%), there was no effort at all, in 61 cells (15%) there was no vessel effort and in 117 cells (28%) there was no aerial effort. Vessel effort over the twenty-year period covered by this report exceeded 100 km in only 177 cells (43%). Effort was highest in coastal areas, particularly in southern Cardigan Bay from New Quay to St David's Head, and around Bardsey Island. There has also been a temporal bias to the distribution of effort, with 78% of all vessel effort in the six months, April to September. All areas would benefit from greater survey effort, but particular gaps occur in Caernarfon Bay, south Pembrokeshire, and the coast of Gwent in South-east Wales, as well as several offshore areas.

In this Atlas, distribution maps are presented separately from the results of vessel surveys, aerial surveys and land-based watches. Within these separate platform types, there is some heterogeneity. Aerial surveys conducted during SCANS II used planes flying at a height of c. 150-160m at speeds of c. 185 kph (Hammond, 2008), whereas those targeting seabirds, such as the ones undertaken by WWT Consulting fly at similar speed but usually at a height of c. 75m (WWT Consulting, 2009). Thus they have rather different fields of view. For their part, vessel surveys range from dedicated line transects to use of platforms of opportunity such as whale-watch operations and ferry trips. Although the data sets used in this project all involved dedicated search effort by a similar number of observers operating only in good field conditions, there is nonetheless inevitable variation in viewing conditions (sea state & glare) as well as in platform height & speed, not to mention differences in observer skills and experience, and thus likely detection efficiency. The effects of some of these variables have been examined here using generalised additive modelling, with appropriate corrections applied, but there may be confounding factors, for some of which information is lacking. Furthermore, platforms of opportunity such as ferries that follow particular narrow band routes or are directed to finding concentrations of marine mammals for their customers are not easily integrated with surveys that cover an area representatively and in a systematic manner. Ideally one should like to combine data from the three main platform types but this introduces further complications. For example, whereas responsive movement (avoidance or attraction) can be an issue affecting detection rates in vessel surveys, aerial surveys on the other hand face a more significant problem of availability bias – the time available for a cetacean to be detected at the surface is much lower for a plane travelling at 185 kph compared with a vessel at 11-18 kph (see Buckland *et al*., 2004; Evans & Hammond, 2004; Dawson *et al*., 2008; Evans, 2011, for reviews of strengths & limitations of the different methods).

Since only a limited number of groups estimated ranges of sightings to the platform, it was not possible to fit detection functions for the various species, and hence to derive absolute density estimates. In future, recording groups should be encouraged to do so on a routine basis, whilst ensuring that all their observers have appropriate training for accurate distance estimation.

Despite the limitations outlined above, the maps produced here show consistency across time periods, giving us some confidence at least at a gross level. With greater survey effort, and some refinement of recording techniques in certain cases, they would undoubtedly be improved still further.

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7. DATA ARCHIVE

Data outputs associated with this project are archived as Project 200 (Media 1317):

[A] This report is archived in Microsoft Word and Adobe Portable Document Formats;

[B] A full set of maps produced by the project in JPEG format;

[C] A series of GIS layers upon which the cell based maps in the report are based;

[D] A set of raster files in ESRI Grid format and ASCII grid format for the interpolated maps is archived;

[E] A database named Marine_mammal_mapping_Wales_v2 in Microsoft Access 2000 file format is archived. The database metadata are described in a Microsoft Word document (Database_outline_2.doc).