E.ON Climate & Renewables

Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 3)

Technical Report

Chapter 3: Birds

Report: 1029455
Authors: Dr Sarah Canning, Dr Gillian Lye, Deborah Kerr
Issued: 18/09/2013

Natural Power Consultants
The Greenhouse
Forrest Estate
Dalry, Dumfries and Galloway
DG15 7XS
Tel: +44 (0) 1644 430 008

Client: **E.ON Climate & Renewables**

Report: 1029455

Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year3) Technical report

Chapter 3: Birds

Authors Dr. Sarah Canning, Dr. Gillian Lye, Deborah Kerr

Checked Dr. Sarah Canning, Dr. Chris Pendlebury

Approved Dr. Chris Pendlebury

Classification COMMERCIAL IN CONFIDENCE

Distribution E.ON Climate & Renewables

Revision History

Issue	Date	Changes
A	28/08/2013	First Issue to E.ON
B	18/09/2013	Draft 1 released to RRMG for comments

3. ORNITHOLOGICAL MONITORING

3.1. Introduction

This chapter contains a summary of the bird data available for analysis to Natural Power Consultants (NPC) and represents an update on previous reports and reviews all data collected up to and including operational year three. All data collected during construction of the Robin Rigg wind farm were undertaken as part of the requirements for the MEMP and agreed by the RRMG. As required by the MEMP, this report includes recommendations as to what (if any) further surveys are required for operational years four and five.

3.1.1. Predicted impacts from Environmental Statement

The Offshore Environmental Statement (submitted in 2008 and hereafter referred to as the ES) assessed the potential impacts of the Robin Rigg OWF on bird species by impact type. The ES concluded the following:

Collision Risk

Generally, predictions from the collision risk modelling were very low, even with unrealistic worst case assumptions. For most of the species assessed, the magnitude of risk was less than 1% above annual baseline mortality rate (see Table 3.1). The one species that exceeded this value was red-throated diver, with a predicted annual collision mortality rate of 22.8% of the overall annual mortality rate. It was felt this high value was due to a combination of a small population within the study area and it being a long-lived species. The overall collision risks predicted from the Robin Rigg development are detailed in Table 3.2 below.

Table 3.1: Worst case collision risk predictions for key species at the Robin Rigg OWF as presented in the ES

Species	Predicted annual collision with wind farm (worst case)	Annual mortality rate	Collision mortality as % of overall annual mortality
Common scoter	3.4	23%	0.3%
Red-throated diver	3.3	10%	22.8%
Oystercatcher	10.9	7%	0.4%
Barnacle goose	11	10%	0.5%

Table 3.2: Summary of collision risks from the Robin Rigg OWF as predicted in the ES

Species	Sensitivity of local population	Magnitude of effect	Significance	Significant impact?
Common scoter	High	Negligible	Very low	No
Red-throated diver	High	Low	Low	No
Migrant waterfowl	Very high	Negligible	Low	No
Other seabirds	Medium	Low/negligible	Low/very low	No
Migrant land birds	Low	Negligible	Very low	No

Habitat Loss

Direct loss of habitat resulting from the development was predicted to be of such a small scale that it would not be significant in terms of its impact on bird habitat (and their foods).

At most, disturbance would affect regionally, rather than nationally important numbers and it was concluded that the development area does not provide particularly important resources for the bird populations discussed.

For the two species known to occur in internationally important numbers, red-throated diver and common scoter, displacement zones of 5 km and 3 km respectively were predicted as being needed to affect nationally important numbers. Studies conducted at existing wind farms (at the time of submission) found small-scale disturbance with the maximum distance reported as 800 m (Pedersen

& Poulsen, 1991), suggesting that disturbance to species of concern around Robin Rigg would be unlikely. A summary of species sensitivities and magnitudes of impacts can be found in Table 3.3. The magnitude of impact is that which would arise if birds were displaced from an area 1 km around the wind farm and what disturbance zone would be needed to result in a significant impact.

Table 3.3: Summary of disturbance assessment from the Robin Rigg OWF, as predicted in the ES.

Species	Sensitivity of local population	Buffer width (for national importance)	Magnitude of effect	Significance	Significant impact?
Common scoter	High	3 km	Low	Low	No
Red-throated diver	High	>5 km	Low	Low	No
Manx shearwater	Medium		Negligible	Very low	No
Storm petrel	Medium		Negligible	Very low	No
Gannet	Medium		Negligible	Very low	No
Cormorant	Medium		Low	Low	No
Scaup	Medium		Low	Low	No
Kittiwake	Medium		Low	Low	No
Guillemot	Medium		Low	Low	No
Razorbill	Medium		Low	Low	No
Other seabirds	Low		Low	Very low	No

3.1.2. Solway bird populations

The Solway Firth is an important area for a wide range of diverse bird species, with a number of areas protected under national and international law (Table 3.4).These protected areas fall into a number of designations/categories:

- Protected areas established under National Legislation, including Sites of Special Scientific Interest (SSSI) and National Nature Reserves.
- Protected areas established as a result of European Union Directives or other European initiatives, including the Natura 2000 network.
- Protected areas set up under Global Agreements, including Ramsar sites.
- Marine Protected Areas

A number of the bird species detailed in Table 3.4 were highlighted within the Robin Rigg ES as being present within the Solway Firth in nationally important numbers. These key species (scaup, common scoter; red-throated diver; Manx shearwater; cormorant; gannet; kittiwake and guillemot) have been chosen as the main focus of the analysis presented here along with data collected on razorbill, herring gull and great black-backed gull.

Table 3.4: *Areas of protection for birds within the Solway Firth.*

Site Name	Designation	Distance from Site (km)	Qualifying Features
Upper Solway Flats and Marshes	RAMSAR	6.4	Non-breeding: bar-tailed godwit; Svalbard barnacle goose; curlew; knot; oystercatcher; pink-footed goose; pintail; scaup
Upper Solway Flats and Marshes	SPA	6.4	Non-breeding: bar-tailed godwit; Svalbard barnacle goose; cormorant; curlew; dunlin; golden plover; goldeneye; great-crested grebe; grey plover; knot; lapwing; oystercatcher; pink-footed goose; pintail; redshank; scaup; shelduck; whooper

			swan Non-breeding & passage: ringed plover
Upper Solway Flats and Marshes	SSSI	6.4	Breeding bird assemblage[1] Non-breeding: bar-tailed godwit; barnacle goose; curlew; dunlin; golden plover; goldeneye; grey plover; knot; oystercatcher; pintail; redshank; ringed plover; sanderling; scaup; shelduck
Abbey Burn Foot to Balcary Point	SSSI	8.5	Breeding: cormorant; fulmar; guillemot; kittiwake; razorbill
Borgue Coast	SSSI	22	Breeding: common gull; great black-backed gull
St Bees Head	SSSI	23	Breeding: guillemot; fulmar; kittiwake; razorbill; puffin; shag; herring gull; black guillemot
Cree Estuary	SSSI	40	Non-breeding: pink-footed goose
Scare Rocks	SSSI	62	Breeding: gannet; guillemot; shag
Loch of Inch and Torrs Warren	RAMSAR	69	Non-breeding: Greenland white-fronted goose
Loch of Inch and Torrs Warren	SPA	69	Non-breeding: Greenland white-fronted goose; hen harrier
Torrs Warren to Luce Sands	SSSI	69	Non-breeding: hen harrier
Mull of Galloway	SSSI	73	Breeding: fulmar; kittiwake; razorbill
Ailsa Craig[2]	SPA	100	Breeding: gannet; lesser black-backed gull; guillemot; kittiwake; herring gull

Scaup (Aythya marila)

The scaup is the most northerly distributed of the *Aythya* species (Forrester *et al*., 2007). Scaup are mainly present in the UK during the winter, with the majority arriving in late October and leaving again in February. They winter in sheltered sea lochs and firths, brackish coastal lagoons and freshwater lochs close to the coast where molluscs are available in shallow water - much less than 10 m deep (Forrester *et al*., 2007).

The winter population in Britain has been estimated at 5,200 birds (Musgrove *et al*., 2011) with apparent declines occurring in the Solway Firth compared to earlier estimates (Kershaw & Cranswick, 2003; Musgrove *et al*., 2011). Strong links have been found between wintering birds in the UK and breeding populations in Iceland, but the limited tagging data available suggest that birds observed in the UK disperse to a wide range of sites in northwest Europe (Wernham *et al*., 2002).

Most individuals spend the winter in marine coastal areas where they typically feed on molluscs such as mussels and tend to congregate in large flocks. Scaup are usually active at night making regular feeding flights to the sea in the evening and returning at dawn (Nilsson 1970). While scaup are able to switch feeding sites according to prey availability, appropriate habitat availability is limited by water depth as they require shallow waters to forage (Nilson, 1970; Jones and Drobney, 1986).

Scaup can be susceptible to human disturbance, diving or hiding when low-flying helicopters approach (Austin *et al*., 2000), and are disturbed by passing ships up to 400m away (Platteeuw and Beekman 1994).

[1] Localities that support an especially good range of bird species characteristic of that habitat or semi-natural habitats where at least 70 breeding species have been recorded in recent years. From: Guidelines for the selection of biological SSSIs (http://jncc.defra.gov.uk/page-2303#download)

2 Although not within the Solway Firth this is within the foraging range for gannet

Common scoter (Melanitta nigra)

Common scoters breed on inland waters near moorland lochs or on wooded islets. They mostly breed in Scandinavia with fewer than 100 pairs reported as breeding in Britain (Baker *et al*., 2006; Musgrove *et al*., 2013) and only a few breeding sites are known in Scotland. Some birds will overwinter near their breeding grounds while others migrate to transitional sites to moult. Although small wintering populations occur widely around British coastlines, the majority occur in just a few large congregations with the total UK wintering population estimated at approximately 100,000 birds (Musgrove *et al*., 2011). Wintering birds arrive in September with the majority thought to originate from the Baltic (Cabot, 2009).

Moulting occurs between July and October, rendering the birds flightless for 3-4 weeks. Moulting flocks occur in the UK between June and September, predominantly from Scandinavia and Russia, with these birds numbering as many as 30,000. Their migration route is unknown but it can be assumed they cross the North Sea. They feed predominantly on molluscs, in particular the blue mussel. They are also known to eat cockles, clams, small fish and plant material.

Common scoter are listed on Annex 2 of the Birds Directive, Schedule 1 of the Wildlife and Countryside Act, are listed on the IUCN Red List of threatened species and a UK Priority BAP species. Ten SPAs list common scoter as a designated species with two of these for breeding birds. Only two of these sites occur on the west coast of the UK, one on the Rinns of Islay for breeding birds and containing 13% of the national population, and the other for non-breeding birds in the Ribble and Alt estuaries containing 2% of the national population (JNCC, 2001). In addition there are two marine SPAs designated for common scoter. The Bae Caerfyrddin/ Carmarthen Bay SPA (Wales) was classified in 2003 and the Liverpool Bay/Bae Lerpwl SPA in 2010 for their non-breeding aggregations of common scoter.

Common scoters were recorded throughout the wider ES study area, with the highest numbers recorded in August/September and May/June. Observations were primarily in the north-western edge of the study area.

Common scoter were considered by MacLean *et al*., (2009) to be highly sensitive to disturbance, habitat loss, demonstrate medium sensitivity to barrier effects and exhibit a 99% avoidance rate of wind turbines. Studies of common scoter provide an average flight height 9.4 m (Walls *et al*., 2004; Parnell *et al*., 2005; Petersen *et al*., 2006; Sadoti *et al*., 2005). Data collected from 18 wind farm sites found that approximately 1% of birds are likely to fly at a height that will put them at risk of collision with turbine blades (Cook *et al*., 2012).

Red-throated diver (Gavia stellata)

Three species of diver (red-throated, black-throated and great northern) have been recorded in the study area, primarily during the winter and spring. Of these, 90% were identified as red-throated divers and so analysis has focussed on this species.

Red-throated divers breed around shallow pools on upland moors and bogs, travelling to the coast to feed. Fewer than 1,500 pairs breed in Britain (Baker *et al*., 2006). Breeding pairs are distributed throughout the north and west of Scotland, with almost half of the Scottish population breeding in Shetland. Outside of the breeding season, they can be found around the coast, in shallow sandy bays. The UK winter population contains around 17,000 birds (Musgrove *et al*., 2013) with the largest concentrations occurring off the Welsh and northwest English coasts and in the southern North Sea. They develop their breeding plumage between February and April, moulting after breeding has finished. All three species of diver feed predominantly on marine fishes such as cod, herring, sandeel and sprat.

The red-throated (and great northern) diver is listed on Annex 1 of the Birds Directive, Schedule 1 of the Wildlife and Countryside Act and are Amber listed Birds of Conservation Concern (Eaton *et al*., 2009). Eleven SPAs have been designated for red-throated diver, ten for breeding birds. The Outer Thames Estuary and Liverpool Bay/Bae Lerpwl marine SPAs were classified in 2010 for their non-breeding aggregations of red-throated diver.

MacLean et al., (2009) consider red-throated divers to show very high sensitivity to disturbance, high sensitivity to habitat loss and barrier effects and a minimum of 98% avoidance rates of wind turbines.

Studies of red-throated diver provide an average flight height of 4.5 m (Walls *et al*., 2004; Parnell *et al*., 2005; Petersen *et al.,* 2005; Sadoti *et al.,* 2005). Data collected from 19 wind farm sites found that approximately 2% of birds are likely to fly at a height that will put them at risk of collision with turbine blades (Cook *et al*., 2012).

Diver distribution was generally scattered throughout the study area for the ES, although there was a tendency for red-throated divers to occur in shallow waters of between 5-10 m.

Manx shearwater (Puffinus puffinus)

The Manx shearwater is the commonest shearwater observed around Britain. The breeding population in Great Britain and Ireland is approximately 300,000 pairs (estimated from AOS[3] data 1998-2002; Mitchell *et al*., 2004; Musgrove *et al*., 2013), breeding in 40 colonies in the west of the UK (Mitchell *et al*., 2004; Figure 3. 1). However, this estimate is based on a survey that overlooked 14 further potential colonies so this may be an underestimate. The populations of Great Britain and Ireland form approximately 68-91% and 7-18% respectively, of the global population of 340,000-410,000 pairs.

Approximately 38% of the British and Irish Manx population breed in Scotland with 95% of these on Rum. JNCC analysis of ESAS data collected between 1980 and 2006 (Mitchell *et al.*, 2004) provide at sea density distributions highlighting areas to the west of the Isle of Man as having high densities (Figure 3. 2).

Manx shearwaters prefer the open ocean except when nesting, returning to breeding sites in late March (Forrester *et al*., 2007). They burrow on flat or sloping land close to the sea and only approach land after dark. The nearest breeding grounds to the Solway Firth are on Sanda, Argyll and the Calf of Man (Mitchell *et al*., 2004). They are a long distance migrant, travelling between breeding grounds in the spring to their wintering grounds in South America from July.

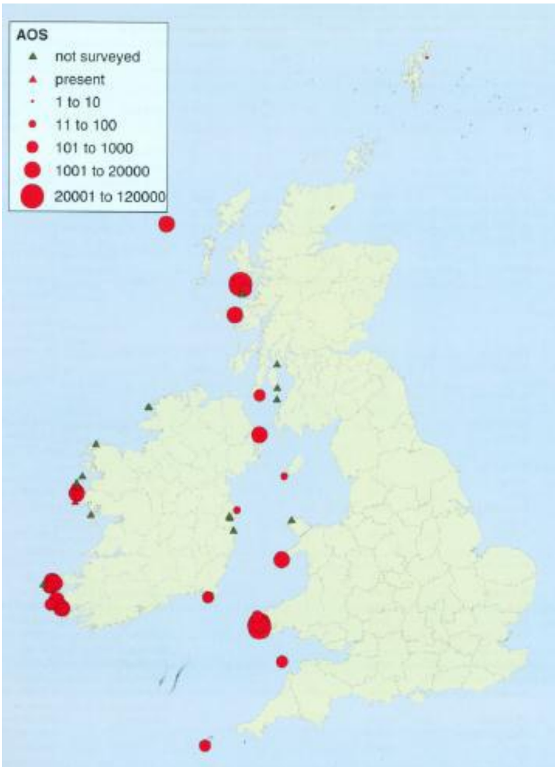


Figure 3.1: Breeding distribution of breeding Manx shearwater 1998-2002 (Mitchell et al., 2004)

[3] Apparently occupied sites

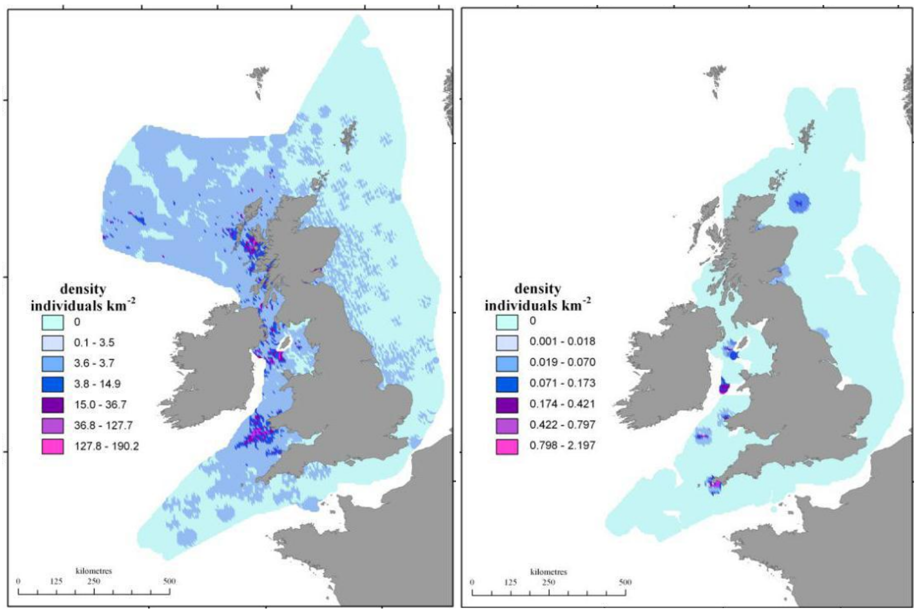


Figure 3.2: JNCC predicted density surface map produced from ESAS data collected between 1980 and 2006. Left = breeding birds; Right = October to November (reproduced from Kober et al., 2010)

Manx shearwaters feed at the sea-surface, either making plunge dives from a height of 1-2m, or making shallow, wing-propelled dives to catch prey items. They feed on fish such as herring, sardine and sprat plus sometimes squid (Snow & Perrins, 1998). Studies suggest that breeding Manx shearwater frequently travel large distances from their colonies during foraging trips. GPS tracked birds from Skomer were observed to have foraging ranges of over 330 km, as they travelled to areas around the Mull of Galloway (Guilford *et al.*, 2008). Boat-based surveys conducted around the west of Scotland during the chick rearing period found that most Manx shearwaters were observed within a 50 km radius of Rum (Harrison *et al.*, 1994). Elsewhere, through analysing data from boat-based seabird surveys in relation to distances from colonies, maximum foraging ranges of between 160 and 260 km have been estimated (Birdlife International; Stone *et al*., 1994 & 1995; Lloyd *et al.,* 1991).

Manx shearwater are considered to be of conservation concern under the Birds Directive and are Amber listed Birds of Conservation Concern (Eaton *et al*., 2009). The four main British breeding sites have been designated SPAs listing Manx shearwater as qualifying species (Rum and St Kilda in Scotland; Skomer, Skokholm and Middleholm, and Glannau Aberdaron and Ynys Enlli/ Aberdaron Coast and Bardsey Island in Wales).

Data collected from 10 wind farm sites found that less than 1% of birds are likely to fly at a height that will put them at risk of collision with turbine blades (Cook *et al*., 2012) with this species generally flying close to the sea surface. Survey work for the ES only recorded Manx shearwater during the summer months with no birds observed after August. They were observed predominantly over deeper waters to the south and west of the study area.

Gannet (Morus bassanus)

Gannets breed on both sides of the Atlantic with the British and Irish breeding population containing approximately 259,500 pairs breeding in 21 colonies (Mitchell *et al*., 2004). This forms approximately 67% of the global population (390,000 pairs), of which approximately 80% (312,300 pairs) breed in Europe (Mitchell *et al*., 2004). The majority of the British and Irish population breeds around Scotland (72%) with the British population estimated at 220,000 nests (Musgrove *et al*., 2013). The two nearest breeding colonies to the wind farm are Ailsa Craig (Kyle and Carrisk) and Scare Rocks (Wigtown). It was estimated there were 35,825 breeding pairs on Ailsa Craig in 1998-2000 (extrapolated data based on colony trends) and 1,670 on Scare Rocks (Mitchell *et al*., 2004).

Gannet are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and a qualifying feature of the Scare Rocks Site of Special Scientific Interest (SSSI). The nearest Special Protected Area (SPA) for gannets to the Solway Firth is Ailsa Craig, roughly 100 km to the north of the Solway Firth.

Satellite telemetry studies of the Bass Rock colony found considerable variation in foraging behaviour with maximum foraging distances during the breeding season of up to 540 km (Hamer *et al*., 2007) suggesting that the Solway Firth is well within the maximum foraging range of birds from this colony.

At the Hermaness colony in Shetland, temperature loggers inferred foraging ranges of between 32 and 128 km (Garthe *et al*., 1999), considerably less than the ranges observed at the Bass Rock colony although the sample size was much smaller (three adults). It was also noted that flying and foraging activity were only recorded during daylight hours (Garthe *et al*., 1999). Voiter *et al.,* (unpublished data) estimated that birds from Grassholm in Pembrokeshire travel up to 900 km from their breeding colony during foraging trips. However, satellite tracked birds breeding relatively nearby across the Irish Sea on Great Saltee (Co. Wexford, Ireland) had a mean foraging range of 90 km, and a maximum of 240 km (Hamer *et al.*, 2000).

JNCC analysis of ESAS data, collected between 1980 and 2006, to provide at-sea distributions of gannet during the summer and winter is shown in Figure 3.3 (Kober *et al*., 2010). These data indicate that comparatively low numbers of gannets could be found within the Solway Firth prior to the construction of the wind farm.

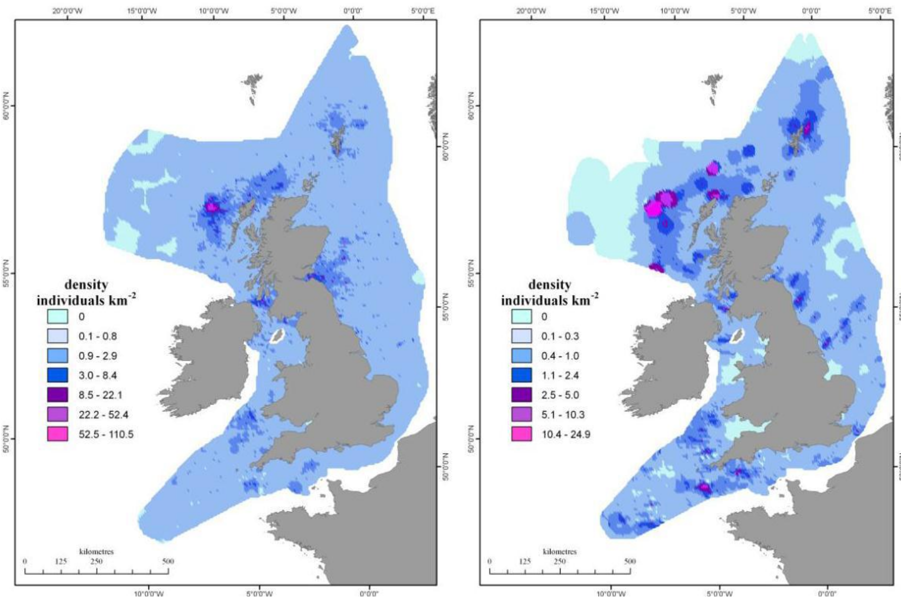


Figure 3.3: JNCC predicted density surface maps produced from ESAS data collected between 1980 and 2006. Left: summer. Right: winter (taken from Kober et al., 2010)

Gannets live on the open ocean for most of the year, first visiting nest sites from January with breeding beginning around April. Most British breeding colonies occur in the north and west, including the one at Scare Rock in Luce Bay (SSSI) where 2,394 nests were counted in 2003-2004. Eggs are typically laid between April and mid July. Nestlings fledge in Scotland between August and November, with peak numbers in mid to late September (Forrester *et al*., 2007). They are largely incapable of flight for a brief initial period, after which most fledglings move relatively quickly south towards waters off Iberia and west Africa (Wernham *et al*., 2002). Small numbers of fledglings from the Bass Rock colony have been recorded dispersing north and west around the Scottish coast before moving south (Wernham *et al*., 2002).

The gannet is a pelagic feeder, foraging primarily on lipid-rich pelagic fish up to 30 cm in length such as mackerel, herring and sandeel but also forages extensively for fishery discards (Snow & Perrins, 1998; Hamer *et al*., 2007). Many birds are present in British waters throughout the year, although young will leave their colonies during August/September to head to the African coast.

The majority of gannets recorded as part of the ES were done so during the summer, with only sporadic sightings between October and March. They were fairly evenly distributed throughout the study area, apart from the shallower waters to the north-west.

Cormorant (Phalacrocorax carbo)

Globally the cormorant has a large distribution and is found around all coastlines of the UK with reasonably large numbers observed in the Solway Firth (Figure 3.4). The global population is estimated at c1,400,000-2,900,000 individuals (Wetlands International, 2006) with the UK population estimated at 41,000 wintering birds and 9,000 breeding pairs (Musgrove *et al*., 2013). Two breeding colonies are monitored within the Solway Firth, Port o' Warren and Balcary Point. Between 1999 and 2000, these colonies held an estimated 126 and 95 breeding pairs (Mitchell *et al*., 2004).

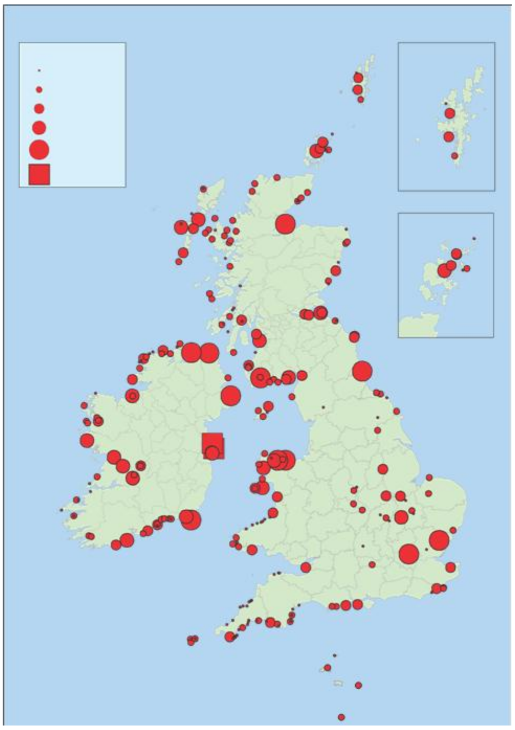


Figure 3.4: Abundance and distribution of breeding cormorants in Britain and Ireland 1998-2000 (Mitchell et al., 2004)

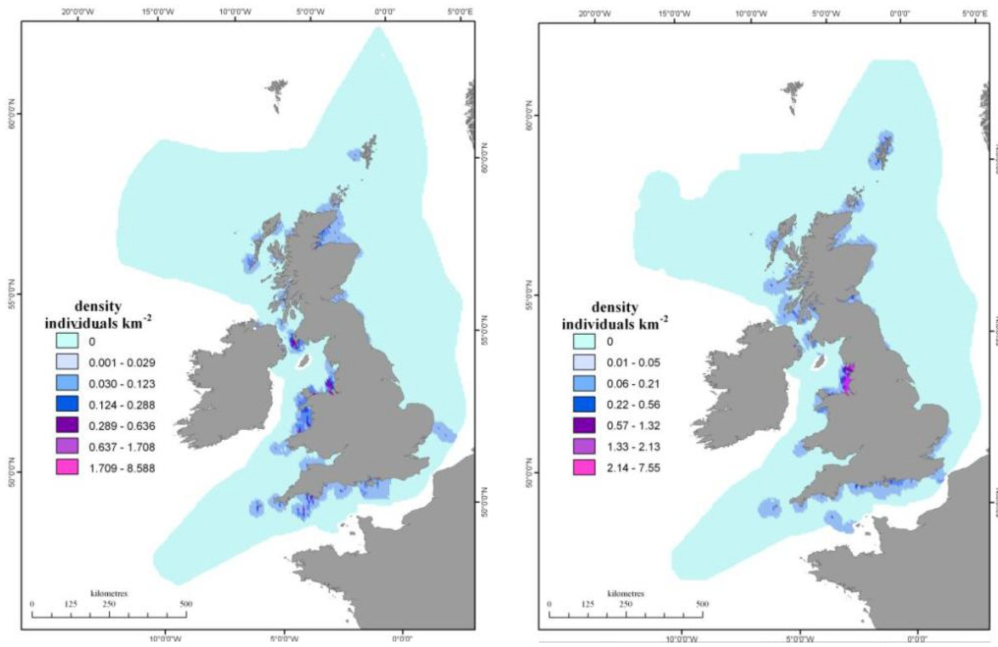


Figure 3.5: JNCC predicted density surface maps produced from ESAS data collected between 1980 and 2006. Left: breeding (April - August); Right: winter (September - March; taken from Kober et al., 2010)

Cormorant are primarily associated with rocky coasts and estuaries, although are also found by inland lakes and rivers, particularly during the winter. Coastal breeding sites are found on cliffs, stacks and rocky islets. They are usually a solitary feeder (Brown *et al*., 1981) but may form large fishing flocks in some areas (del Hoyo *et al*., 1992). The species' diet consists predominantly of fish, including sculpins, Capelin, gadids (Gremillet *et al.,* 2003) and flatfish (Leopold *et al.,* 1998) as well as crustaceans, amphibians (del Hoyo *et al.,* 1992), molluscs and nestling birds (Brown *et al.,* 1981). At sea the species preys mostly on bottom-dwelling fish, occasionally also taking shoaling fish in deeper waters (del Hoyo *et al.,* 1992). It is a generalist, having been shown to feed on at least 22 different fish species (Gremillet 1997).

The cormorant has a largely neritic distribution. At sea, it rarely wanders far from the coast, preferring sheltered areas and estuaries where it normally feeds in shallow water. It preys mainly on benthic fish species. It is rarely observed to dive below 10 m (BirdLife International 2000, Gremillet *et al.,* 2003) although it has been recorded at up to 35 m (Gremillet *et al.,* 2003). Several studies have shown that this species is able to forage up to 20-25 km from its wintering roosts or breeding colonies. Most foraging trips are confined to within 10 km of the colony (Gremillet 1997, BirdLife International 2000), but trips up to a 35 km radius have been recorded (Gremillet 1997). Off the coasts of eastern Jutland and at Læsø, Denmark, 75% of recorded birds were seen within 3 km of the coast (Petersen *et al.,* 2003). Preferred habitats include granitic boulder, since this is the favoured habitat of labrids, the commonest prey in the diet (Gremillet 1997). The species is also likely to select sandy areas with a high abundance of flatfish or rocky substrates where gobies, wrasse, sea scorpions and small gadoids occur (BirdLife International 2000).

Cormorants are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and are listed as a qualifying feature for the SSSI between Abbey Burn Foot to Balcary Point and Upper Solway Flats SPA. Breeding occurs during the spring with birds moving away from breeding colonies once the young have fledged. They feed on fish such as plaice, flounder, cod and spat.

During the survey work for the ES, the highest numbers of cormorants were recorded during the summer with the greatest numbers recorded in the north-western part of the study area.

Kittiwake (Rissa tridactyla)

The breeding population of kittiwake in Great Britain and Northern Ireland is approximately 380,000 breeding pairs (Musgrove *et al*., 2013) distributed all around the coastline, with the largest populations being found in the north-east (Figure 3.6). The highest concentration is found in Scotland, where 68% of AON were located (Mitchell *et al*., 2004). The UK kittiwake population declined by 30% between 2000 and 2010 (JNCC 2011).

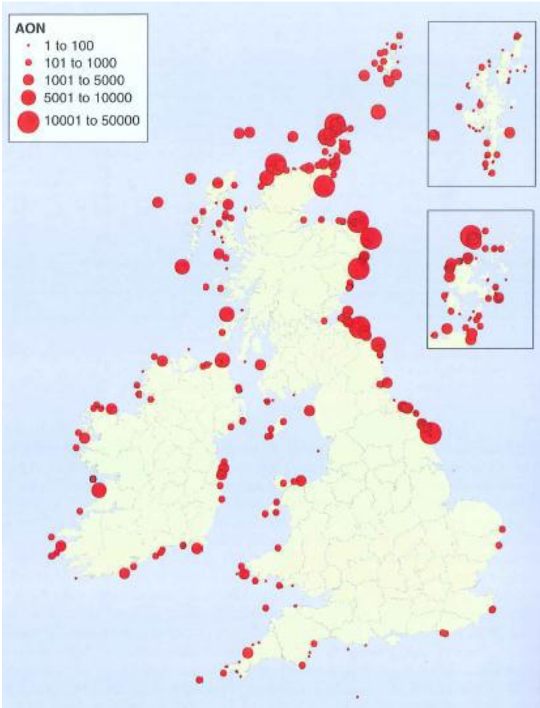


Figure 3.6: Distribution of breeding kittiwake 1998-2002 (taken from Mitchell et al., 2004)

JNCC analysis of ESAS data collected between 1980 and 2006, to provide at-sea distributions of kittiwake during the breeding season and winter period, are shown in Figure 3.7 (Kober *et al*., 2010). These data show low densities of kittiwake occurring in the Solway Firth during the breeding season prior to the construction of the wind farm.

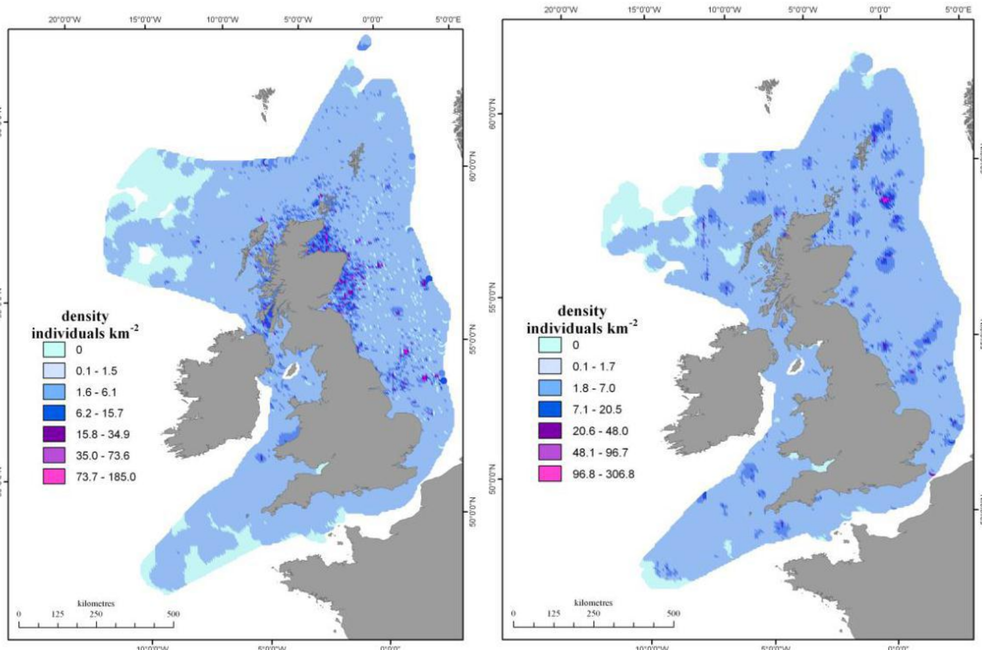


Figure 3.7: JNCC predicted density surface maps produced from ESAS data collected between 1980 and 2006. Left (a): breeding. Right (b): winter (taken from Kober et al., 2010)

During the spring and summer, kittiwakes can be seen around rocky coasts, nesting on tall sea cliffs. Most Scottish colonies are re-occupied in late February to March, with eggs typically laid in May. Adults leave their breeding colonies in July/August, heading out to sea were they remain for the rest of the year, often beyond the continental shelf. Most fledglings rapidly head west after departing from their breeding colonies, towards wintering areas in the north Atlantic (Wernham *et al*., 2002).

Kittiwake feed on fish species such as capelin, herring, sprat and sand eel and have been known to take crustaceans such as shrimps. Prey species tend to be surface dwelling with most food obtained by shallow splash diving. Other food items are picked from the sea surface, and trawler discards are taken where available (Cramp and Simmons, 1985; Ratcliffe *et al*., 2000). Tagging of kittiwakes from the East Caithness Cliffs SPA during the incubation and early chick-rearing stage recorded a mean foraging range of 41.9 km and a maximum range of 119.6 km from the cliffs (Moray Firth ES, Technical Appendix 4.5C)

Kittiwake are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and breeding kittiwake are listed as qualifying features for the SSSIs between Abbey Burn Foot and Balcary Point, at St Bees Head and Mull of Galloway. Highest numbers recorded for the ES occurred during the spring and summer, with numbers dropping through the winter. Their distribution was not associated with any particular areas through the study area.

Herring gull (Larus argentatus)

The breeding population of herring gulls in Great Britain and Northern Ireland is approximately 140,000 pairs with an additional 7,100 on the Isle of Man (Musgrove *et al*., 2013). The UK winter population is estimated at 740,000 birds (Musgrove *et al*., 2013). This species is absent only from the coastline of small parts of the east coasts of England and Ireland (Figure 3.8; Mitchell *et al*., 2004). The Great Britain and Ireland populations of herring gull form approximately 12-13% and 0.5-0.6%, respectively, of the global population of 1,100,000-1,200,000 pairs (Mitchell *et al*., 2004). The UK herring gull population declined by 38% between 2000 and 2010 (JNCC 2011).

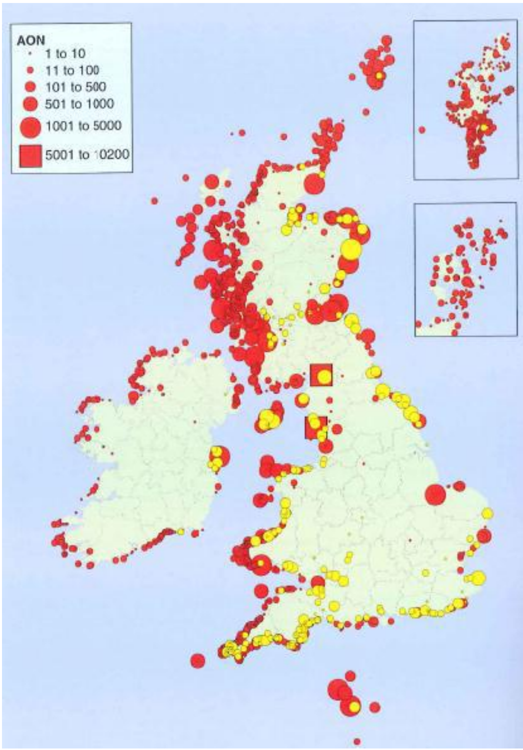


Figure 3.8: Distribution of breeding herring gull 1998-2002 (taken from Mitchell et al., 2004). Red marked sites = natural colonies. Yellow marked sites = man-made colonies

JNCC analysis of ESAS data, collected between 1980 and 2006, to provide at-sea distributions of herring gull during the breeding season and winter period are shown in Figure 3.9 (Kober *et al*., 2010). These data suggest low abundance within the Solway Firth, particularly in inshore areas.

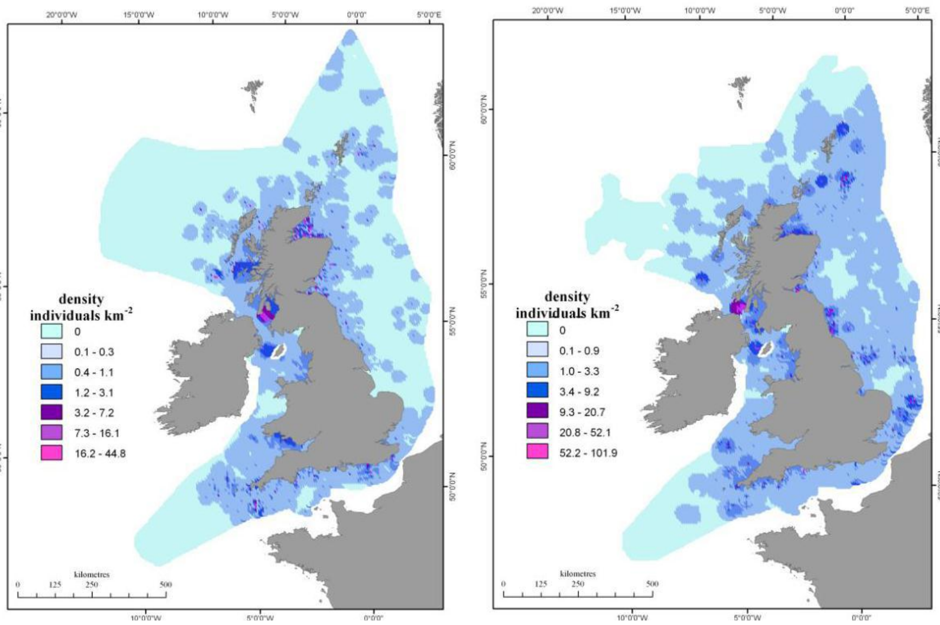


Figure 3.9: JNCC predicted density surface maps produced from ESAS data collected between 1980 and 2006. Left (a): breeding. Right (b): winter (taken from Kober et al., 2010)

Although some birds remain within the vicinity of their breeding colonies throughout the year, most return in the spring. They usually nest in colonies on sea cliffs or in sand dunes but will also nest on building roofs. Egg laying commences in late April and peaks in mid-May (Forrester *et al*., 2007). After nesting, adults and juveniles mostly only travel short distances to favourite feeding grounds although some will migrate to southern Europe and the Mediterranean. A large proportion of birds from breeding colonies in the north of Scotland (particularly juveniles and females) move south (Monaghan *et al*., 1985) to central Scotland, north-east England and, to a lesser extent, continental Europe. Population levels may increase in the winter with the arrival of birds from Iceland and Scandinavia.

Herring gulls are omnivorous and the diet of adults differs markedly from that of nestlings. Nestling diet largely compromises of fish and meat, while the adult diet is very variable and also contains large proportions of insects and plant material (Nogales *et al*., 1995). Herring gulls are opportunistic feeders, taking a range of fish, crabs, insects, young birds and garbage.

Herring gull marine foraging ranges have been little studied for UK colonies, and are likely to be influenced by the spatial distribution of fishing vessels in the proximity of breeding areas (Camphuysen, 1995; Garthe, 1997). In the southern North Sea Camphuysen (1995) recorded 95% of herring gulls within 54 km of breeding colonies. Other studies have variously reported herring gull foraging ranges as 35 km (Netherlands: Spaans, 1971), 50 km (Morocco: Witt *et al*., 1981) and 70-100 km (Denmark; Klein: 1994). These estimates provide a mean maximum of 60 km.

Herring gulls are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and a UK BAP Priority Species. Breeding herring gulls are a qualifying feature of the St Bees Head SSSI.

Great black-backed gull (Larus marinus)

The great black-backed gull has an extremely large distribution globally with the overall trend for the species considered to be increasing (Birdlife International, 2013). The breeding population of great black-backed gulls in the UK is approximately 17,000 pairs (Musgrove *et al*., 2013), largely concentrated in the west of the region and in the Scottish Northern Isles (Mitchell *et al*., 2004). The UK winter population is estimated at 77,000 birds (Musgrove *et al*., 2013). The Great Britain and Ireland populations of great black-backed gull form approximately 8-10% and 1%, respectively, of the global population of 170,000-180,000 pairs, of which 100,000-110,000 breeds in Europe (Mitchell *et al*., 2004).

Breeding begins in March or April with eggs laid between April and late June. The species inhabits rocky or sandy coasts, estuaries and inshore and offshore waters, breeding on vegetated islands, dunes, flat-topped stacks, rocky shores (del Hoyo *et al.,* 1996), flat beaches (Snow and Perrins 1998) and islands in saltmarsh (del Hoyo *et al.,* 1996). The species may also breed on undisturbed inland sites including islets in large freshwater lakes and rivers (Snow and Perrins 1998), fields and open moorland (del Hoyo *et al.,* 1996).

The species is omnivorous and opportunistic, its diet consisting of fish, adult and young birds, birds eggs, mammals (e.g. rabbits, lemmings, rats and mice), insects, marine invertebrates (e.g. molluscs), carrion and refuse (del Hoyo *et al.,* 1996).

Great black-backed gulls are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and breeding birds are a qualifying feature of the Borgue coast SSSI.

Guillemot (Uria aalge)

The breeding population of guillemots in the UK is approximately 950,000 pairs (Musgrove *et al*., 2013), breeding all around the coastline, particularly in the north and west although comparatively low numbers within the Solway Firth. These are concentrated in Scotland where approximately 75% of individuals are found (Figure 3.10; Mitchell *et al*., 2004). The population of Great Britain and Ireland forms approximately 14% of the global population of an estimated 7,300,000 pairs, and 35% of the approximately 2,800,000 pairs which breed in Europe (Mitchell *et al*., 2004).

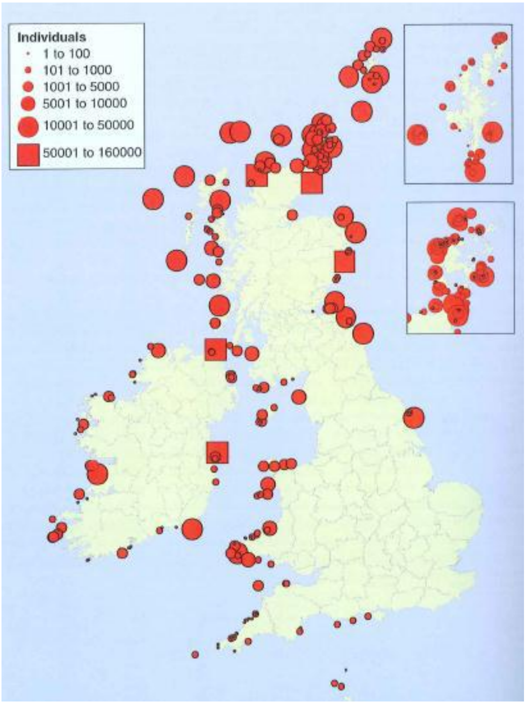


Figure 3.10: Distribution of breeding guillemot 1998-2002 (taken from Mitchell et al., 2004)

JNCC analysis of ESAS data collected between 1980 and 2006, to provide at-sea distributions of guillemots during the breeding season, the post-breeding moult and the winter period, are shown in Figure 3.11 (Kober *et al*., 2010).

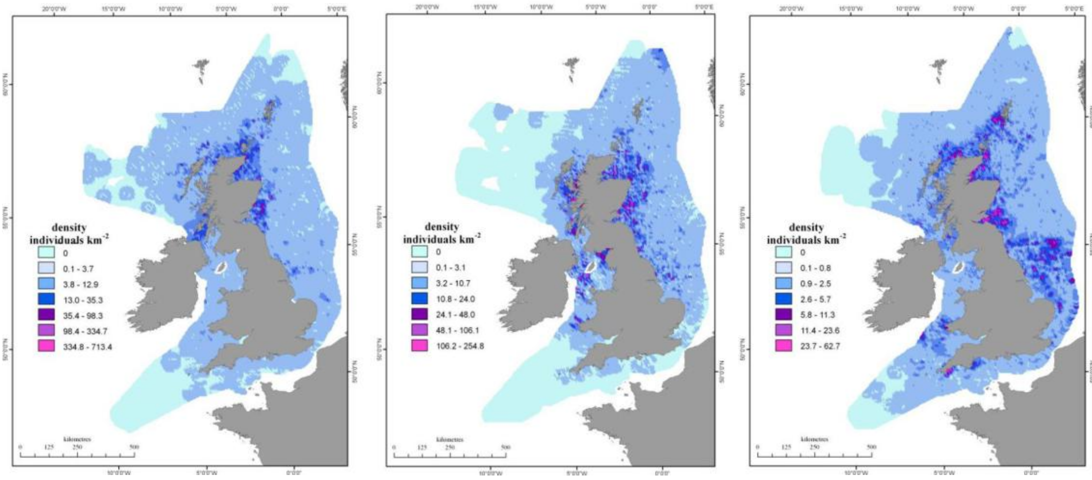


Figure 3.11: JNCC predicted density surface maps for guillemot. Produced from ESAS data collected between 1980 and 2006. Left: breeding; middle: August to September; right: winter (taken from Kober et al., 2010)

Guillemots spend most of the year at sea, only coming to land to breed between May and August. Many adults remain within a few hundred kilometres of the colonies throughout the year, dispersing rather than migrating. At some colonies, adults continue to visit their nest sites in late autumn/winter once they have completed the main moult, during which they are flightless (Harris & Wanless, 1990; Harris & Swann, 2002). Chicks leave the nest without being able to fly, remaining on the sea surface for a further 8-10 weeks, accompanied by the adult male who continues to feed it.

Guillemot are visual pursuit hunters able to perform both benthic and pelagic foraging dives. There is considerable spatial and temporal variation in the composition of prey species (Blake *et al*., 1985), with small lipid rich fish making up the majority of items consumed throughout the year. Several studies around Scotland in the 1980s found that during the breeding season guillemot diet consisted almost entirely of sandeels (Blake *et al*., 1985; Harris and Riddiford, 1989; Harris and Wanless, 1985). In contrast, between 1985 and 1987, birds from Skomer in Wales primarily provisioned their offspring with sprats (Hatchwell, 1991). A wider range of prey species are consumed during the winter (Blake, 1983 & Blake *et al*., 1984; Blake *et al*., 1985). In addition to sandeels and sprat, herring and gadoids constitute considerable proportions of the prey items taken in some areas (Ouwehand *et al*., 2004).

Birdlife International data on foraging distances for guillemot shows a maximum foraging distance of 200 km, a mean maximum of 60.61 km, and a mean foraging distance of 24.49 km. Tracked chick-rearing guillemot breeding on the Isle of May during 2002 and 2003 suggest that male and female parents differ significantly in their foraging ecology (Thaxter *et al.,* 2009). The average maximum distance that foraging birds reached from their breeding site was 14.4 ± 6.6 km (11 trips) for males, but only 7.9 ± 5.3 km (8 trips) for females. Despite this there was a large degree of overlap in the foraging areas used by the different sexes.

Further studies at the Isle of May (Thaxter *et al*., 2010) recorded a mean maximum foraging range from the colony of 14.4 km (± 12.2 km), with an overall foraging area (containing 95% of foraging trips recorded) of 1094 km^2. The foraging location of 60% of these recordings was within 10-20 km of the coast, and little use was made of areas closer to the coast or more than 25 km offshore. Similar observations of foraging close to breeding colonies were made at Sumburgh Head, Shetland where in 1990 birds travelled, on average, 7.1 km to forage (range 3.4–9.4 km), and in 1991 average foraging distances were only 1.2 km (range 0.1-4.8 km; Monaghan *et al.,* 1994). Birds at Fair Isle were sighted feeding within 6-8 km of the colony (Bradstreet & Brown, 1985; Webb *et al.*, 1985) and within 5 km of North Rona and Sula Sgeir (Benn *et al*., 1987).

Guillemots are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and breeding birds are listed as qualifying features at the SSSIs between Abbey Burn Foot and Balcary Point, St Bees head and at Scare Rocks.

The ES surveys recorded peak numbers of guillemots during the spring and early summer, with a decline in numbers from July onwards when nest sites were abandoned. They were observed throughout the study area with concentrations in the relatively deeper waters of the south-western region, close to nesting colonies.

Razorbill (Alca torda)

The total population of razorbill in the UK is estimated at approximately 130,000 breeding pairs (Musgrove *et al*., 2013) distributed around rocky coastlines throughout the UK except the south and southeast coastlines (Figure 3.12). The Great Britain and Ireland populations of razorbill form approximately 17.5-18% and 5.4-5.6%, respectively, of the global population of 610,000-630,000 pairs and 20.8% and 6.6% of the breeding Northwest Europe population (Mitchell *et al*., 2004).

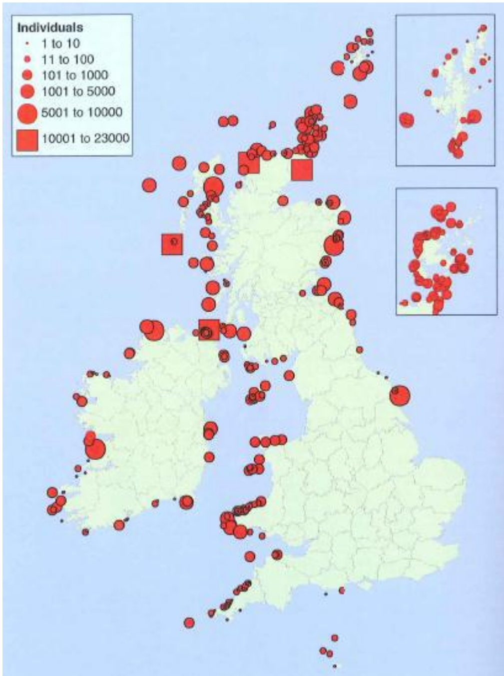


Figure 3. 12: Distribution of breeding razorbill 1998-2002 (taken from Mitchell et al., 2004)

Razorbill are most numerous in the north and west, with 64% of the breeding population in Scotland (Forrester *et al*., 2007; Figure 3.12). JNCC analysis of ESAS data collected between 1980 and 2006, to provide at-sea distributions of razorbill during the breeding season, the post-breeding moult and the winter period area shown in Figure 3.13 (Kober *et al*., 2010) indicating a variable presence in the Solway Firth through the year.

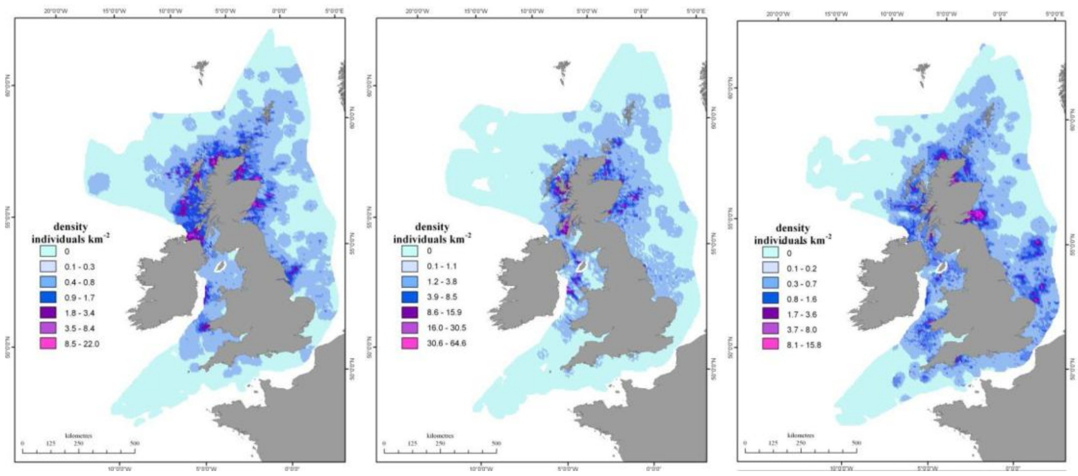


Figure 3.13: JNCC predicted density surface maps for razorbill produced from ESAS data collected between 1980 and 2006. Left: breeding; middle: August to September; right: winter (taken from Kober et al., 2010)

Razorbills breed mainly on small ledges or in cracks of rocky cliffs and in associated screes, and on boulder-fields. Egg-laying usually begins in late April, early May with a peak in mid-May. Chicks fledge partly grown and incapable of flight and, accompanied by the male parent, rapidly disperse away from breeding colonies and out to sea. Shortly after breeding adults undergo a full moult, during which time they are also flightless. Following the post-breeding moult, most razorbill gradually move south, with some birds travelling as far as the western Mediterranean and areas off north-west Africa (Wernham *et al*.,2002).

Razorbills have a diet chiefly consisting of fish with some invertebrates (Snow & Perrins, 1998). Studies on the Isle of May showed that sandeels are the main prey fed to razorbill chicks (Harris & Wanless, 1986). Stomach content analysis of birds killed in an oil spill in the south-east North Sea, found the winter diet of razorbill to be more restricted than that of guillemot (Ouwehand *et al.,* 2004). For razorbill, 8-9 prey species were identified compared to 24- 25 for guillemot, and the vast majority (91%) of razorbill prey items were less than 10 cm in length.

Birdlife International data on foraging distances for razorbill show a maximum foraging distance of 51 km, a mean maximum of 31 km, and a mean foraging distance of 10.27 km. Tagging studies from the Isle of May reported a mean maximum foraging range from the colony of 18.4 km (± 14.8 km), with an overall foraging area (containing 95% of foraging trips recorded) of 2,201 km^2 (Thaxter *et al*., 2010), approximately twice the area utilised by guillemot (1094 km^2). Almost half of the foraging locations recorded were within 10 km of the coast, with most of the remainder 30-40 km from the coast. Boat-based surveys around the Isle of May found the greatest numbers within 5 km of the colony and also 35 km away (Tasker *et al*., 1987; Wanless *et al*., 1998). Similar results were found from surveys around St Kilda (within 5 km and 38 km away; Leaper *et al*., 1988), near Flamborough Head (within 1 km and 28 km away; Webb *et al*., 1985) and around the Pembrokeshire Islands (within 5-10 km and 25-45 km away; Stone *et al*., 1992).

Razorbill are Amber Listed Birds of Conservation Concern (Eaton *et al*., 2009) and breeding birds are listed as qualifying features at the SSSI's between Abbey Burn Foot and Balcary Point, St Bees head and the Mull of Galloway.

3.2. Survey Methods

Ecology Consulting completed the assessment of potential impacts of the development on birds from 2001 as part of the ecological impact assessment (EIA) process and continued to conduct boat-based surveys required under the MEMP until 2012 after which surveys were conducted by Natural Power Consultants. The schedule of surveying is described below.

EIA baseline surveys

- Boat-based surveys consisting of ten transects were conducted on a bi-monthly basis between May 2001 and April 2002 (with exception of May and October 2001 when only one survey was completed).
- Each transect was about 18 km in length with 2 km intervals between.

MEMP monitoring

- Monthly boat-based surveys were conducted in April/May 2003 and between January and September 2004 with an additional two surveys performed in July 2007, just prior to construction commencing.
- Construction phase surveys began in January 2008 and continued on a bi-monthly basis until the end of the construction phase in February 2010. Surveys were completed in all months of the construction phase except November 2009.
- During post-construction, one survey per month is to be carried out for five years with review after year three (February 2013) to establish if further surveys still required.

3.2.1. Timetable

A summary of when data have been collected can be found in Table 3.5 below:

Table 3.5: Summary of when bird surveys were conducted. Number refers to the number of surveys undertaken that month; Light blue = baseline/EIA period; Orange = pre-construction; Purple = construction; Green = operation.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001					1	1	1	1	1	1	1	1
2002	1	1	1	1	1	1	1	1	1	1	1	1
2003				1	1							
2004	1	1	1		1		1	1	1			
2005												
2006												
2007							2					
2008	2	2	2	2	2	2	2	2	2	2	2	2
2009	2	2	2	2	2	2	2	2	2	2		2
2010	2	2	1	1	1	1	1	1	1	1	1	1
2011	1	1	1	1	1	1	1	1	1	1	1	1
2012	1	1	1	1	1	1	1	1	1	1	1	1
2013	1	1										

3.3. Analytical Methods

The analytical methodology has been determined by the data available to Natural Power Consultants, collected as part of the MEMP before, during and after construction.

The approach to analysis has been developed after reviewing the requirements of the MEMP, Food and Environment Protection Act (FEPA) licensing requirements and the recent Centre for Environment, Fisheries and Aquaculture Science (CEFAS) document, "Strategic review of offshore wind farm monitoring data associated with FEPA licence conditions"[4] .

As part of this process, consultation with Marine Scotland and Scottish Natural Heritage (SNH) and Natural England, identified key questions and concerns for specific focus. Data analysis was specifically tailored to the predictions made in the EIA and addresses the licence monitoring conditions. The analysis has focused on key areas highlighted by the Robin Rigg Management Group (RRMG) and where data were available and appropriate, on addressing the uncertainties outlined in the aims of the MEMP.

Specific key questions identified by E.ON (with NPC) and the RRMG for the data analysis relate to:

- Disturbance/displacement of specific species;
- Changes in patterns of abundance and distribution relating to the wind farm; and
- Comparing observed patterns with predicted impacts/sensitivities from the EIA process.

Analysis of the ornithological data has been undertaken by the NPC Ecology & Hydrology Department. Questions have been investigated as fully as possible within limits imposed by the nature of the data, the survey program and methodology and the rigour and consistency of the data collected.

The analysis presented here represents an update to that presented in Report 1012206: "Analysis of MEMP ecological data – operational year two"; incorporating data collected during operational year three.

3.3.1. Data collection

Boat-based visual surveys were conducted monthly or bimonthly, depending on phase (see Section 3.2). A number of vessels have been used through the project (see Table 3. 6), with viewing platforms ranging from 3.5 - 4.5 m above sea level. Although slightly below the recommended 5 m, it was considered these vessels gave suitable viewing platforms without restricting the size or location of the study area (larger vessels would not be able to navigate the shallower areas of the Firth, thus reducing the potential study area).

Table 3.6: Summary of vessels used to bird data between 2001 and 2013, including height of viewing platform above sea level.

Vessel	Viewing Platform Height (m)	No survey days
Solway Protector	4.5	101
Tiger	4.5	18
Catch Me II	4.5	2
Talisman of Wight	3.5	8
Pilgrim	4	5
Maid Good	4.5	55

The survey methodology consists of 10 parallel transects, each about 18 km in length and spaced 2 km apart (see Figure 3.14). The distance between transects was chosen to ensure good sampling of the study area for all species while minimising the likelihood that birds displaced from once transect would be counted on the neighbouring transect. To allow comparison between phases, the same methodology was used for all surveys. Tidal conditions at the time of the survey dictate whether or

[4] Walker, R. & Judd, Adrian. 2010. Strategic Review of offshore wind farm monitoring data associated with FEPA licence conditions. CEFAS, SMRU Ltd, FERA on behalf of DEFRA & MMO.

not the entire survey is covered in a single day or over two days. Access to some parts of the survey area can be restricted at low tide.

Two observers work simultaneously, each observing a 90° angle ahead and to the side of the vessel. Birds are recorded as either in flight or on the sea. Following the JNCC Seabirds at Sea recommendations, birds on the sea are recorded into five distance bands (0-50 m, 50-100 m, 100-200 m, 200-300 m and 300+ m). Birds are recorded continuously, at a steady speed of approximately 12 knots, with the precise time of each observation recorded where possible to give as accurate a position as possible (linking to the GPS position information being recorded simultaneously). A range-finder is used to estimate distances of the birds from the ship. All records of birds observed flying as well as those on the sea was recorded, with the height of flying birds estimated. In operational year three, additional data was collected for birds in flight using the current best practice ESAS methods (see Appendix for full details).

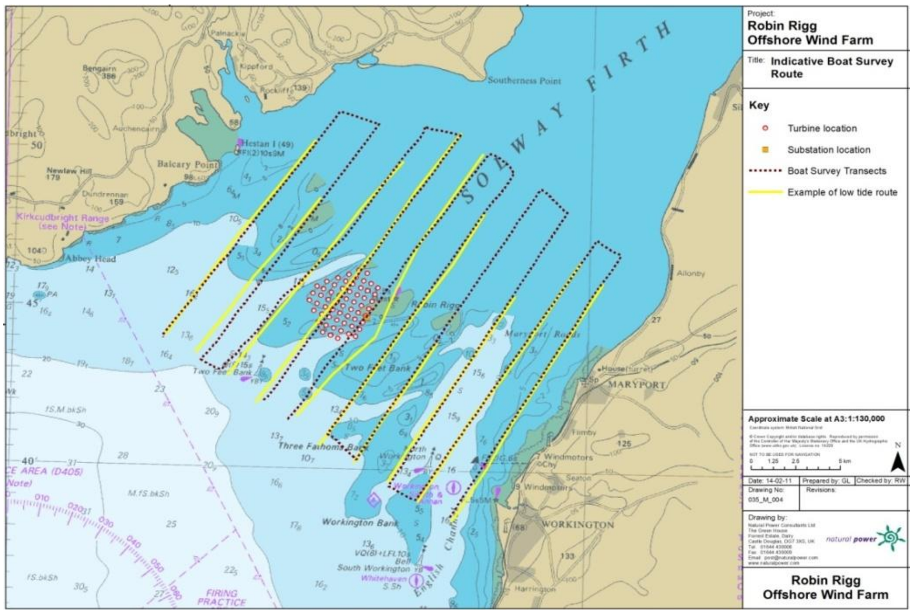


Figure 3.14: Sample survey route followed for bird and marine mammal surveys collected as part of the Robin Rigg MEMP.

3.3.2. Data collation

All data were collated and verified by NPC. Throughout this procedure, all data were visually inspected and any concerns referred back to the surveyors in order that any problems with the dataset could be resolved. All data were stored and managed using Microsoft Excel.

3.3.3. Data processing

Data collected prior to October 2001 were removed from the dataset as data collected during this period were grouped in 10-minute blocks and so precise positions could not be extracted.

GPS tracks from each survey were obtained and imported into ArcGIS v10. Each individual survey transect was divided into survey blocks of 600 m^2 (300 m either side of the transect line: see Figure 3. 15).

Observations were then assigned to survey blocks and environmental data for each block were extracted including sea depth and sediment type at the midpoint of the block (data obtained from SeaZone Solutions Ltd) and distance of the block midpoint to the nearest coastline (see Figure 3.16). Tidal height for each block was also obtained using data supplied by the British Oceanographic Data Centre. Percentage gravel was calculated for each sediment class (in order to allow analysis of sediment type as a continuous covariate). Although sea state data were collected during the majority of surveys, it was not possible to use this as a factor in the analysis as information on sea state was not recorded during early surveys.

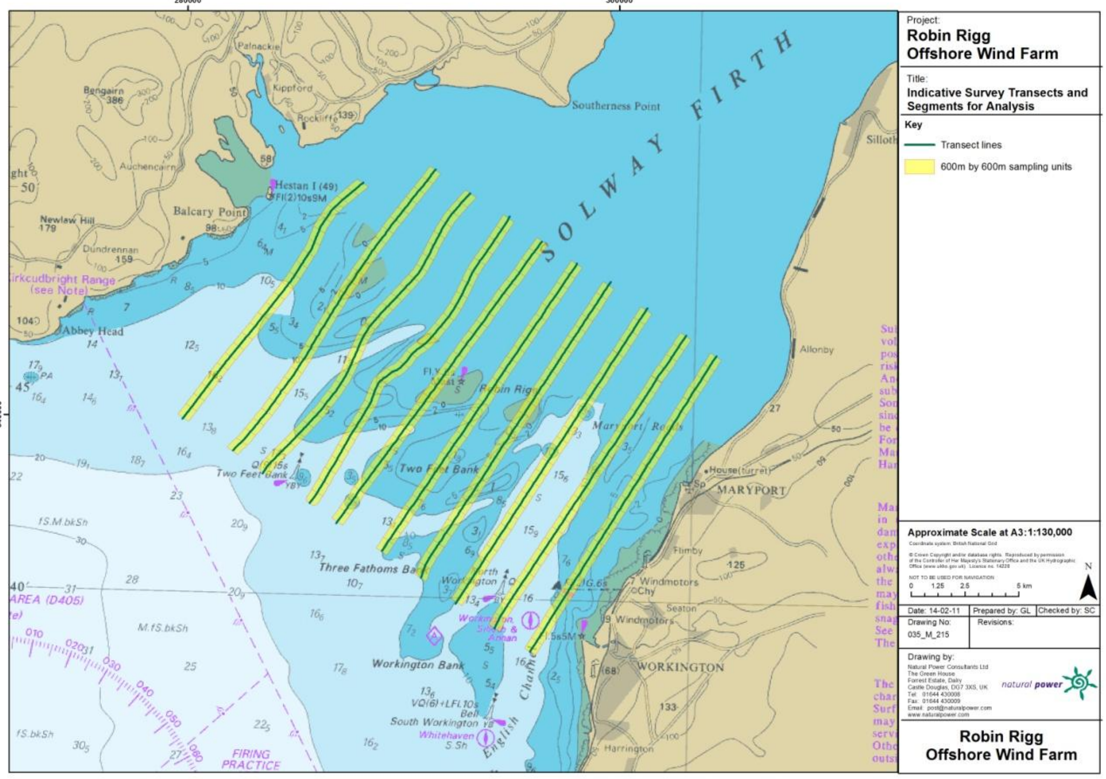


Figure 3.15: Example of 300 m buffers applied to survey transects for analysis.

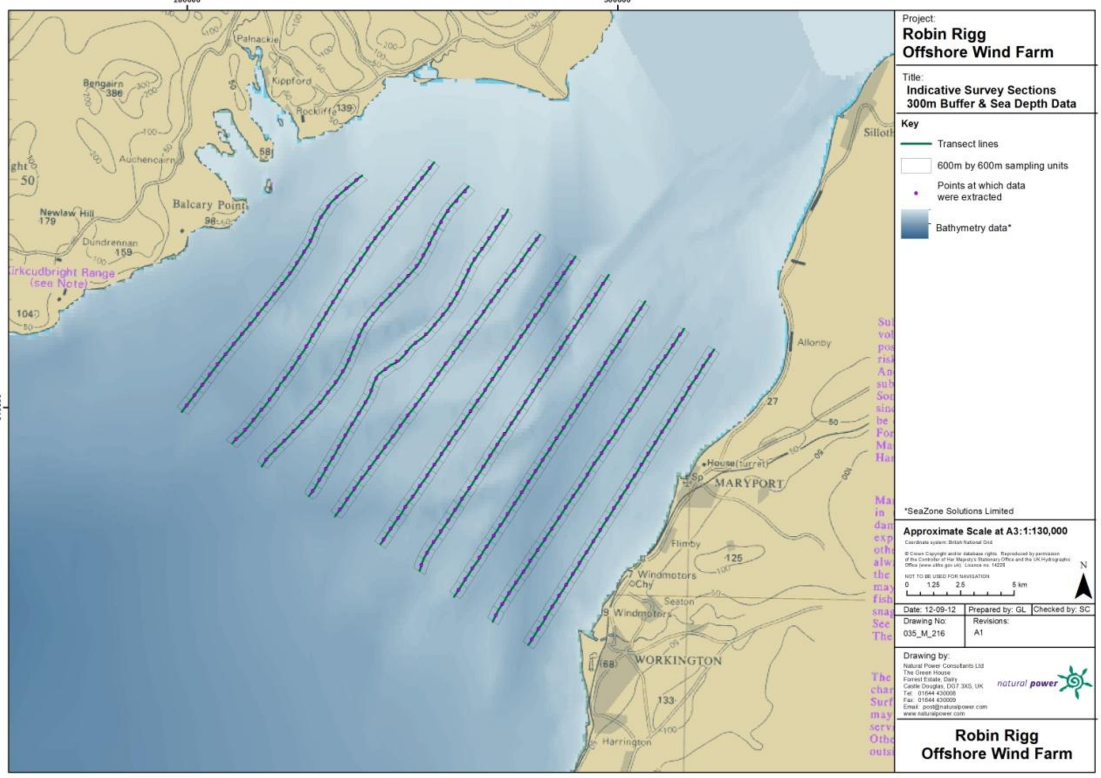


Figure 3.16: Example of sea depth data extracted for survey buffer zones.

3.3.4. Target species

Key species of seabird to be targeted for analysis was defined in consultation with the RRMG and refined during the analysis process. These species are:

- Scaup;
- Common scoter;
- Red-throated diver;
- Manx shearwater;
- Gannet;
- Cormorant;
- Kittiwake;
- Herring gull;
- Great black-backed gull;
- Guillemot; and
- Razorbill.

A complete list of all birds recorded during the boat surveys can be found in the Appendix 2 Table 2 along with maps illustrating the location sightings for all target species (section 3.2).

3.3.5. Data exploration

All data exploration and subsequent analysis was performed using R[5] version 2.13.1. Data exploration followed the protocol described by Zuur *et al*., (2009). This involves asking the following questions:

- Are there outliers in the explanatory variables;
- Is there even coverage of the explanatory variables;
- Is there collinearity among explanatory variables;
- Are there potential outliers in the response variable;
- Might the response variable be zero-inflated

Covariates examined included sea depth, distance to coast, distance to the centre of the wind farm, sediment type, latitude, longitude, sea state, construction period, month (or season) and time of day. The following issues with the explanatory variables were identified:

- Uneven sampling among construction periods: The data were divided into three wind farm phases: pre-construction, construction and operation. Sampling regime (surveys per month; Table 3.5) and area surveyed (number of transects and length of transects surveyed; Figure 3.17) differed among these phases. In order to standardise the dataset and allow like-for-like comparisons, data from a single randomly selected survey was used for any months where more than one survey was carried out. In addition, the study area was cropped to remove an area to the northeast where shallow sea depth often prevented access, and the first two transects in the southeast which were under-surveyed during the pre-construction and construction phases. In addition, any surveys which were missing more than 2 transects following standardisation of the dataset were removed.

[5] R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

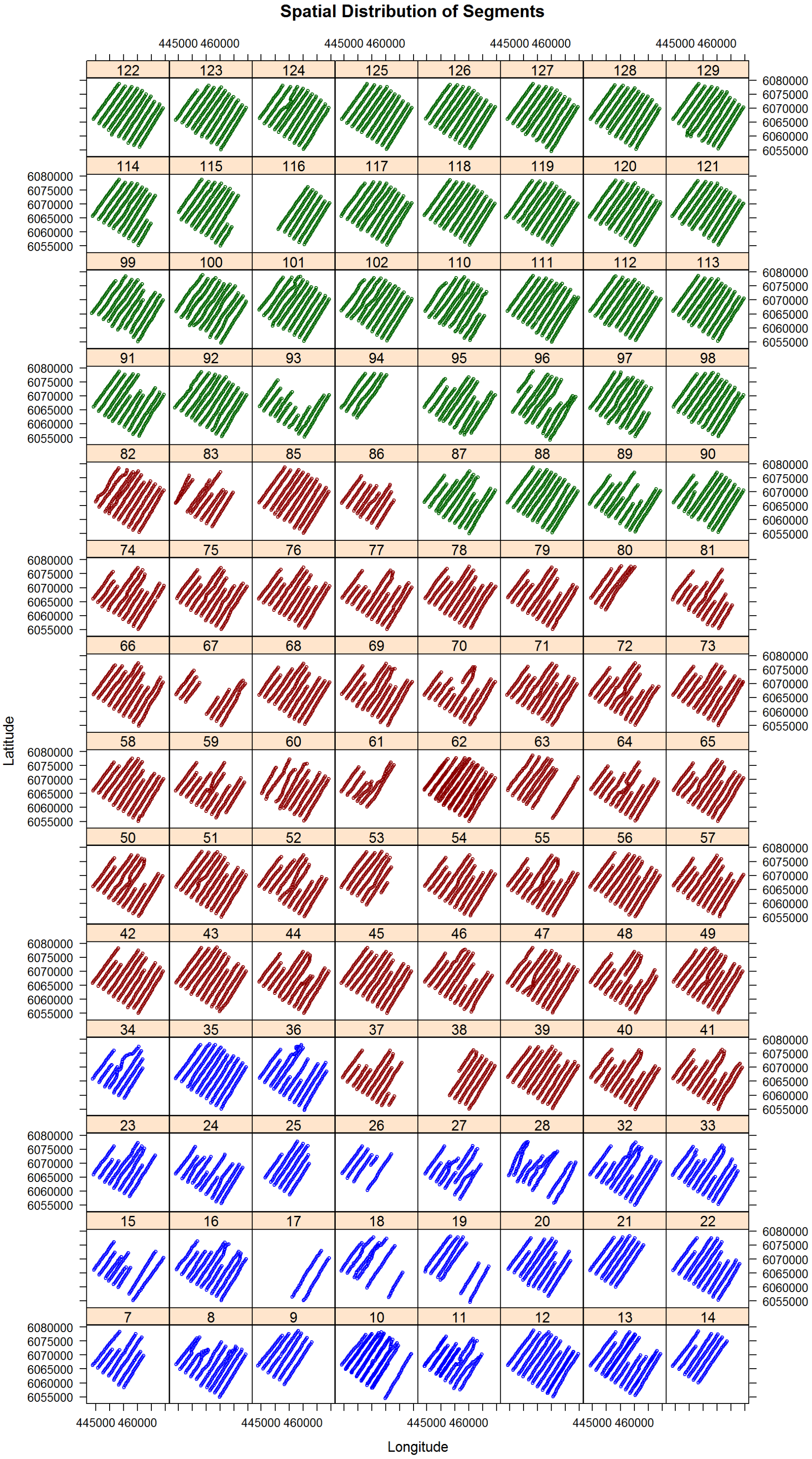


Figure 3.17: Distribution of segments available for analysis. Note the patchy coverage of the study area, particularly during the pre- and construction phases to the north-east and south-east.

- It was highlighted by the RRMG that a small number of piles were installed during January 2008 followed by a period of inactivity until August 2008, when piling recommenced. As a result, it was decided that the data from between January and July 2008 would also be removed from the dataset to prevent this period of inactivity masking potential effects during construction.
- Collinearity: Pearson's coefficients and a range of plots were used to look for linear or non-linear relationships among continuous covariates (longitude, latitude, sea depth, distance to coast, distance to wind farm). Bivariate comparisons showed little evidence for collinearity, however, plotting relationships among covariates by transect revealed strong collinearity among all continuous covariates (for example see Figure 3.18). Boxplots were used to investigate relationships between continuous and non-continuous covariates and tables were used to assess relationships among combinations of factor variables. No obvious collinearity was found among factor variables but sediment type was collinear with most of the continuous covariates (Figure 3.19).

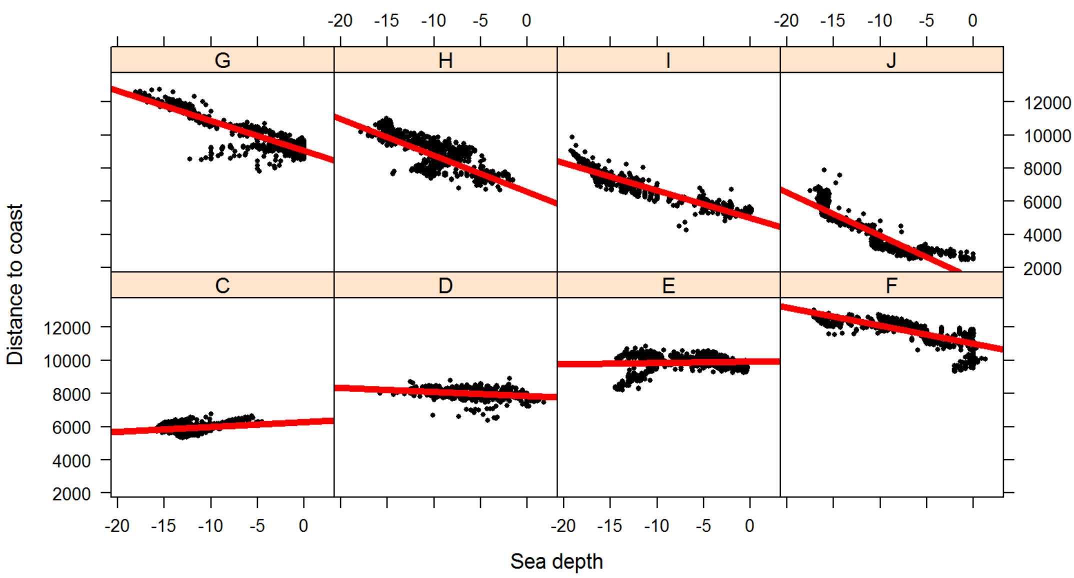


Figure 3.18: Relationship between depth and distance to coast. When continuous covariates are plotted against one another by transect, the strong collinearity among these variables becomes apparent.

The following potential issues were identified with the response variables (i.e. species specific):

- Zero inflated data: Calculating numbers of segments with zero observations as a proportion of the total number of segments suggested that zero-inflation could be a potential problem for all species datasets.
- Outliers in response variables: Several species (specifically Manx shearwater and common scoter) can occur singly or as very large groups meaning that the data do not readily comply with distributions routinely used for analysis of these types of datasets.
- Outputs from the data exploration on the final data set can be found in Appendix 2, Section 3.3.

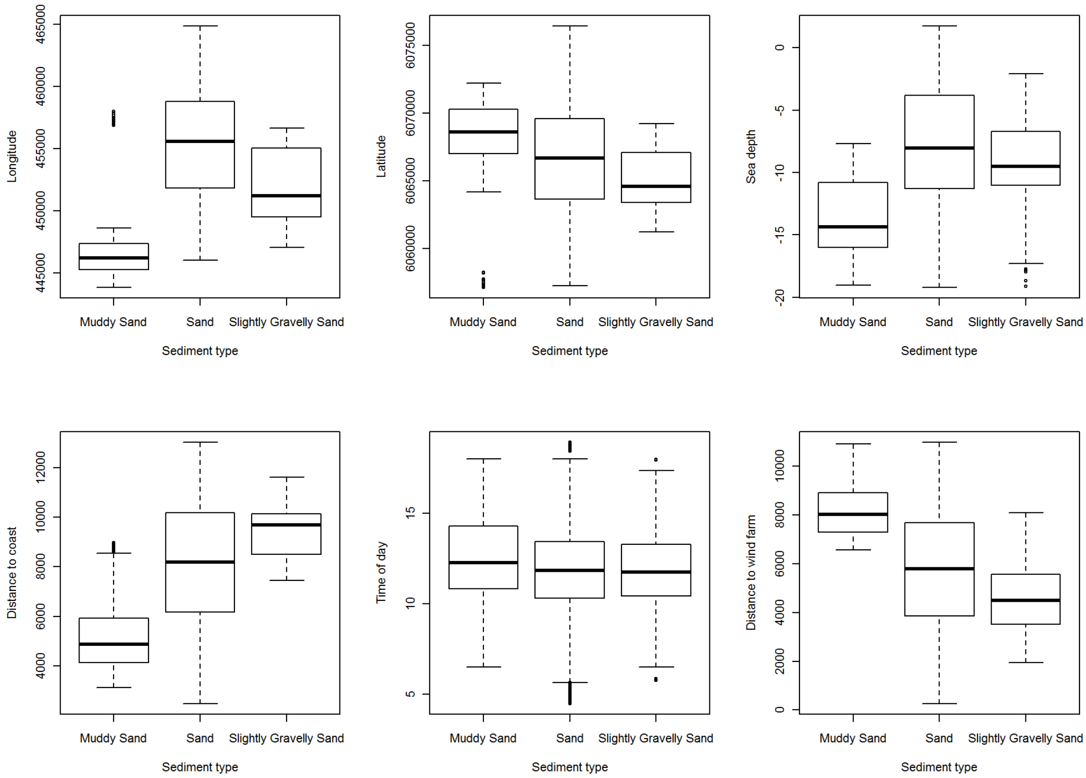


Figure 3.19: Relationship between sediment type and the continuous covariates. Clear relationships can be seen in most of these boxplots indicating that sediment type is collinear with these continuous covariates.

3.3.6. Data analysis

The Robin Rigg datasets are very complex with the main issues being spatio-temporal autocorrelation and zero-inflation. In addition, different species-specific datasets have very different properties, meaning that a species by species approach must be adopted (see Section 5: Discussion for further details). The general approach taken to analysing the data is outlined below.

Analysis was carried out separately for birds in flight and on the water since any response to the wind farm might be expected to differ dependent on behaviour. No attempt was made to model datasets for which fewer than 300 non-zero observations were made.

Summary statistics

For all species of concern, raw observations were mapped and summary statistics were calculated to provide an initial indication of any changes in abundance or behaviour among the different wind farm phases. Summary statistics calculated were mean number of sightings (groups of animals) and individuals observed per segment per phase, and mean number of individuals per segment per surveyed month. In addition, individuals per segment were calculated for each of the three years of the operational phase separately in order to provide a basis to inform the requirement for additional survey years.

Modelling approach

- ***Choice of covariates***

Due to issues with collinearity, the number of covariates that could be used for modelling the data was low. For this reason, it was impossible to model bird abundance based on biologically relevant explanatory variables. However, since the main questions relate to changes in bird abundance and distribution due to the wind farm rather than factors affecting distribution of animals, an x-y smooth approach is appropriate for analysing the data. This is because the latitude and longitude of an observation acts as a proxy for the environmental conditions at the location. Covariates used in the models were therefore latitude, longitude, month (or season) and time of day.

- ***Accounting for spatio-temporal autocorrelation***

Due to the nature of the survey methodology, all of the Robin Rigg bird datasets would be expected to exhibit some degree of spatio-temporal autocorrelation (relationships among data collected close to one another in space and time over and above those due to similarity of the measured covariates). A CAR (conditional autoregressive) correlation structure can be applied to model the correlation among the residuals, however, the Robin Rigg bird datasets are too large to allow such an analysis to be carried out. Instead, transect and survey were incorporated as random effects in the models allowing variation associated with location in space and time to be accounted for. The effectiveness of this approach can be assessed using semivariograms and residual plots following analysis. All datasets with more than 300 non-zero observations were analysed in this way. These analyses were used to produce density surface maps and to predict numbers and densities of animals within the wind farm site and the study area as a whole. It should be noted that zero-inflation is still a common issue with these analyses as indicated by over-dispersion values provided in the species accounts. Ignoring overdispersion leads to p-values that are smaller than they should be meaning relationships between the response and the covariates may seem to be significant when in reality they are not (type I error). This could be considered to be a precautionary approach.

- ***Dealing with Zero-inflation***

Data with a high proportion of zero observations that are not explained by the model covariates can be modelled using a two-step mixture model. In this type of model, separate modelling processes are used to analyse the count part of the data versus the additional unexplained zeros. These zeros are sometimes known as 'false zeros' and can come about for several different reasons including animals that were present but not seen (missed detections) or areas that are suitable for the animals but that the animals happen not to be there. The latter is common where replicate sampling areas are very small. Although these models are the most appropriate type of model for the datasets, the combination of using additive modelling to allow non-linear patterns to be modelled, using mixed effects modelling to account for spatio-temporal autocorrelation and dealing with zero-inflation using mixture models is very demanding on both in terms of the raw data required and in terms of the computational power involved. We will therefore use generalised additive mixed effects mixture modelling implemented within a Bayesian framework using R and JAGS for the final report but only on those datasets with the most non-zero observations.

- ***Incorporation of Distance sampling techniques***

Although data were collected in a manner that would allow Distance Sampling techniques to be applied to the data, distance sampling was not used for this analysis. Distance Sampling uses declines in the number of observations recorded at increasing distances from the observer to model the drop off in detectability of animals with distance. In order to correct for this drop off, observations are multiplied by a correction factor calculated using the detection function to give a more realistic estimate of the genuine number of animals likely to be present.

This works very well when averaging over a large area. However, in this case, sampling units are small and animals are present at relatively low density so that a likely result of a missed detection is zero observations within that sampling block. Multiplying zero by anything will give zero. In contrast, there is no reason to assume that sampling blocks in which animals were observed also represent sampling blocks in which additional animals went undetected. However, using a detection function to adjust the observations would apply this distinction. Therefore, although applying a detection function may increase the accuracy of an overall abundance estimate, it is likely to interfere with modelling the relationship between the response and the covariates because missed detections become linked to the particular covariate values associated with the segments in which animals were observed. We therefore feel that using Distance sampling to correct numbers of observations per sampling block is not appropriate when using covariates to predict distribution of animals on a small scale.

Secondly, incorporating Distance sampling techniques into the modelling process introduces an additional source of uncertainty which may reduce the ability to detect any significant changes that might have taken place on the wind farm site. Since the purpose of the MEMP was to monitor any

changes taking place as a result of the construction and operation of the wind farm, we believe that an index-based approach is better suited to answering the question.

The main benefit of using Distance Sampling versus using indices such as number of observations when making comparisons is that differences in detectability due to, for example, differing locations or conditions with different visual properties can be controlled for by fitting different detection functions. However, in this case we are surveying the same area under similar conditions and therefore believe that the standardised method of the surveying should help to eliminate such biases. Whilst it is acknowledged that weather conditions may well influence detectability of animals, environmental data provided with the survey data are not sufficient to investigate this relationship.

Model outputs: distribution and abundance

Outputs of the mixed effects models were used to produce density surface maps showing the predicted distribution of each species during the pre-construction, construction and operational phases. In addition, predictions for the abundance and density of each species within the wind farm site and study area were produced for each phase.

Avoidance

In order to investigate potential avoidance of the wind farm area, model outputs were used to predict numbers of animals present within the wind farm site and within buffers of the wind farm site at 0.5 km, 1 km, 1.5 km and 2 km during each of the three wind farm phases. Predicted numbers of birds within the study area (excluding the buffer zones) were also calculated. If the pattern of bird distribution among the buffers varies among phases this could be an indication for avoidance of (or attraction to) the wind farm area. However, it should be borne in mind that this type of analysis assumes that the response to the wind farm doesn't differ in different positions relative to the wind farm (i.e. that the effect to the north is the same as that to the south, east and west).

Collision risk

Available flight height data were grouped into six bands (0-5 m; 6-25 m; 26-34 m; 35-125 m; 126-200 m and 200 m plus).These bands were chosen based on the known rotor height of the turbines used at Robin Rigg (35-125 m), bird behaviour and practicalities of collecting data. Where sufficient data were available, the proportion of birds flying in each band for each construction phase was calculated and compared using Chi-square tests. To aid this analysis and interpretation, all data above and below rotor height were combined into single bands (i.e. 0-34 m; 35-125 m and 126 m plus).

Comparison among methods

Surveys at Robin Rigg began prior to the publication of formal guidance on best practise for recording bird data from boat-based surveys. For this reason, the method used to record birds in flight differs to that routinely used today. For the last year of operation, Natural Power Consultants used both the original Robin Rigg methodology and the currently recommended ESAS (European Seabirds at Sea) 'snapshot methodology' to record birds in flight (see Technical Appendix 2 section A3.1 for more details) to allow a comparison of these differing methodologies. The total number of birds recorded in flight (i.e. all observations including those not recorded on effort) using each method were compared and the number recorded as "in transect" (original method) or "in snapshot" (new method) (i.e. just those observations recorded on effort) were also compared. In each case, the ratio of the numbers of birds observed using the original methodology versus those recorded using the ESAS method for each survey was calculated. This was then averaged across surveys. Yearly averages are presented for each species.

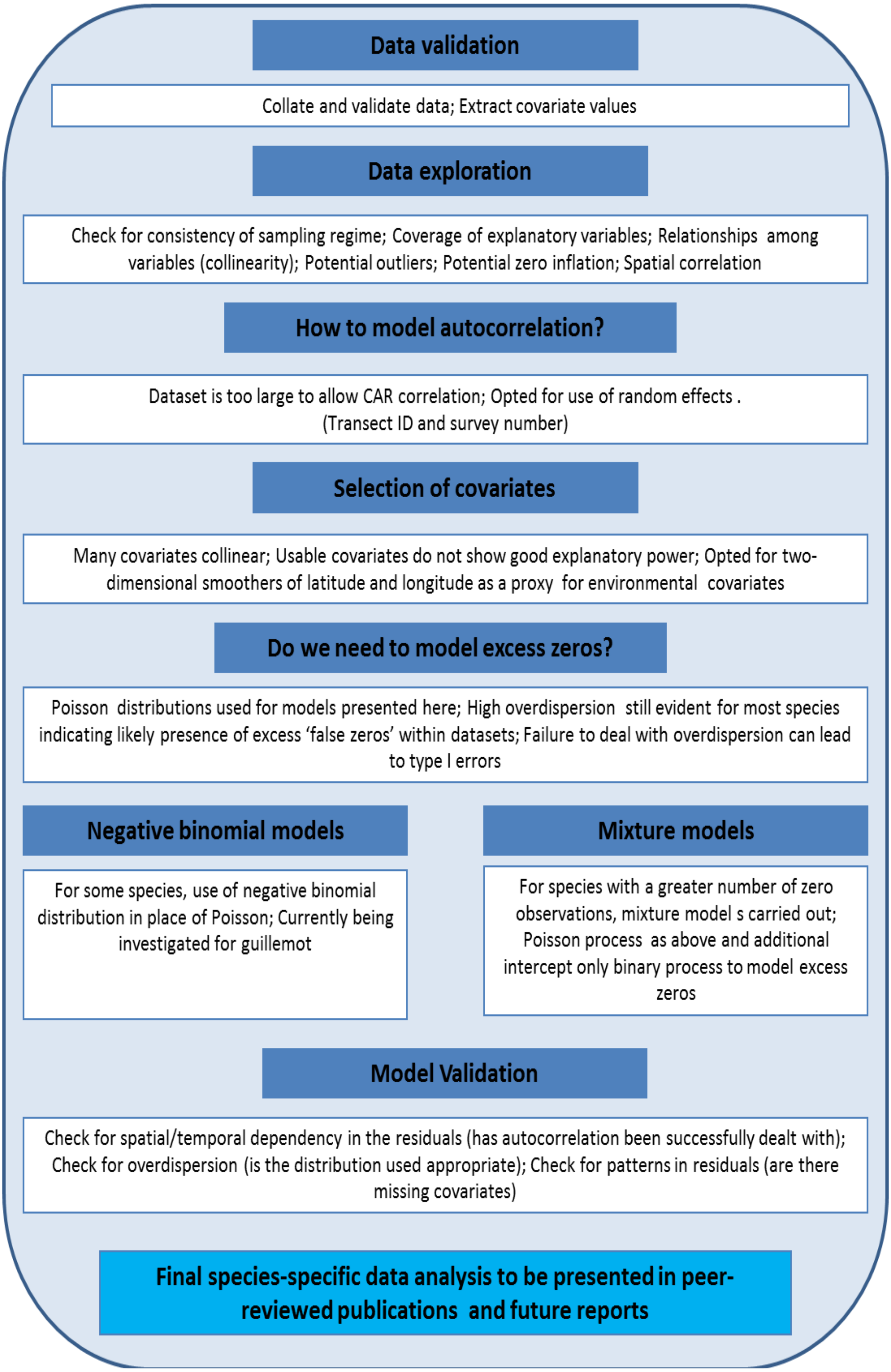


Figure 3.20: Visual representation of the process followed to analyse bird data collected at the Robin Rigg Offshore Wind Farm.

3.4. Results: Scaup

3.4.1. Summary statistics

Few sightings of scaup were recorded during any phases of the development (see Table 3.7) and just two individuals are present in the final standardised dataset (Table 3.8). The mean number of scaup recorded each survey month (from the raw data) is illustrated in Figure 3.22 and the distribution of the sightings in Figure 3.21. All sightings occurred during the winter months (November-January). No scaup were observed in operational year two. The majority of the birds were observed in the north-west part of the study area, close to the Scottish shore (see Figure 3.21). Though some birds were recorded close to the site during the pre-construction phase, these were recorded out of transect (perhaps as they were the same group recorded several times or because they were observed too far away to be included in the survey) and therefore cannot reliably be used in comparisons.

The average group size through the different construction periods can be seen in Figure 3.23. The raw data suggest an increase in group size during the operational phase although this may be an artefact of data collection. The surveyors report that scaup are usually observed far ahead of the vessel when flushed from the surface by the approaching survey vessel. The distance at which the birds react can be great.

The low number of individual sightings for this species prevents further modelling from being undertaken.

Table 3.7: Raw data for scaup recorded per segment during each phase of the construction of the wind farm. SPUE = sightings per unit effort; IPUE = individuals per unit effort

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	5/<0.001	9/0.001	4/<0.001	0/0	10/0.001	6/<0.001
Total number individuals/IPUE	387/0.06	318/0.05	351/0.03	0/0	3736/0.36	235/0.02

Table 3.8: Standardised data for scaup recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE
Total number individuals/ IPUE	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Number per km^2	0.00		0.00		0.00		0.00		0.00		0	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE	No	SPUE/ IPUE
Total number individuals/ IPUE	0	0.00	2	<0.01	0	0.00	0	0.00	0	0.00	0	0.00
Number per km^2	0.00		<0.01		0.00		0.00		0.00		0.00	

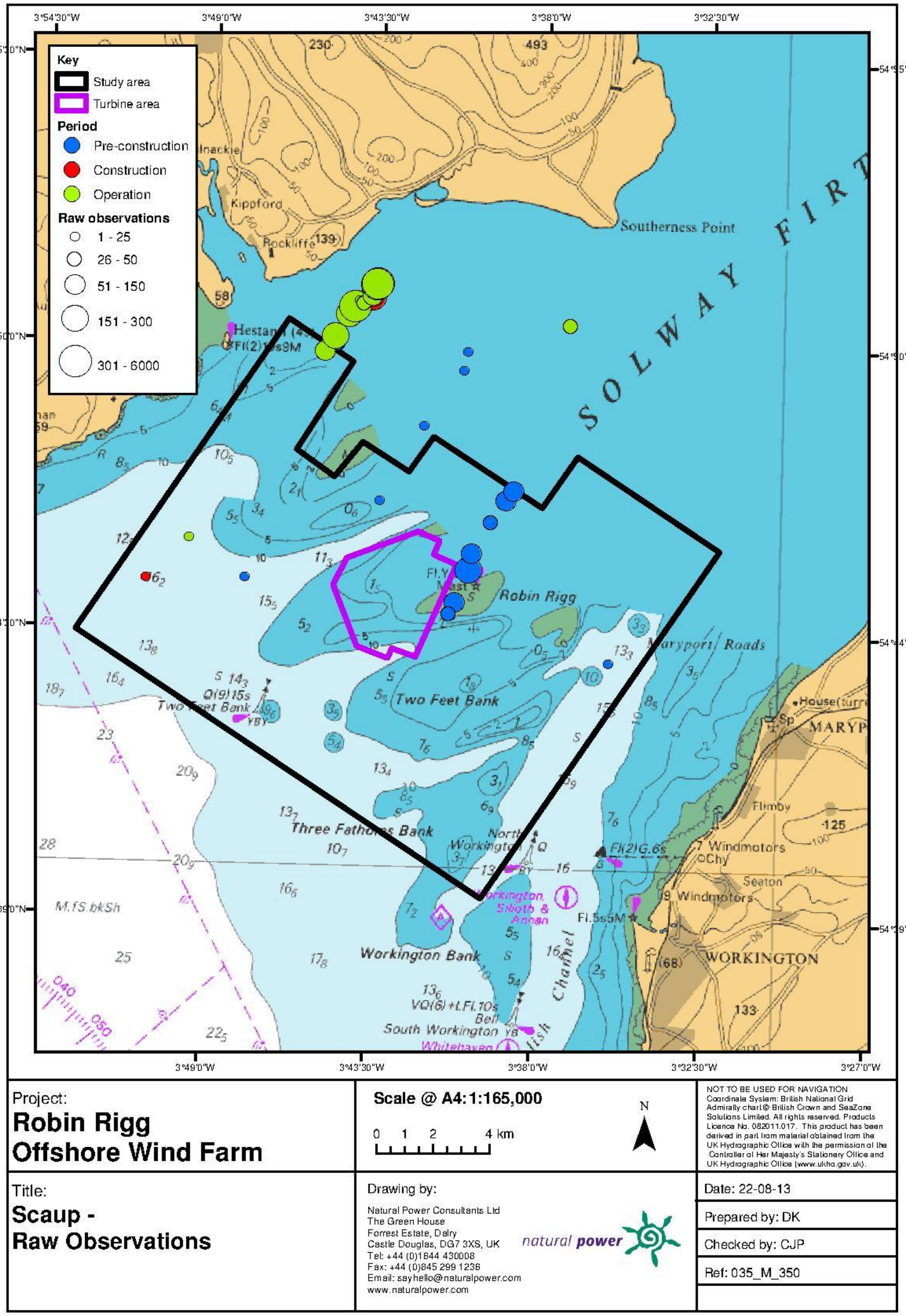


Figure 3.21: Locations of raw observations of scaup during the pre-construction (blue), construction (red) and operational (green) phases. The size of the symbols represents the size of the group of animals observed.

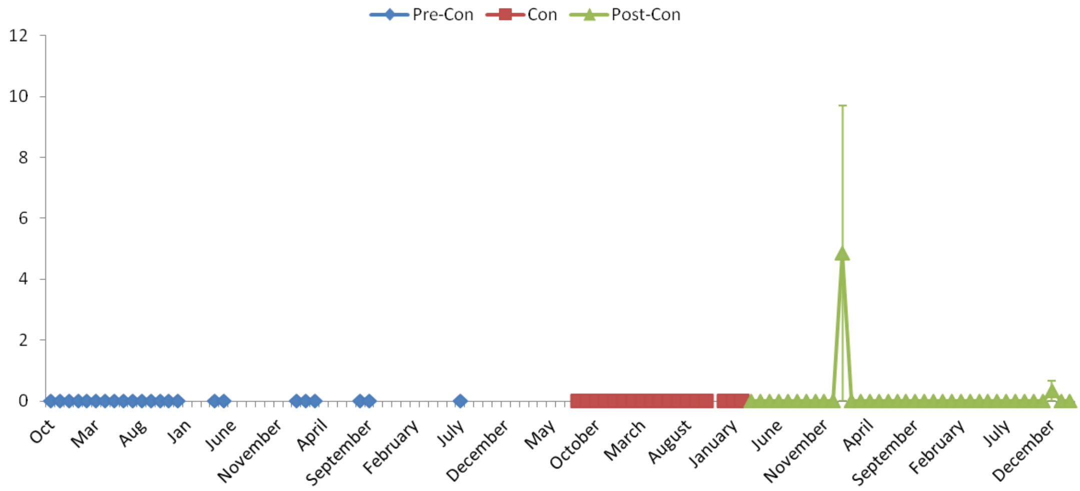


Figure 3.22: Mean number of scaup observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water combined) ±standard error

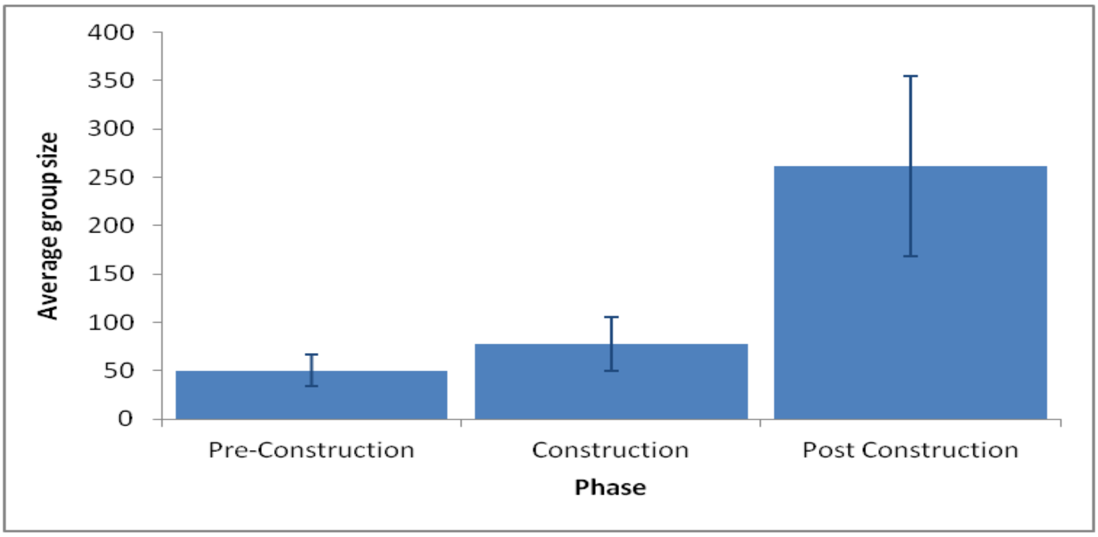


Figure 3.23: Mean group size for scaup observed per sighting during the pre-construction, construction and operational phases (±standard error)

3.4.2. Collision risk

The percentage of birds recorded in different height bands are illustrated in Table 3.9 below. No birds were observed flying at rotor height and therefore no Chi-square test was conducted. Scaup are not considered at risk from collision with turbine blades as they generally fly close to the water's surface, as was found with birds observed at Robin Rigg (Table 3.9).

Table 3.9: Percentage of scaup recorded in different height bands. Rotor height = 35-125 m

	Flight band (m)					
	1 (0–5)	**2 (6–25)**	**3 (26–34)**	**4 (35– 125)**	**5 (126–200)**	**6 (200+)**
Pre-construction	71.07	28.93	0	0	0	0
Construction	100	0	0	0	0	0
Operation	100	0	0	0	0	0

3.5. Results: Common scoter

3.5.1. Summary statistics

The number of common scoter recorded during each of the three development phases can be found in Table 3.10 and Table 3.11. The mean number of common scoter recorded each month is presented in Figure 3.24 and average group size recorded in each of the three phases in Figure 3.25.

Table 3.10: Raw data for common scoter recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort

	Pre-construction		Construction		Operation years 1-3	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	373/0.06	366/0.06	1117/0.09	831/0.07	10424/0.13	881/0.08
Total number individuals/IPUE	58399/9.3	12261/1.95	67648/5.57	18313/1.51	92304/8.85	13538/1.3

Table 3.11: Standardised data for common scoter recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	Pre-construction				Construction				Operation years 1-3			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	3	0.02	5301	2.23	0	0.00	4686	1.73	12	0.03	18805	3.51
Number per km^2	0.06		6.24		0.00		4.84		0.08		9.83	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	0	0.00	8520	3.58	6	0.04	3717	1.37	18	0.05	3473	0.65
Number per km^2	0.00		10.0		0.76		3.84		0.28		1.82	

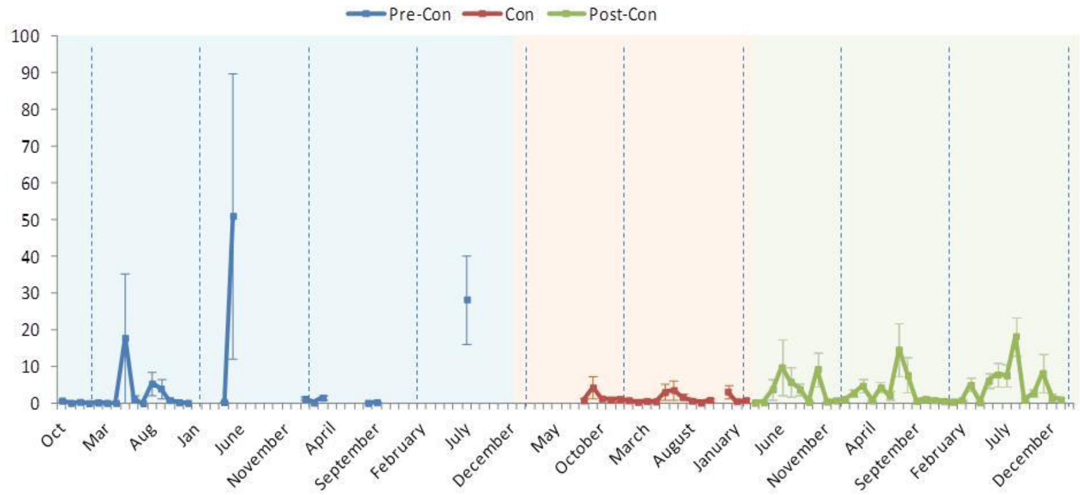


Figure 3.24: Mean number of common scoter observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

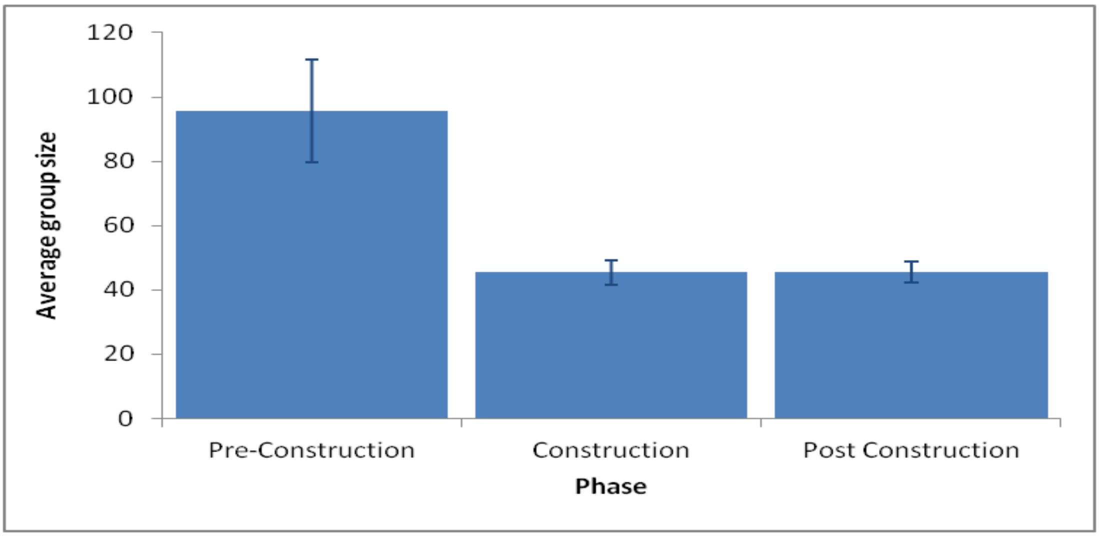


Figure 3.25: Mean group size for common scoter observed per sighting during the pre-construction, construction and operational phases (±standard error)

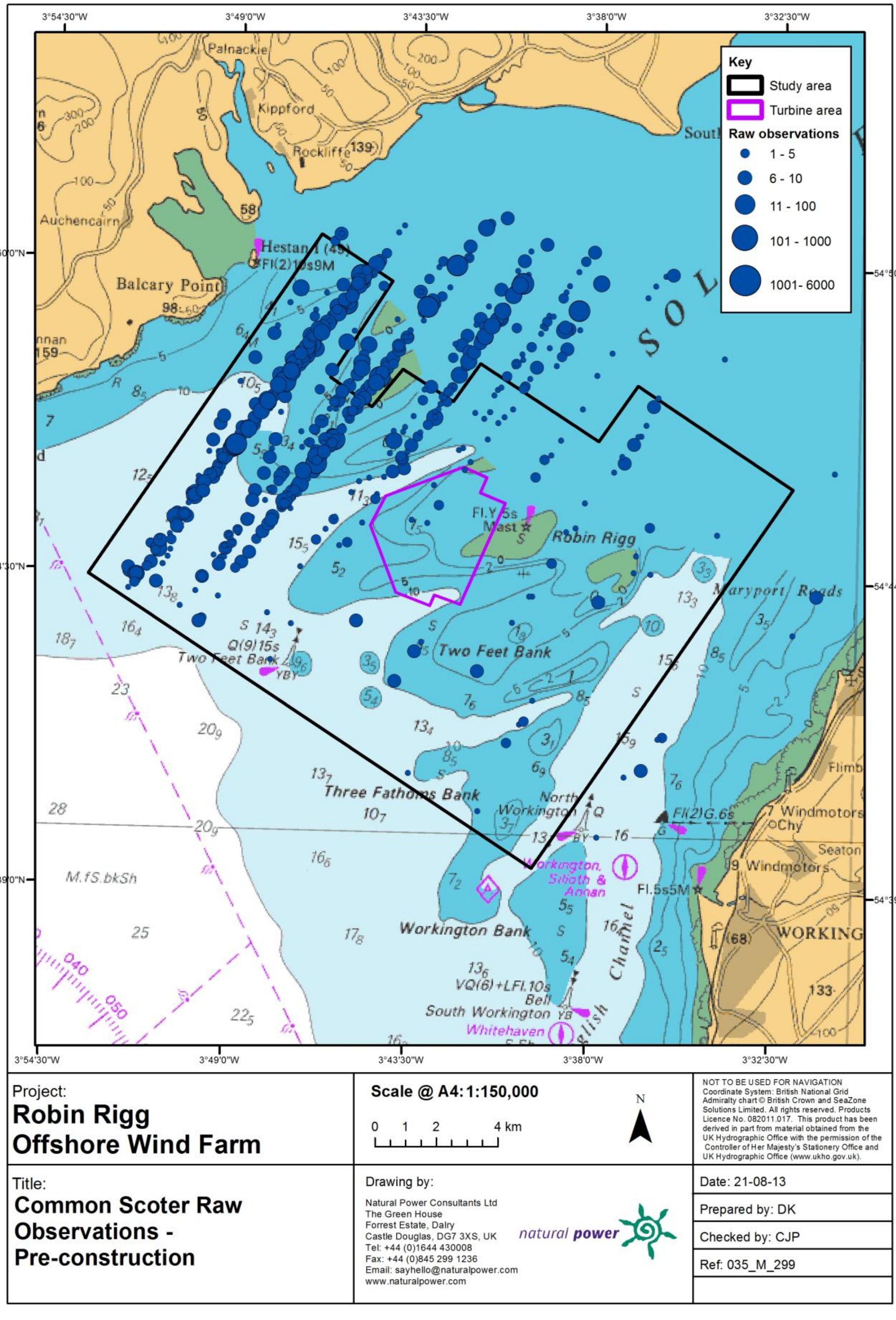


Figure 3.26 Location of common scoter recorded across the study area during pre-construction phase of the development.

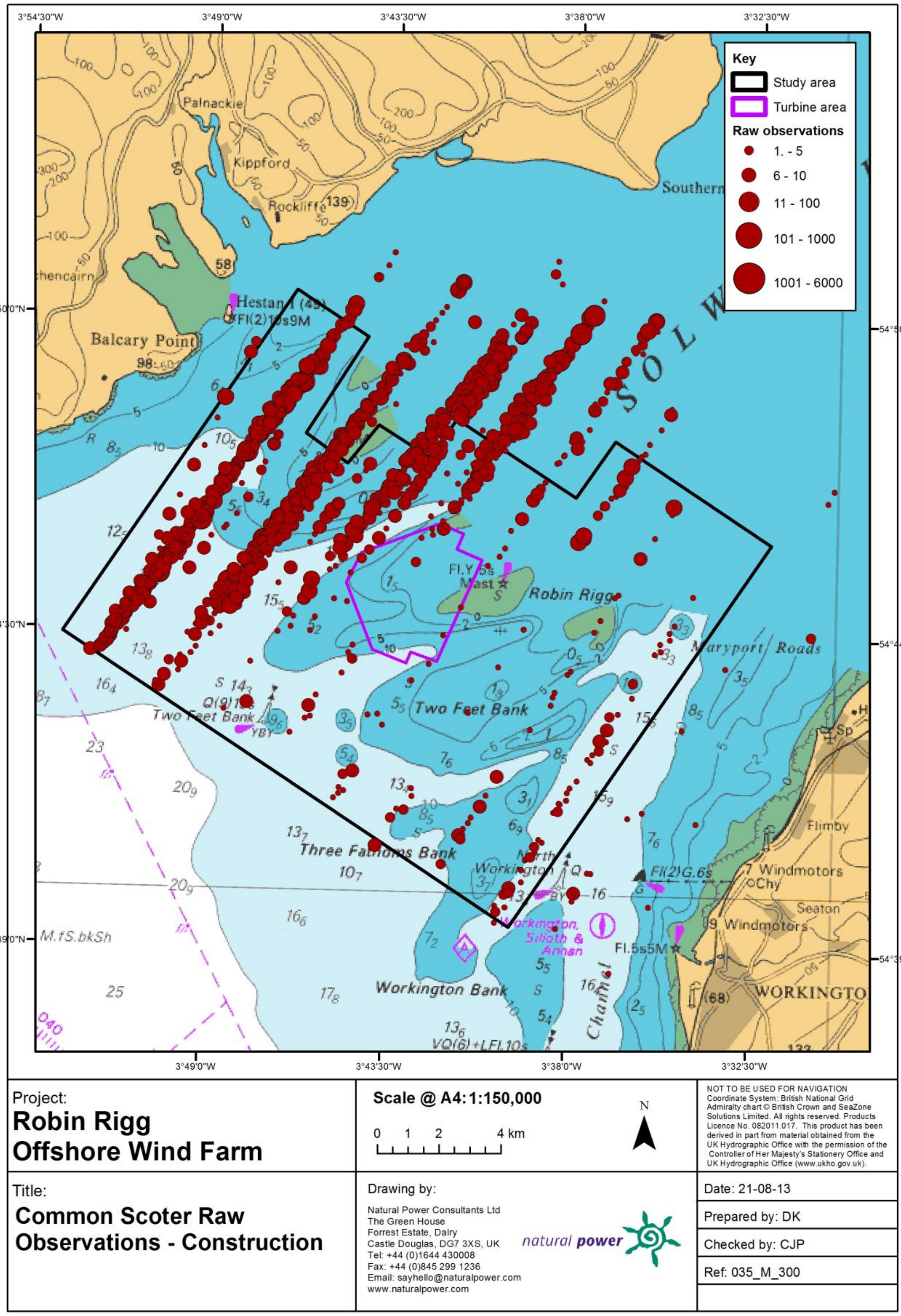


Figure 3.27: Location of common scoter recorded across the study area during construction phase of the development.

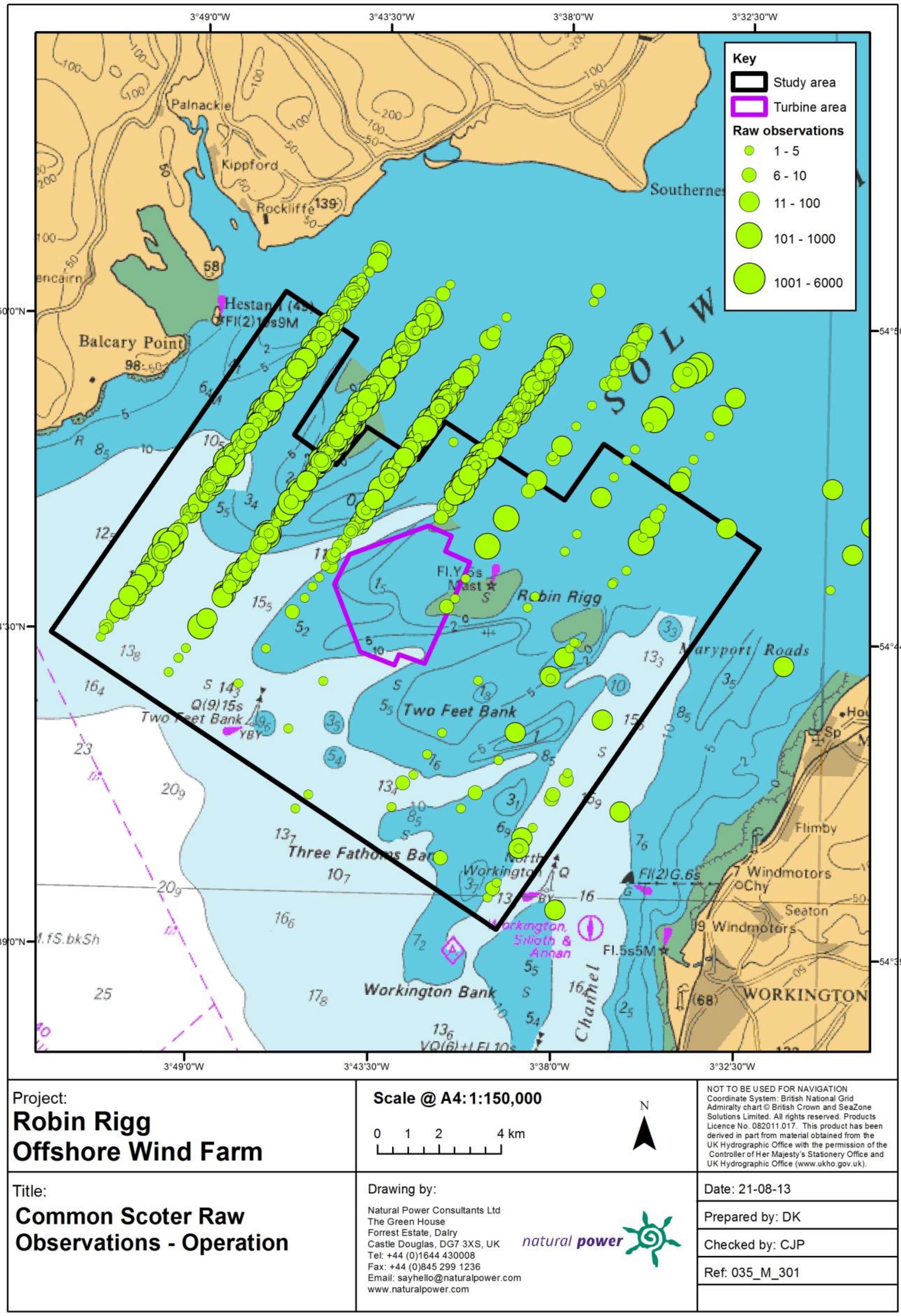


Figure 3.28: Location of common scoter recorded across the study area during the operational phase of the development.

3.5.2. Distribution and abundance

Common scoters were recorded predominantly to the northwest of the study area (see Figure 3.26 – Figure 3.28). Although there were sufficient sightings to attempt modelling for this species, the models would not converge, most likely due to the localised nature of the sightings and lack of sightings across the remainder of the study area. The number of sightings within the wind farm site are extremely few and there is no evidence for a change in usage of this area by common scoter (Figure 3.29 a and c). Within the study area as a whole, birds in flight appear to have decreased while birds on the sea have remained fairly constant, perhaps increasing in number during the operational phase (Figure 3.29 b and d). Average group size (Figure 3.25) seems to have decreased during the construction and operational phases (Figure 3.25).

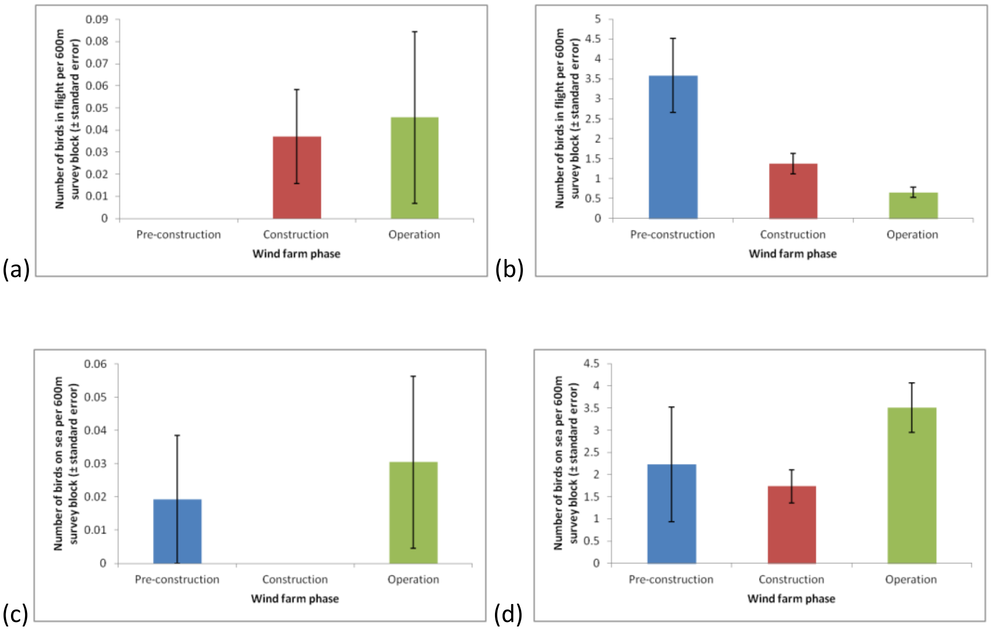


Figure 3.29: Mean number of common scoter observed per segment per month during the pre-construction, construction and operational phase (a) in flight within the site, (b) in flight within the buffer (c) on sea within the site and (d) on sea within the buffer ±standard error

3.5.3. Collision risk

The percentage of common scoter recorded in different height bands relative to rotor height can be found in Table 3.12. The band 35-125 represents rotor height. As would be expected for this species, the majority of scoter were observed flying at less than 25 m height, resulting in less than 1% observed flying at rotor height in any phase. As the majority of observations occurred below rotor height a Chi Square was not attempted.

Table 3.12: Percentage of common scoter recorded in different height bands. Rotor height = 35-125 m

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	61	39	0	<1	0	0
Construction	61	39	<1	<1	0	0
Operation	88	11	<1	<1	0	0

3.6. Red-throated diver

3.6.1. Summary statistics

The number of red-throated diver recorded during each of the three development phases can be found in Table 3.13 and Table 3.14 below. The mean number of red-throated diver recorded each month can be found in Figure 3.27 and the average group size recorded in each of the three phases in see Figure 3.28.

The raw data suggest a possible increase in abundance during the operational phase. Red-throated diver were recorded throughout the year, although numbers in operational year two were lower than those recorded in operational year one (Figure 3.27). Peak abundance pre-construction was in September. While a large number of birds were recorded for this month during the operational years, a greater abundance was recorded in April. Average group size observed does not appear to have changed between the different stages of the wind farm (see Figure 3.28).

Table 3.13: Raw data for red-throated diver recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	160/0.03	94/0.01	197/0.02	178/0.01	370/0.04	451/0.04
Total number individuals/IPUE	378/0.06	170/0.03	300/0.02	241/0.02	818/0.08	717/0.07

Table 3.14: Standardised data for red-throated diver recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	9	0.03	257	0.11	0	0.00	17	0.01	1	0.00	141	0.03
Number per km^2	0.08		0.31		0.00		0.03		0.01		0.08	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	13	0.08	84	0.04	1	0.01	18	0.01	8	0.02	143	0.03
Number per km^2	0.22		0.08		0.01		0.03		0.08		0.08	

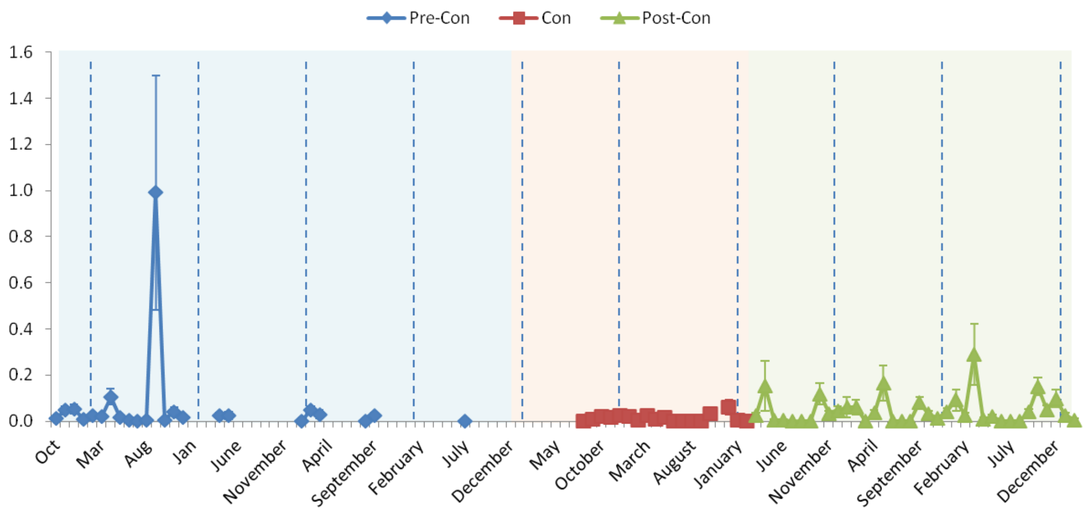


Figure 3.30: Mean number of red-throated diver observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

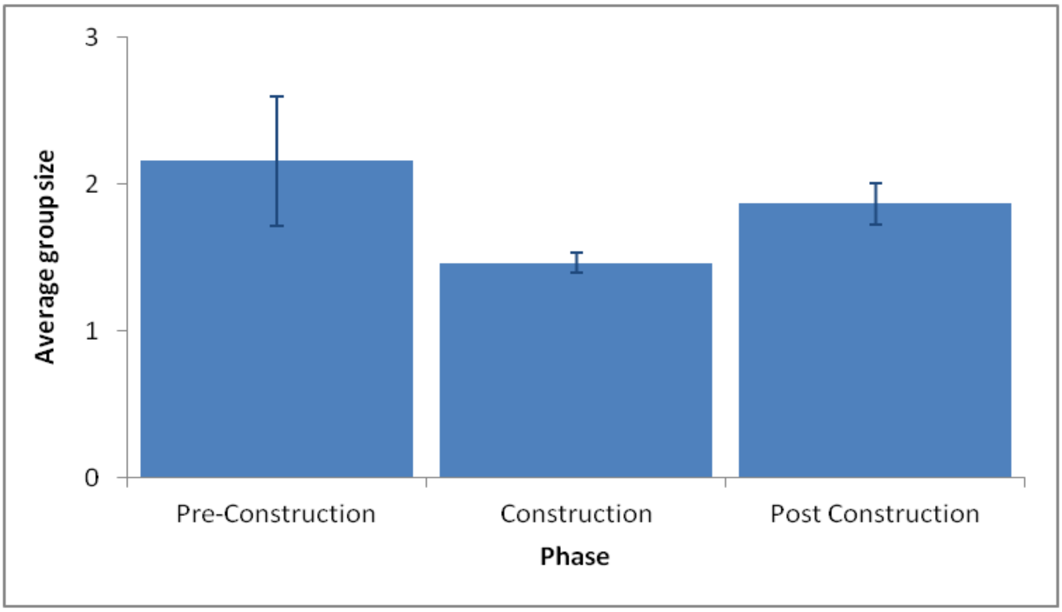


Figure 3.31: Mean group size for red-throated diver observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.6.2. Distribution and abundance

Both the standardised raw data and the model outputs suggest that red-throated diver abundance may have dropped during the construction phase (Table 3.13 and Table 3.14; Figure 3.32 and Figure 3.33). However, this effect was not found to be significant (Table 3.16 and Table 3.17).

The standardised raw data suggest an increase from the pre-construction to the operation phase for birds in flight and a slight decrease for birds on the sea (Table 3.14). These patterns were reflected in the model outputs (Table 3.16 and Table 3.17). The increase in flying birds from the pre-construction to the operation phase is weakly significant, however this significance is likely to disappear once over-dispersion has been properly dealt with.

For birds on the sea, predicted values for the wind farm site and buffer regions do not suggest any particular avoidance or attraction to the wind farm area for red-throated diver on sea (Figure 3.33) although the distribution appears to be more even across the study area during the construction and operation phases compared to the pre-construction phase. Significant decreases in abundance were found to the east of the study area between the pre-construction and construction phases and also between the pre-construction and operation phases (Figure 3.37 and Figure 3.39).

For birds in flight, there is a slight suggestion of avoidance of the wind farm area during construction phase (Figure 3.32) and significant decreases in abundance were found to the west side of the wind farm site during both the construction and operational phases (Figure 3.37 and Figure 3.39).

Table 3.16: Parameter estimates and p-values for construction phase comparisons for red-throated diver in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-2.178	1.442	-1.510	0.1310
Pre-construction to operation	1.546	0.610	2.533	0.0113*

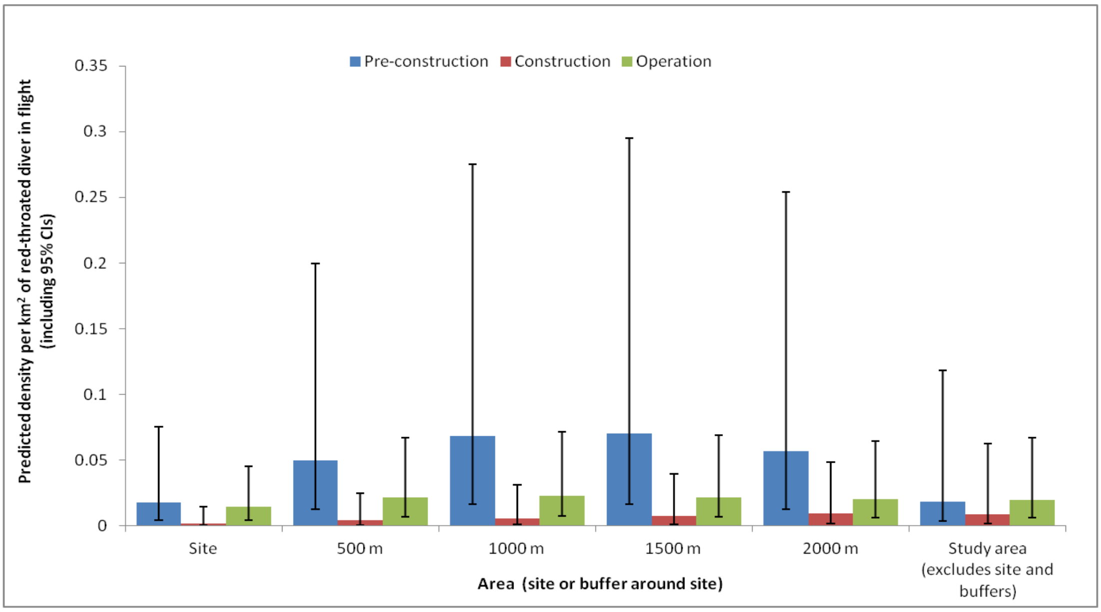


Figure 3.32: Predicted density for red-throated diver in flight in the spring (March-May) with 95% confidence intervals

Table 3.17: Parameter estimates and p-values for construction phase comparisons for red-throated diver on the sea

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-2.631	1.357	-1.939	0.0525
Pre-construction to operation	-1.283	0.664	-1.932	0.0534

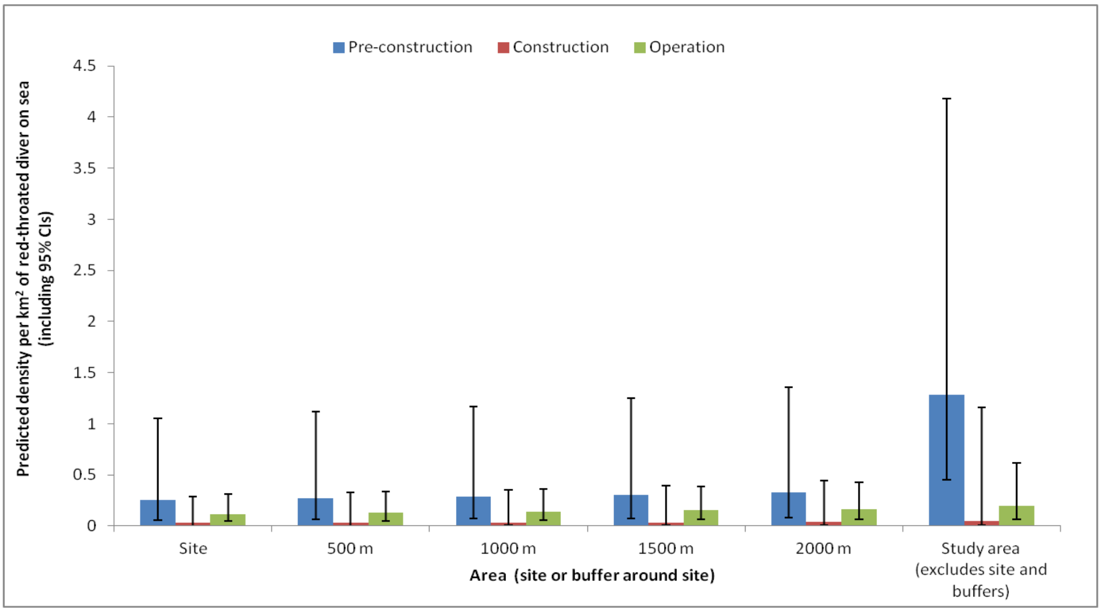


Figure 3.33: Predicted density for red-throated diver on the sea in the winter (November-February) with 95% confidence intervals

A map illustrating the location of the standardised raw sightings can be found in Appendix 2. Density surface maps based on the model outputs for birds on the sea and in flight are presented as Figure 3.34 through to Figure 3.45.

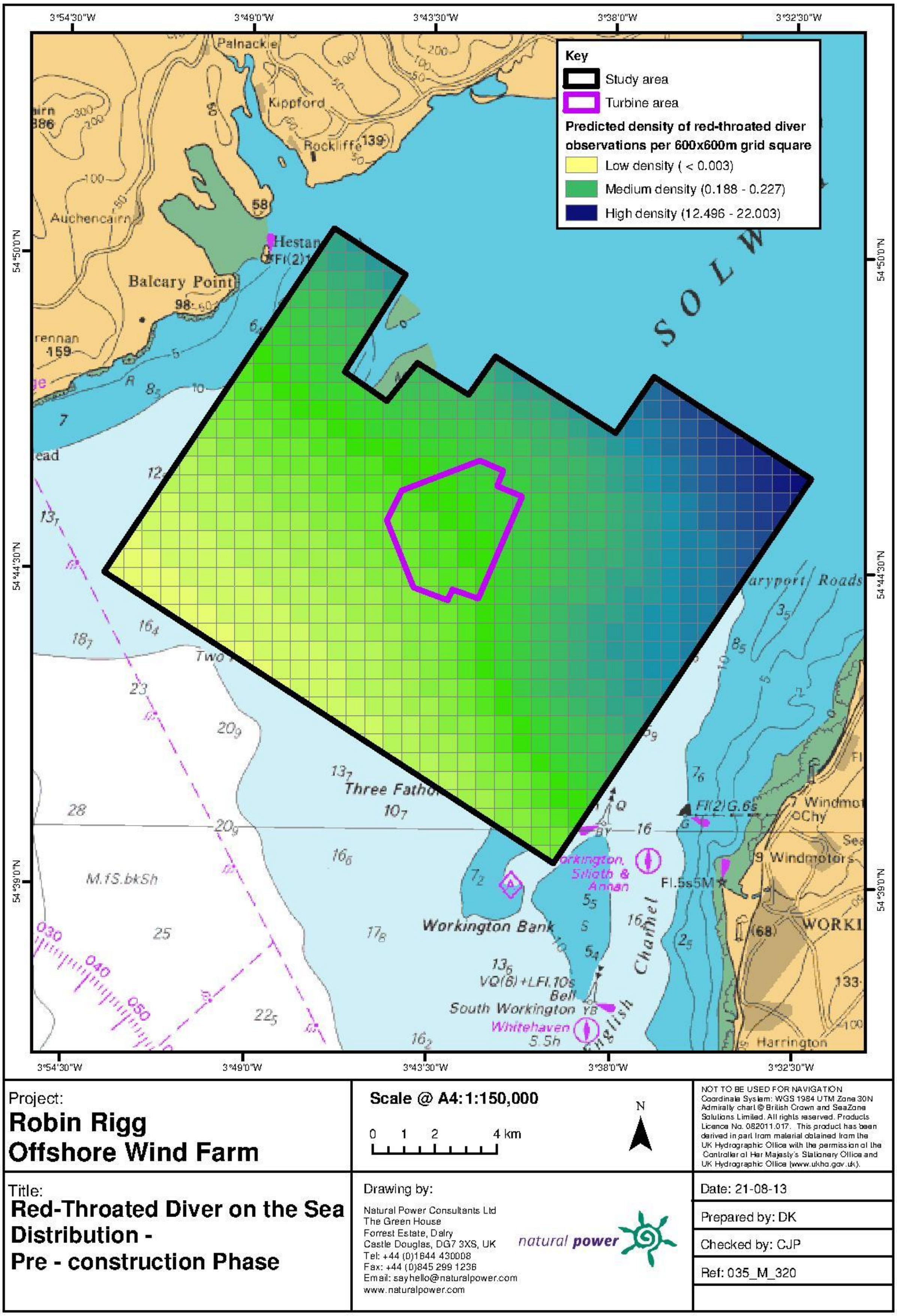


Figure 3.34: Density surface map of the predicted density of red-throated diver on the sea across the study area during the pre-construction phase of the development. Hashed areas represent grid cells for which 95% confidence intervals around predictions did not overlap.

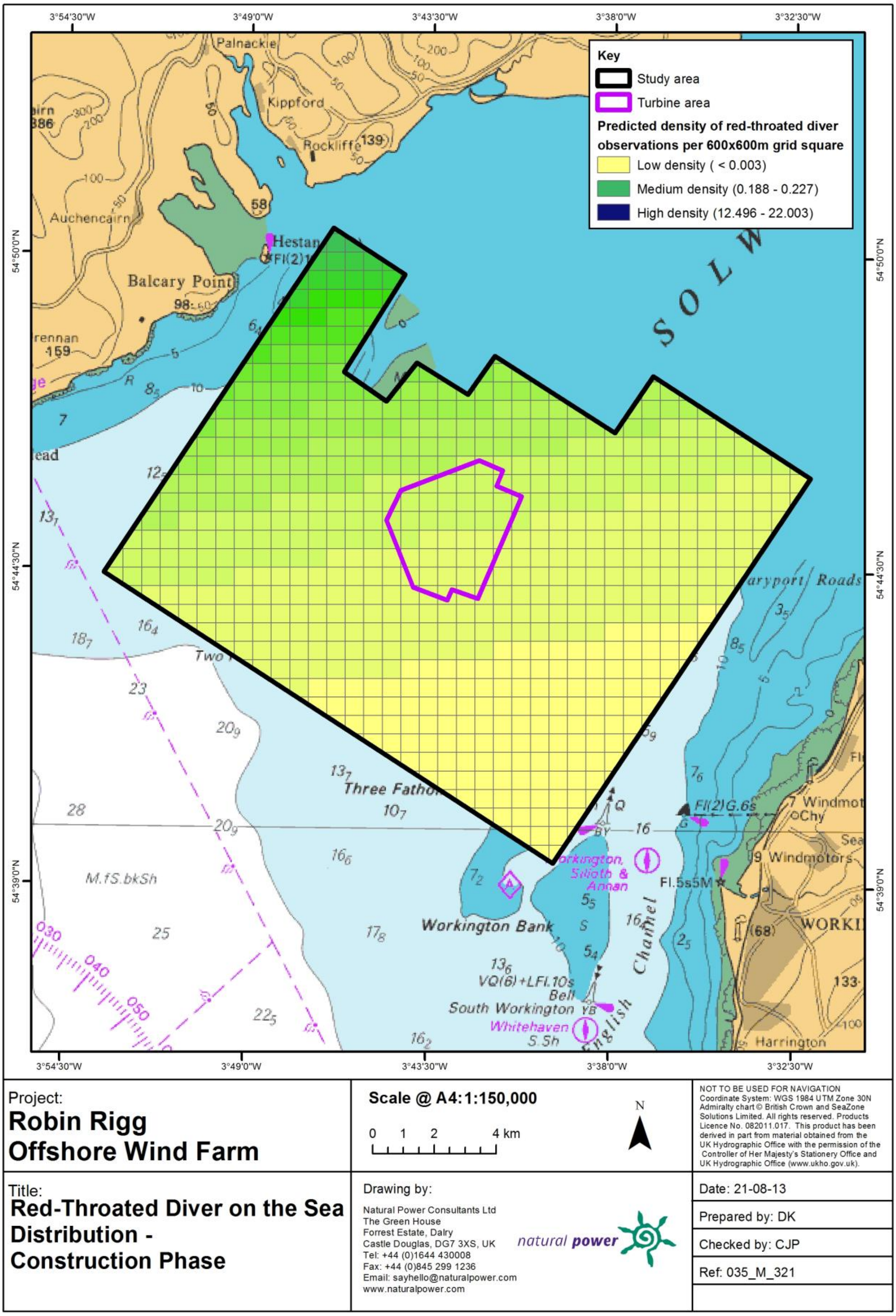


Figure 3.35: Density surface map of the predicted density of red-throated diver on the sea across the study area during the construction phase of the development

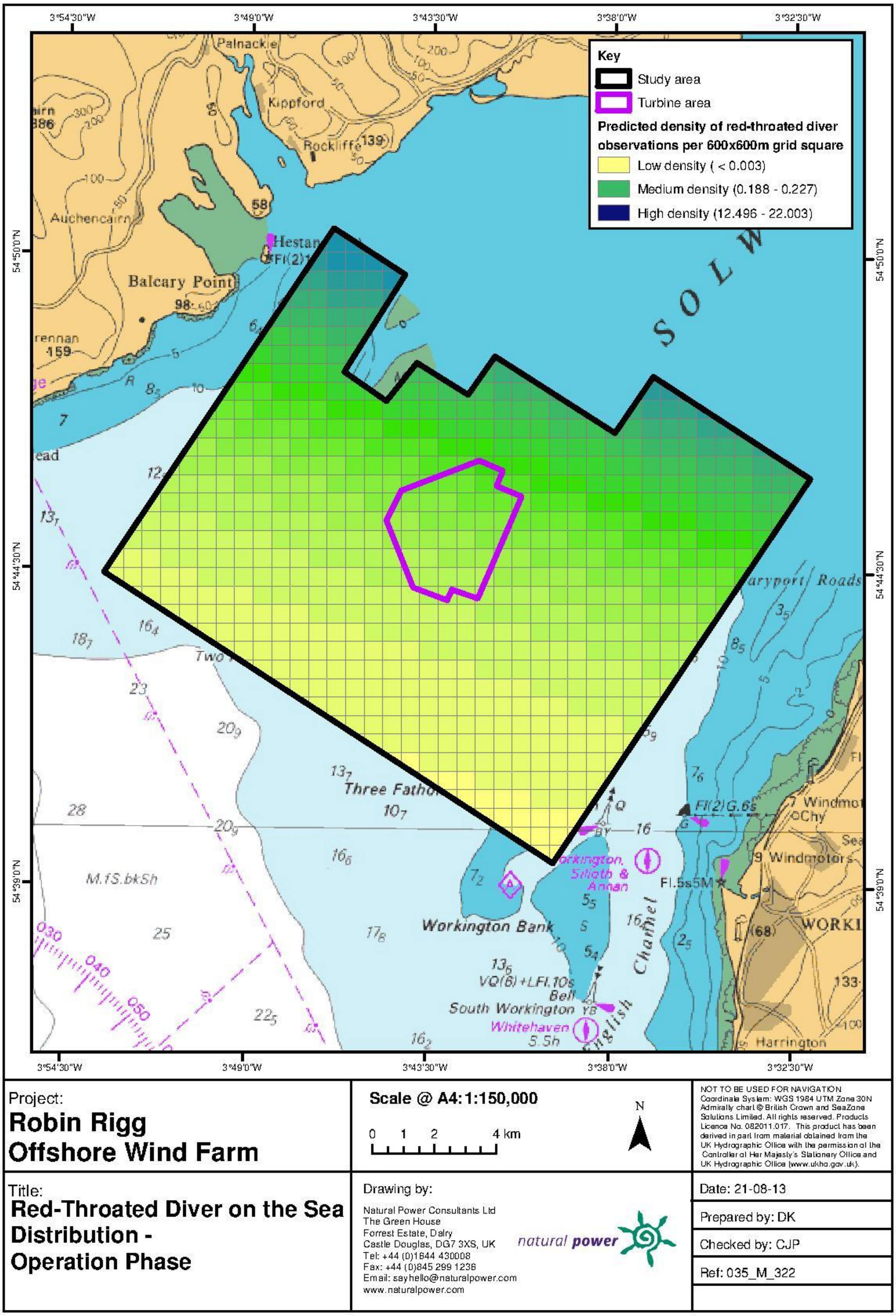


Figure 3.36: Density surface map of the predicted density of red-throated diver on the sea across the study area during the operational phase of the development

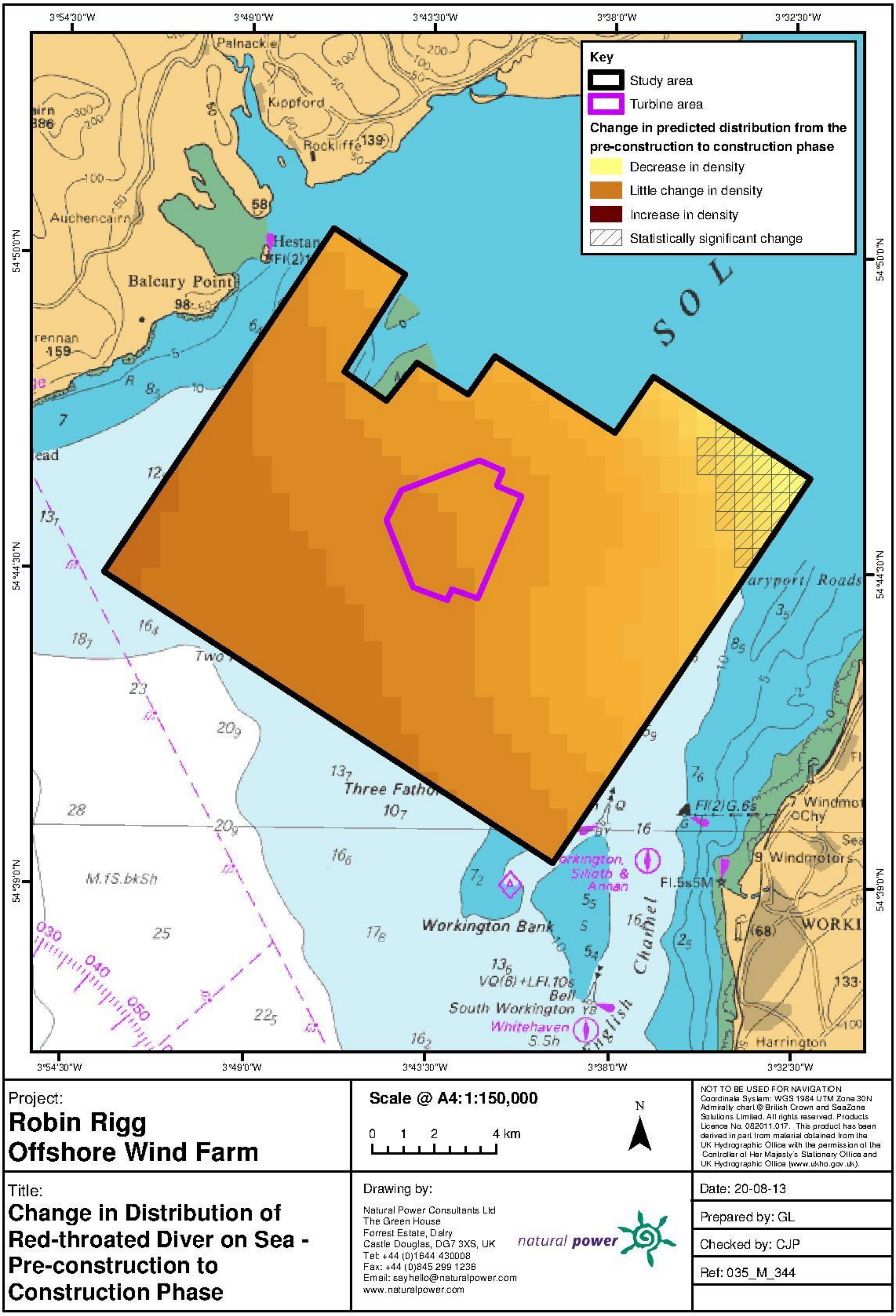
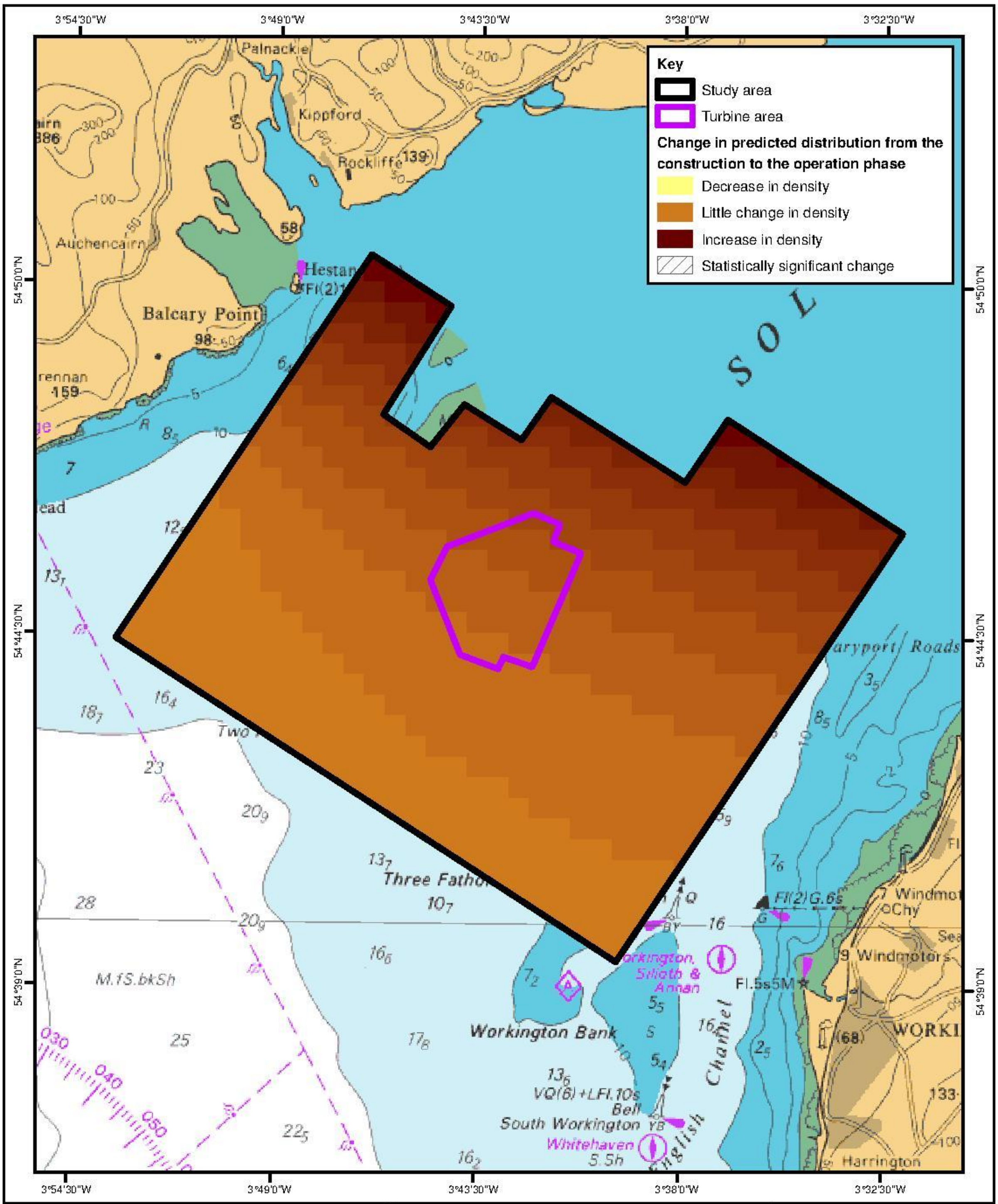


Figure 3.37: Plot of the difference in predicted density of red-throated diver on the sea between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Red-throated Diver on Sea - Construction to Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_345

Figure 3.38: Plot of the difference in predicted density of red-throated diver on the sea between the construction and operational phases of the development. Significant differences are marked with diagonal lines

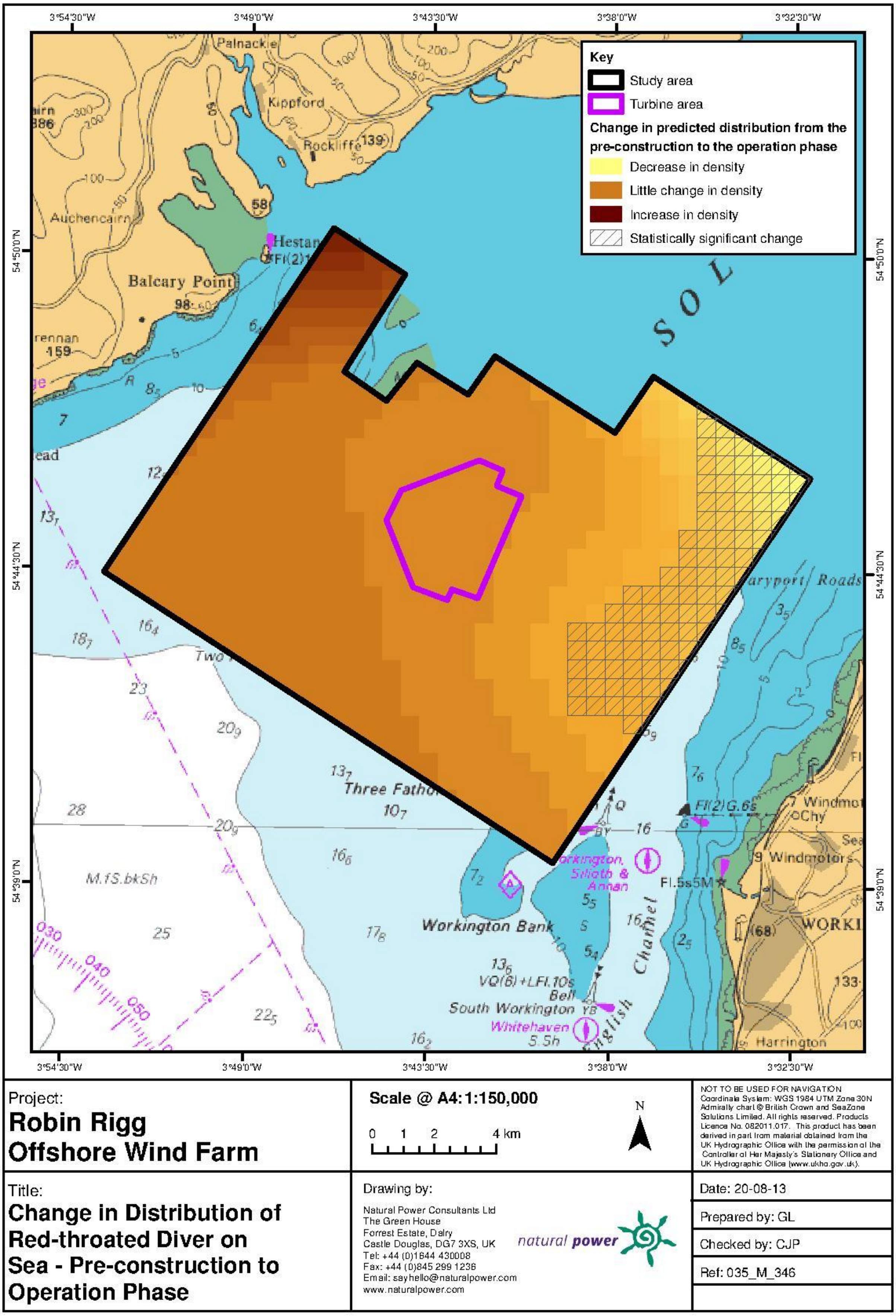


Figure 3.39: Plot of the difference in predicted density of red-throated diver on the sea between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

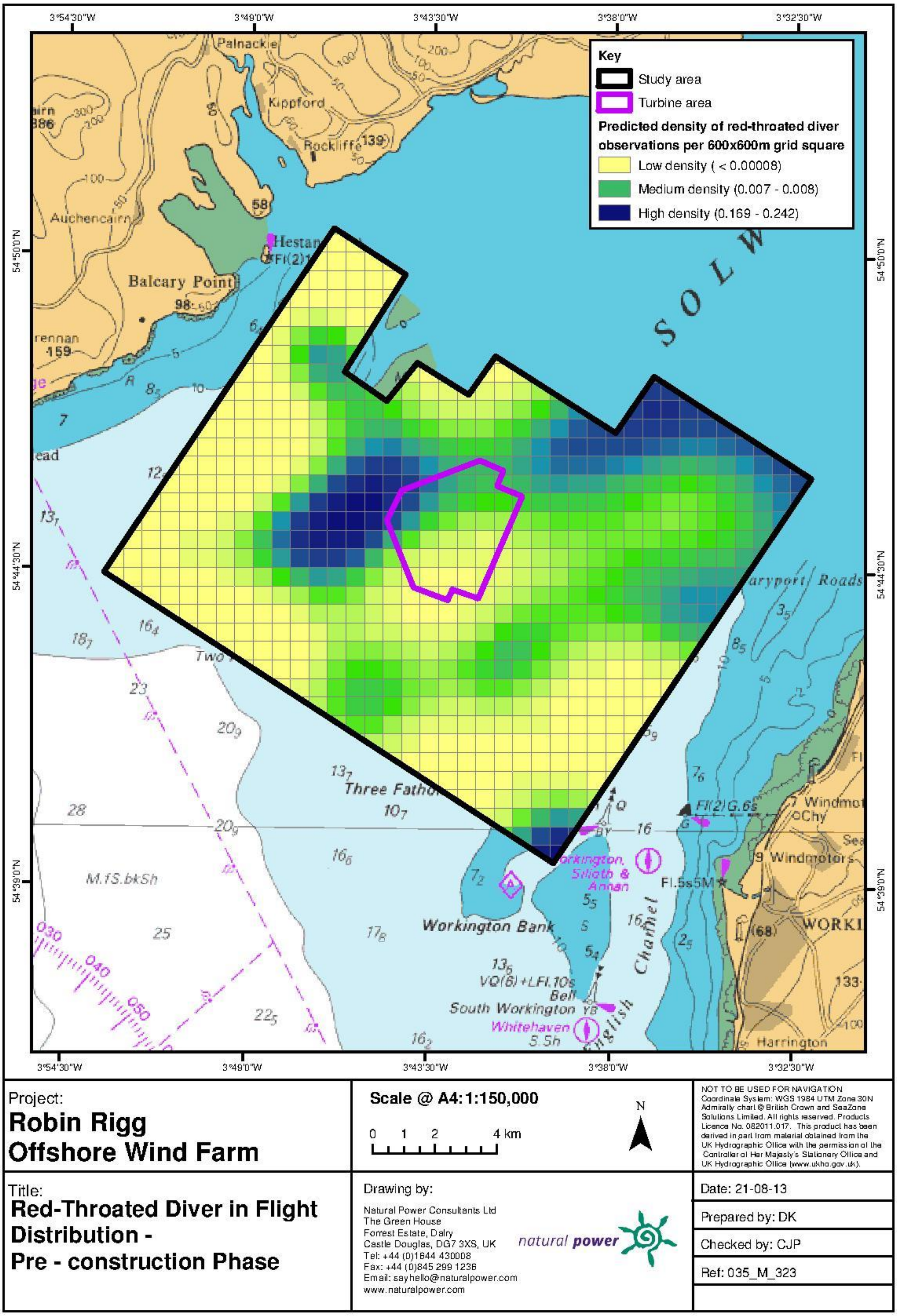


Figure 3.40: Density surface map of the predicted density of red-throated diver in flight across the study area during the pre-construction phase of the development

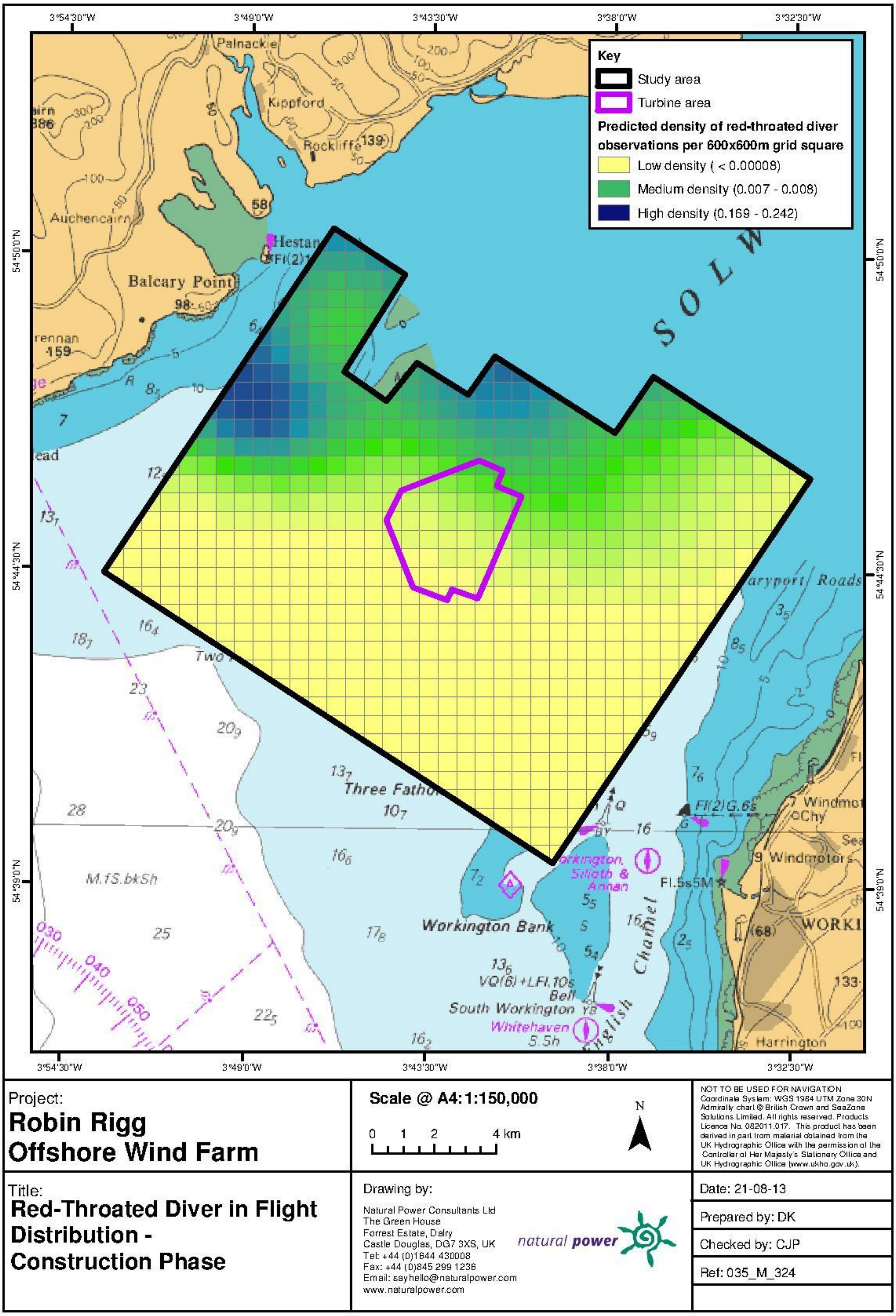


Figure 3.41: Density surface map of the predicted density of red-throated diver in flight across the study area during the construction phase of the development

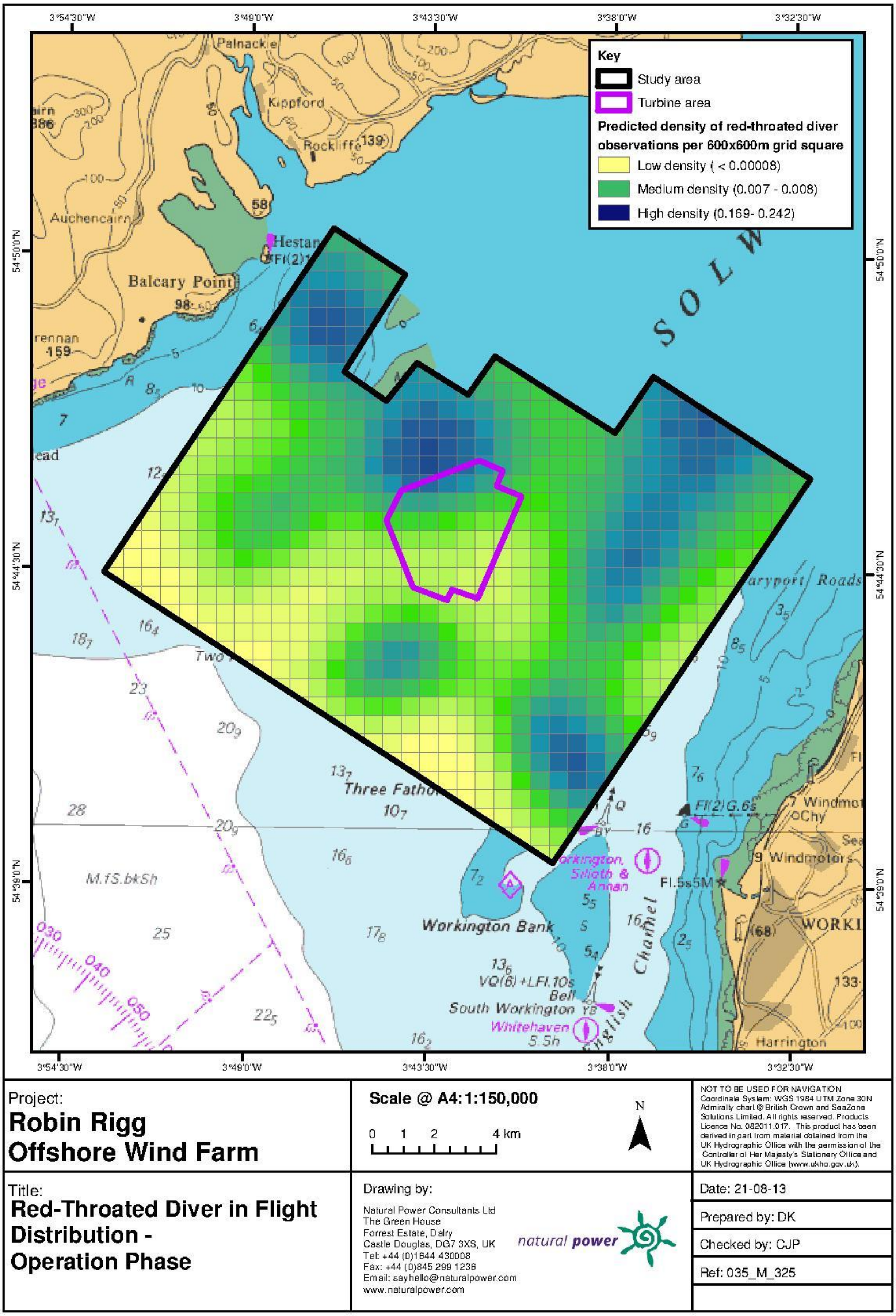


Figure 3.42: Density surface map of the predicted density of red-throated diver in flight across the study area during the operational phase of the development

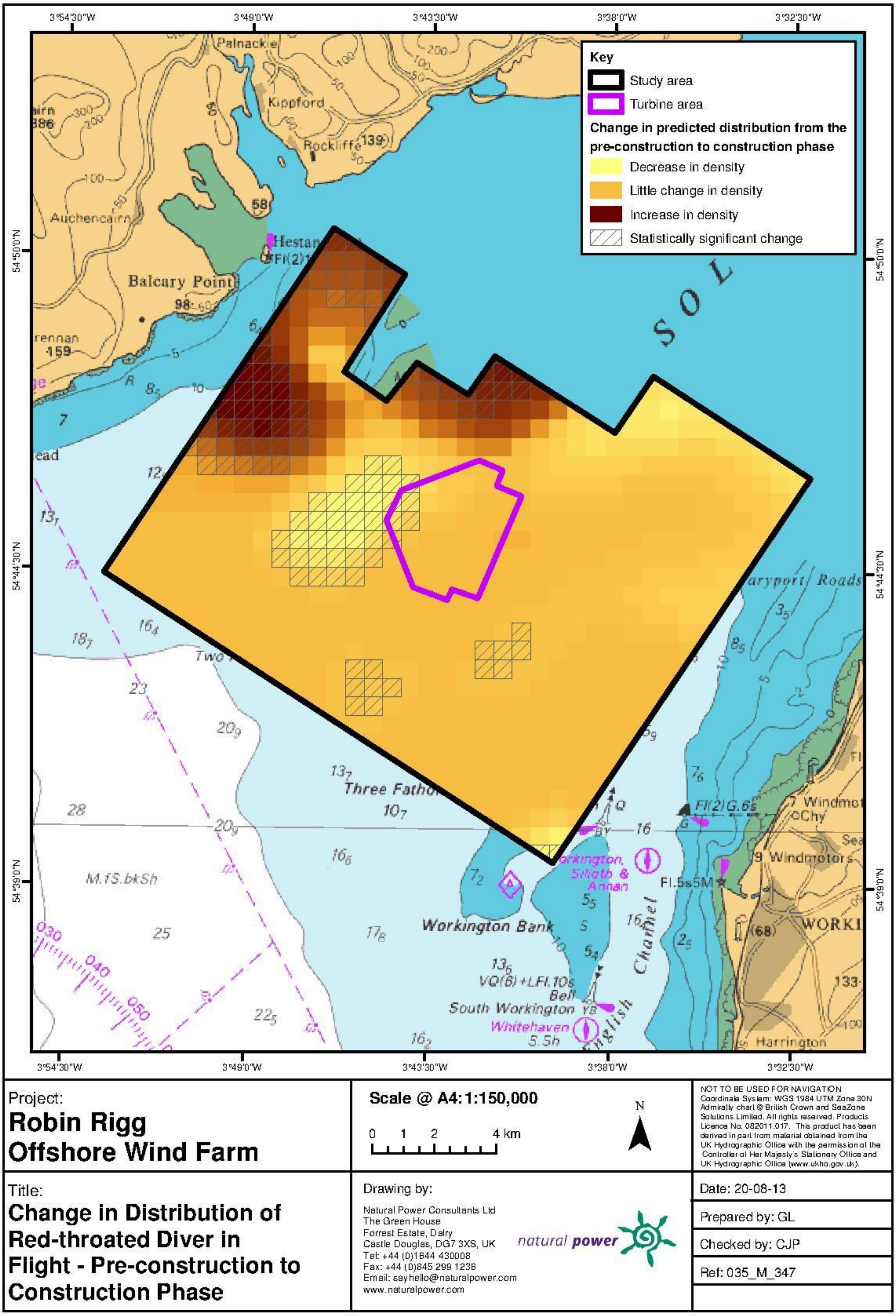


Figure 3.43: Plot of the difference in predicted density of red-throated diver in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

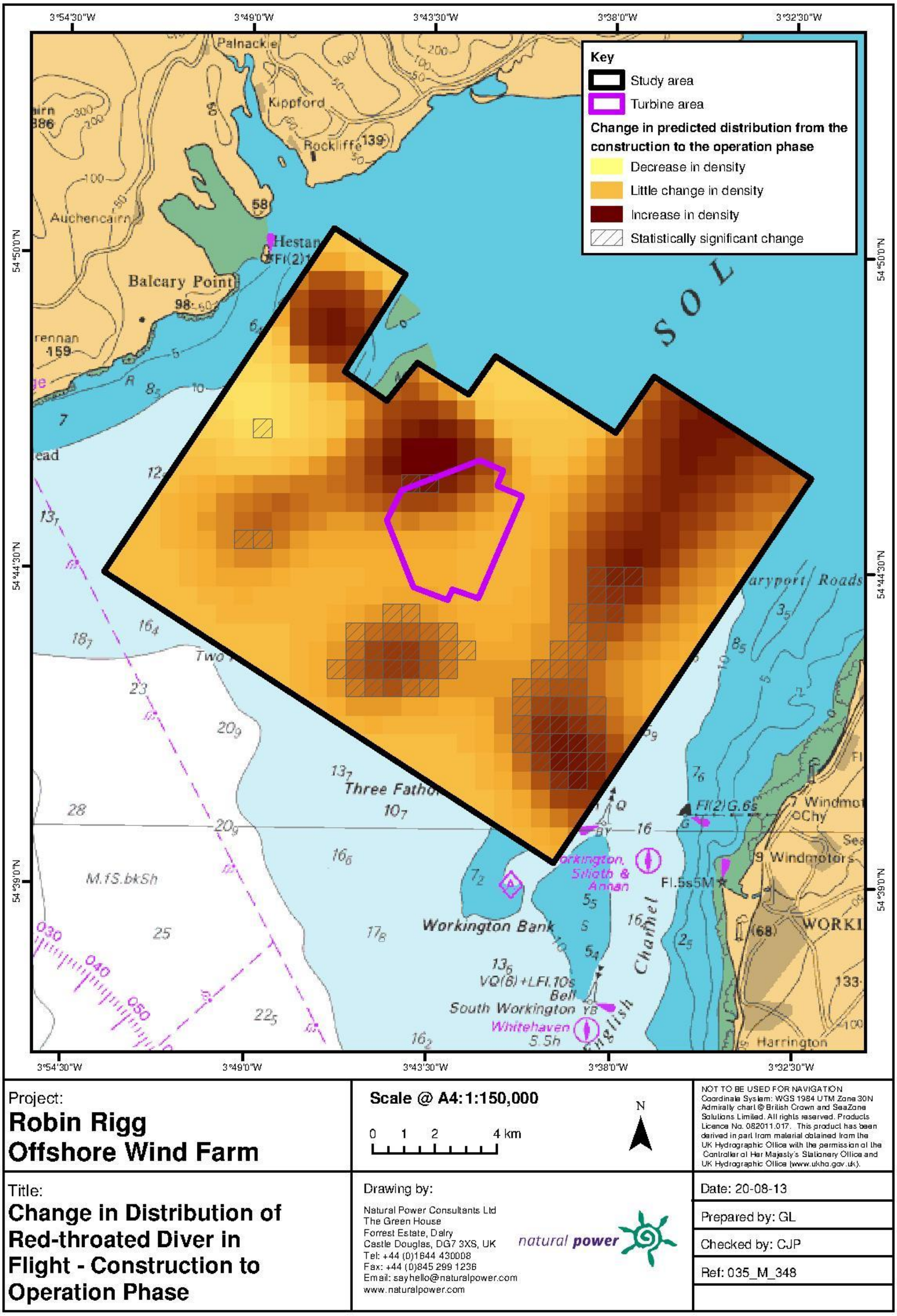
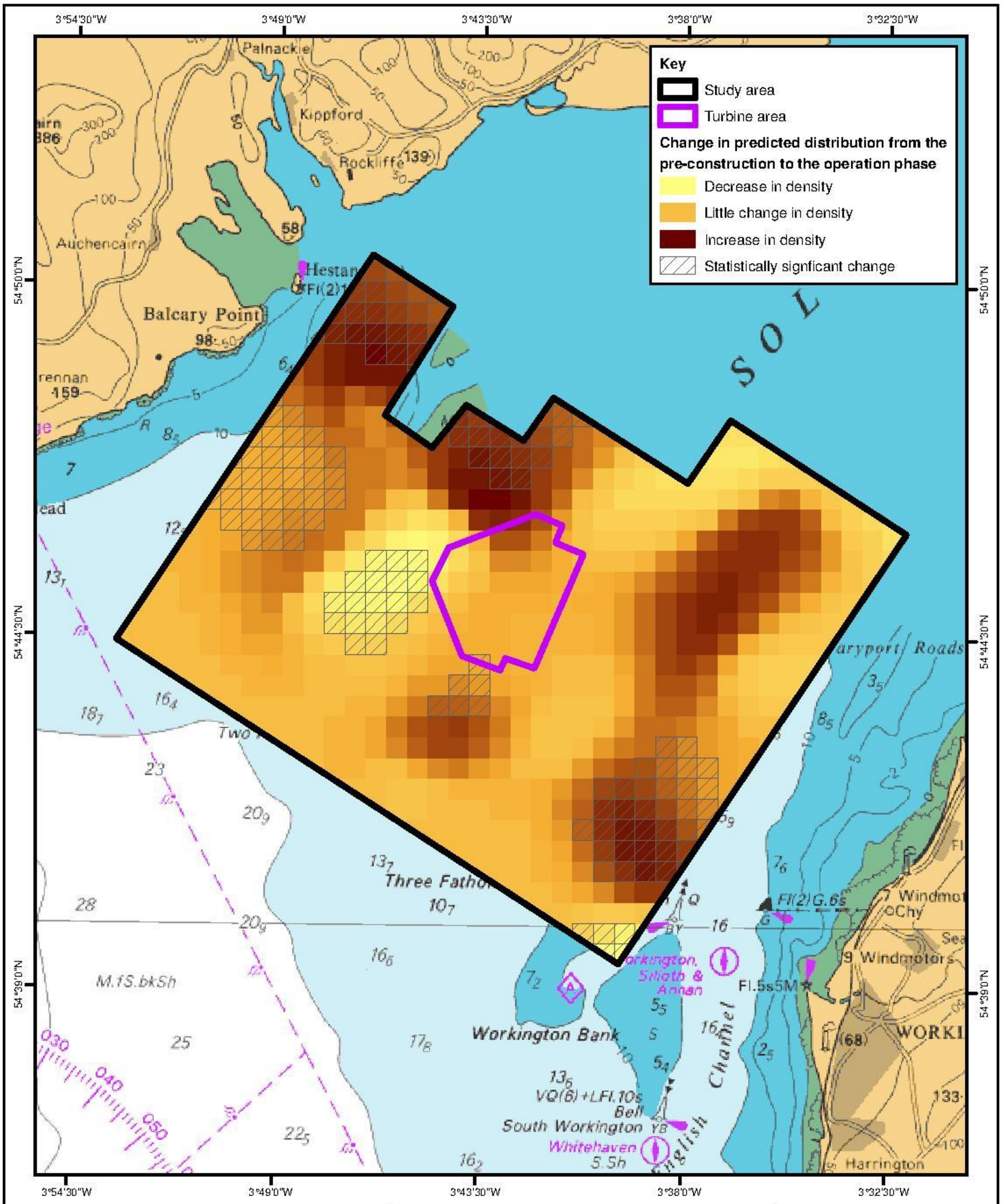


Figure 3.44: Plot of the difference in predicted density of red-throated diver in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Red-throated Diver in Flight - Pre-construction to Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_349

Figure 3.45: Plot of the difference in predicted density of red-throated diver in flight between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines.

3.6.3. Collision risk

The percentage of red-throated diver recorded in different height bands relative to rotor height can be found in Table 3.18 and Figure 3.46. The band 35-125 represents rotor height. As such a small number were observed flying at rotor height, Chi Square was not attempted.

Table 3.18: Percentage of red-throated diver recorded in different height bands through the different stages of the development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	82	18	0	0	0	0
Construction	64	32	2	2	0	0
Operation	70	23	6	1	0	0

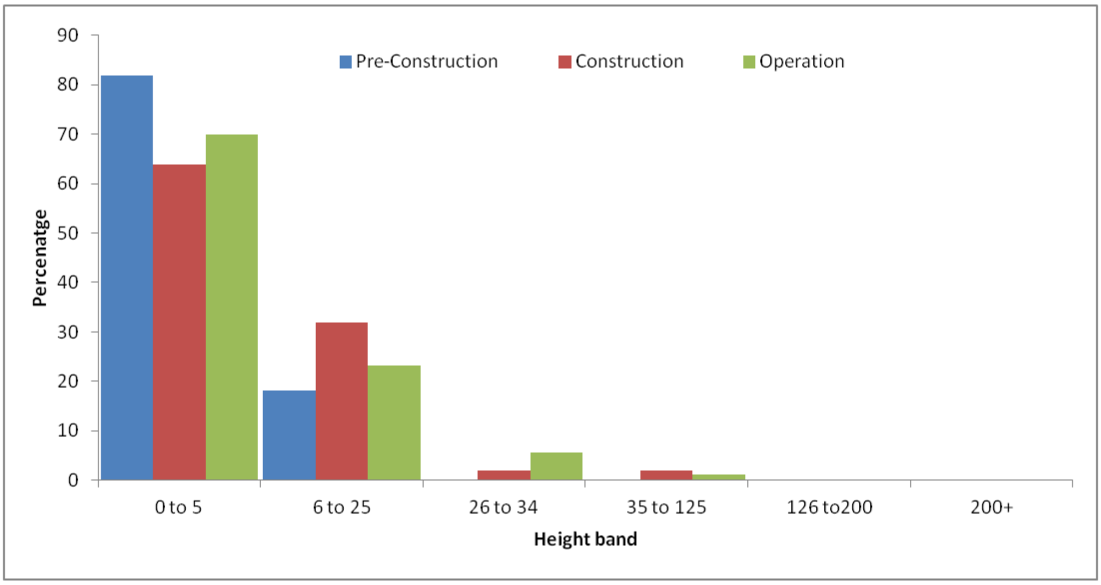


Figure 3.46: Percentage of red-throated diver recorded in different flight bands during the different stages of the development.

3.7. Results: Manx shearwater

3.7.1. Summary statistics

The number of Manx shearwater recorded during each of the development phases can be found in Table 3.19 below. The number of Manx shearwater recorded during each of the three development phases can be found in Figure 3.48 and average group size recorded in each of the three phases in Figure 3.49. They were rarely seen on wind farm site, with slightly fewer birds observed during operational year two compared to one. The raw data indicate a decrease in observations during construction and operation combined with a change in when peak abundance occurs (Figure 3.48).

Fewer than 300 sightings recorded for this species in flight and on the sea. For this reason, no modelling was carried out in this data set.

Table 3. 9: Number of sightings of Manx shearwater recorded per *300 x 600 m segment* during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		Construction		Operation years 1-3	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	17/<0.00	123/0.02	101/0.01	208/0.02	82/0.01	146/0.01
Total number individuals/IPUE	99/0.02	1467/0.23	1021/0.08	664/0.05	377/0.04	726/0.03

Table 3.20: Standardised data for Manx shearwater recorded per 300 x 600 m segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	0	0.00	85	0.04	0	0.00	21	0.01	2	0.01	314	0.06
Number per km^2	0		0.11		0.02		0.03		0.02		0.17	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	0	0.00	1367	0.58	0	0.00	63	0.02	4	0.01	194	0.04
Number per km^2	0.00		1.62		0.00		0.06		0.03		0.11	

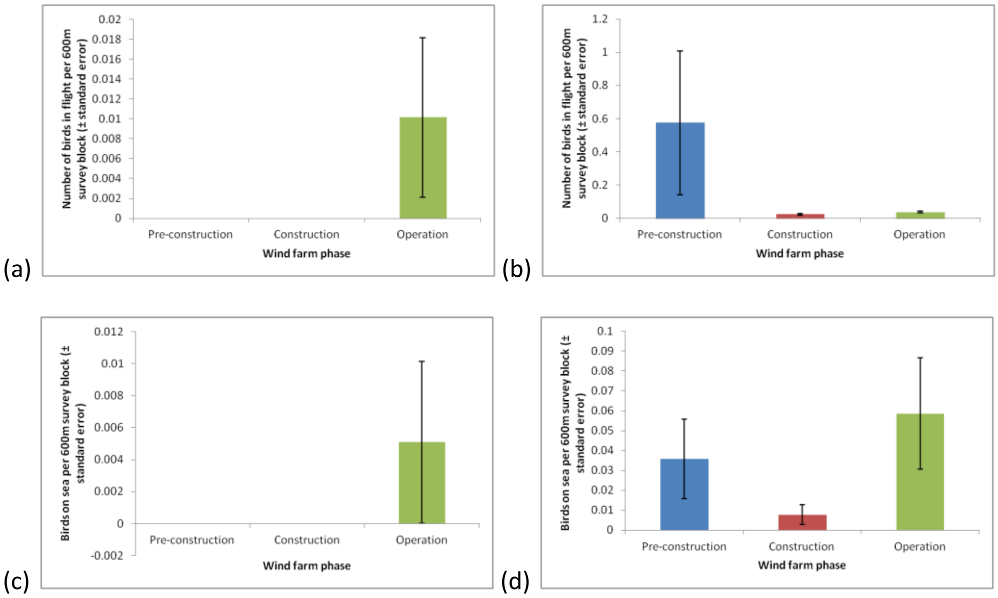


Figure 3.47: Individuals observed per unit effort (±standard error) during the three phases of the wind farm development (a) in flight within the site, (b) in flight within the remainder of the study area, (c) on sea within the site and (d) on sea within the remainder of the study area.

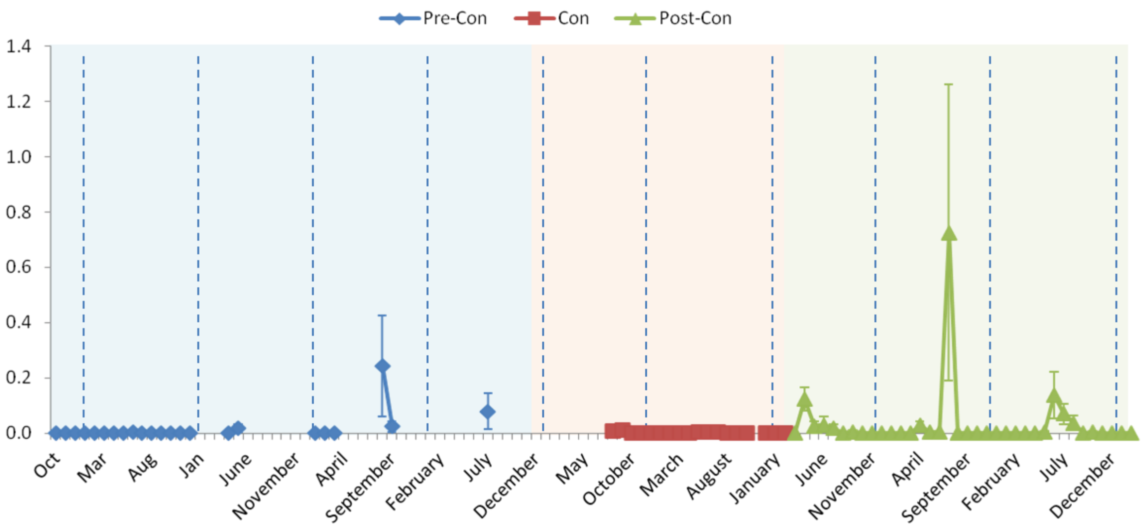


Figure 3.48: Mean number of Manx shearwater observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

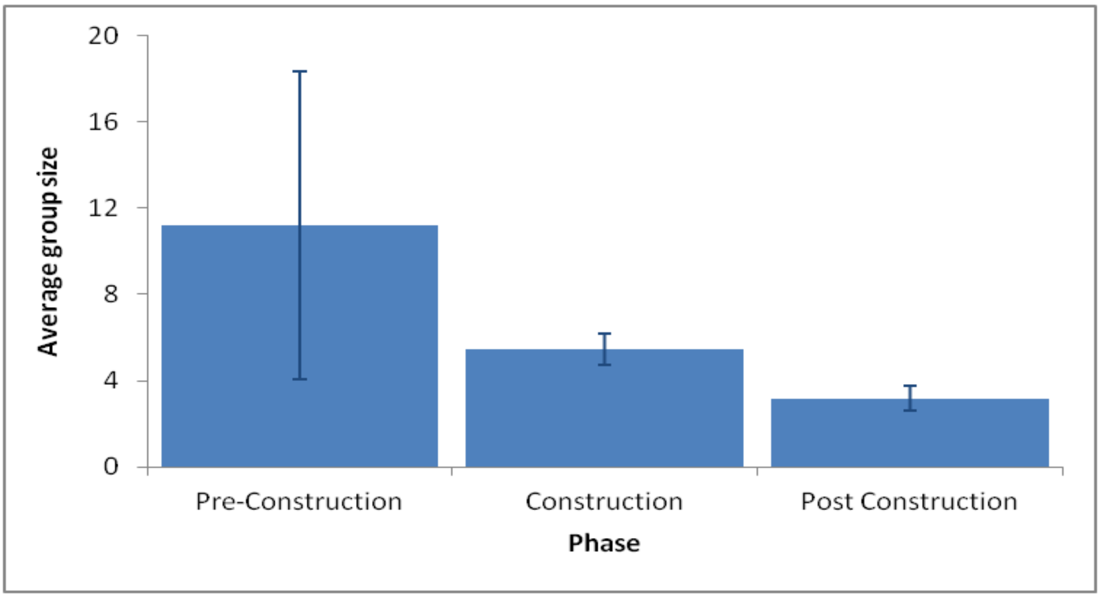


Figure 3.49: Mean group size for Manx shearwater observed per sighting during the pre-construction, construction and operational phases (±standard error)

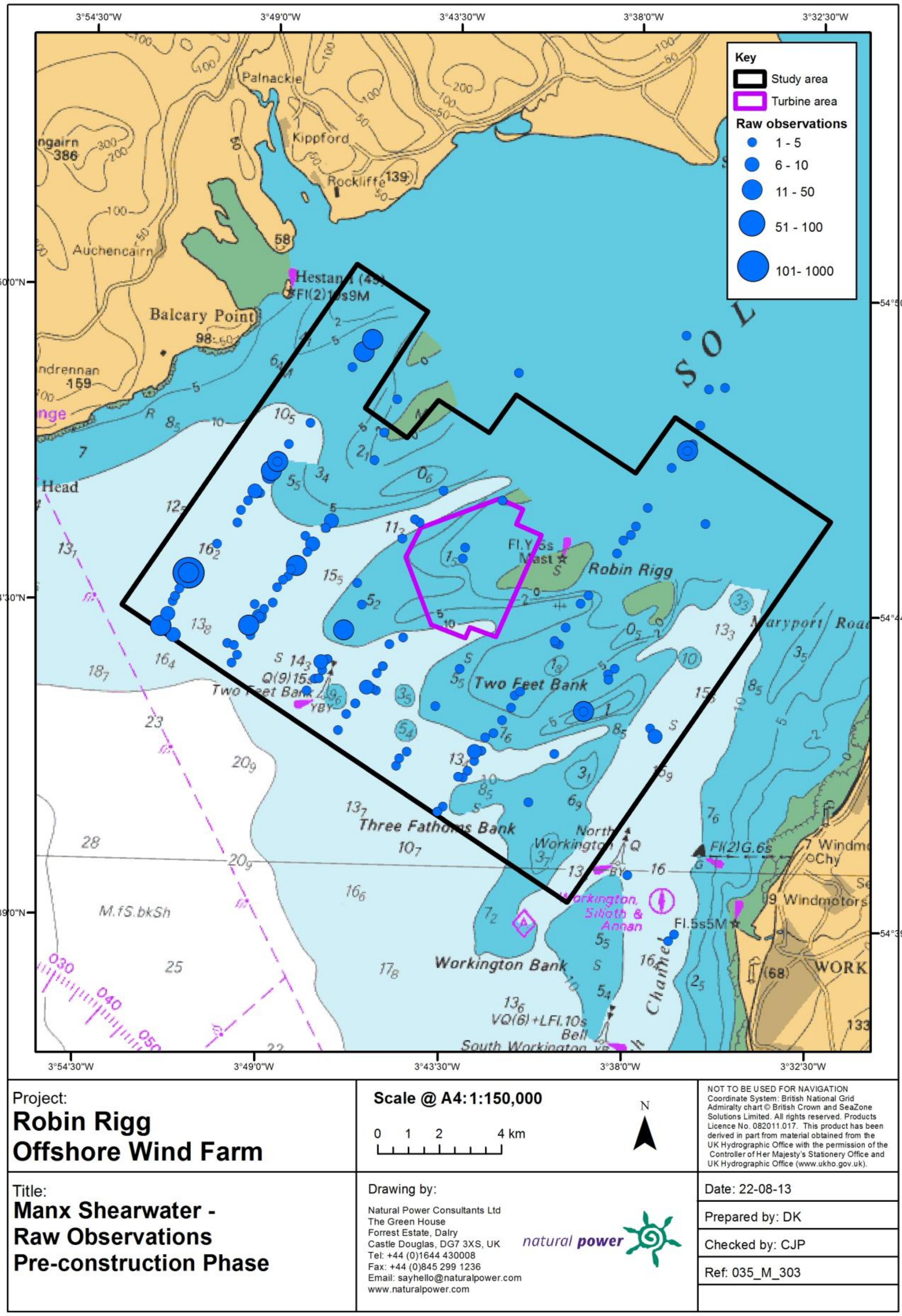


Figure 3.50: Map of Manx shearwater observations across the study area during the pre-construction phase of the development.

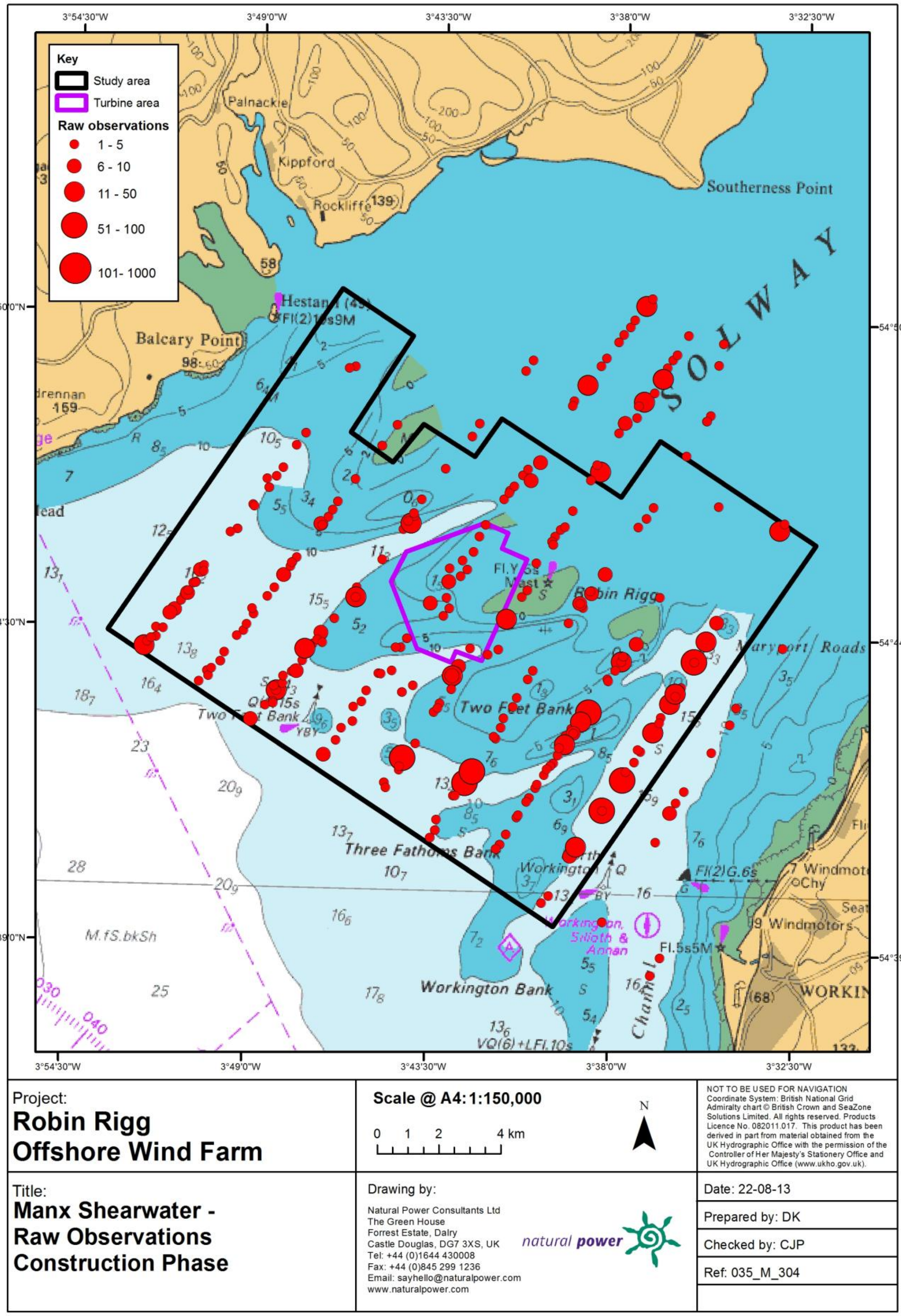


Figure 3.51: Map of Manx shearwater observations across the study area during the construction phase of the development.

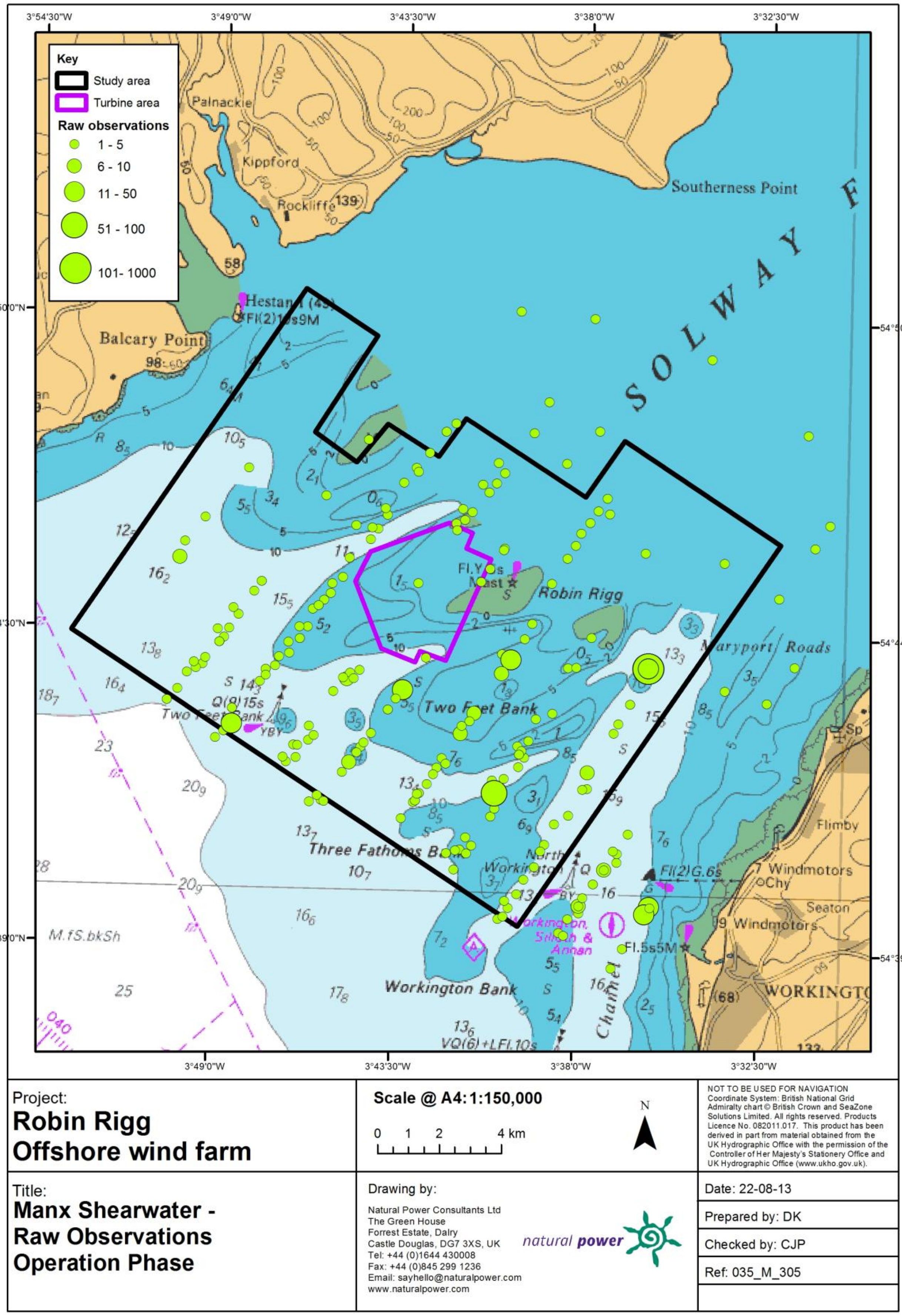


Figure 3.52: Map of Manx shearwater observations across the study area during the operational phase of the development.

3.7.2. Distribution and abundance

Manx shearwater were seen in low numbers across the study area (Figure 3.50 - Figure 3.52) however, few were observed within the wind farm site and there is no difference in usage of the wind farm site among the three phases (Figure 3.50 - Figure 3.52, Table 3.20). There is some evidence that numbers may have dropped during the construction phase, and for flying birds may also remain lower during the operational phase, however, it is difficult to draw conclusions based on the small number of observations available in the standardised dataset. Distribution of manx shearwater does not appear to have changed across the three wind farm phases (Figure 3.50 - Figure 3.52).

3.7.3. Collision risk

The percentage of Manx shearwater recorded in different height bands relative to rotor height can be found in Table 3.21. The band 35-125 represents rotor height. A proportion of Manx shearwater were recorded in height Band 2 (6-25 m) during the construction period but the reasons for this are unclear. Only two birds have been recorded in Band 2 during the operational phase, both during operational year one. No Chi-square test was carried out for this species as no flights were observed at turbine rotor height.

Table 3.21: Percentage of Manx shearwater recorded at different flight bands through the spate stages of the development.

	Flight band (m)					
	1 (0–5)	**2 (6–25)**	**3 (26–34)**	**4 (35– 125)**	**5 (126–200)**	**6 (200+)**
Pre-construction	100	0	0	0	0	0
Construction	82	18	0	0	0	0
Operation	99	1	0	0	0	0

3.8. Results: Gannet

3.8.1. Summary statistics

The number of gannet recorded during each of the three development phases can be found in Table 3.22 and Table 3.23. The mean number of gannet recorded each month is presented in Figure 3.53 and average group size recorded in each of the three phases in Figure 3.54. While the number of sightings appears to have remained fairly constant, the raw data suggest a slight decline in the number of gannet recorded during and after construction. Gannet were seen primarily during the summer and autumn months.

Gannets have never been abundant across the study area and too few sightings were recorded on the sea to allow modelling to be undertaken. Modelling was carried out for birds in flight and the results are presented below.

Table 3.22: Raw data for gannet recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	77/0.01	235/0.04	152/0.01	434/0.01	136/0.01	293/0.03
Total number individuals/IPUE	124/0.02	352/0.06	246/0.02	602/0.05	191/0.02	397/0.04

Table 3.23: Standardised data for gannet recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	3	0.02	37	0.02	0	0.00	26	0.01	3	0.01	100	0.02
Number per km^2	0.06		0.06		0.00		0.03		0.03		0.06	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	9	0.06	131	0.06	7	0.01	183	0.07	1	0.02	258	0.05
Number per km^2	0.18		0.17		0.27		0.20		0.01		0.14	

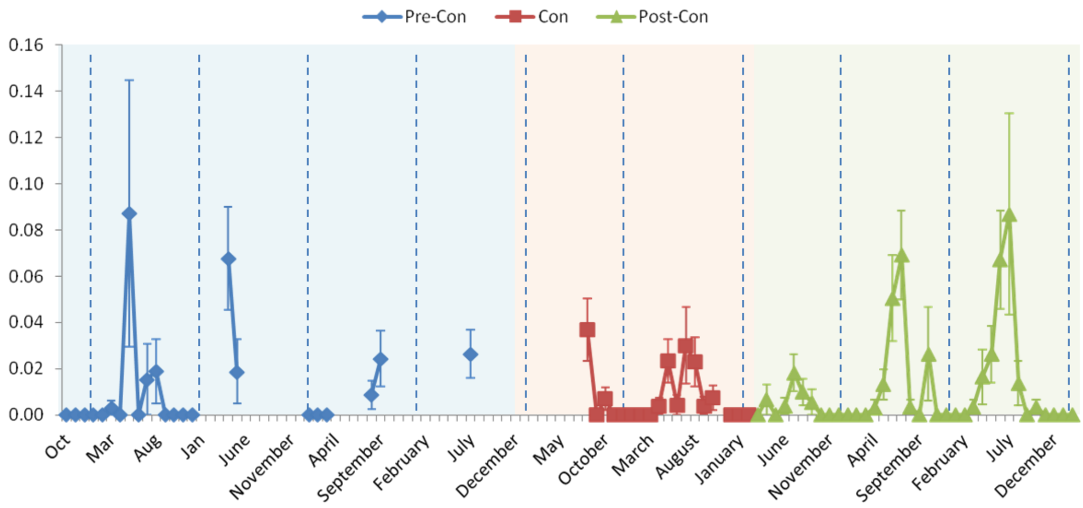


Figure 3.53: Mean number of gannet observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

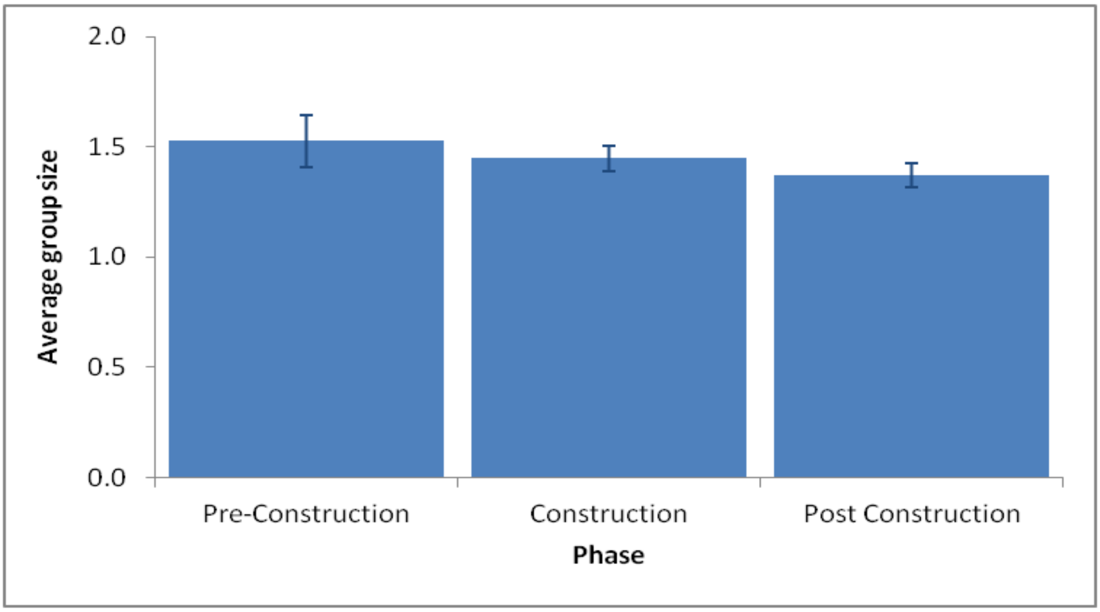


Figure 3.54: Mean group size for gannet observed per sighting during the pre-construction, construction and operational phases (±standard error)

3.8.2. Distribution and abundance

The standardised raw data suggest a possible increase in birds in flight during the construction phase followed by a subsequent decrease across the operational years (Table 3.23). The model output however is more consistent with a gradual (although non-significant) decline across the three phases of the development (Figure 3.55).

The density plots (Figure 3.56 - Figure 3.61) suggest little change in overall distribution across the study area between the three phases with gannet never having been abundant within the wind farm site area.

Table 3.24: Model outputs for gannets in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	0.004392	0.381383	0.012	0.990813
Pre-construction to operation	-0.499770	0.334270	-1.495	0.134931

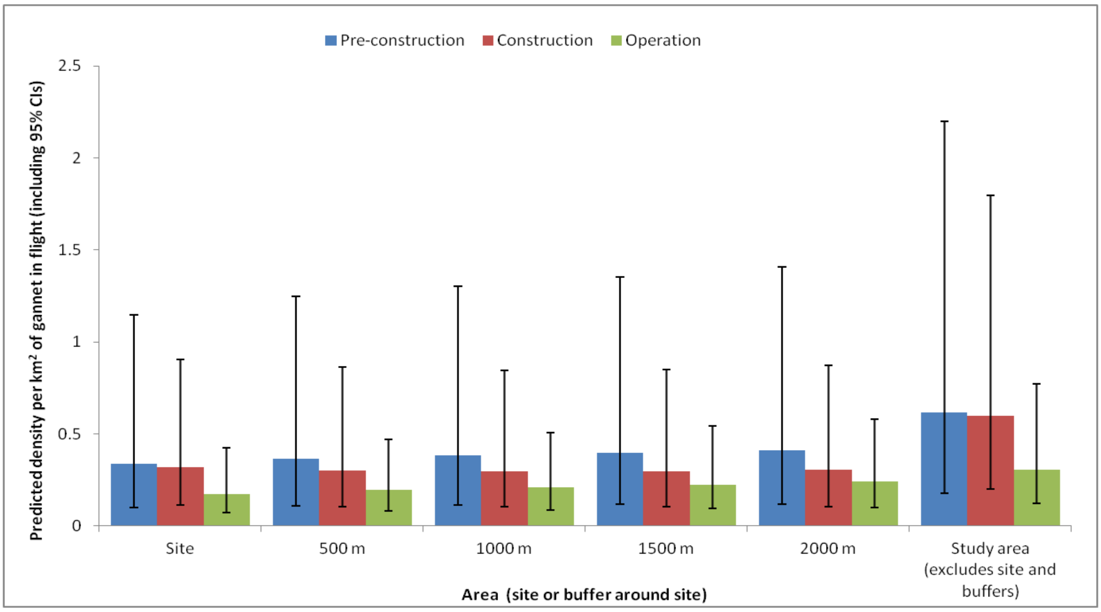


Figure 3.55: Predicted density of gannets in July with 95% confidence intervals (95%CI)

Gannet were recorded throughout the study area (for map of standardised raw data see Appendix 2, section 3.2).

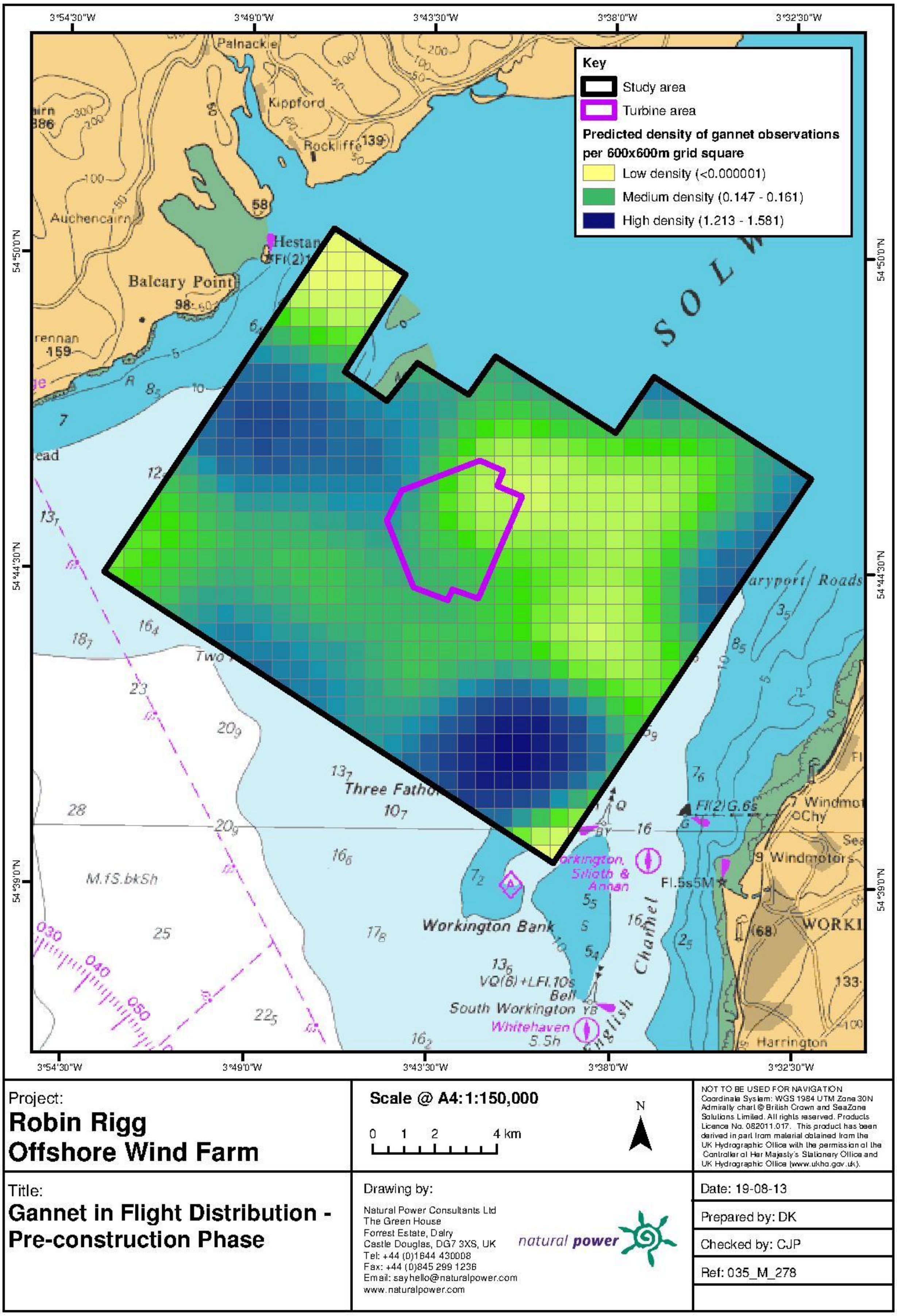


Figure 3.56: Density surface map of the predicted density of gannet in flight across the study area during the pre-construction phase of the development.

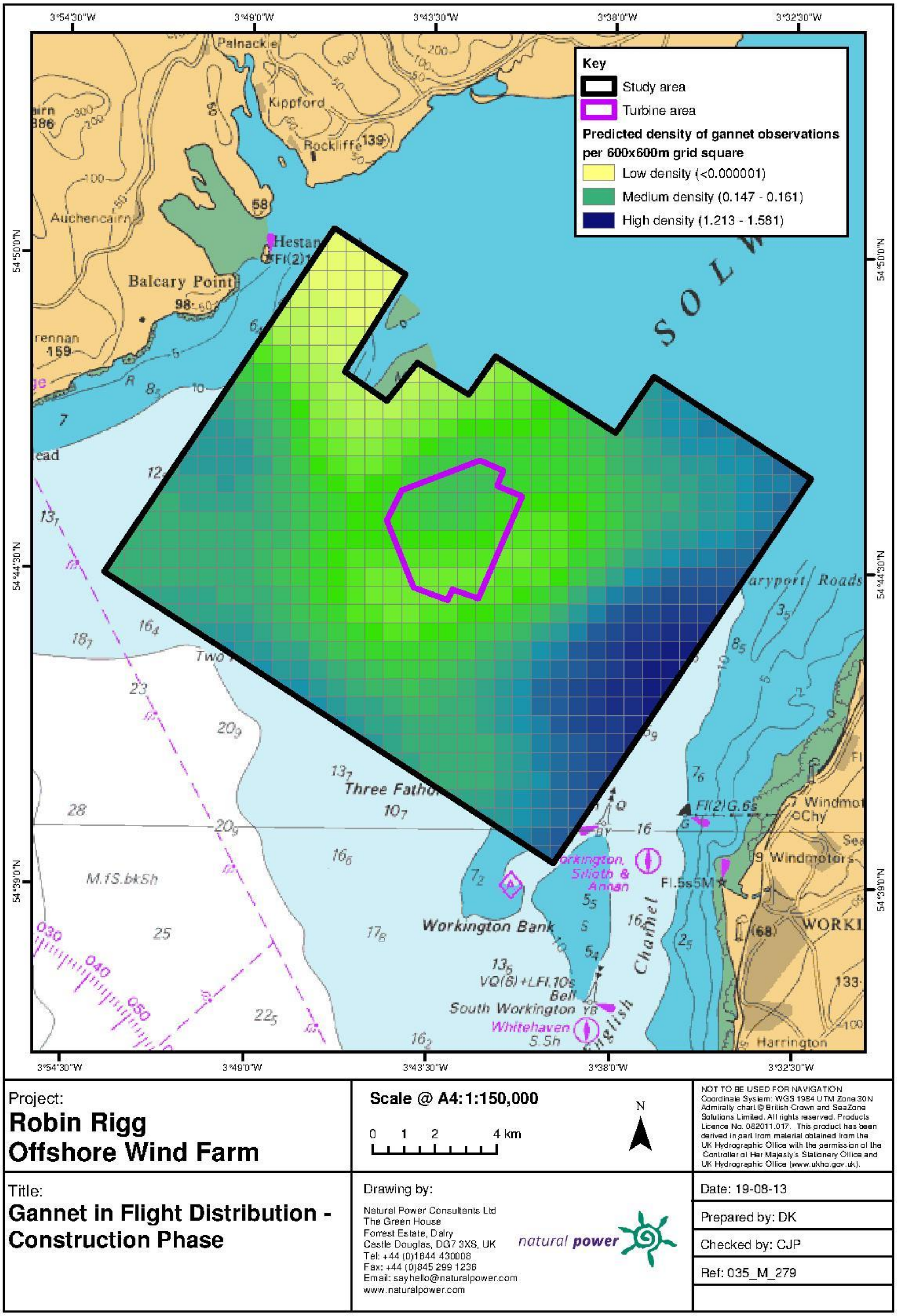


Figure 3.57: Density surface map of the predicted density of gannet in flight across the study area during the construction phase of the development.

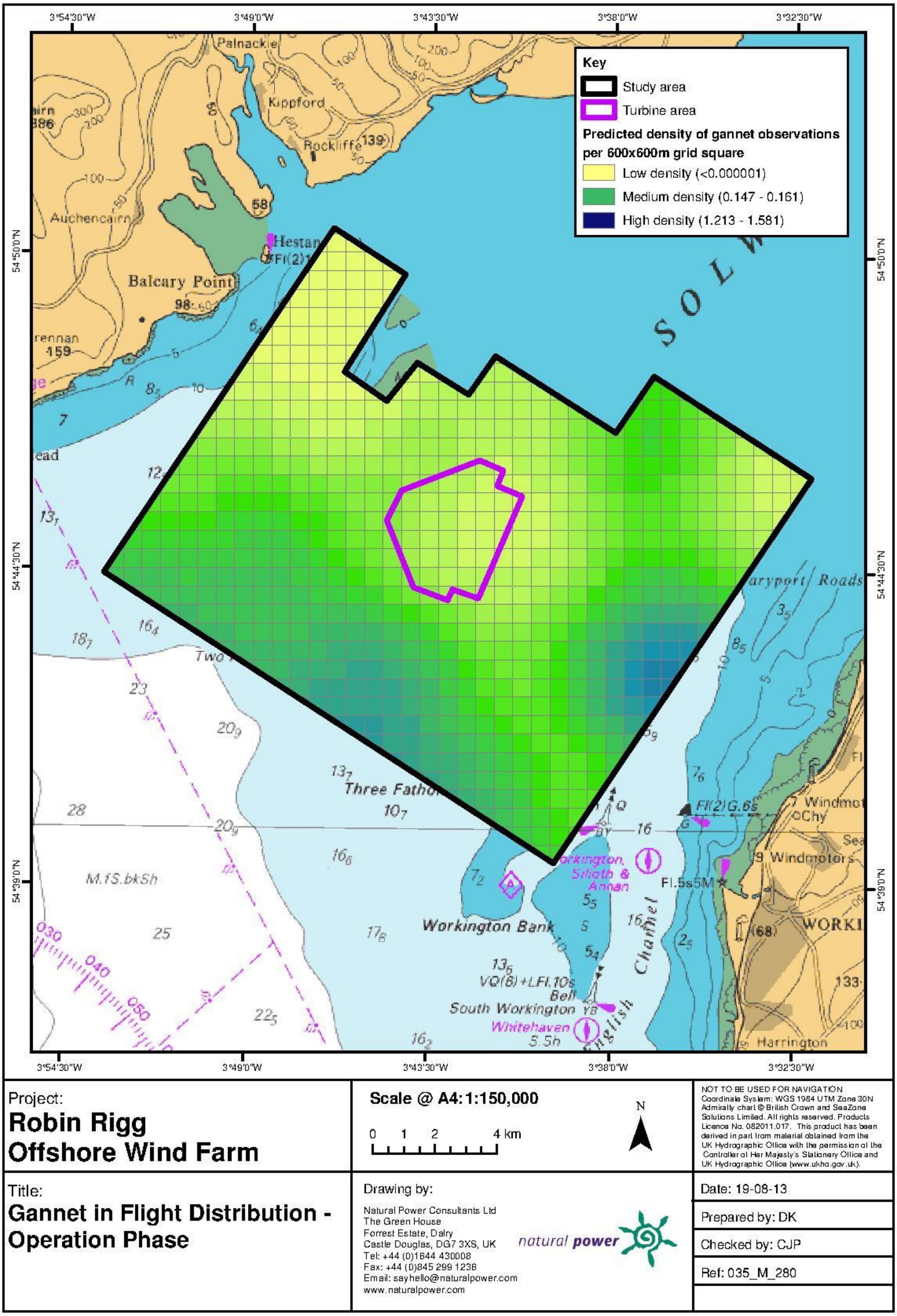


Figure 3.58: Density surface map of the predicted density of gannet in flight across the study area during the operational phase of the development.

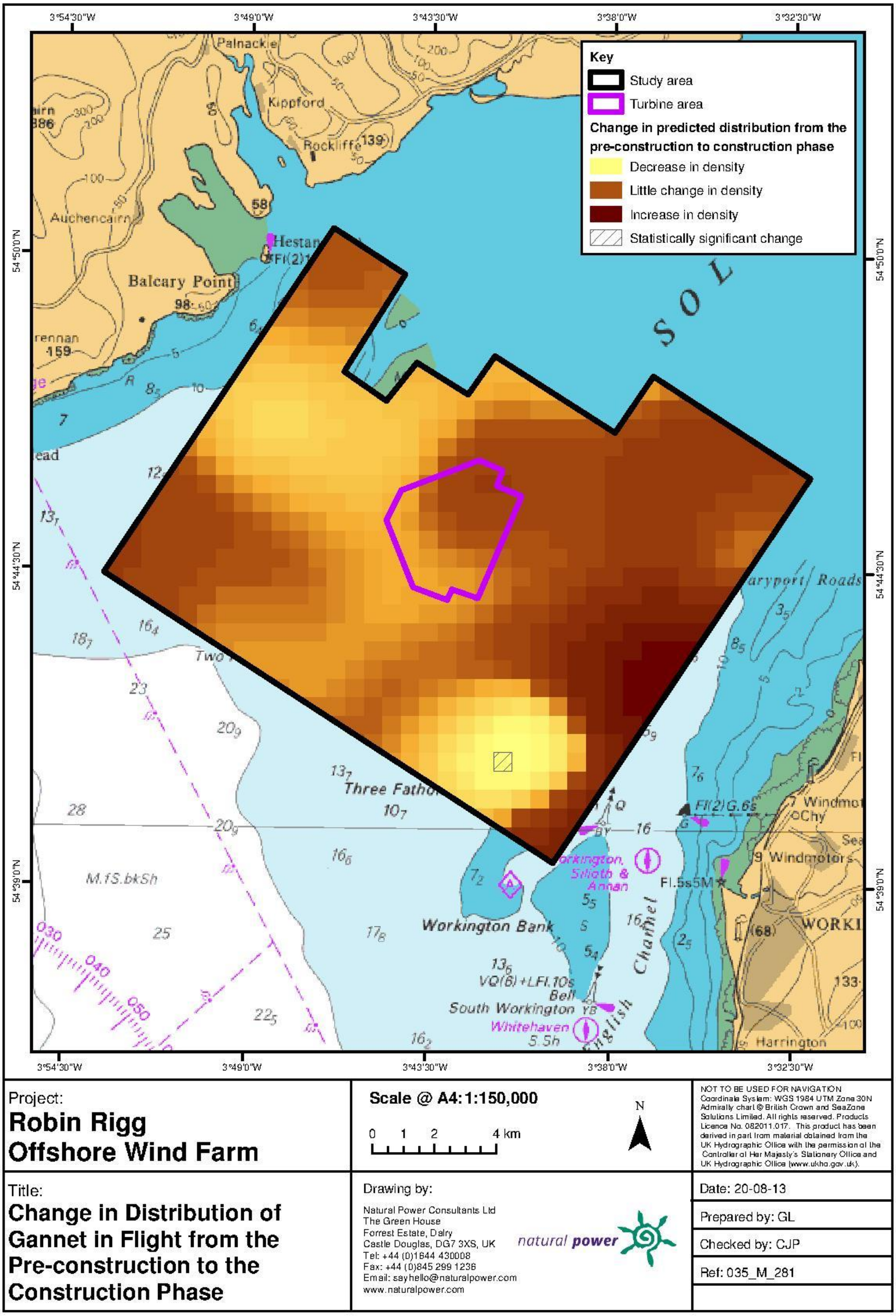


Figure 3.59: Plot of the difference in predicted density of gannets in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines.

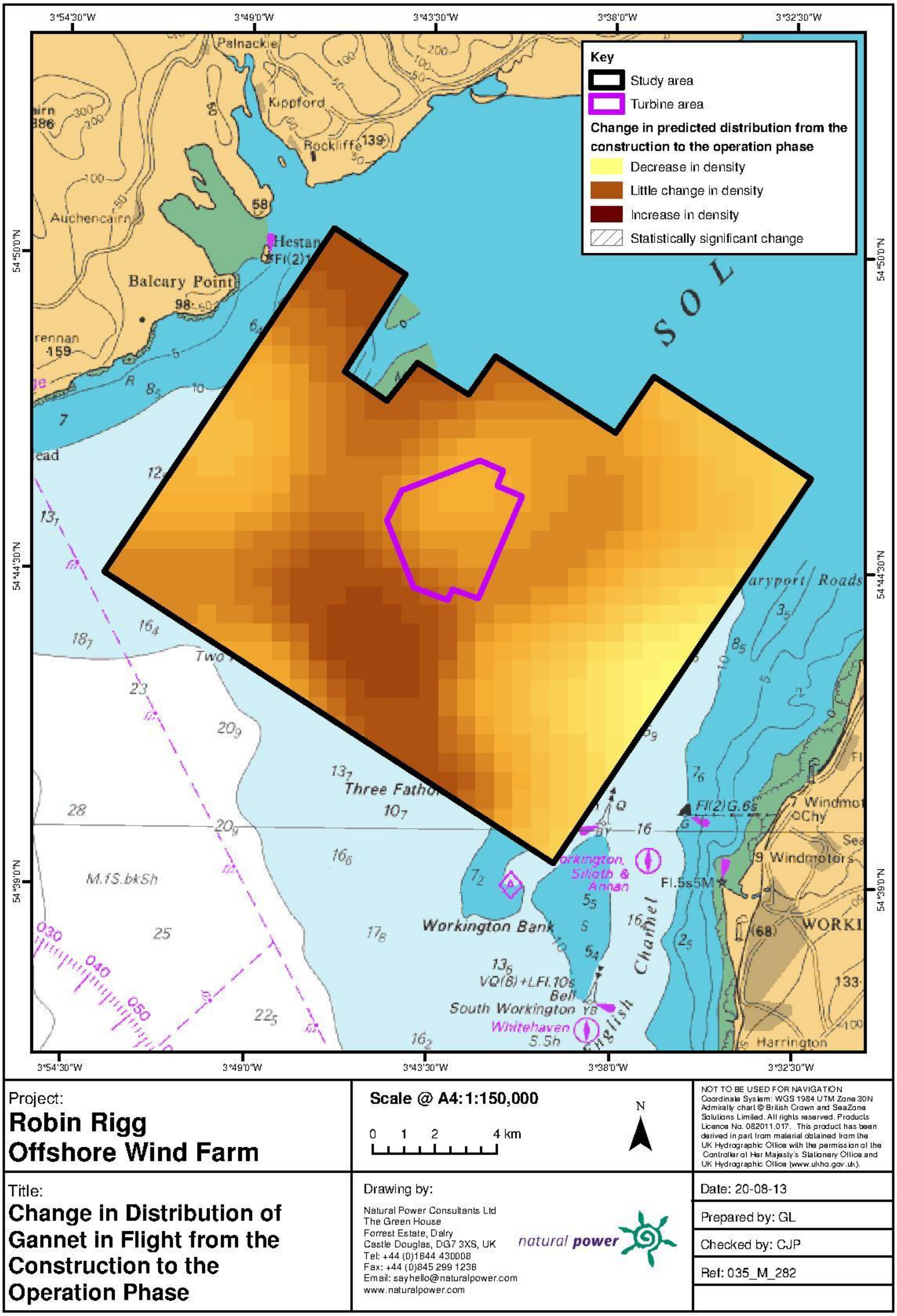


Figure 3.60: Plot of the difference in predicted density of gannets in flight between the construction and operation phases of the development. Significant differences are marked with diagonal lines.

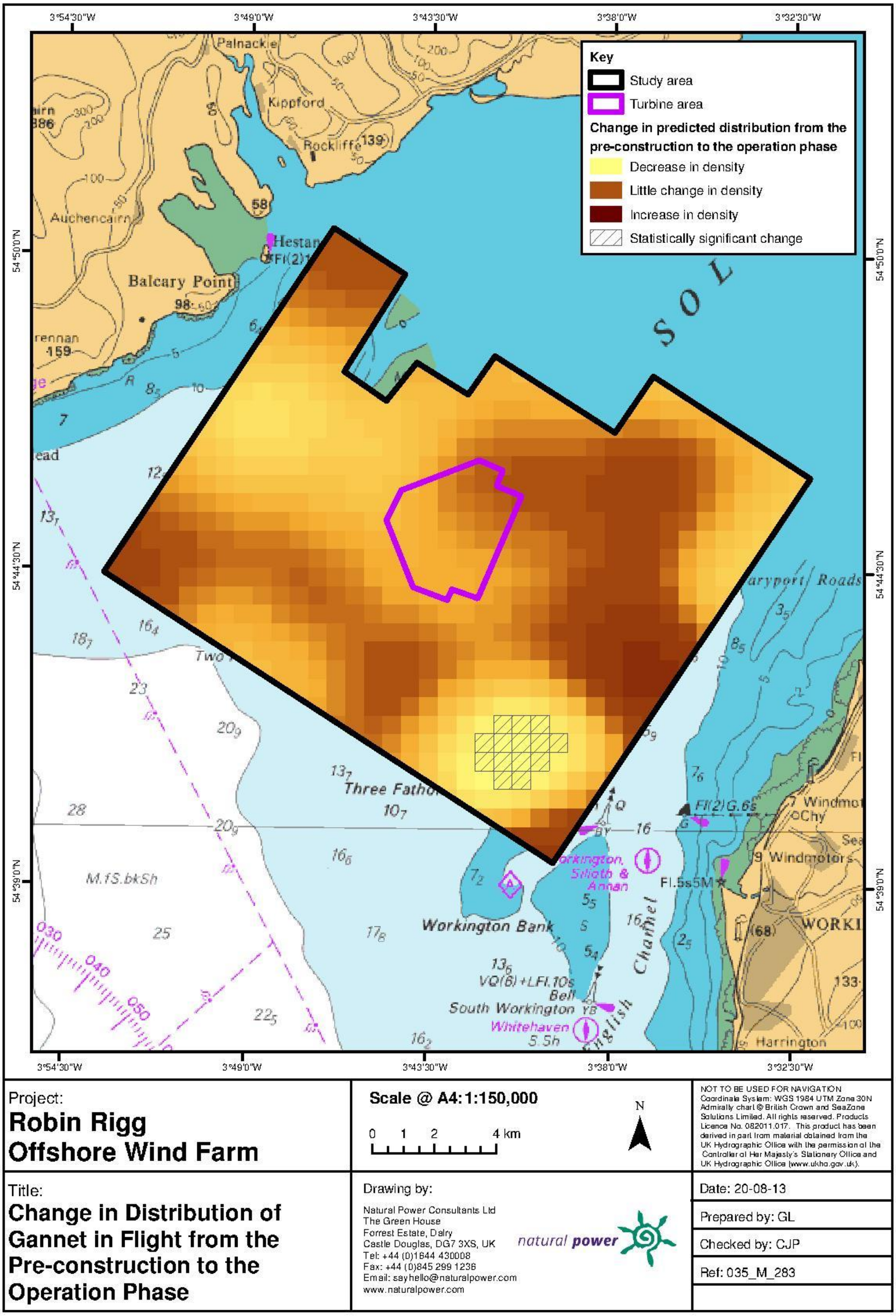


Figure 3.61: Plot of the difference in predicted density of gannets in flight between the pre-construction and operation phases of the development. Significant differences are marked with diagonal lines.

3.8.3. Collision risk

The percentage of gannet recorded in different height bands relative to rotor height can be found in Table 3.25 and Figure 3.62. The band 35-125 represents rotor height. While the majority of flights were recorded below rotor height, sufficient were recorded in Band 4 to justify Chi Square analysis. Data were combined for Chi-squared analysis. As no birds were observed at rotor height pre-construction, only the construction and operational data were tested. No significant difference was found between flight bands across the two periods ($\chi^2 = 2.77$, $p = 0.10$, 1 df).

Table 3.25: Proportion of gannet recorded at different flight height bands through the different stages of the development. No birds were recorded above rotor height.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	33	65	2	0	0	0
Construction	27	61	8	4	0	0
Operation	57	32	5	6	0	0

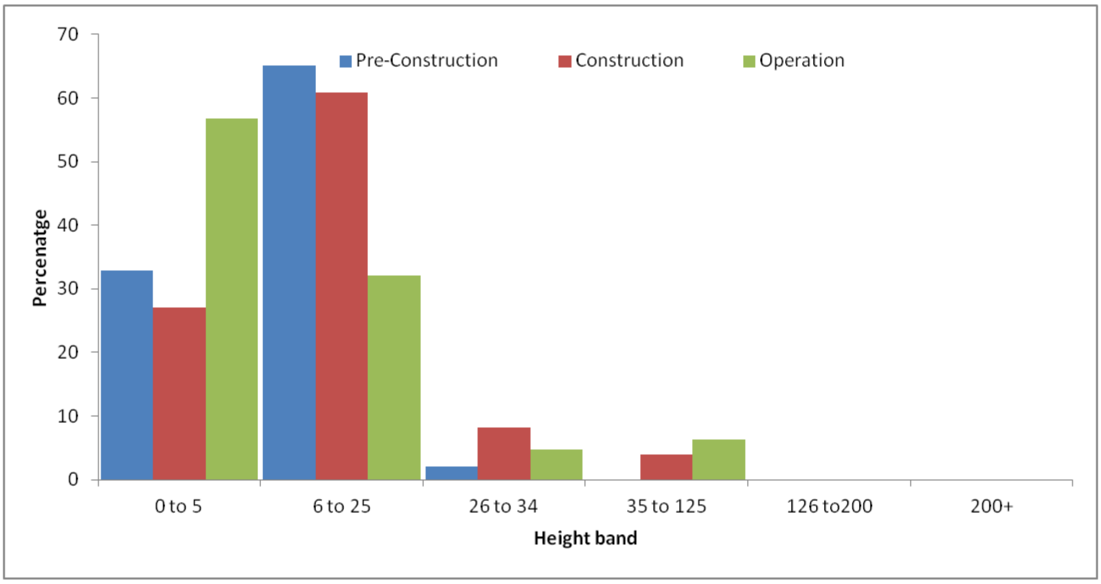


Figure 3.62: Percentage of gannet recorded in different flight bands during the different stages of the development. Figures in brackets represent total number.

3.9. Results: Cormorant

3.9.1. Summary statistics

The number of cormorant recorded during each of the three development phases can be found in Table 3.26. The average group size observed through the different phases of the development can be found in Figure 3.64.

The raw data suggest an increase in abundance during the construction and operational phases despite fewer cormorants being observed in operational year two compared to one. More cormorants have been observed during the winter months during and after construction of the wind farm (Figure 3.63). The average group size observed through the different phases of the development appears to have increased dramatically (Figure 3.64).

Table 3.26: Raw data for cormorant recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	141/0.02	152/0.02	392/0.03	587/0.05	447/0.04	778/0.07
Total number individuals/IPUE	260/0.04	192/0.03	1800/0.15	1552/0.13	1857/0.18	1786/0.17

Table 3.27: Standardised data for cormorant recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	9	0.06	50	0.02	57	0.35	70	0.03	266	0.68	357	0.07
Number per km^2	0.17		0.06		0.98		0.08		1.90		0.20	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	6	0.04	59	0.02	58	0.36	366	0.14	73	0.19	641	0.12
Number per km^2	0.11		0.06		1.01		0.39		0.53		0.34	

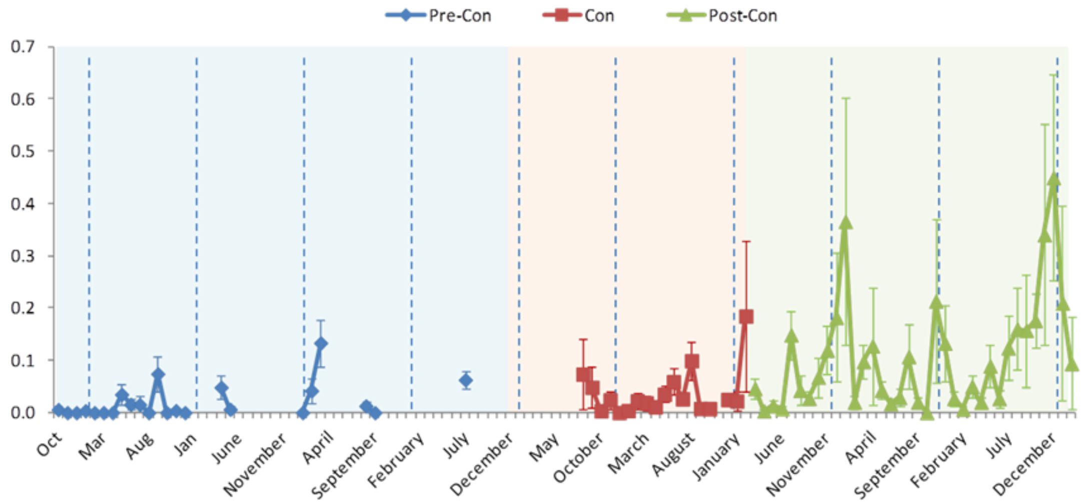


Figure 3.63: Mean number of cormorant observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

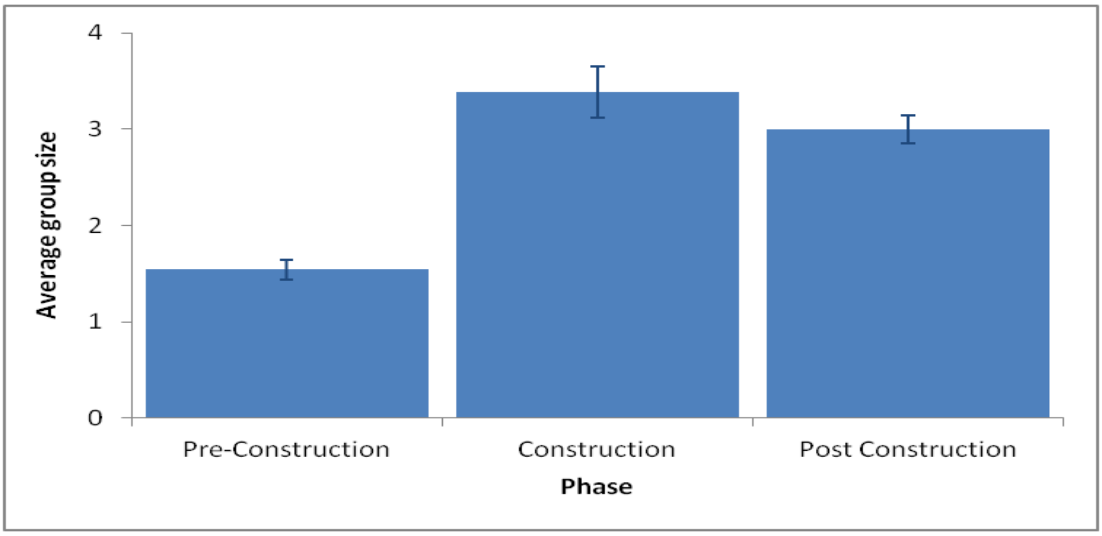


Figure 3.64: Mean group size for cormorant observed per sighting during the pre-construction, construction and operational phases (±standard error)

3.9.2. Distribution and abundance

The standardised raw data suggest an increase in abundance during the construction and operational phases. This pattern is reflected in the model outputs (Table 3.27). Changes in overall abundances are either weakly or non-significant (Table 3.28 and Table 3.29) however the density surface maps demonstrate clear significant changes in distribution (Figure 3.67 through to Figure 3.78) with many more cormorants observed on the sea within the site boundary during the construction and operational phases.

Table 3.28: Model outputs for cormorant on the sea

Comparison	Parameter Estimate	Standard error	t-value	P
Pre-construction to construction.	0.396	0.617	0.641	0.5216
Pre-construction to operation.	0.433	0.615	0.704	0.4814

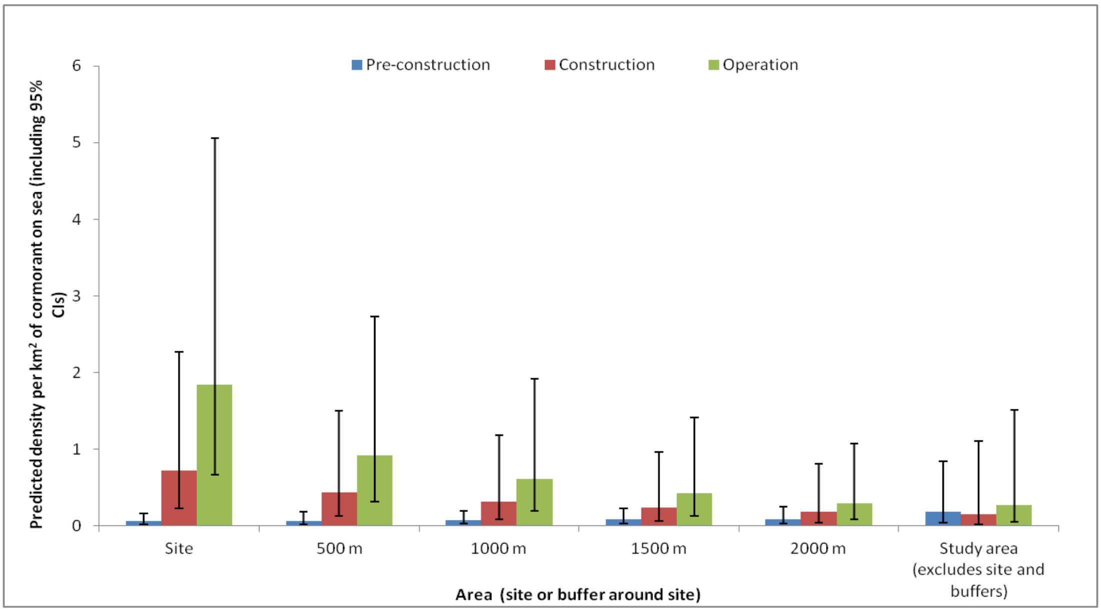


Figure 3.65: Predicted density of cormorants on the sea for August (with 95% confidence intervals)

Table 3.29: Model outputs for cormorant in flight

Comparison	Estimate	Standard error	t-value	P
Pre-construction to construction	0.759	0.433	1.752	0.0798
Pre-construction to operation	0.877	0.386	2.272	0.0231 *

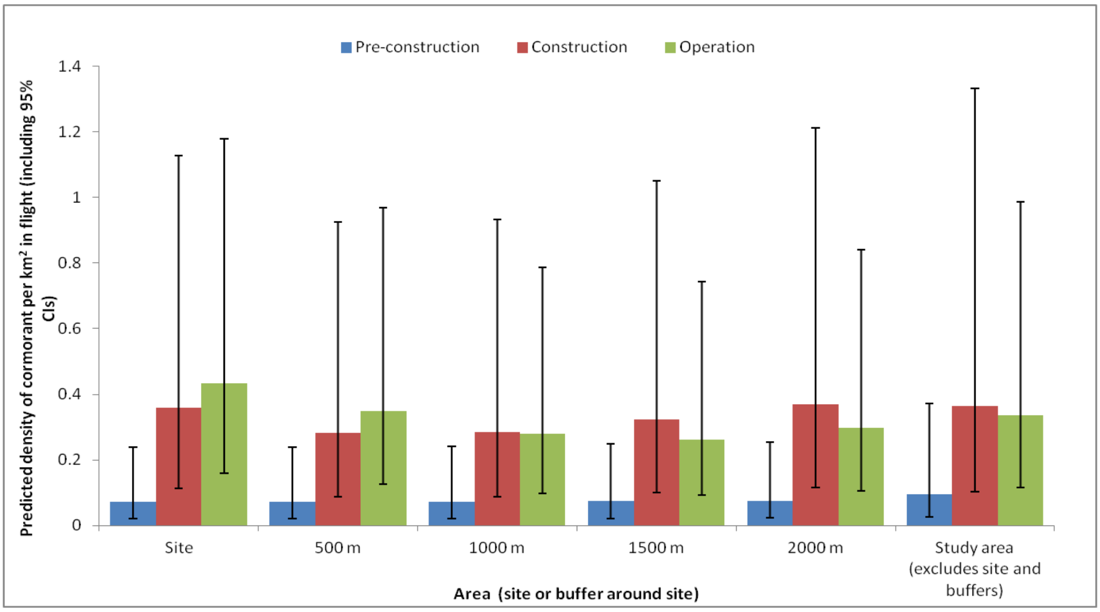


Figure 3.66: Predicted density of cormorants in flight for January (with 95% confidence intervals)

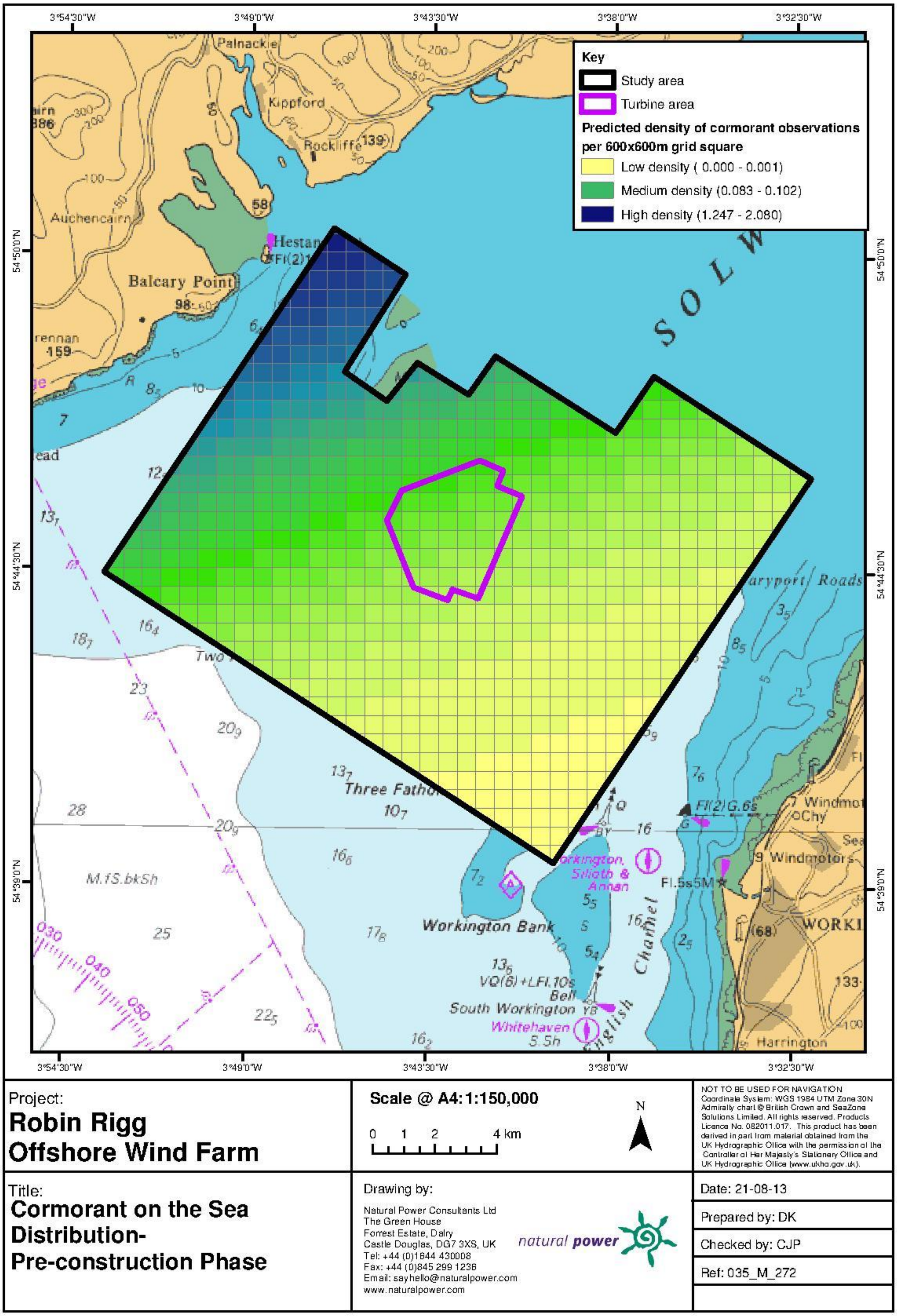


Figure 3.67: Density surface map of the predicted density of cormorants on the sea across the study area during the pre-construction phase of the development

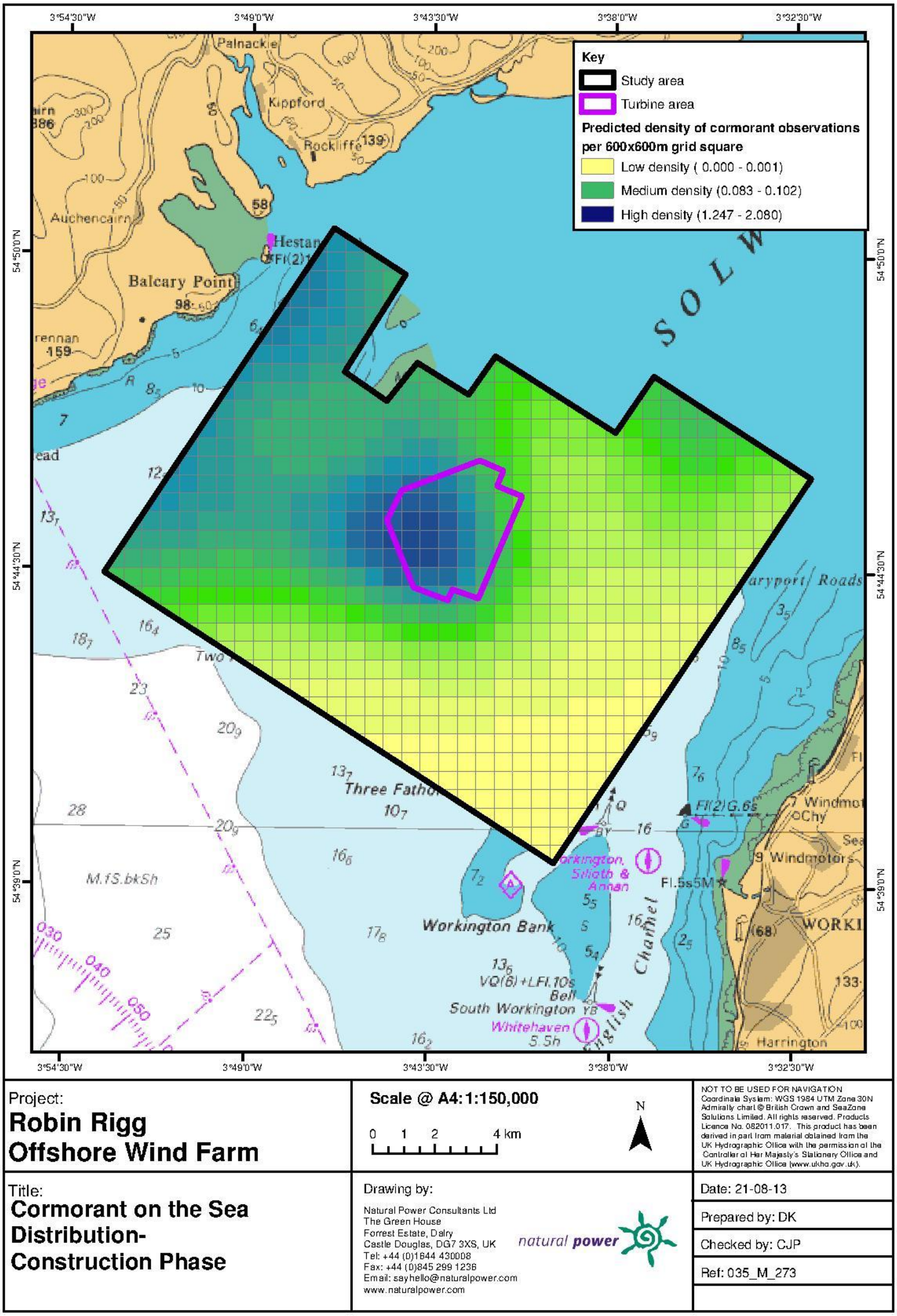


Figure 3.68: Density surface map of the predicted density of cormorants on the sea across the study area during the construction phase of the development

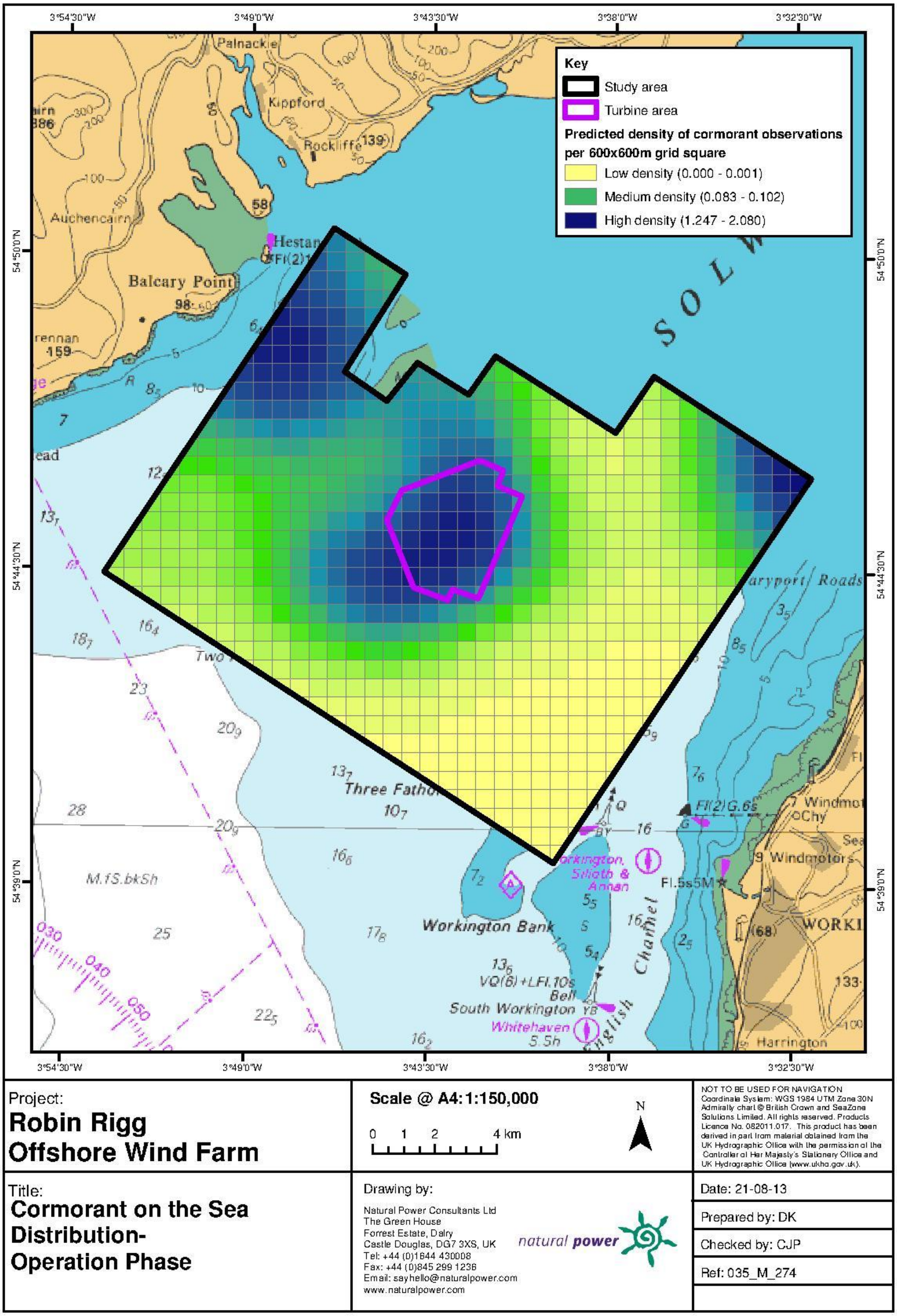


Figure 3.69: Density surface map of the predicted density of cormorants on the sea across the study area during the operational phase of the development

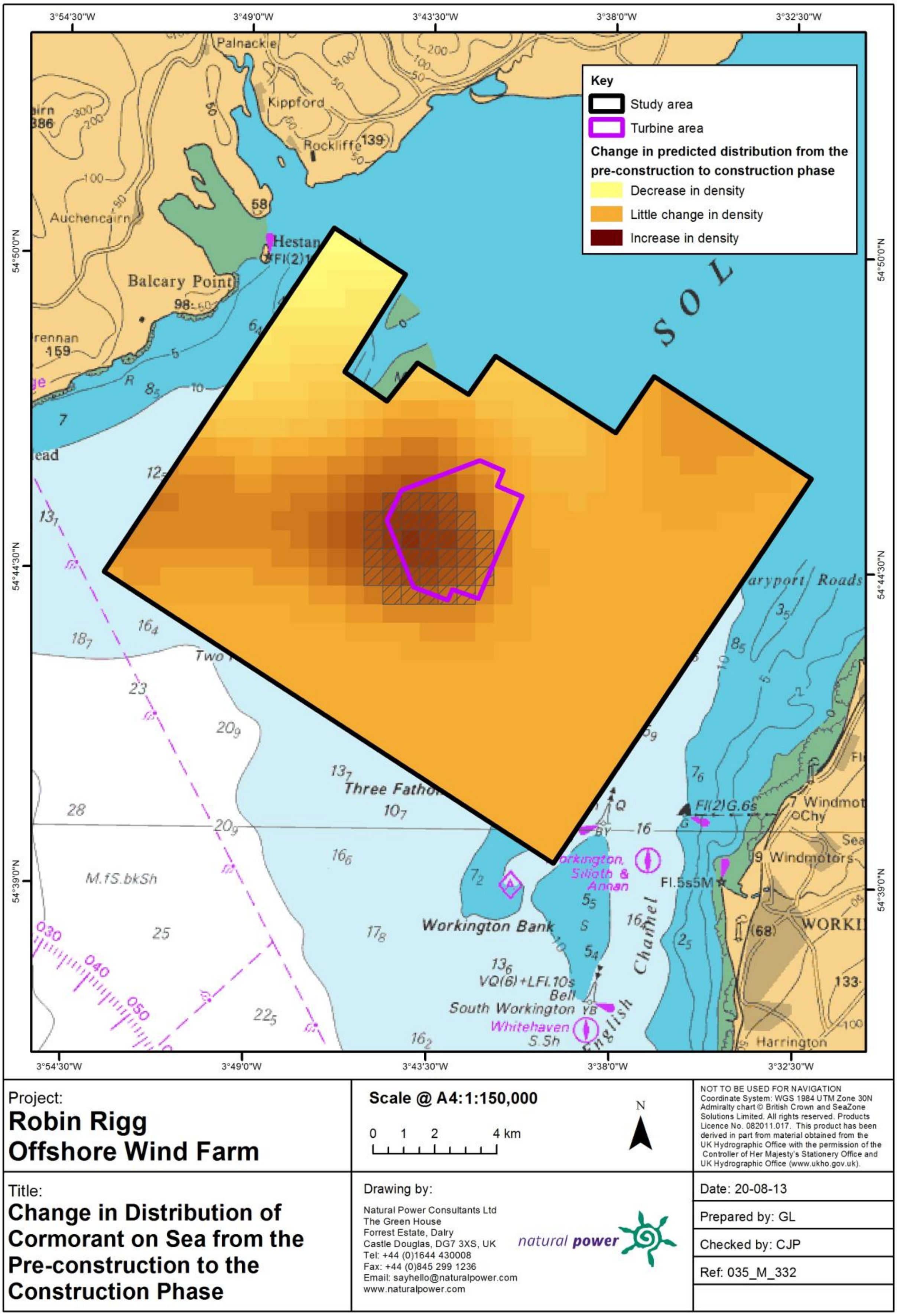
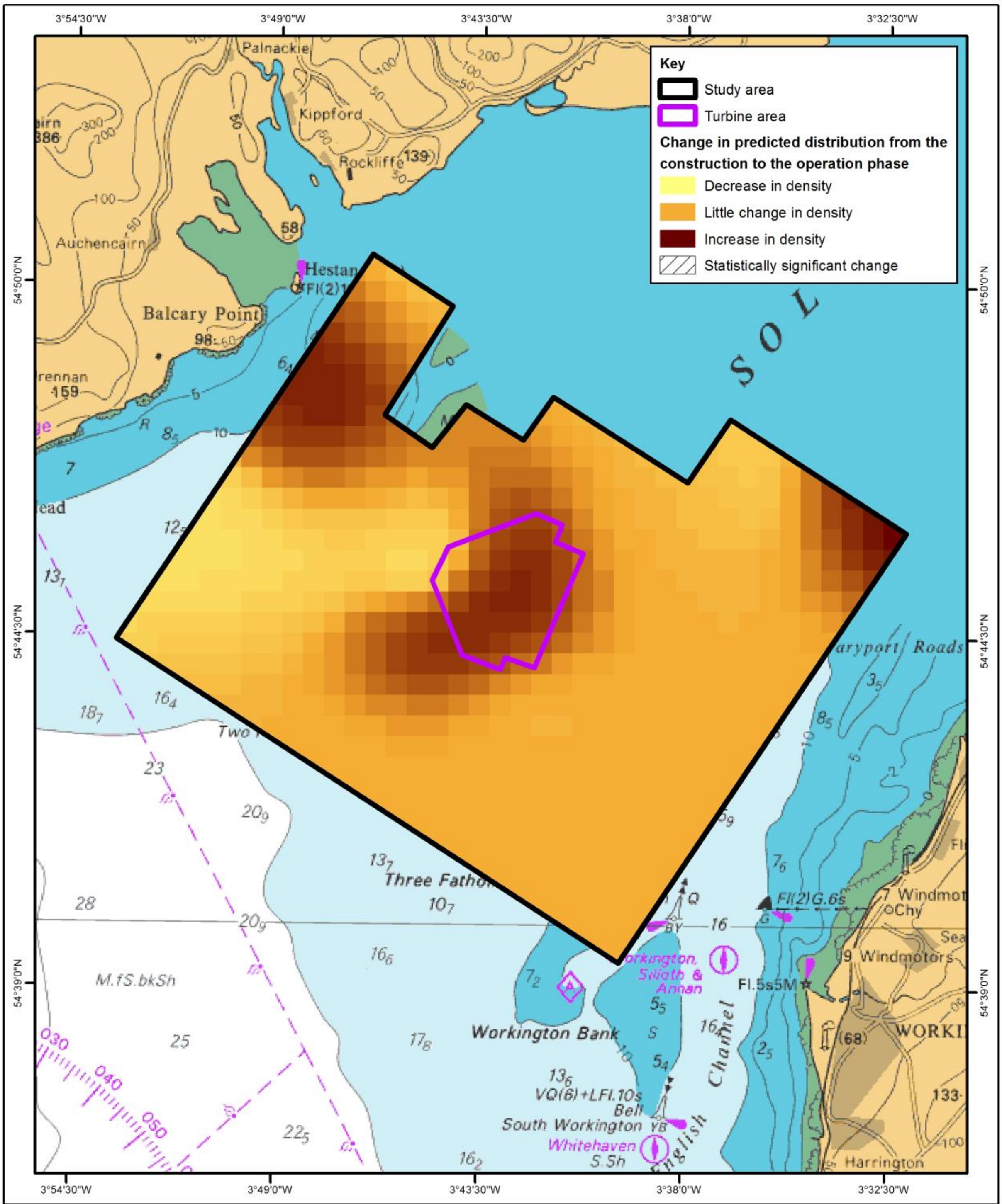


Figure 3.70: Plot of the difference in predicted density of cormorants on the sea between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Cormorant on Sea from the Construction to the Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_333

Figure 3.71: Plot of the difference in predicted density of cormorants on the sea between the construction and operational phases of the development. Significant differences are marked with diagonal lines

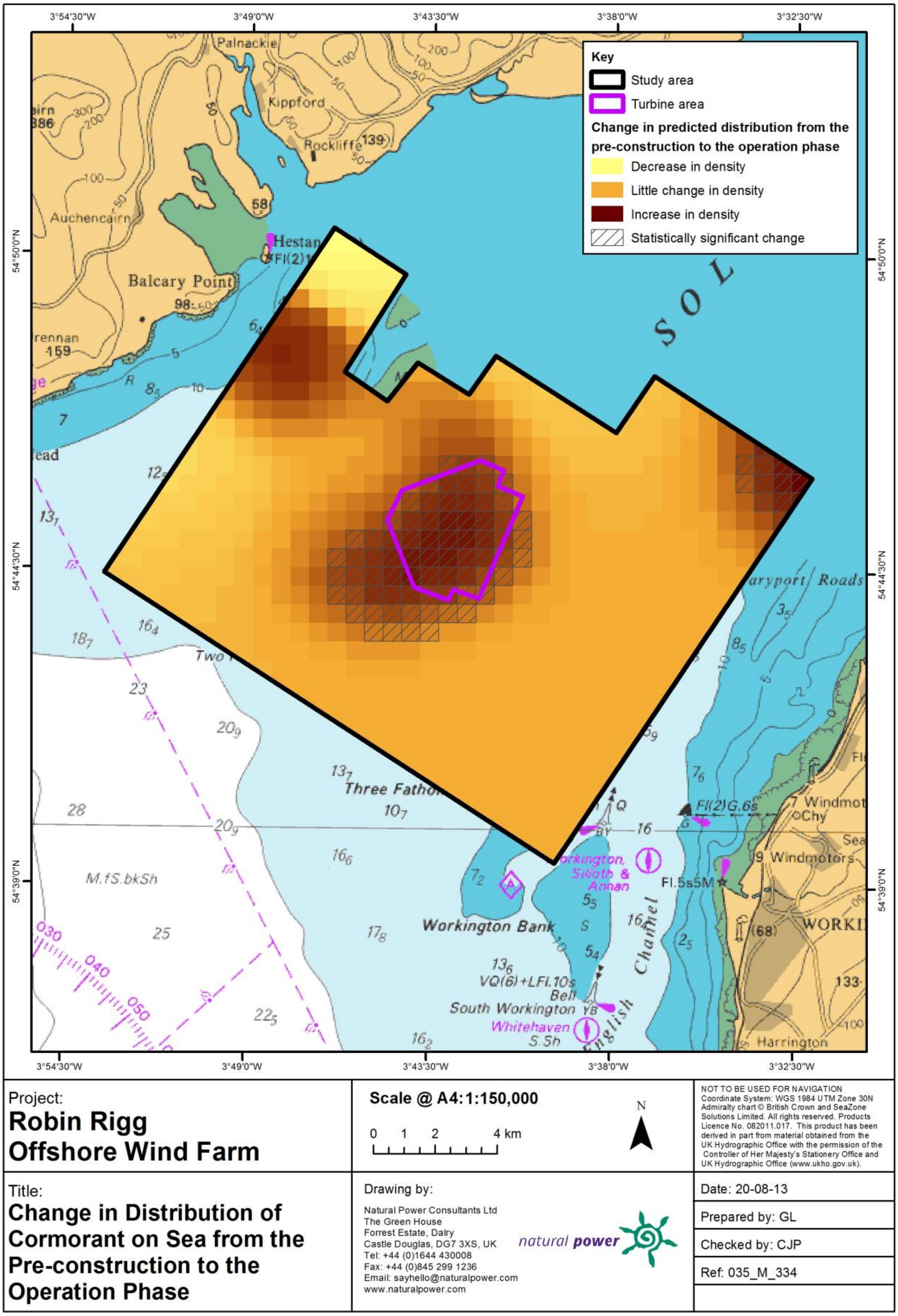
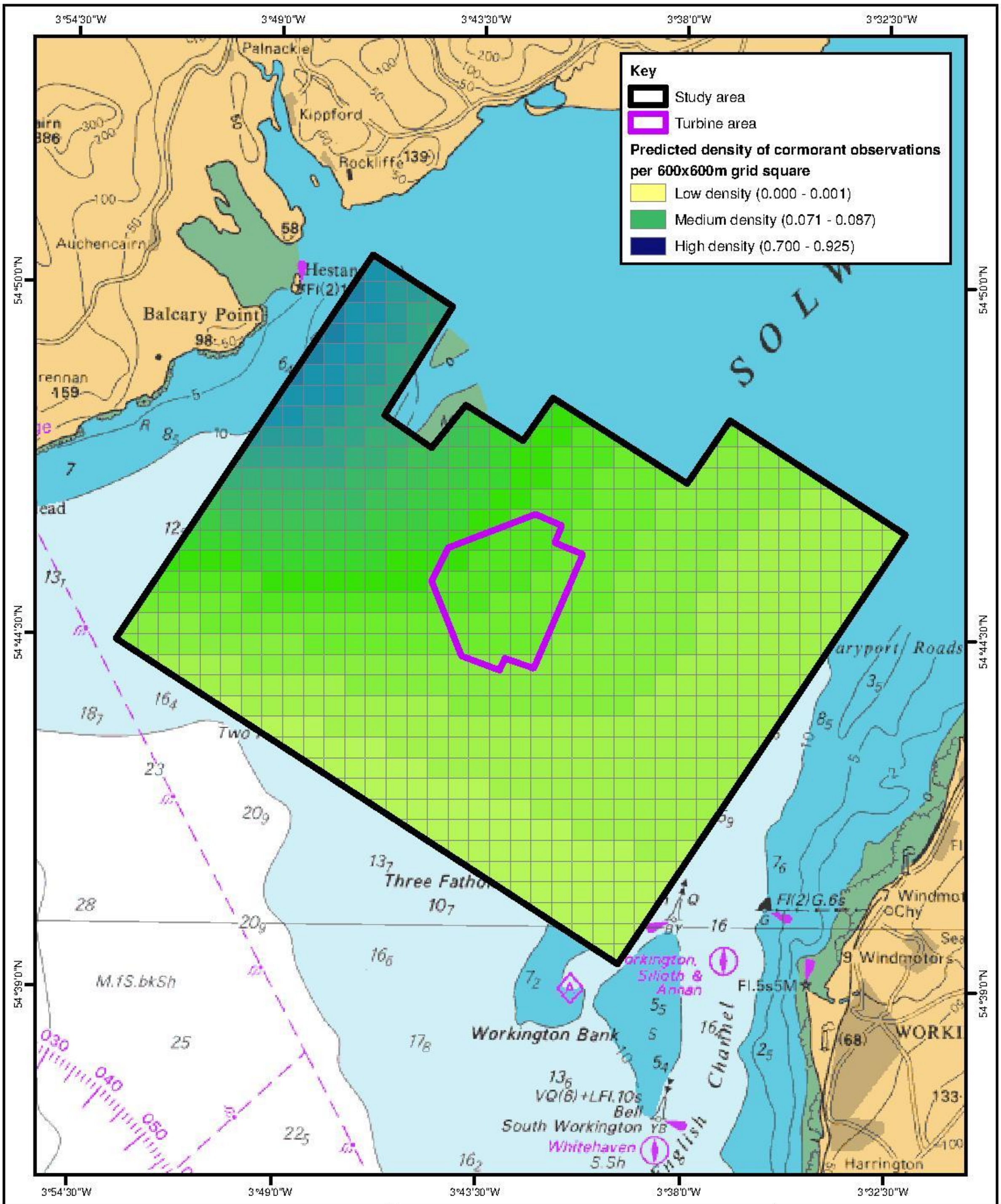


Figure 3.72: Plot of the difference in predicted density of cormorants on the sea between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines



Project: **Robin Rigg Offshore Wind Farm**	**Scale @ A4:1:150,000** 0 1 2 4 km N	NOT TO BE USED FOR NAVIGATION Coordinate System: WGS 1984 UTM Zone 30N Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).
Title: **Cormorant in Flight Distribution- Pre-construction Phase**	Drawing by: Natural Power Consultants Ltd The Green House Forrest Estate, Dalry Castle Douglas, DG7 3XS, UK Tel: +44 (0)1644 430008 Fax: +44 (0)845 299 1236 Email: sayhello@naturalpower.com www.naturalpower.com natural power	Date: 21-08-13 Prepared by: DK Checked by: CJP Ref: 035_M_314

Figure 3.73: Density surface map of the predicted density of cormorants in flight across the study area during the pre-construction phase of the development

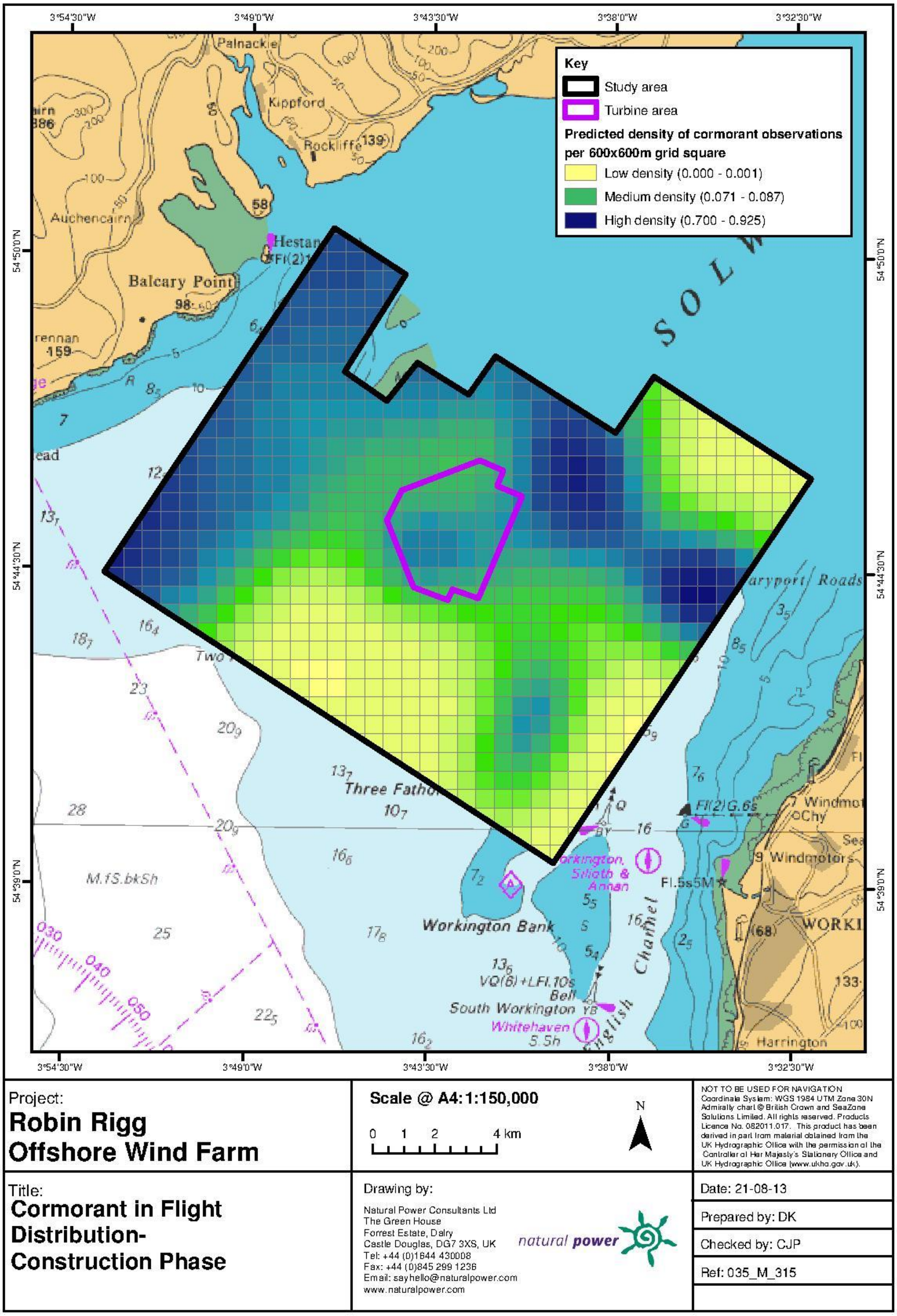


Figure 3.74: Density surface map of the predicted density of cormorants in flight across the study area during the construction phase of the development

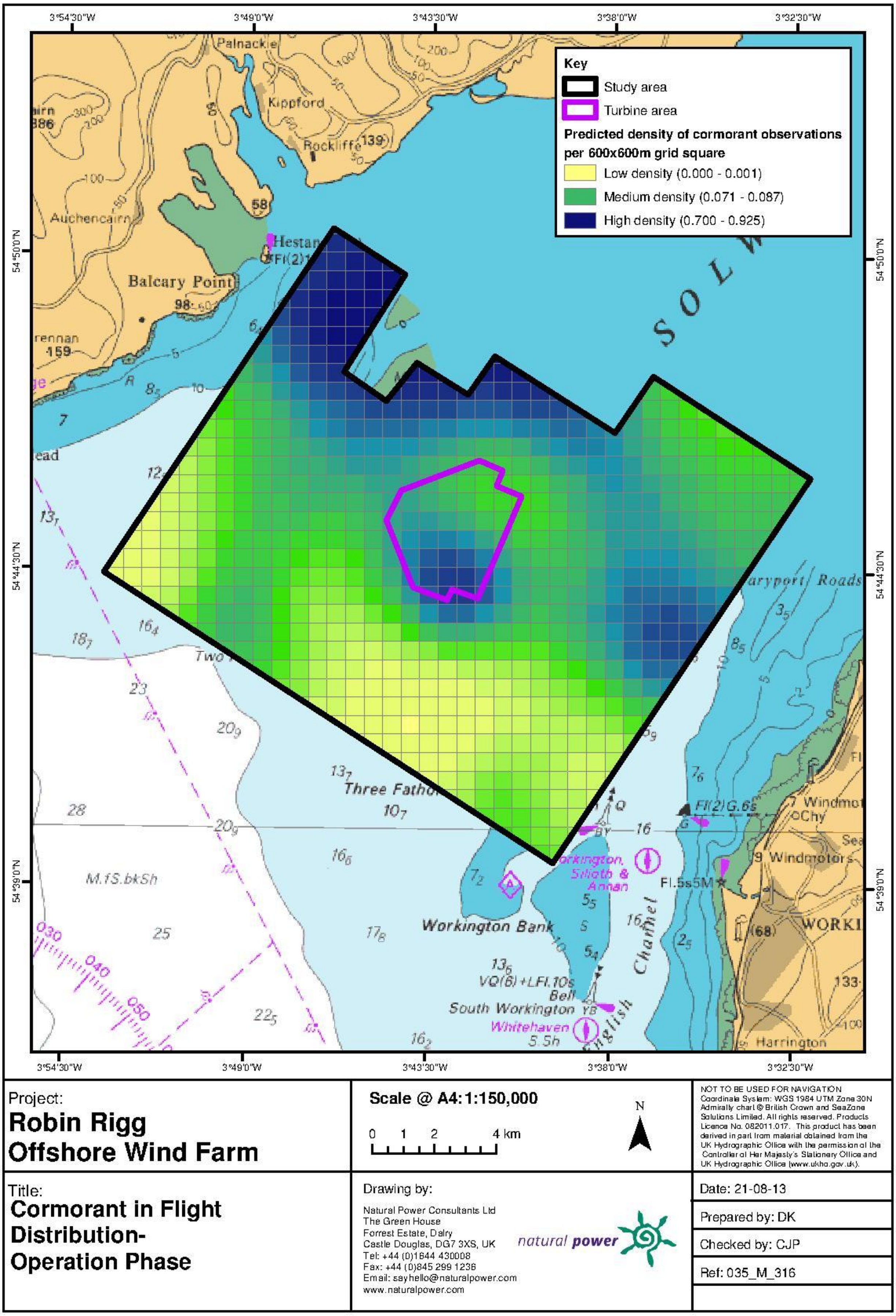
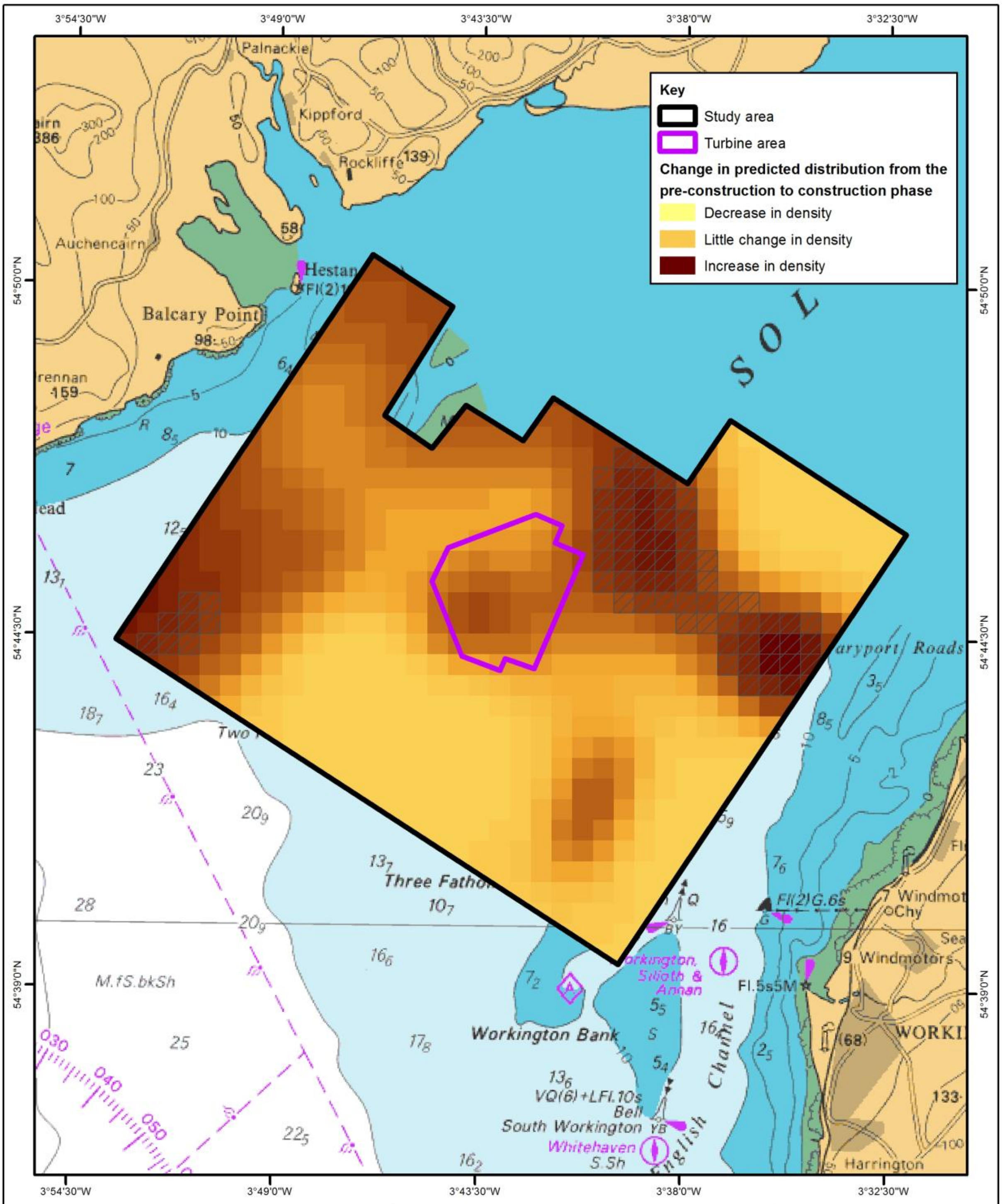
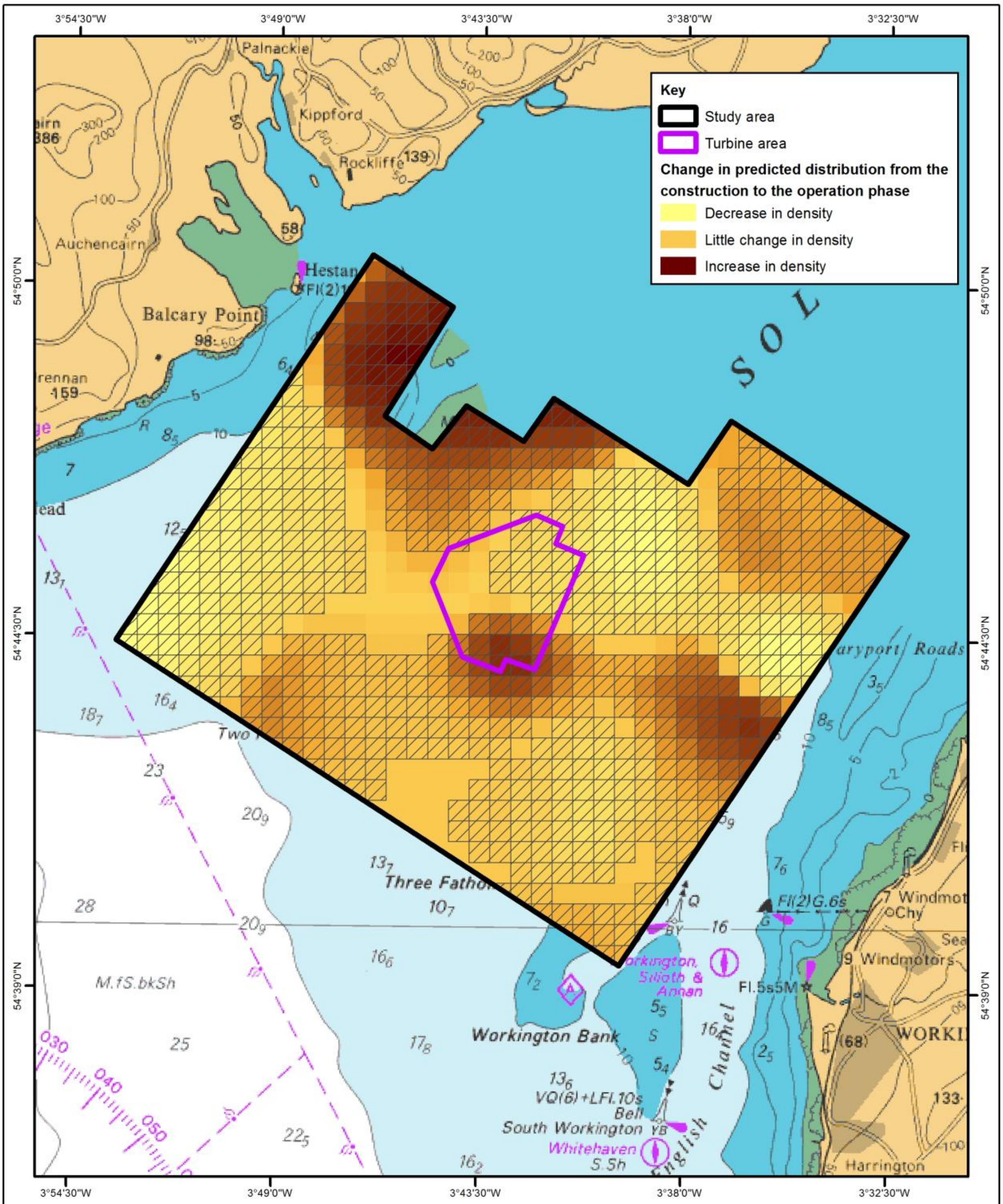


Figure 3.75: Density surface map of the predicted density of cormorants in flight across the study area during the operational phase of the development



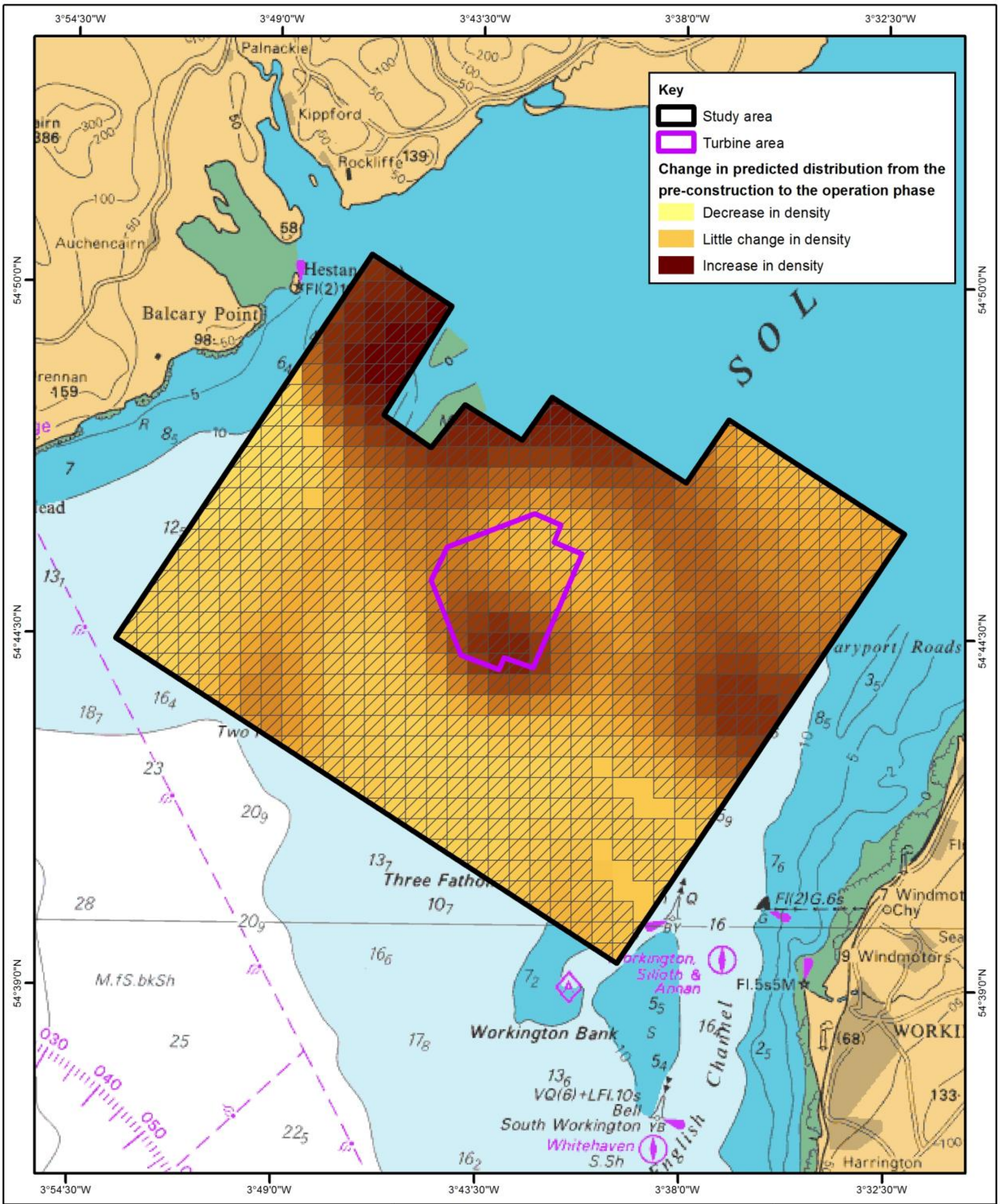
Project: **Robin Rigg Offshore Wind Farm**	Scale @ A4:1:150,000 0 1 2 4 km	NOT TO BE USED FOR NAVIGATION Coordinate System: WGS 1984 UTM Zone 30N Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).
Title: **Change in Distribution of Cormorant in Flight from the Pre-construction to the Construction Phase**	Drawing by: Natural Power Consultants Ltd The Green House Forrest Estate, Dalry Castle Douglas, DG7 3XS, UK Tel: +44 (0)1644 430008 Fax: +44 (0)845 299 1236 Email: sayhello@naturalpower.com www.naturalpower.com natural power	Date: 20-08-13 Prepared by: GL Checked by: CJP Ref: 035_M_334

Figure 3.76: Plot of the difference in predicted density of cormorants in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project: **Robin Rigg Offshore Wind Farm**	**Scale @ A4:1:150,000** 0 1 2 4 km N	NOT TO BE USED FOR NAVIGATION Coordinate System: WGS 1984 UTM Zone 30N Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).
Title: **Change in Distribution of Cormorant in Flight from the Construction to the Operation Phase**	Drawing by: Natural Power Consultants Ltd The Green House Forrest Estate, Dalry Castle Douglas, DG7 3XS, UK Tel: +44 (0)1644 430008 Fax: +44 (0)845 299 1236 Email: sayhello@naturalpower.com www.naturalpower.com natural power	Date: 20-08-13 Prepared by: GL Checked by: CJP Ref: 035_M_336

Figure 3.77: Plot of the difference in predicted density of cormorants in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Cormorant in Flight from the Pre-construction to the Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13

Prepared by: GL

Checked by: CJP

Ref: 035_M_337

Figure 3.78: Plot of the difference in predicted density of cormorants in flight between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

3.9.3. Collision risk

The percentage of cormorant recorded in different height bands relative to rotor height can be found in Table 3.30 and Figure 3.79. The band 4 (35-125 m) represents rotor height. Although a low number of cormorant were recorded at rotor height, it was still considered that this species is not generally at risk from collision and so Chi Squared was not attempted.

Table 3.30: Proportion of cormorant observed flying in different height bands through the three stages of the development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	75	24	1	0	0	0
Construction	65	33	2	1	0	0
Operation	79	16	4	2	0	0

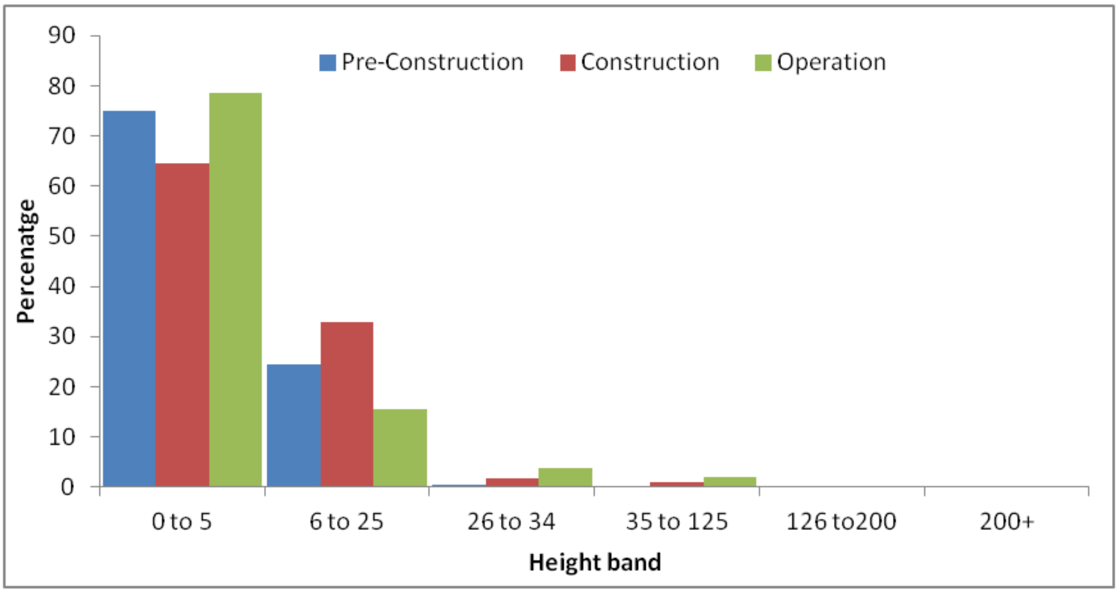


Figure 3.79: Percentage of cormorant recorded in different flight bands during the different stages of the development.

3.10. Results: Kittiwake

3.10.1. Summary statistics

The number of kittiwake recorded through the three phases of the development can be found in Table 3.31 and Table 3.32. The mean number of kittiwake recorded each month is presented in Figure 3.80 and average group size recorded in each of the three phases in Figure 3.81.

The raw data suggest that, overall, abundance within the study area has remained fairly constant during all periods. Monthly numbers of kittiwake observed during all operational years were similar although compared to pre-construction data they appear to be lower (Figure 3.80). The average group size observed through the different stages of the development can be found in Figure 3.81.

Table 3.31: Raw data for Kittiwake recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	168/0.03	298/0.05	408/0.03	495/0.04	340/0.03	467/0.04
Total number individuals/IPUE	443/0.07	992/0.08	883/0.07	946/0.08	840/0.08	691/0.07

Table 3.32: Standardised data for Kittiwake recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	10	0.06	188	0.08	5	0.03	133	0.05	153	0.39	478	0.09
Number per km^2	0.17		0.22		0.08		0.14		1.09		0.25	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	12	0.08	189	0.08	7	0.04	264	0.10	52	0.13	474	0.09
Number per km^2	0.22		0.22		0.11		0.28		0.36		0.25	

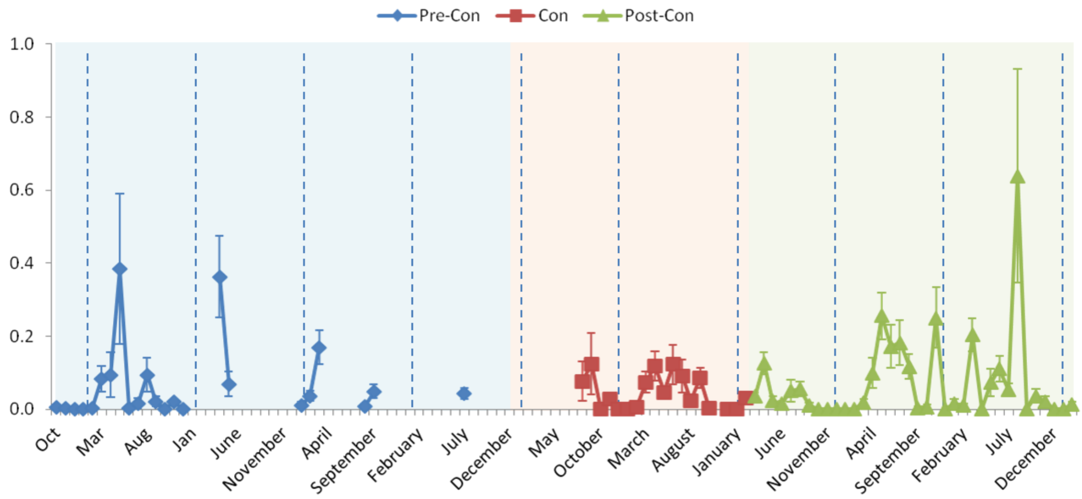


Figure 3.80: Mean number of kittiwake observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

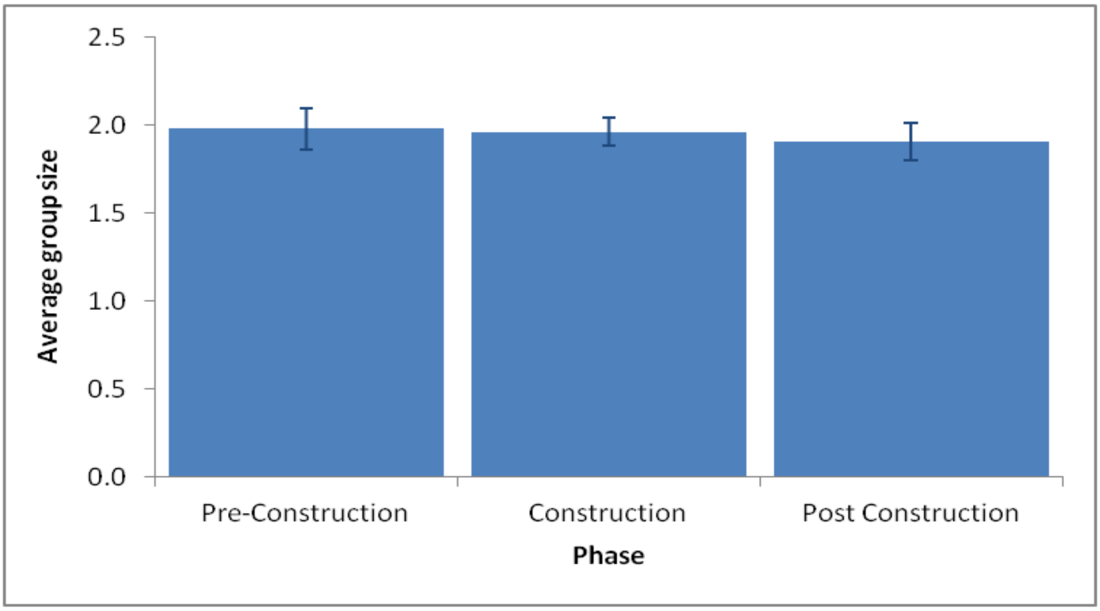


Figure 3.81: Mean group size for kittiwake observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.10.2. Distribution and abundance

The standardised raw data suggest there are fewer kittiwakes on the sea within the wind farm site during the construction period (Table 3.32). The model outputs however suggest little change in abundance between pre-construction and construction. Both the model and the standardised raw data suggest an increase in abundance during the operational phase. There is evidence of greater usage of the wind farm site during operation for kittiwake on the sea (Figure 3.82 and Figure 3.89).

The standardised raw data suggest kittiwakes in flight are reflecting patterns seen for birds on sea. The models, however, do not provide any evidence of change in abundance between the three phases. There may have been slight avoidance of the wind farm site during the construction period (Figure 3.82) but this is not significant.

Table 3.33: Model outputs for kittiwake on the sea

Comparison	Estimate	Standard error	t-value	P
Pre-construction to construction	0.072	0.566	0.126	0.899
Pre-construction to operation	0.623	0.490	1.272	0.203

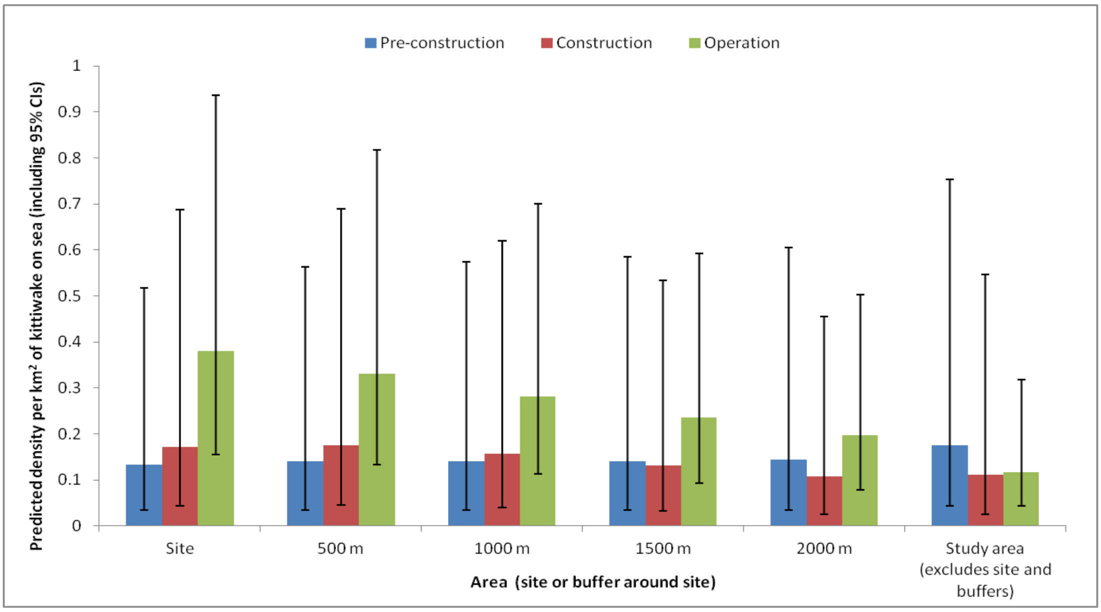


Figure 3.82: Predicted density of kittiwake on the sea in May (with 95% confidence intervals)

Table 3.34: Model outputs for kittiwake in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-0.175	0.366	-0.478	0.6323
Pre-construction to operation	-0.202	0.317	-0.638	0.5236

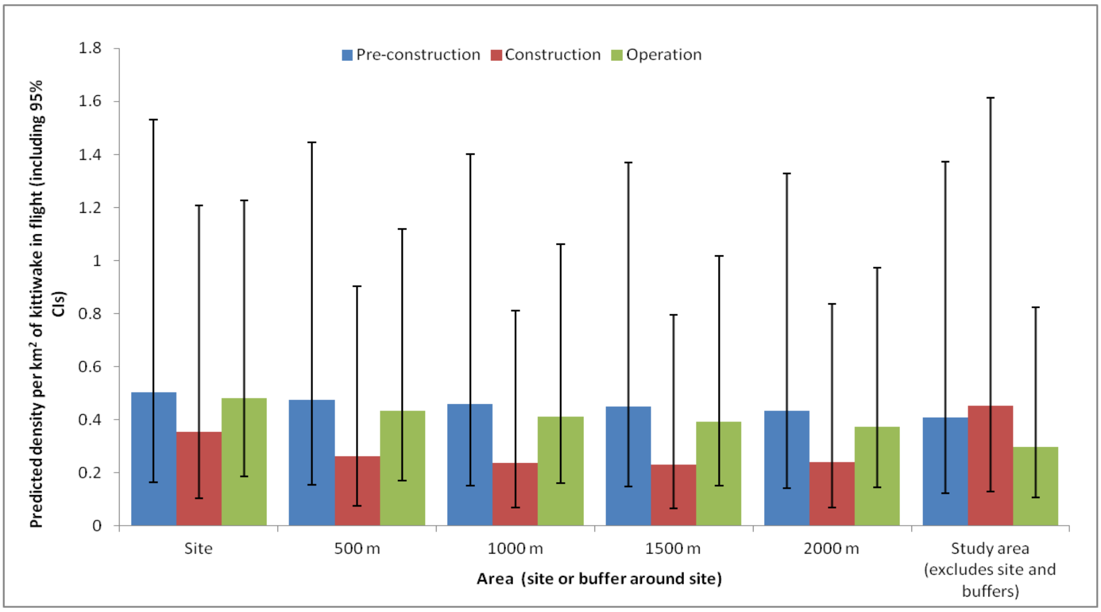


Figure 3.83: Predicted density of kittiwake in flight for June (with 95% confidence intervals)

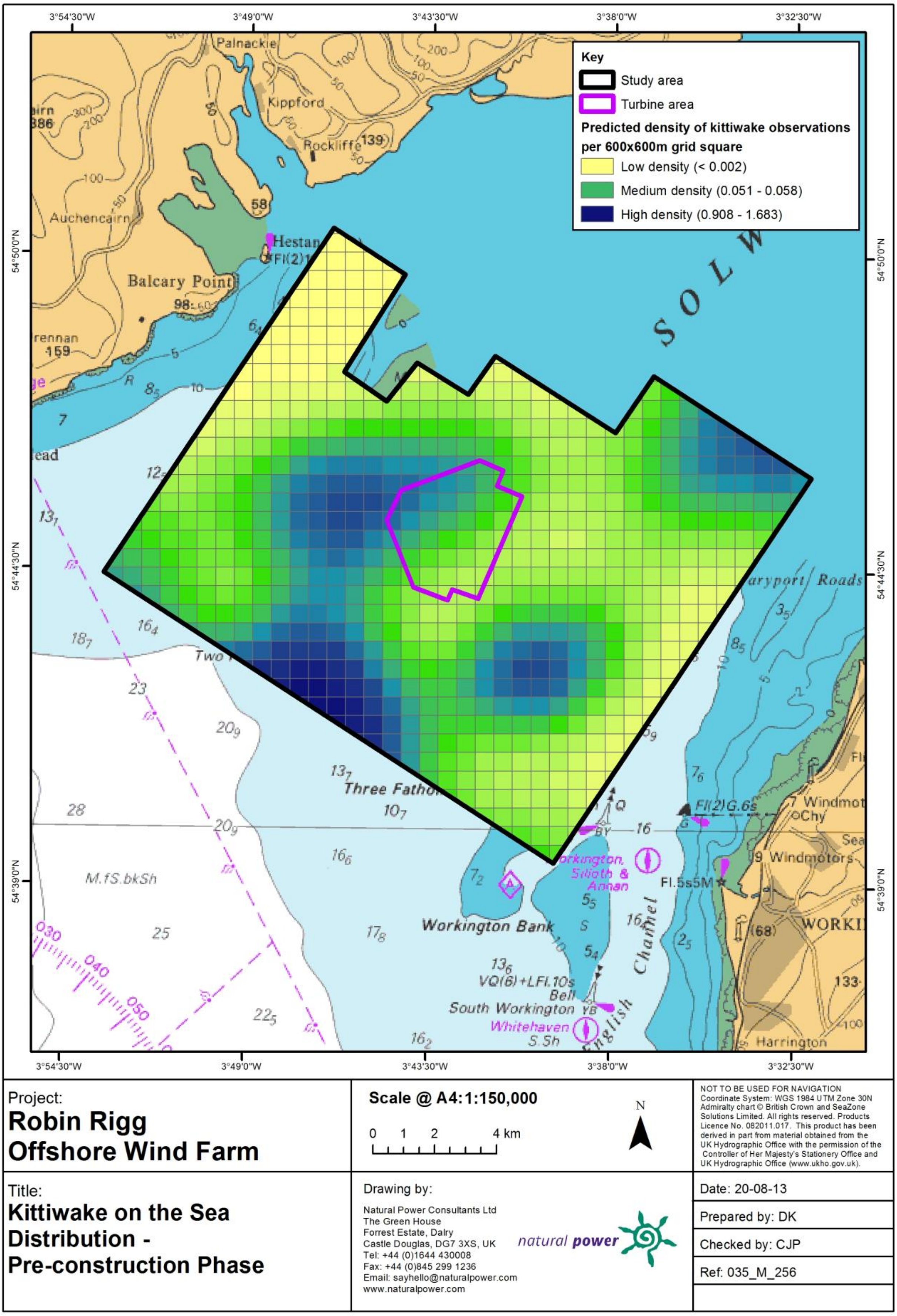


Figure 3.84: Density surface map of the predicted density of kittiwake on the sea across the study area during the pre-construction phase of the development

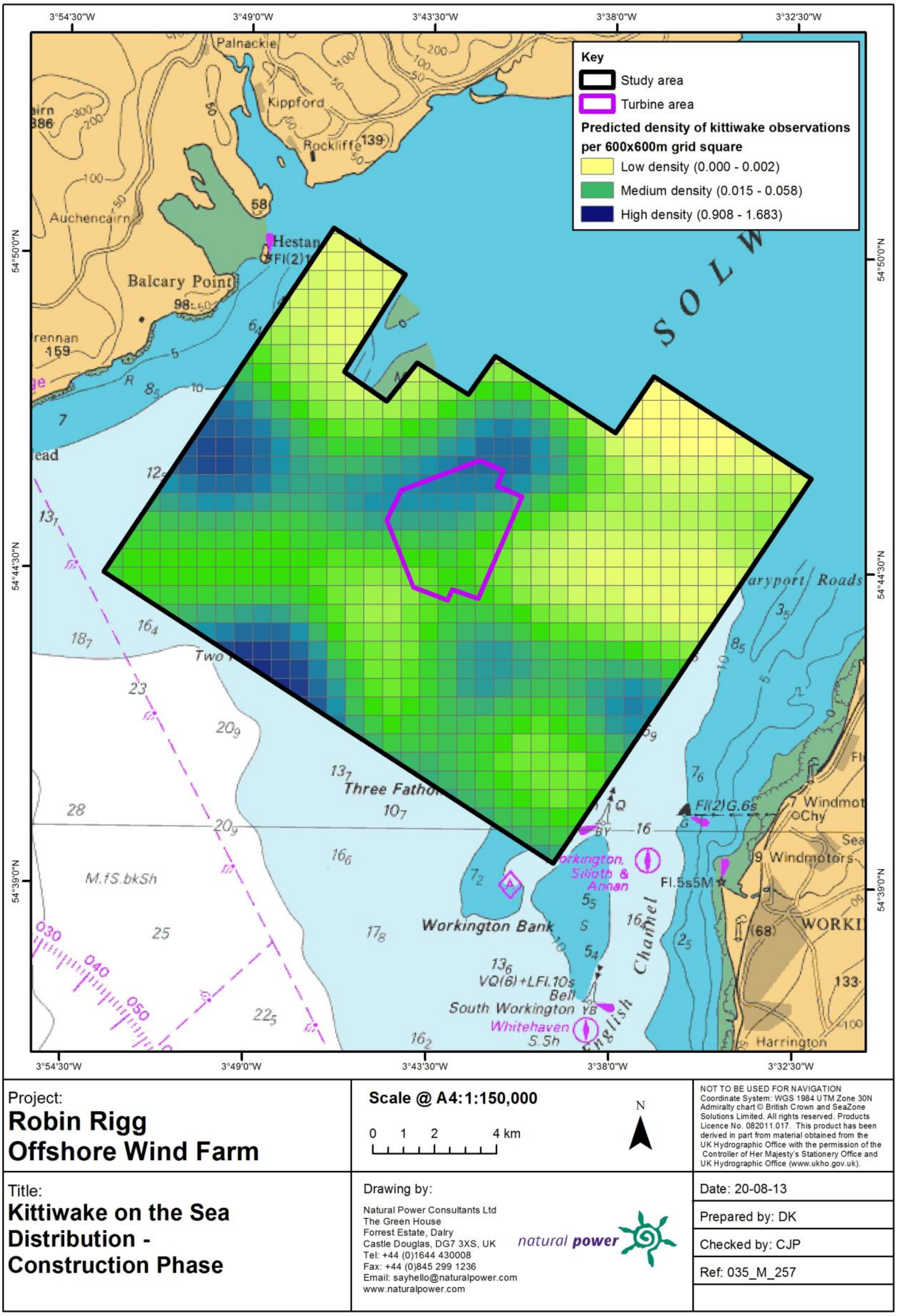


Figure 3.85: Density surface map of the predicted density of kittiwake on the sea across the study area during the construction phase of the development

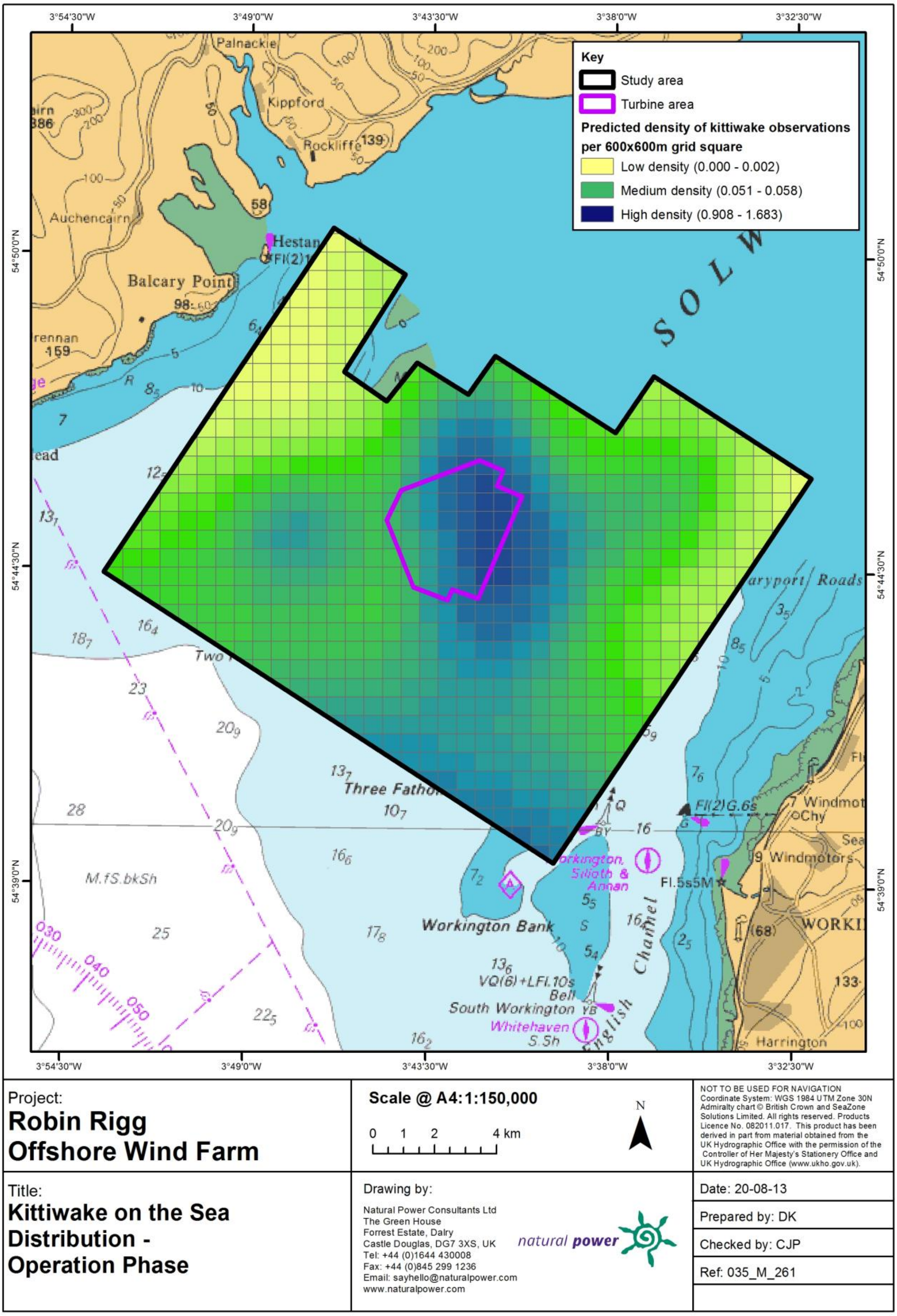


Figure 3.86: Density surface map of the predicted density of kittiwake on the sea across the study area during the operational phase of the development

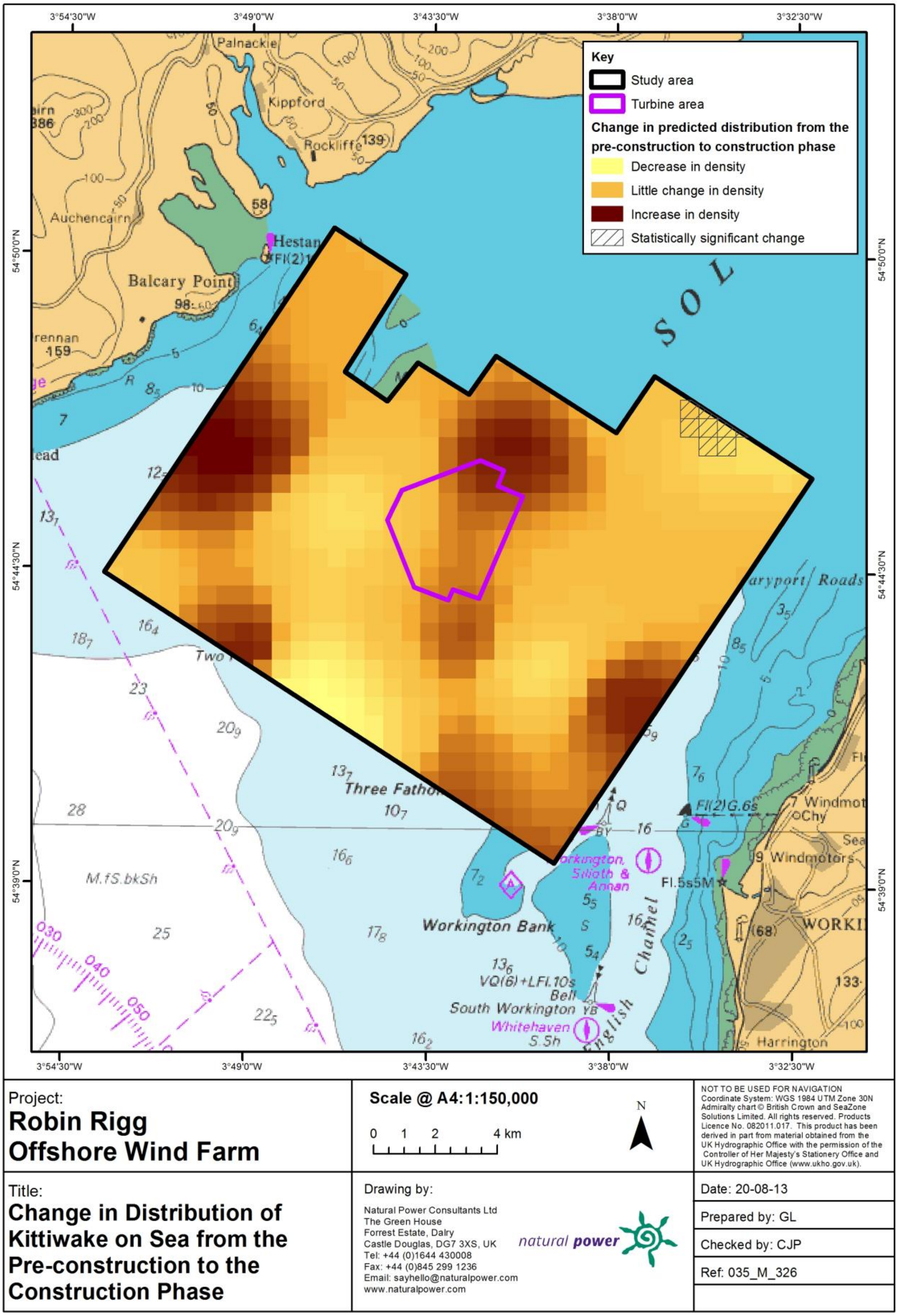
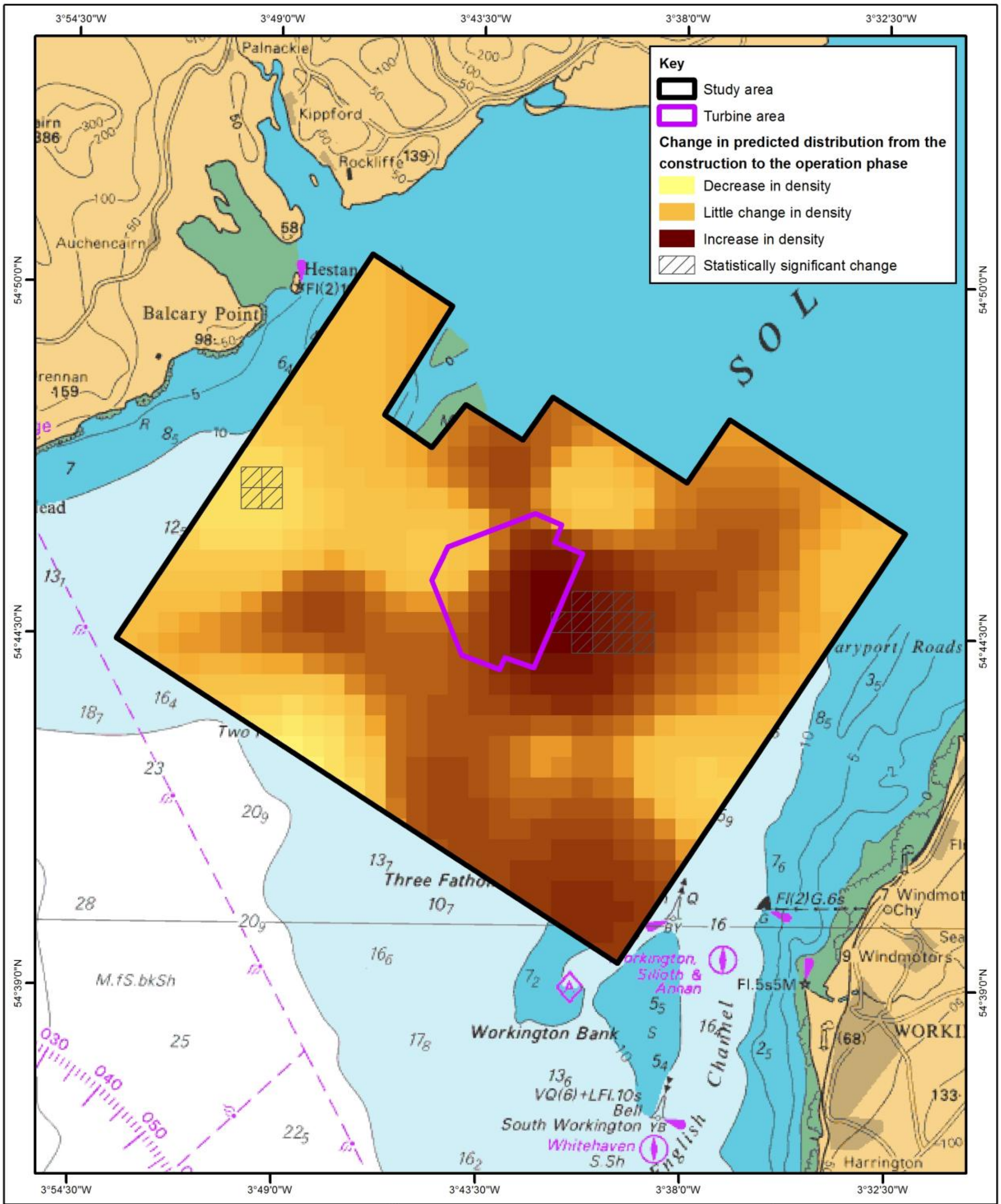


Figure 3.87: Plot of the difference in predicted density of kittiwake on the sea between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Kittiwake on Sea from the Construction to the Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13

Prepared by: GL

Checked by: CJP

Ref: 035_M_327

Figure 3.88: Plot of the difference in predicted density of kittiwake on the sea between the construction and operational phases of the development. Significant differences are marked with diagonal lines

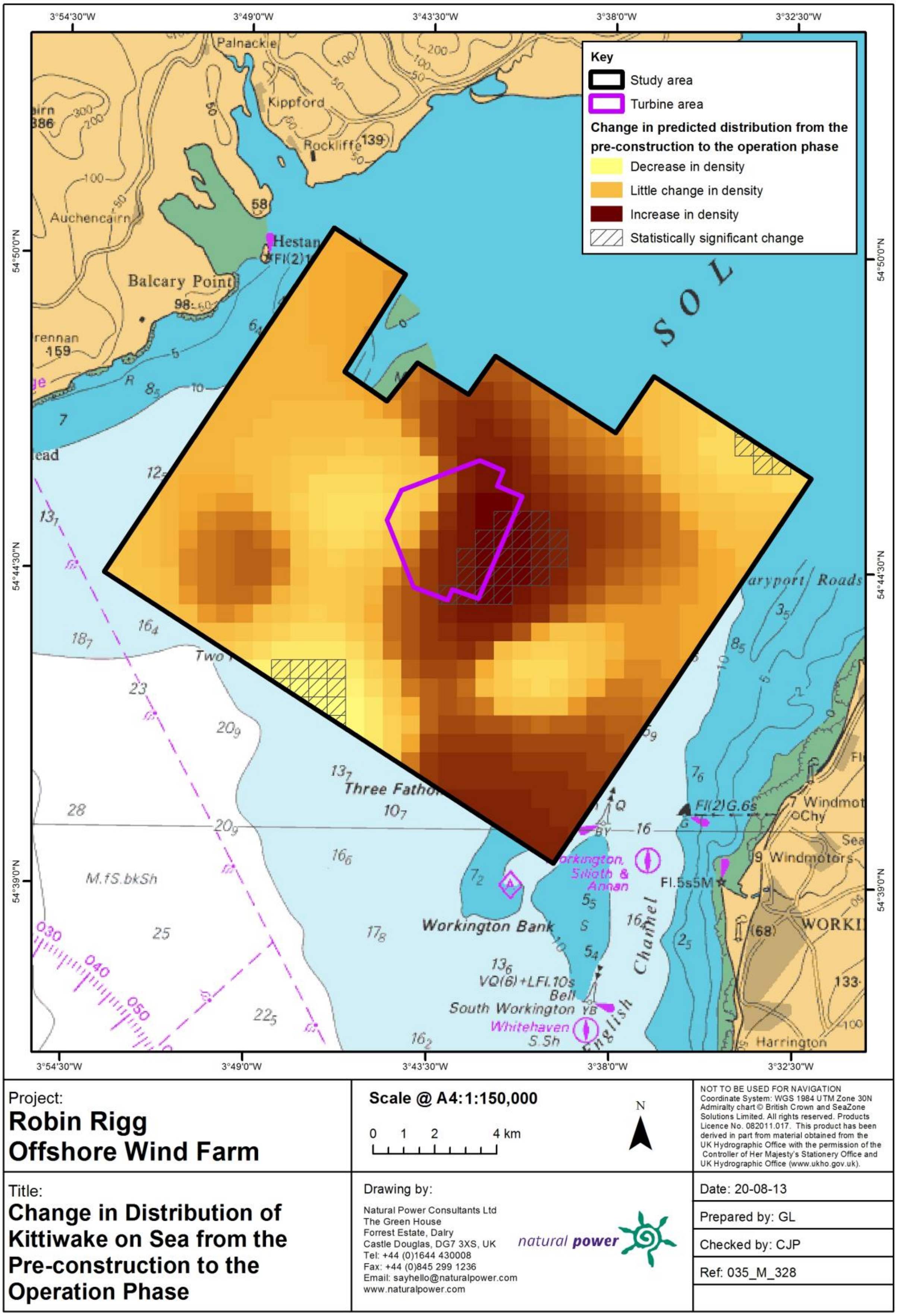


Figure 3.89: Plot of the difference in predicted density of kittiwake on the sea between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

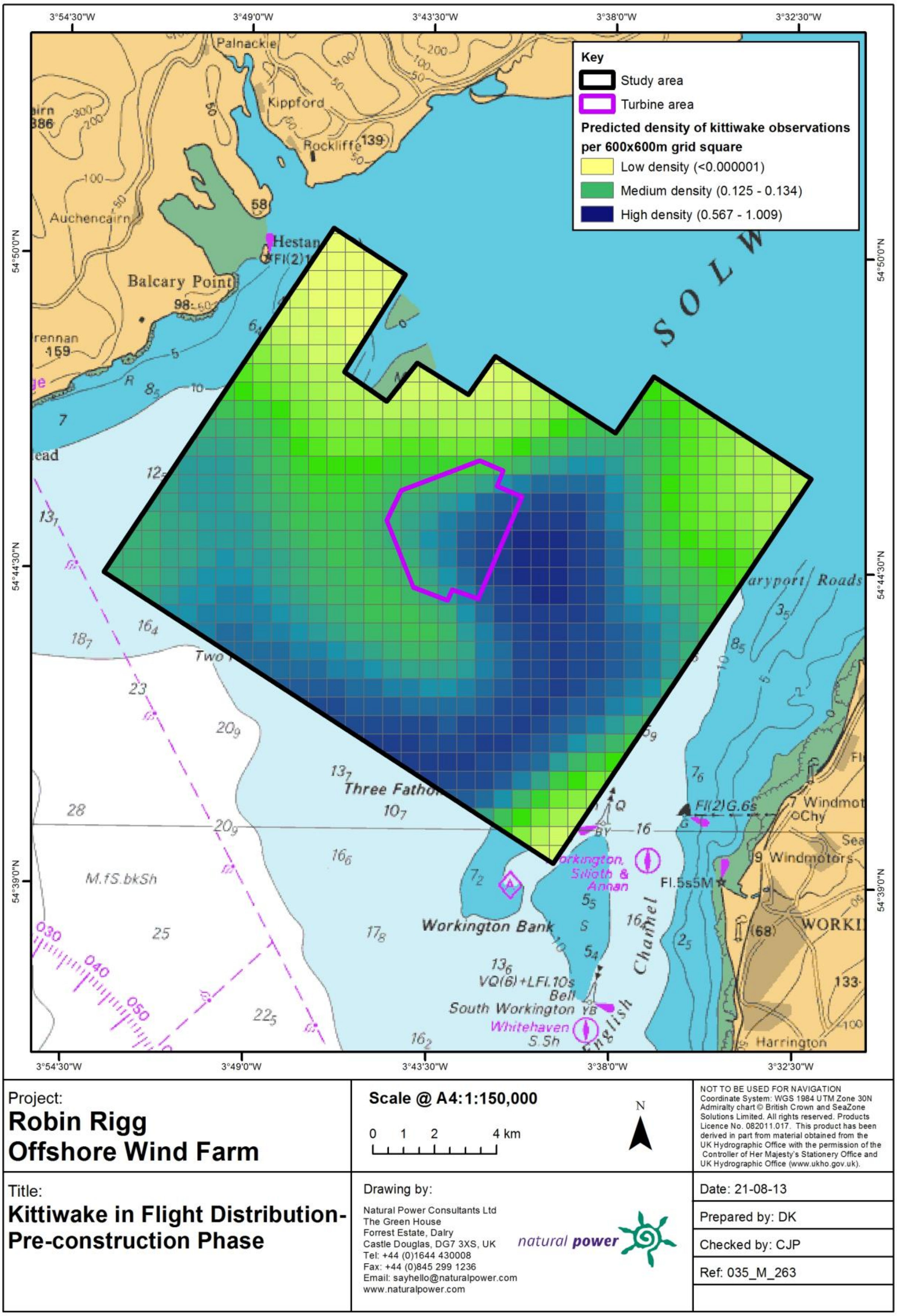


Figure 3.90: Density surface map of the predicted density of kittiwake in flight across the study area during the pre-construction phase of the development

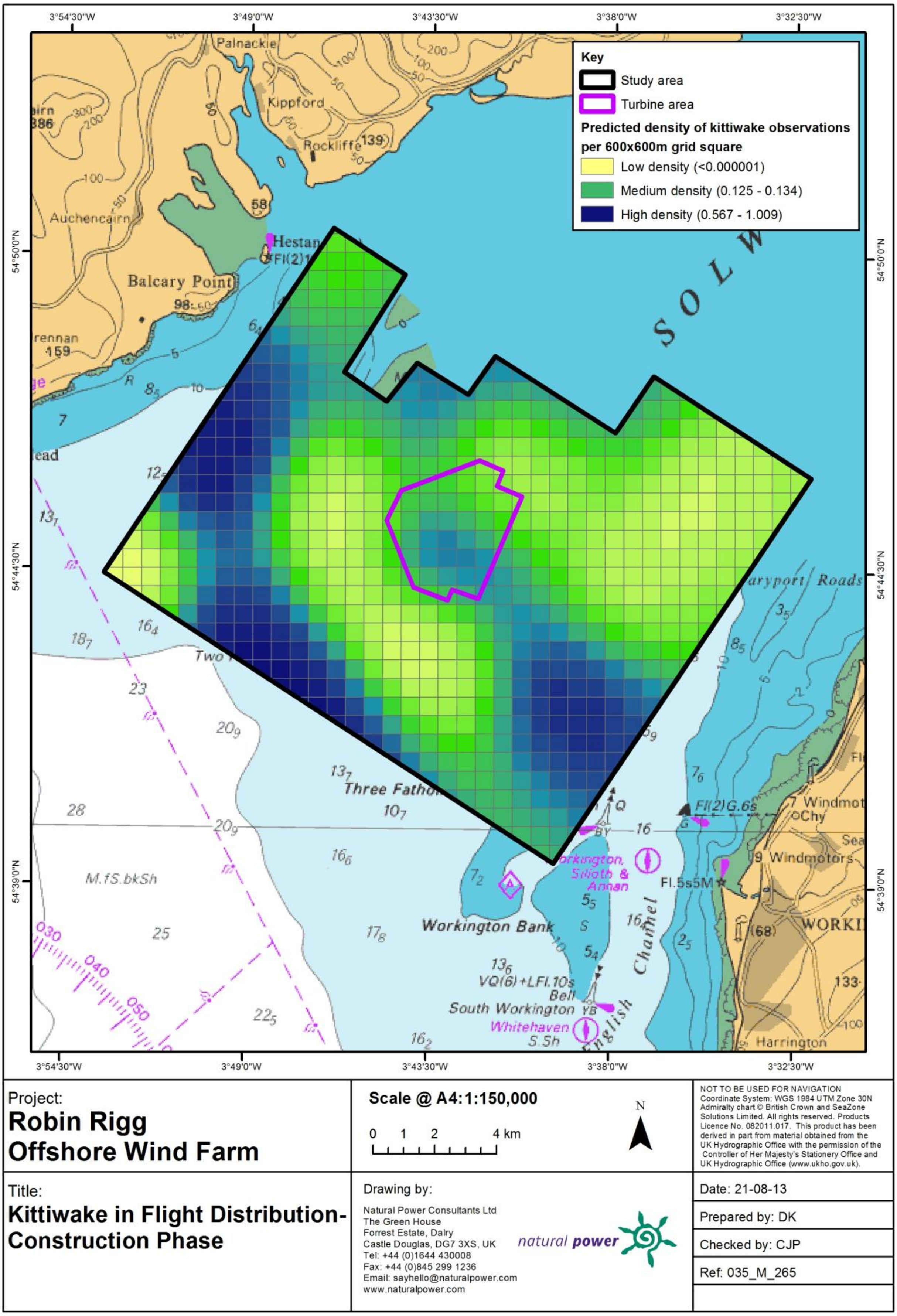


Figure 3.91: Density surface map of the predicted density of kittiwake in flight across the study area during the construction phase of the development

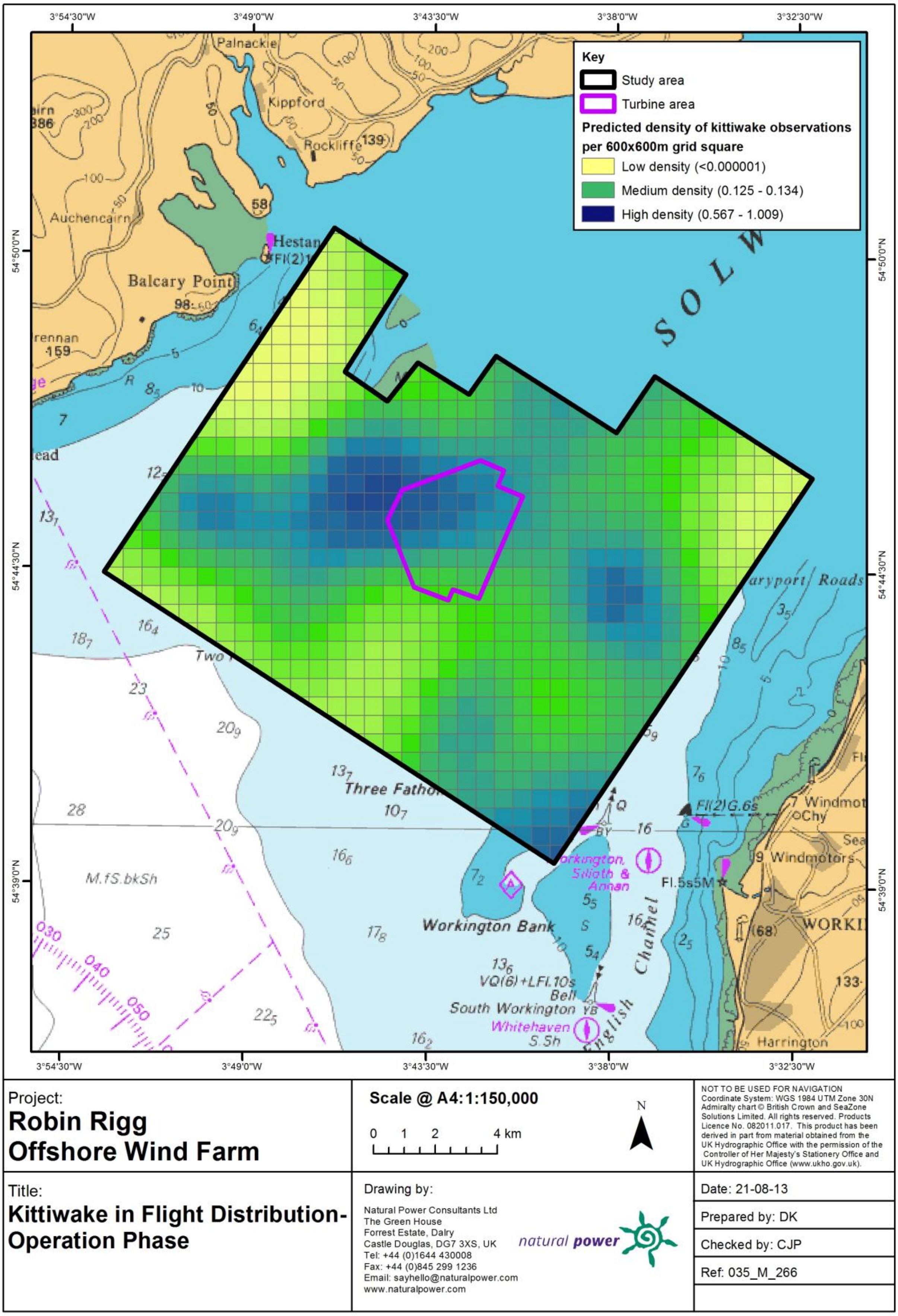
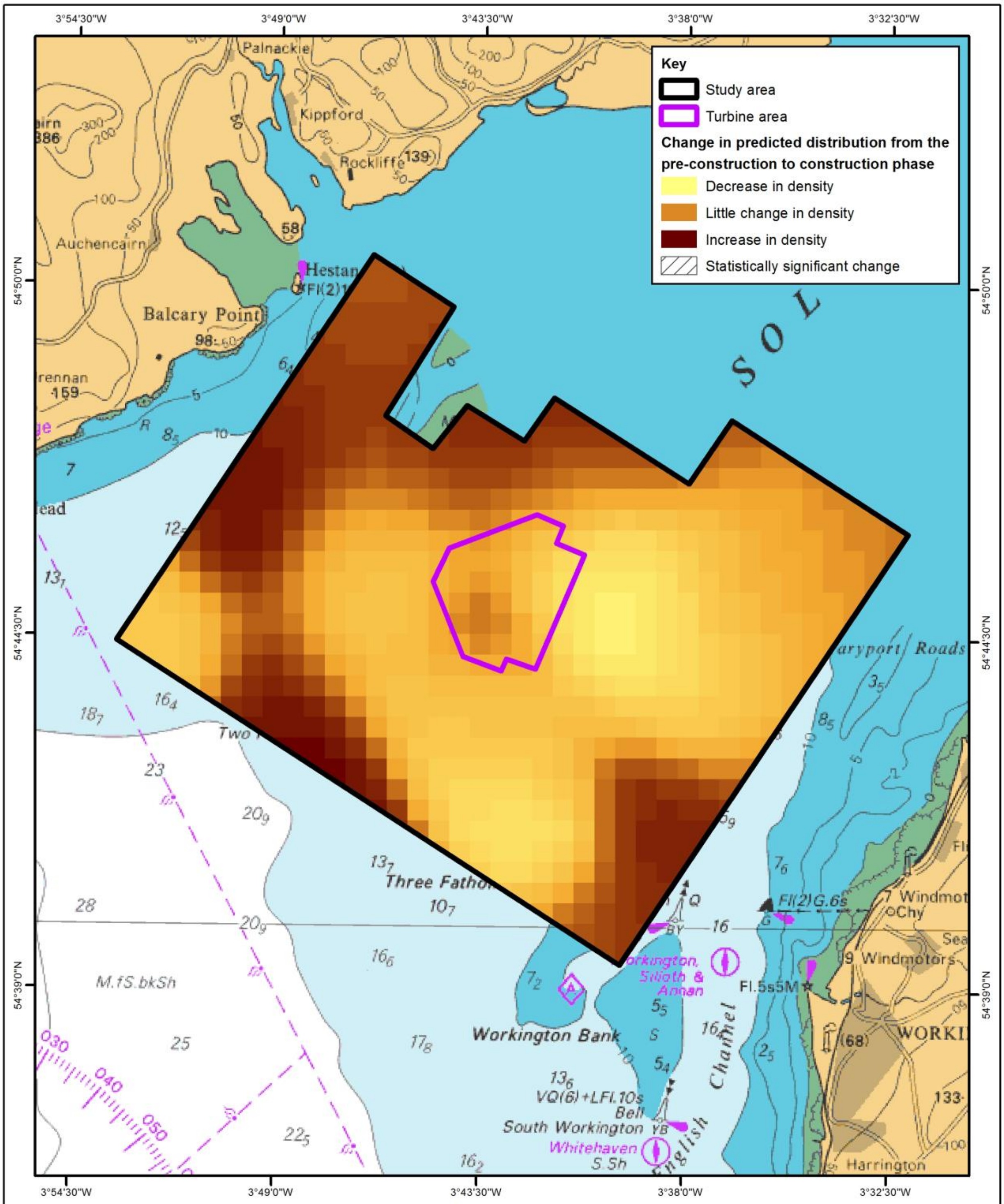


Figure 3.92: Density surface map of the predicted density of kittiwake in flight across the study area during the operational phase of the development



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

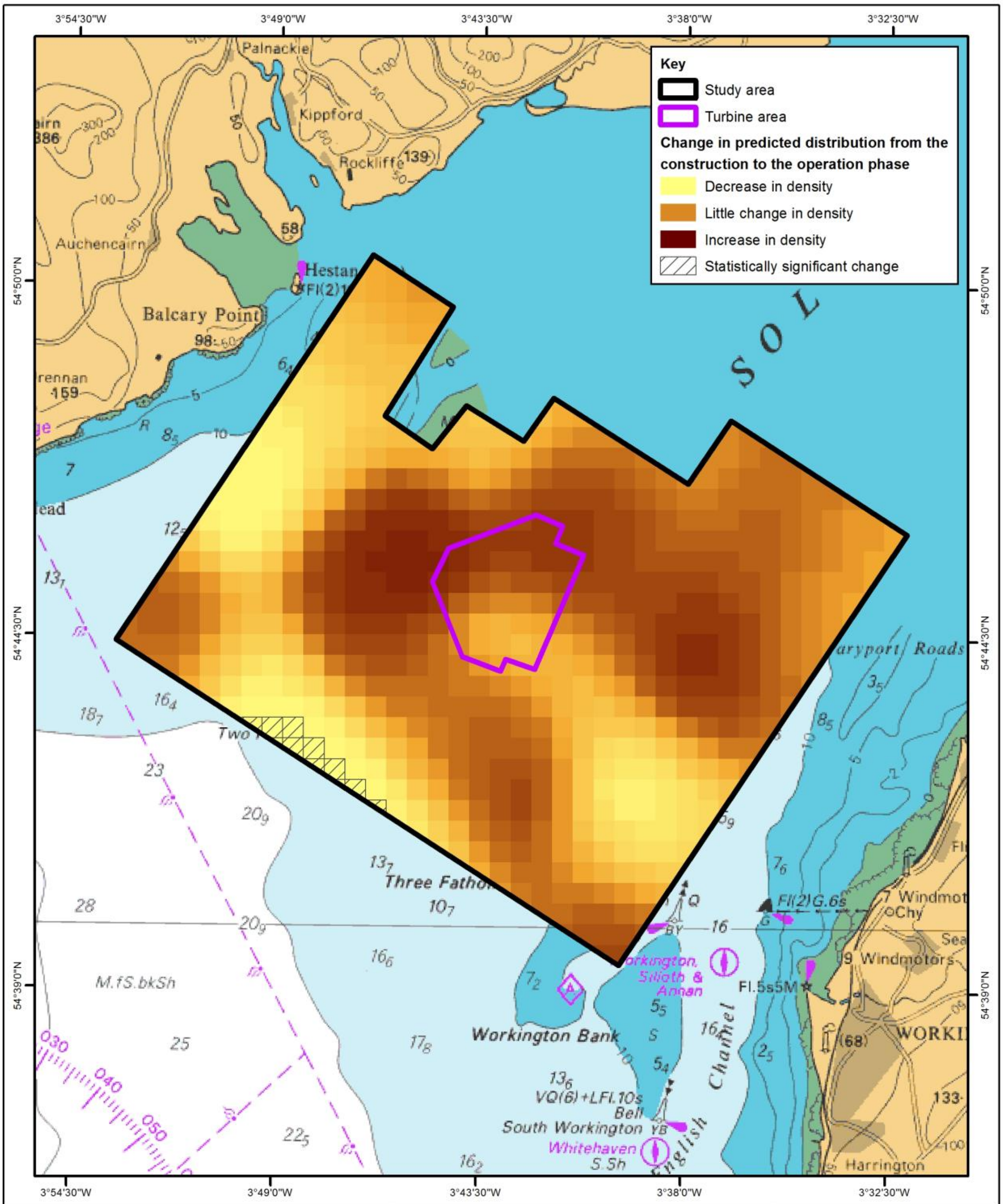
Title:
Change in Distribution of Kittiwake in Flight from the Pre-construction to the Construction Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_329

Figure 3.93: Plot of the difference in predicted density of kittiwake in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Kittiwake in Flight from the Construction to the Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_330

Figure 3.94: Plot of the difference in predicted density of kittiwake in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines

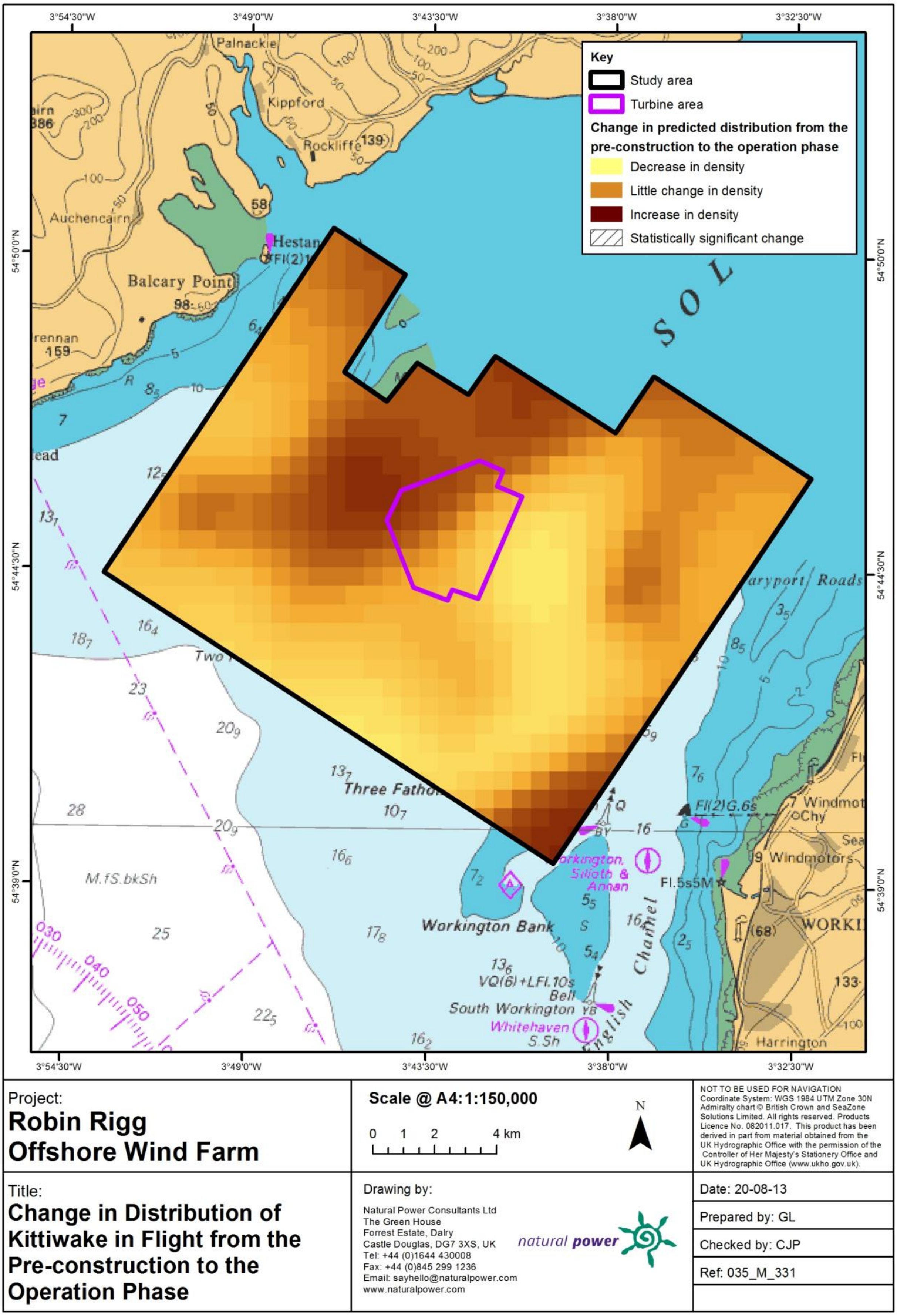


Figure 3.95: Plot of the difference in predicted density of kittiwake in flight between the pre-construction and operational phases of the development. Significant differences are marked with

3.10.3. Collision risk

The percentage of kittiwake recorded in different height bands relative to rotor height can be found in Table 3.35 and Figure 3.96. Band 4 (35-125 m) represents rotor height. As such a small number of birds were observed at rotor height, it is considered that generally, this species is at a low risk of collision and so Chi Squared was not attempted.

Table 3.34: Proportion of kittiwake observed flying at different height bands during the three stages of development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	50	48	1	1	0	0
Construction	26	70	23	2	0	0
Operation	52	43	2	2	0	0

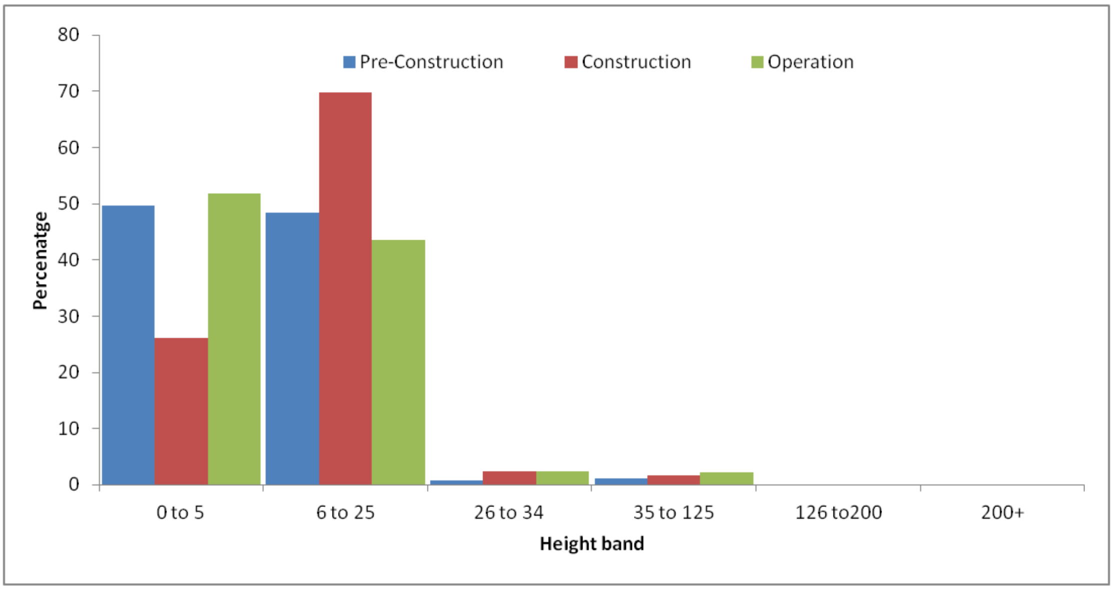


Figure 3.96: Percentage of kittiwake recorded in different flight bands during the different stages of the development.

.

3.11. Results: Herring gull

3.11.1. Summary statistics

The number of herring gull recorded through the three phases of the development can be found in Table 3.36 and Table 3.37. The mean number of herring gull recorded each month is presented in Figure 3.97) and average group size recorded in each of the three phases in Figure 3.98.

The raw data suggest that while numbers during construction and operation are fairly consistent, numbers observed are lower than those recorded pre-construction. Monthly fluctuations recorded through the three development phases are also similar (Figure 3.97).

Too few sightings were recorded of birds on the sea to allow modelling to be undertaken. Modelling was carried out for birds in flight and the results are presented below.

Table 3.36: Raw data for herring gull recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		Construction		Operation years 1-3	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	65/0.01	459/0.07	139/0.01	646/0.05	288/0.03	529/0.05
Total number individuals/IPUE	384/0.06	910/.014	584/0.05	1143/0.09	1098/0.11	995/0.10

Table 3.37: Standardised data for herring gull recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	1	0.01	58	0.02	9	0.06	198	0.07	228	0.58	246	0.05
Number per km^2	0.03		0.06		0.17		0.20		1.62		0.14	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	12	0.08	247	0.10	6	0.04	115	0.04	77	0.20	353	0.07
Number per km^2	0.22		0.28		0.11		0.11		0.56		0.20	

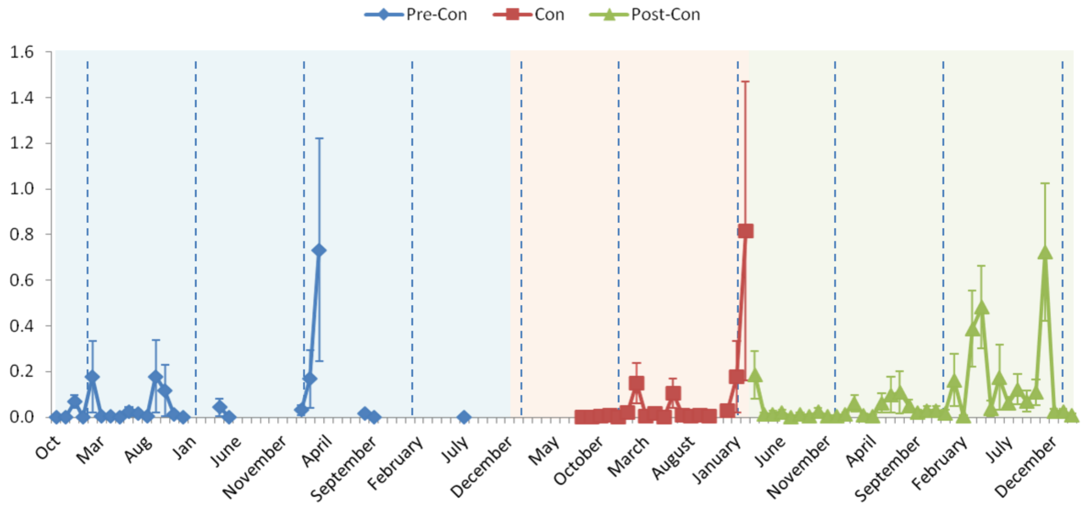


Figure 3.97: Mean number of herring gull observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

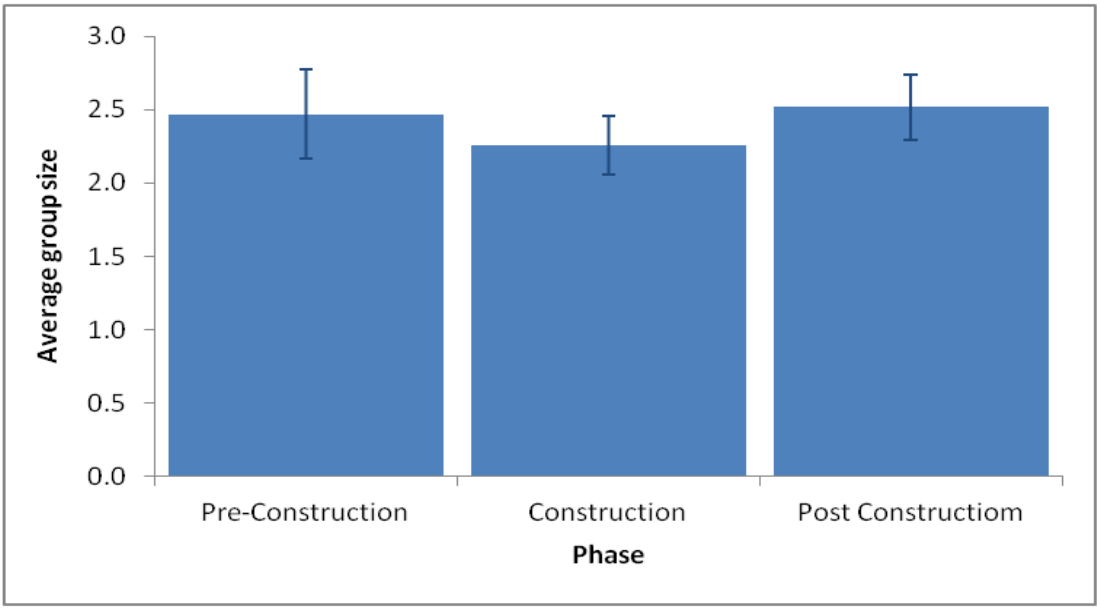


Figure 3.98: Mean group size for herring gull observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.11.2. Distribution and abundance

The standardised raw data suggest that herring gull abundance on the sea have gone up slightly across the study area but have increased dramatically within the wind farm site during operation (Table 3.37). Due to low numbers of observations on the water no modelling was carried out on this data set.

The standardised raw data suggest that herring gull abundance in flight have declined across the study area but increasing numbers within the wind farm site itself. This supported by the model outputs which demonstrate a significant decline in both the construction and operational phases (Table 3.38). However, numbers within the wind farm site have significantly increased during the operational phase (Figure 3.104).

Table 3.38: Model outputs for herring gull in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-0.841	0.273	-3.084	0.0021 **
Pre-construction to operation	-0.750	0.233	-3.219	0.0013 **

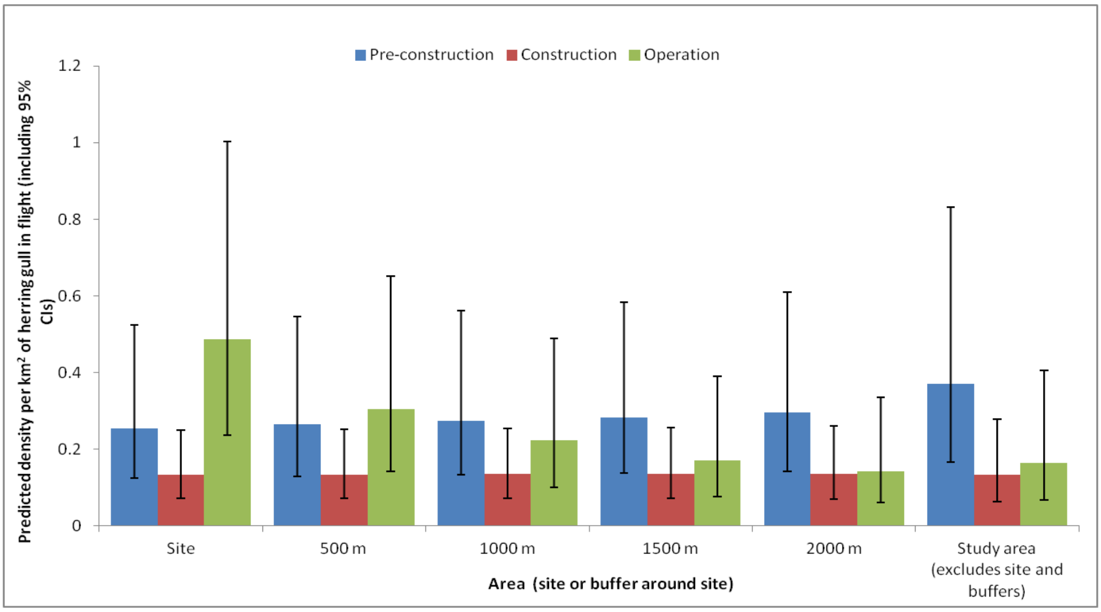


Figure 3.99: Predicted density of herring gull in February with 95% confidence intervals (95% CI)

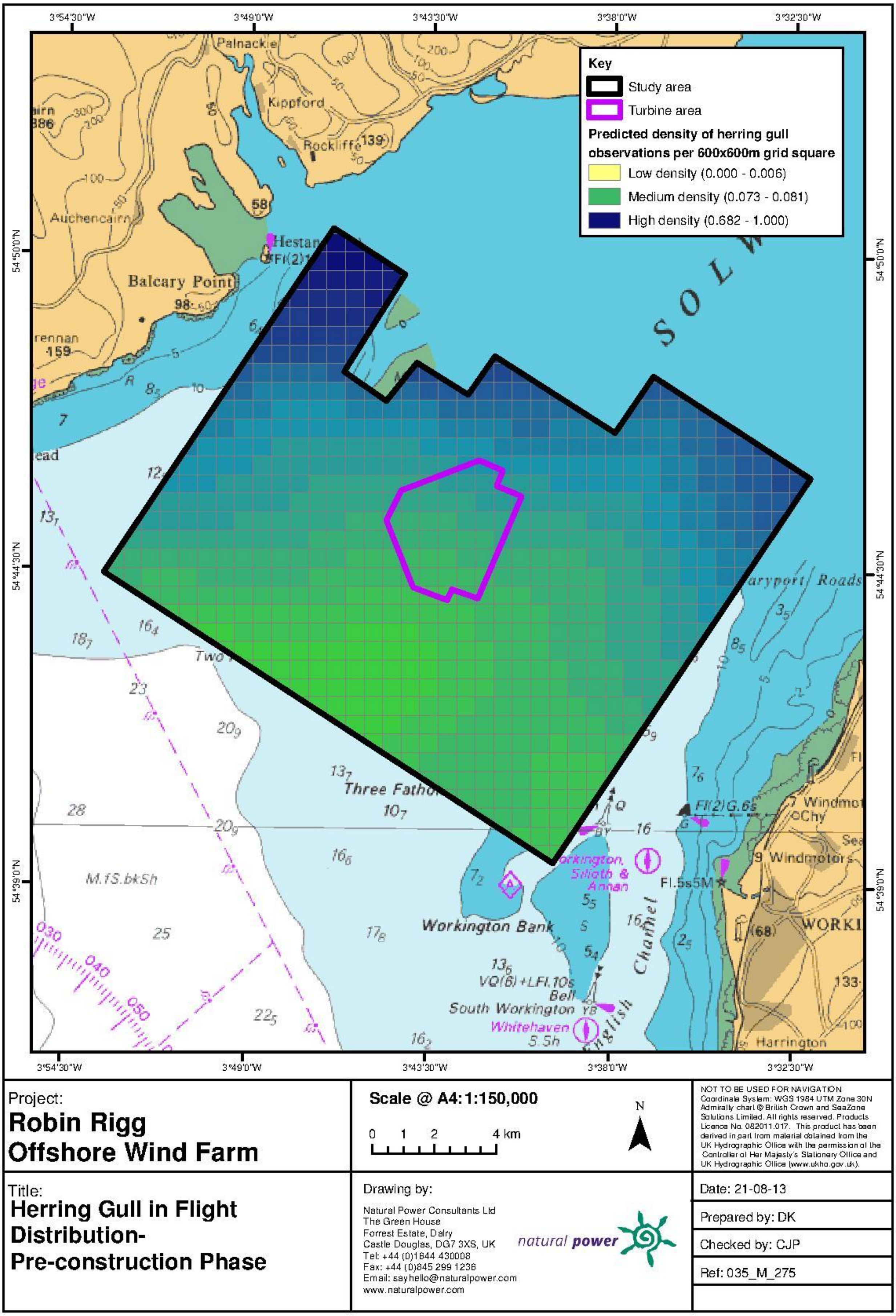


Figure 3.100: Density surface map of the predicted density of herring gull in flight across the study area during the pre-construction phase of the development

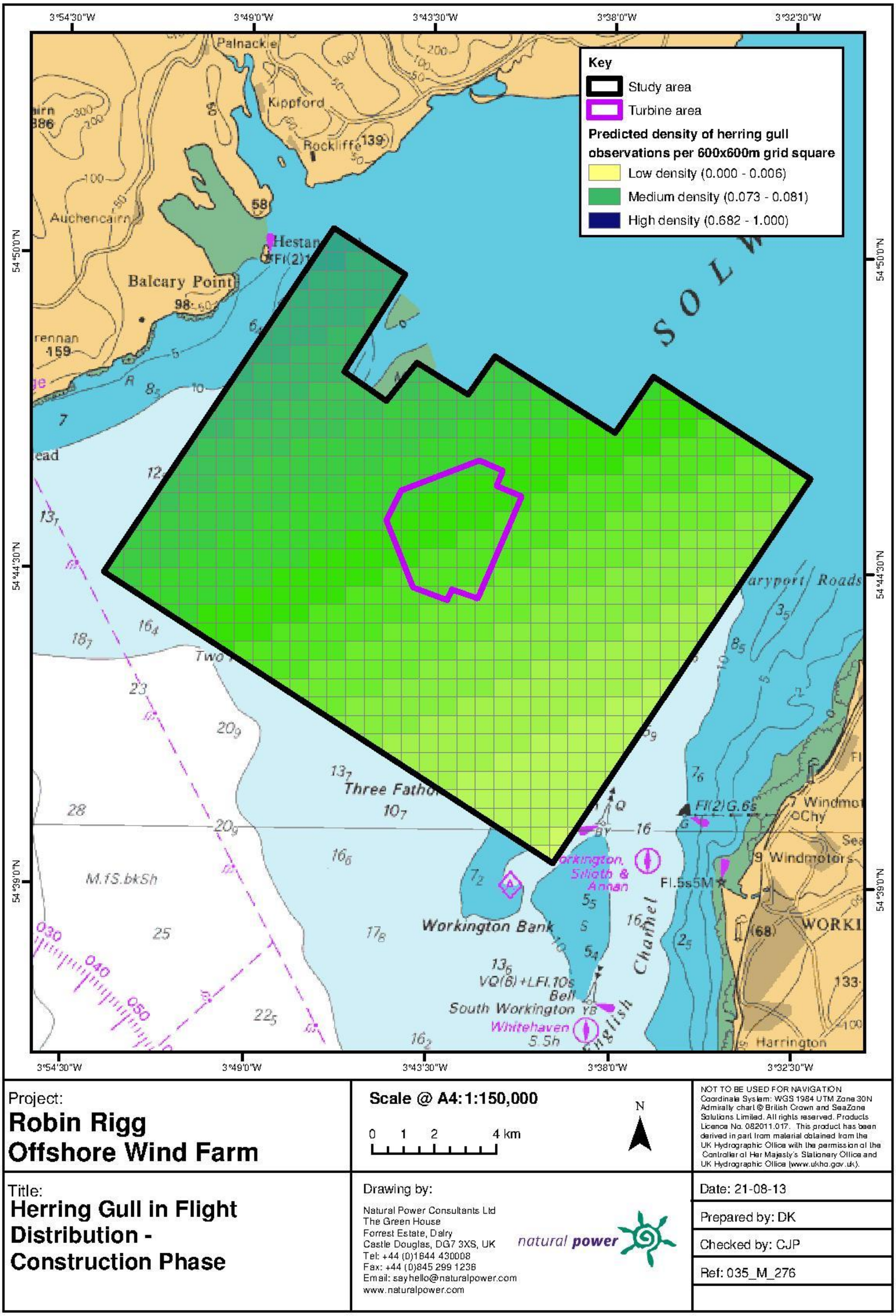


Figure 3.101: Density surface map of the predicted density of herring gull in flight across the study area during the construction phase of the development

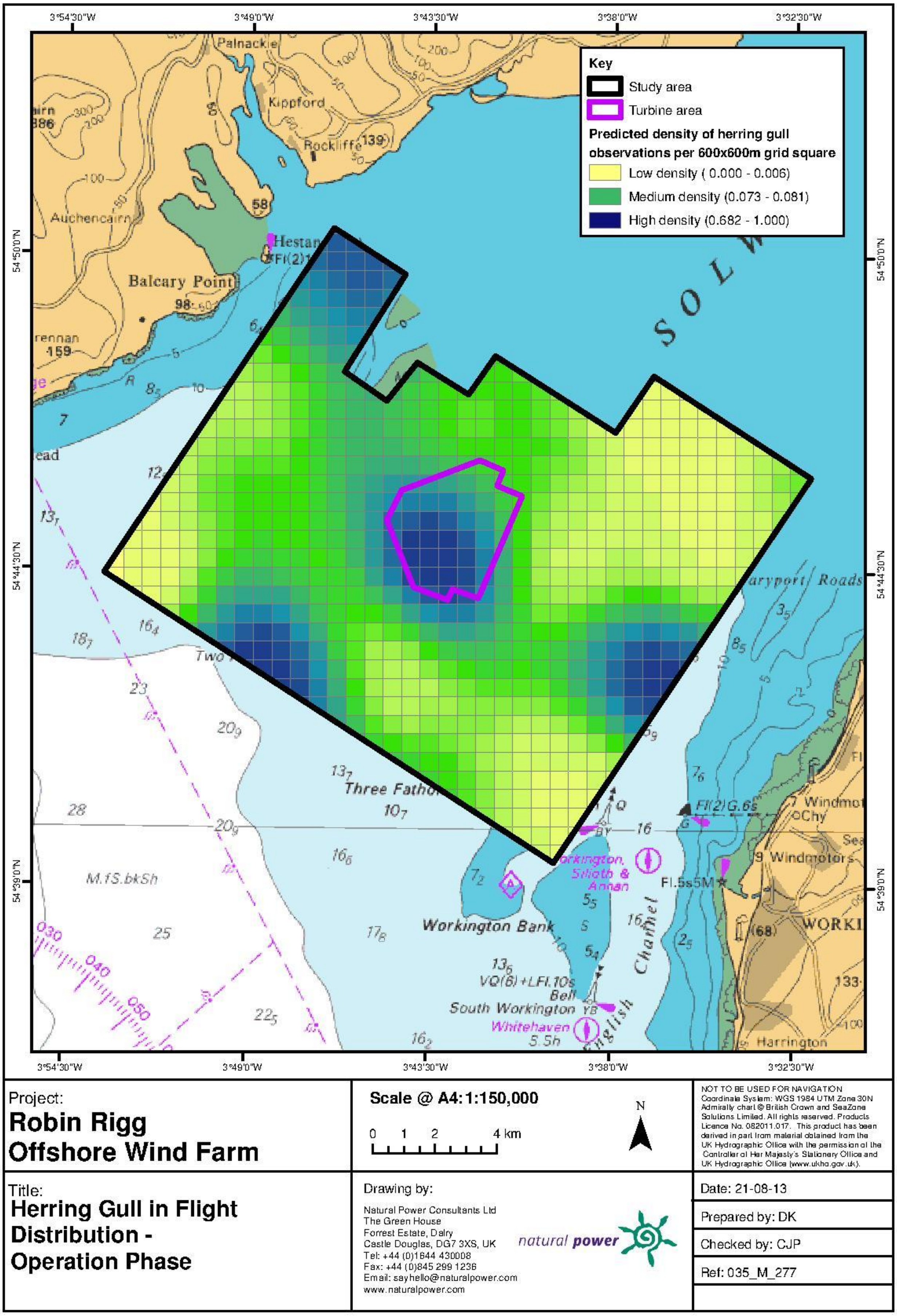


Figure 3.102: Density surface map of the predicted density of herring gull in flight across the study area during the operational phase of the development

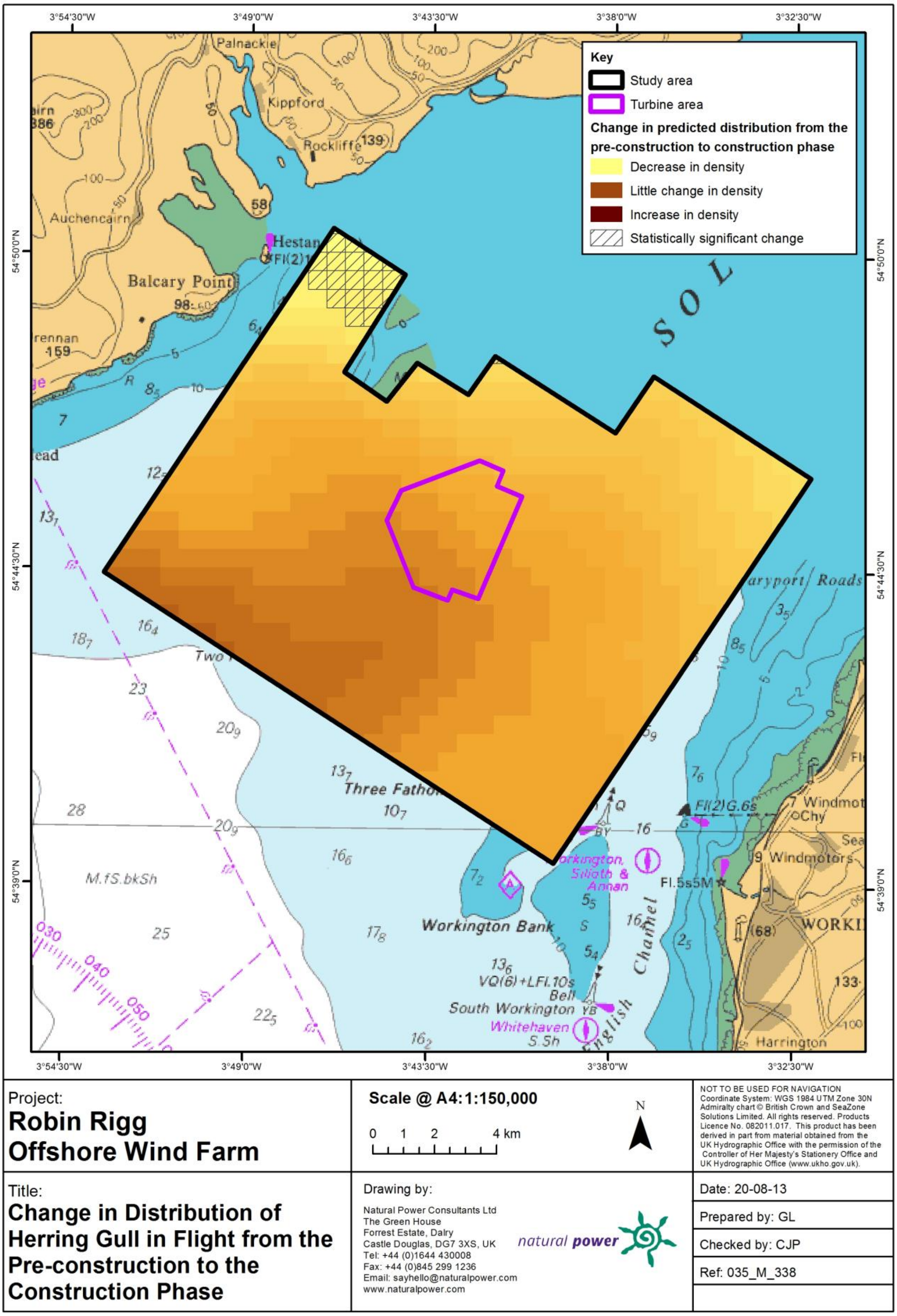


Figure 3.103: Plot of the difference in predicted density of herring gull in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

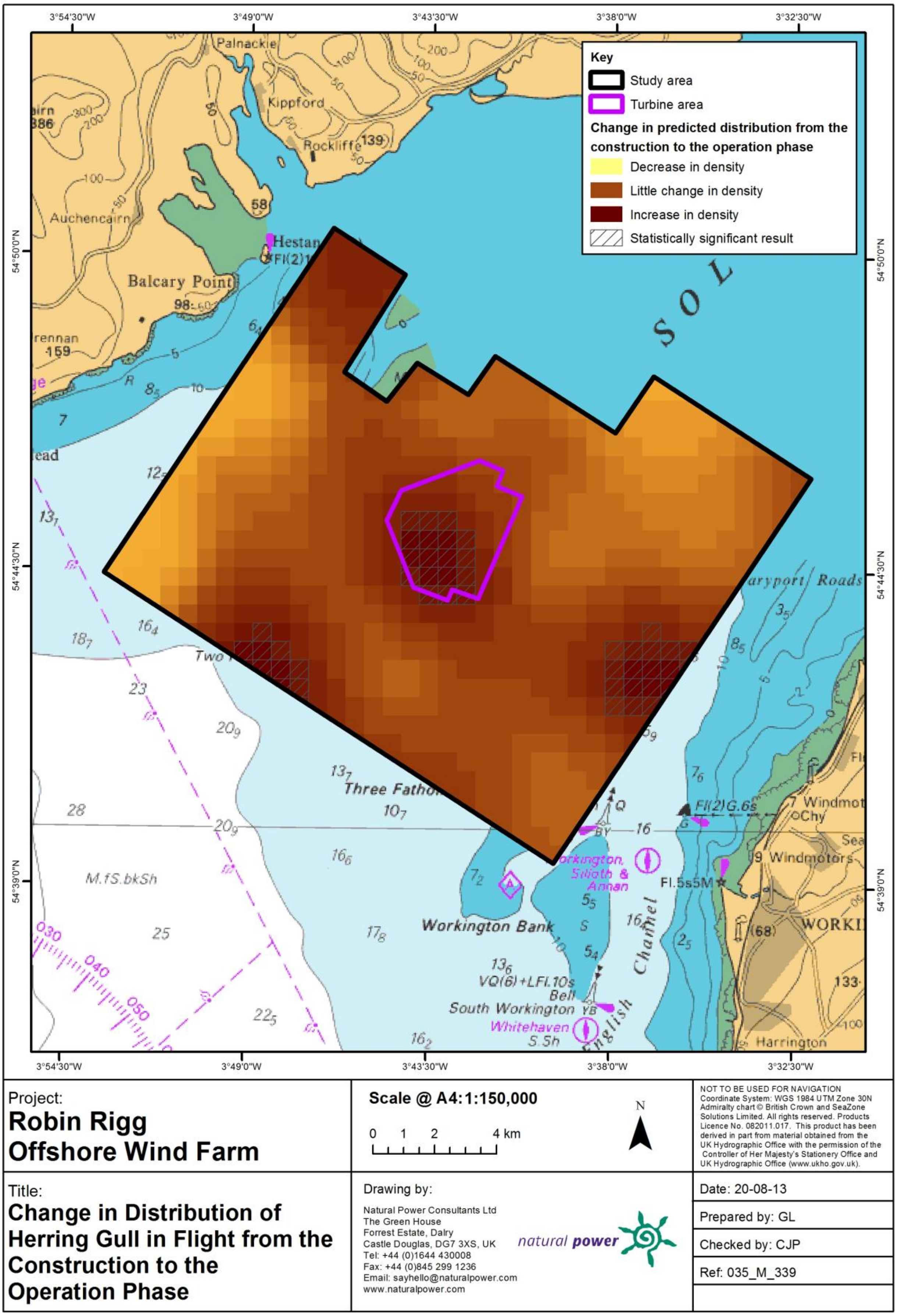


Figure 3.104: Plot of the difference in predicted density of herring gull in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines

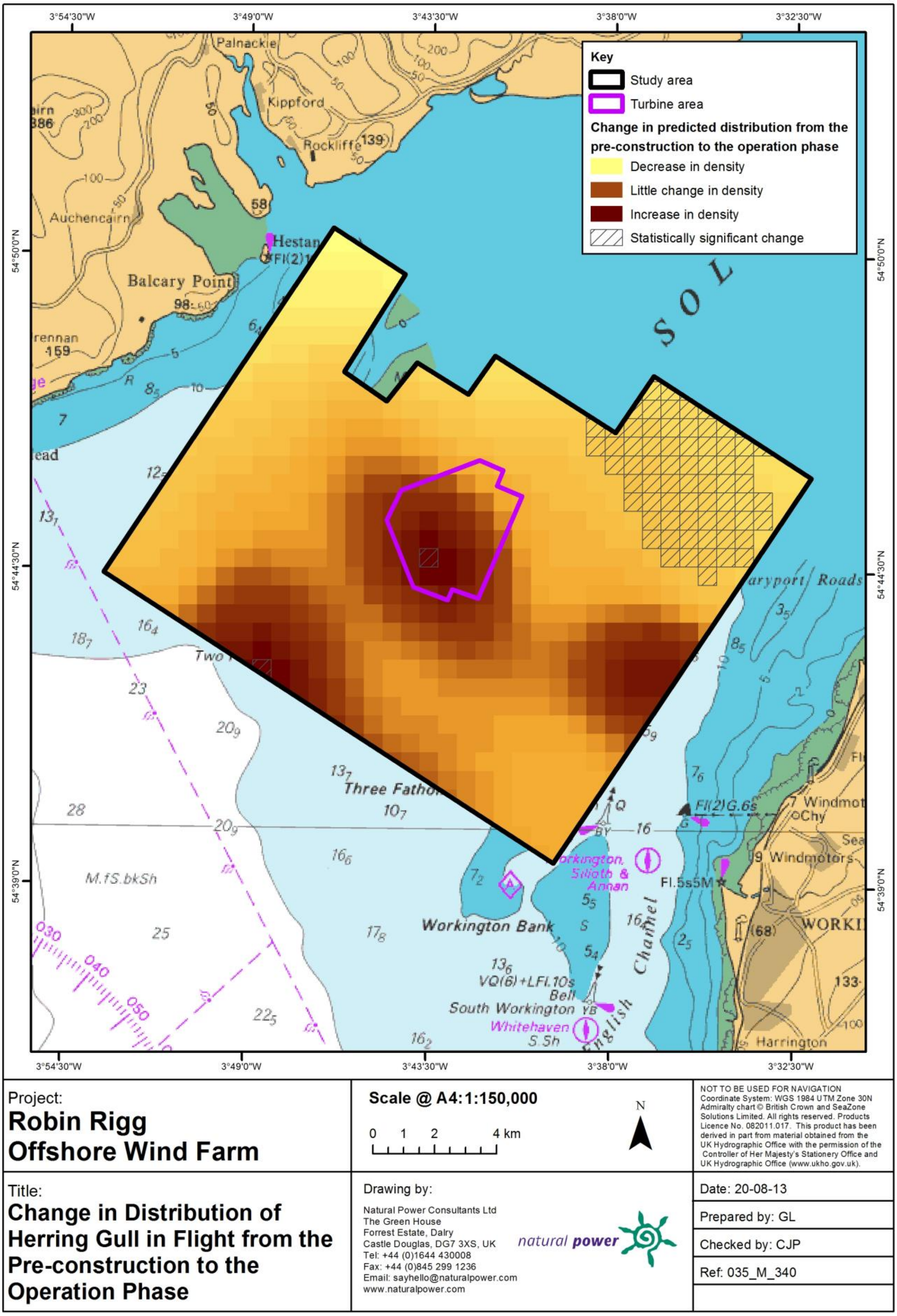


Figure 3.105: Plot of the difference in predicted density of herring gull in flight between the pre-construction and operational phases of the development. Significant differences are marked with

3.11.3. Collision risk

The percentage of herring gulls recorded in different height bands relative to rotor height can be found in Table 3.39 and Figure 3.106. Height band 4 (35-125) represents rotor height. Data were combined for Chi-squared analysis and a significant difference was found between flight bands (χ^2 = 1, $p < 0.001$, 2 df). Fewer herring gulls than expected were observed flying at rotor height pre-construction although this may be the result of there being no structures being present within the study area to use as a reference height (i.e. a turbine).

Table 3.39: Proportion of herring gull observed flying at different height bands during the three stages of development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	36	60	3	1	0	0
Construction	17	68	9	6	0	0
Operation	60	22	10	9	0	0

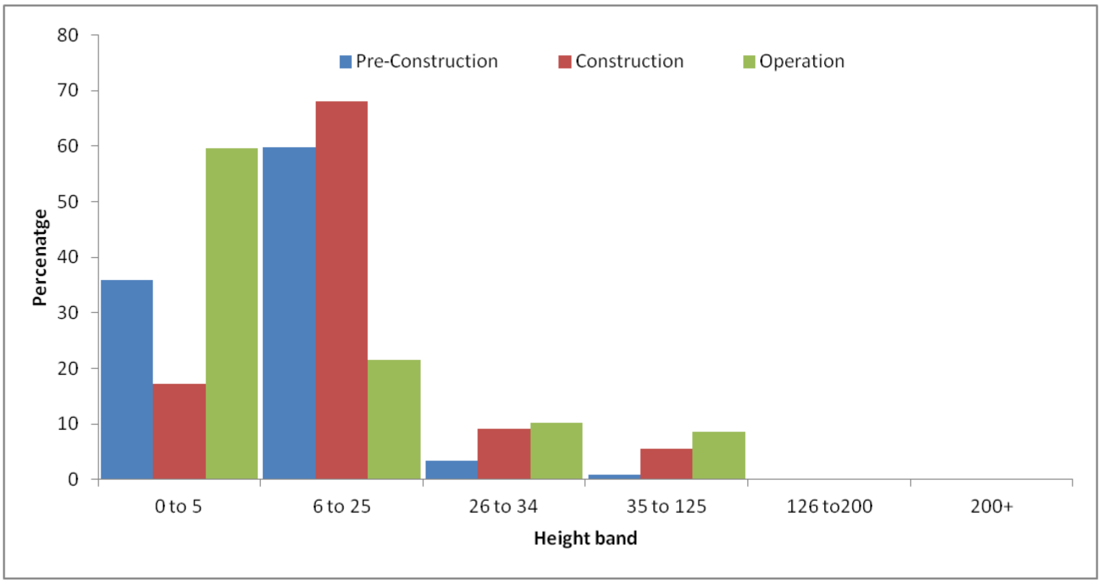


Figure 3.106 Percentage of herring gull recorded in different flight bands during the different stages of the development.

3.12. Results: Great black-backed gull

3.12.1. Summary statistics

The number of great black-backed gulls recorded during the three phases of the development can be found in Table 3.40. The mean number of great black-backed gulls recorded each month is presented in Figure 3.107 and average group size recorded in each of the three phases in Figure 3.108.

The raw data suggest an increase in abundance during the operational years with similar numbers recorded in all years. The data also suggest an increase in winter abundance post-construction compared to pre-construction (Figure 3.107). The average group size recorded during the three phases suggests an increase in recent years (Figure 3.108).

Too few sightings were recorded of birds on the sea to allow modelling to be undertaken. Modelling was carried out for birds in flight and the results are presented below.

Table 3.40: Raw data for great black-backed gull recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		**Construction**		**Operation years 1-3**	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	42/0.01	120/0.02	156/0.01	211/0.02	248/0.02	273/0.03
Total number individuals/IPUE	65/0.01	142/0.02	307/0.03	273/0.02	470/0.05	384/0.04

Table 3.41: Standardised data for great black-backed gull recorded per segment during each phase of the construction of the wind farm and equivalent number per km^2. SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	4	0.03	21	0.01	2	0.01	37	0.01	7	0.02	69	0.01
Number per km^2	0.08		0.03		0.03		0.03		0.06		0.03	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	1	0.01	49	0.02	6	0.04	32	0.01	6	0.02	72	0.01
Number per km^2	0.03		0.06		0.11		0.03		0.06		0.03	

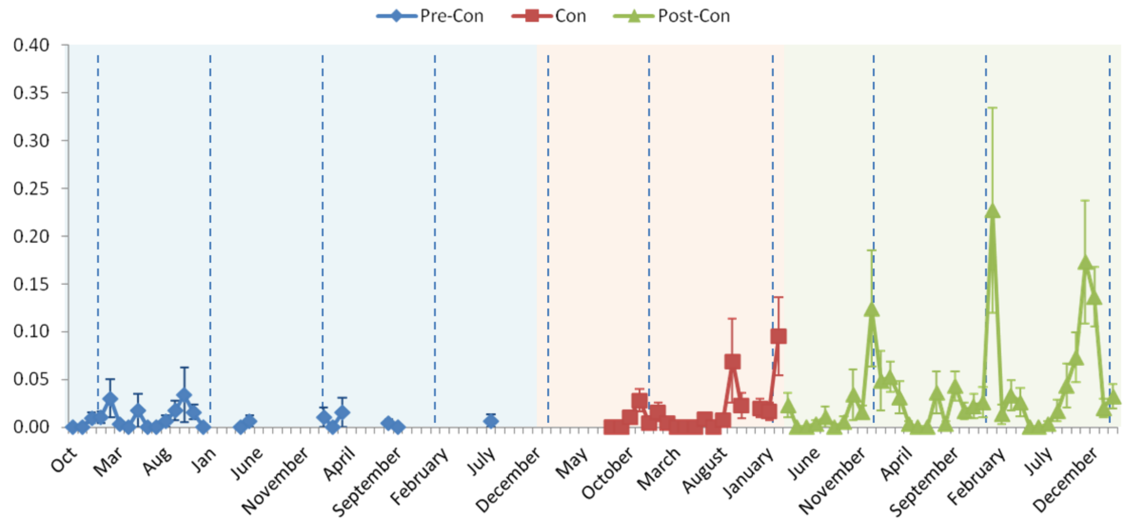


Figure 3.107: Mean number of great black-backed gull observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

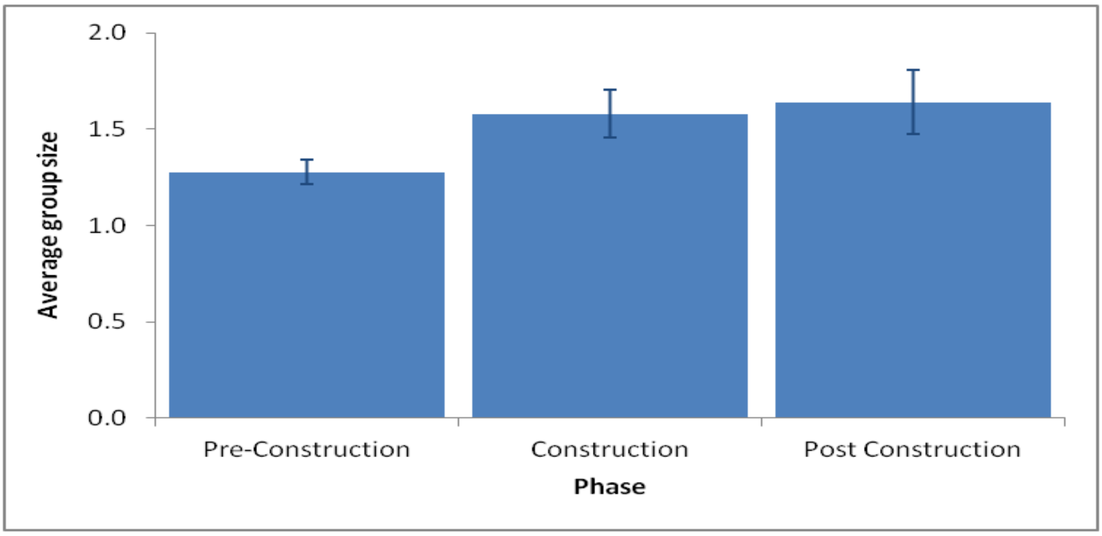


Figure 3.108: Mean group size for great black-backed gull observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.12.2. Distribution and abundance

The standardised raw data for birds on the sea suggests abundance remains fairly consistent across the study area and perhaps decreases slightly within the wind farm area through the three phases of the development (Table 3.41). The standardised raw data for birds in flight suggest an increase in abundance within the wind farm site through all three phases despite an overall decrease in numbers during the construction phase across the entire study area.

The model outputs reflect this pattern with a weakly significant drop in abundance across the study area during the construction phase (Table 3.42) with predicted density within the wind farm site remaining fairly constant (Figure 3.110 through to Figure 3.115).

Table 3.42: Model outputs for great black-backed gulls in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-1.133	0.473	-2.396	0.0166 *
Pre-construction to operation	-0.101	0.371	-0.272	0.7854

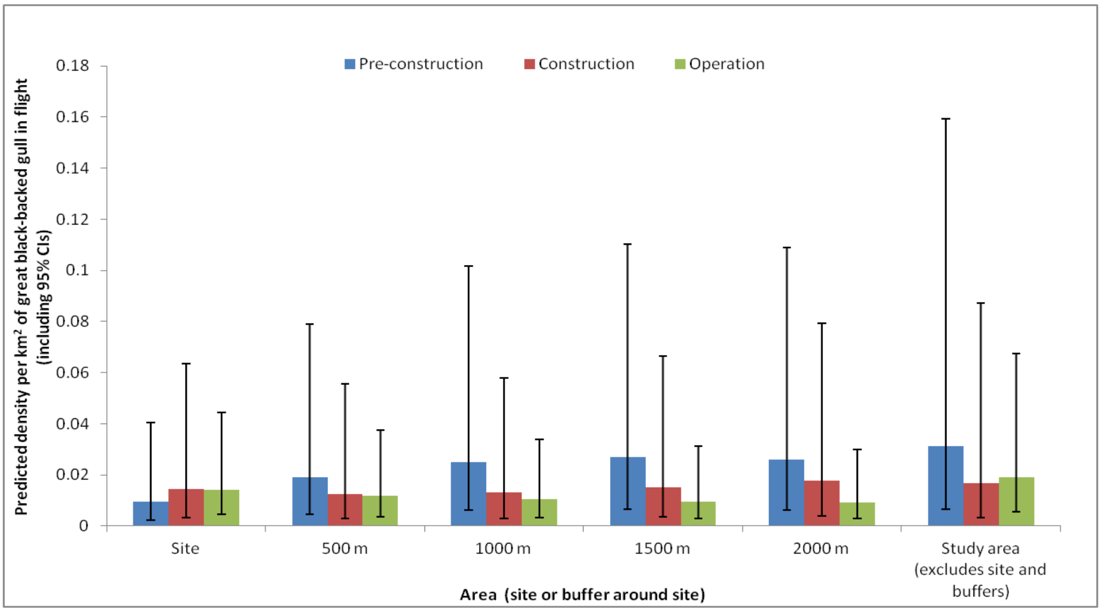


Figure 3.109: Predicted density of great black-backed gulls in December with 95% confidence intervals (95% CI)

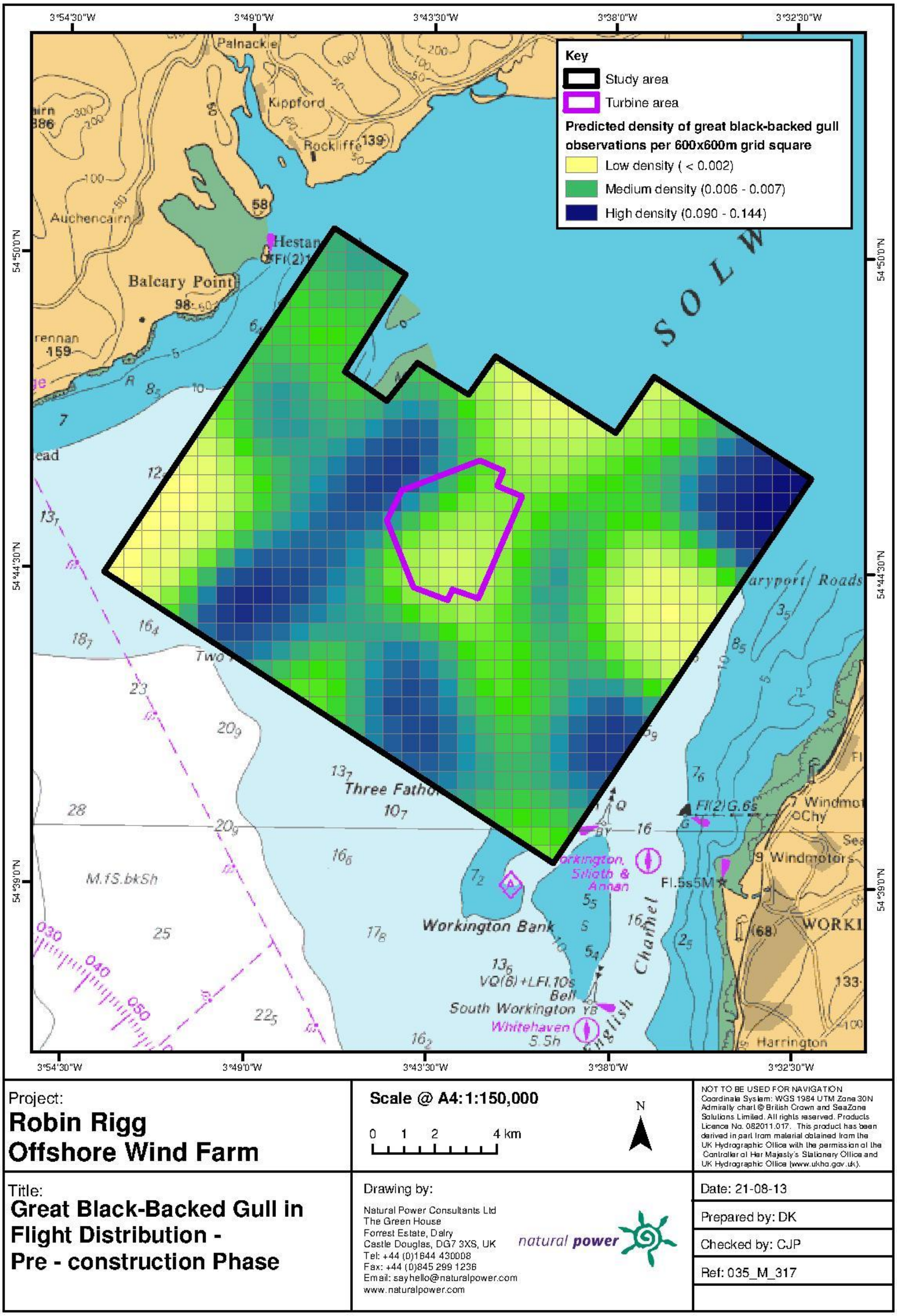


Figure 3.110: Density surface map of the predicted density of great black-backed gulls in flight across the study area during the pre-construction phase of the development

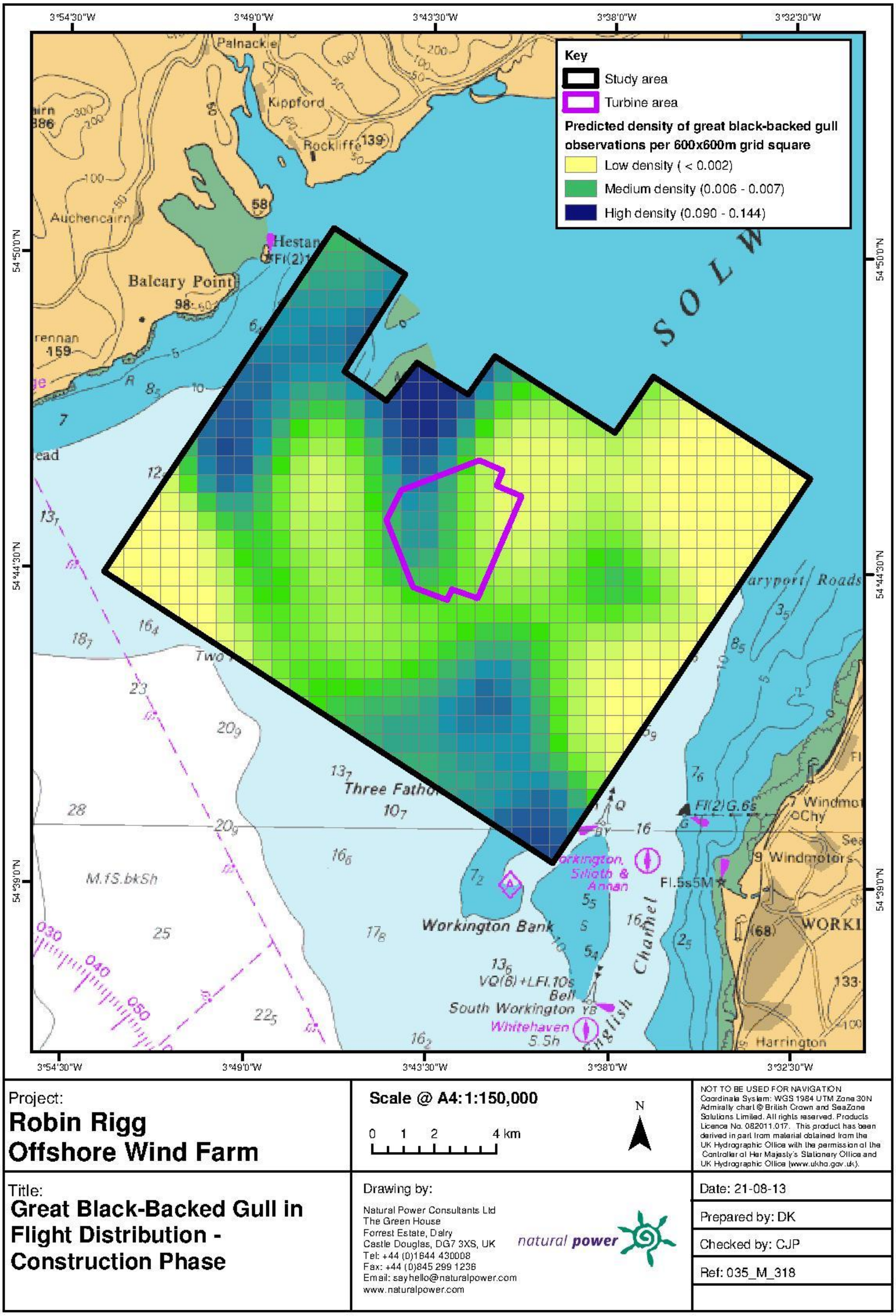


Figure 3.111: Density surface map of the predicted density of great black-backed gulls in flight across the study area during the construction phase of the development

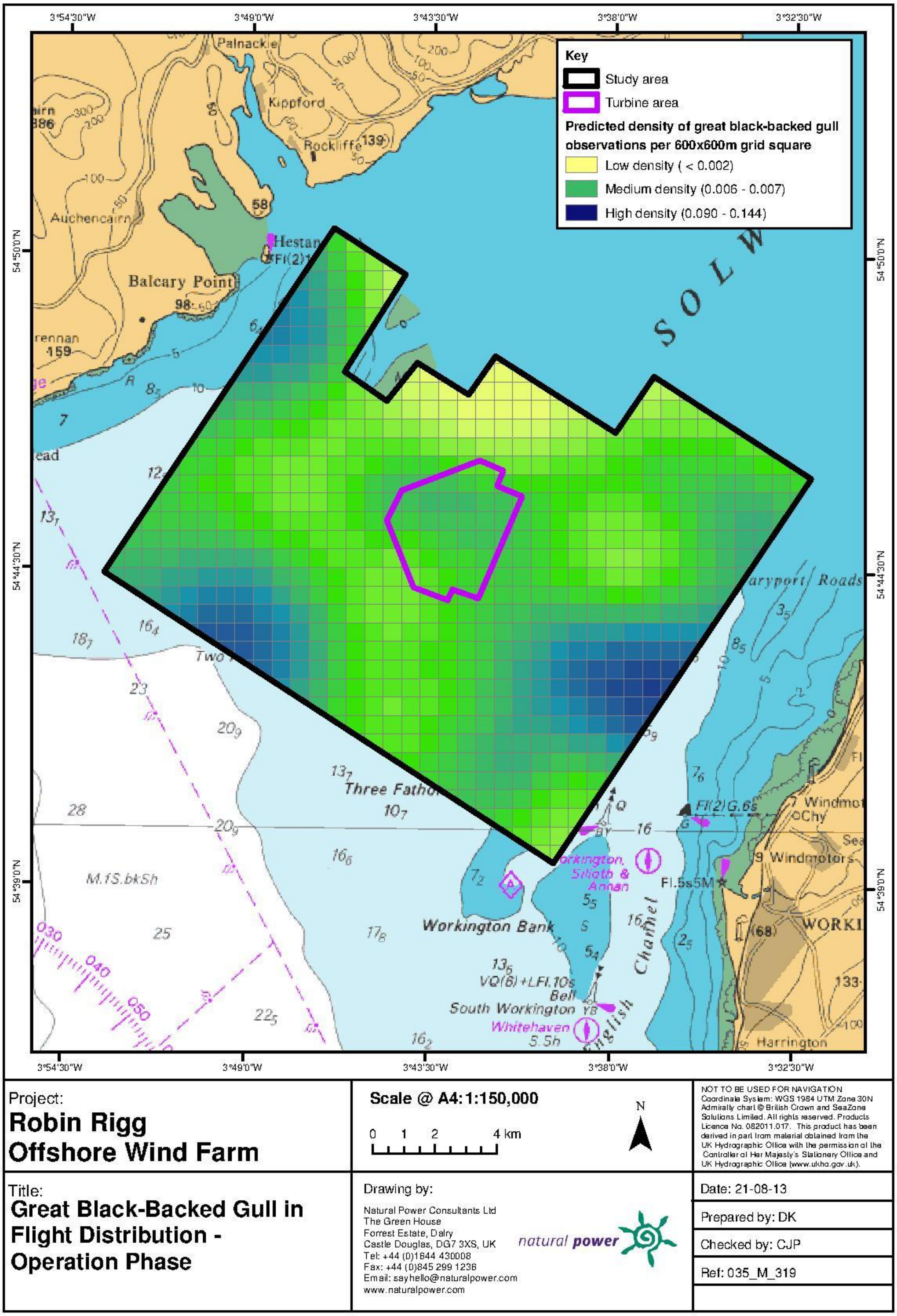


Figure 3.112: Density surface map of the predicted density of great black-backed gulls in flight across the study area during the operational phase of the development

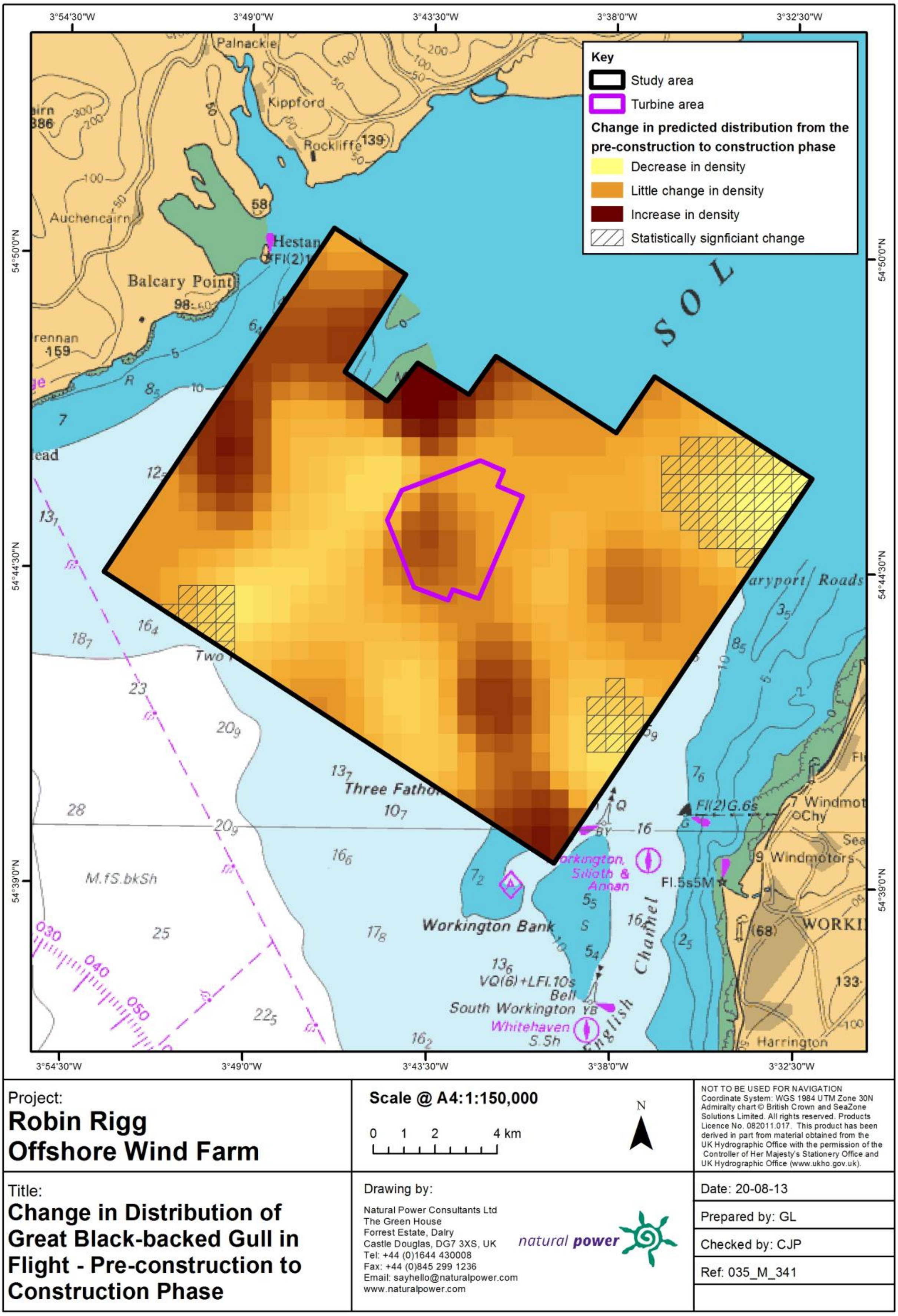
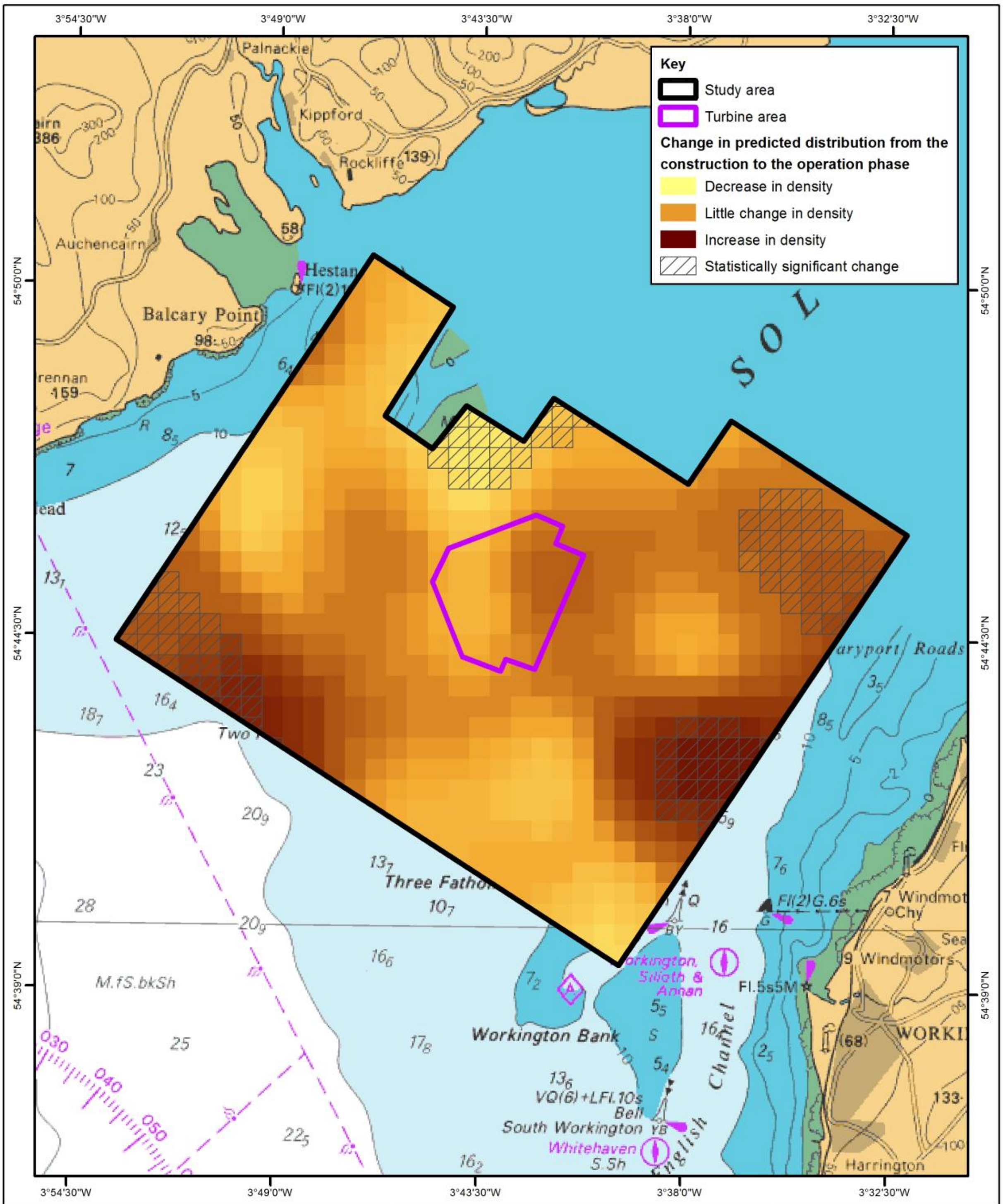


Figure 3.113: Plot of the difference in predicted density of great black-backed gulls in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Great Black-backed Gull in Flight - Construction to Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

natural power

Date: 20-08-13
Prepared by: GL
Checked by: CJP
Ref: 035_M_342

Figure 3.114: Plot of the difference in predicted density of great black-backed gulls in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines

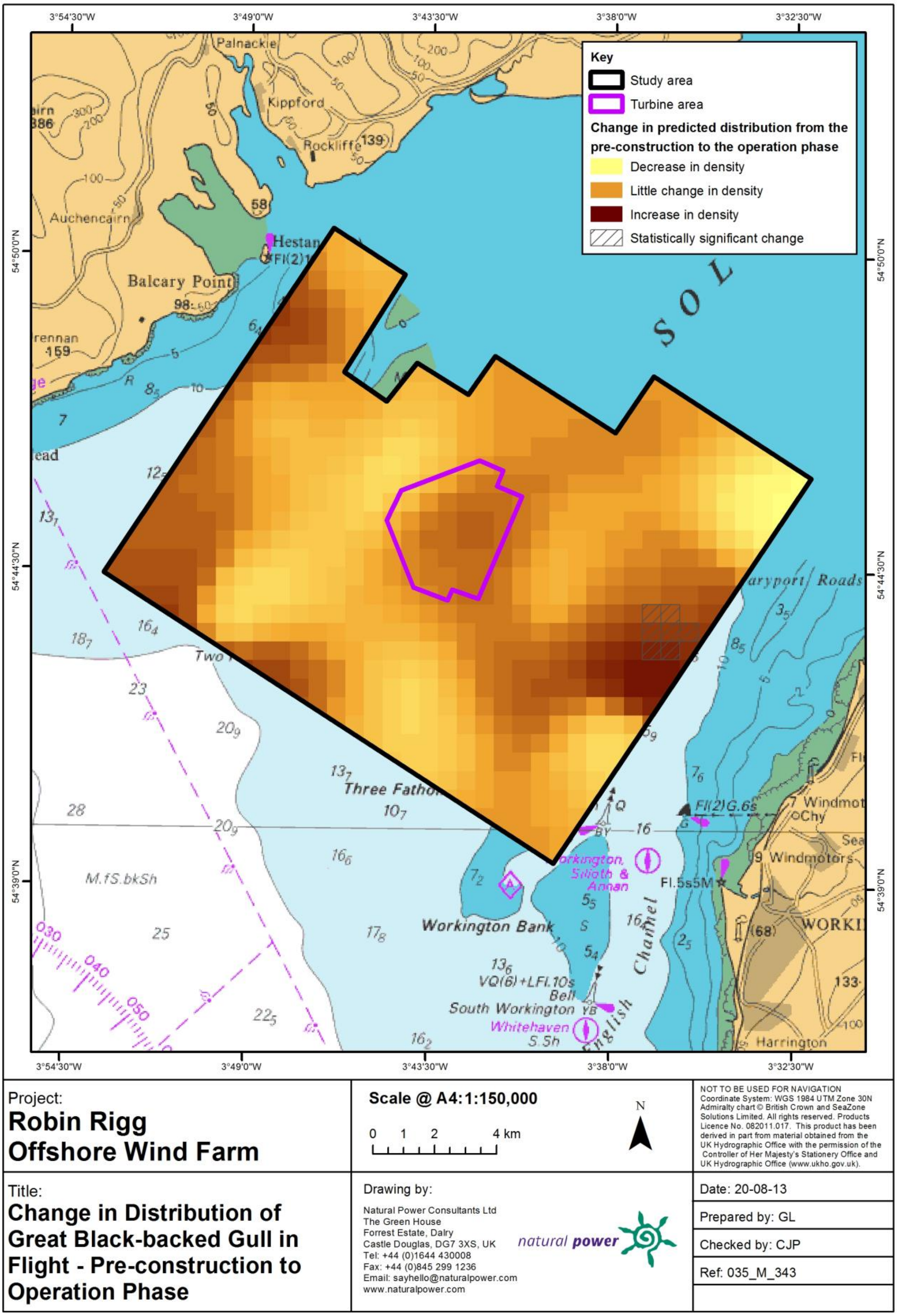


Figure 3.115: Plot of the difference in predicted density of great black-backed gulls in flight between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

3.12.3. Collision risk

The percentage of great black-backed gulls recorded in different height bands relative to rotor height can be found in Table 3.43 and Figure 3.116. The band 35-125 represents rotor height. Data were combined for Chi-squared analysis and a significant difference was found between flight bands (χ^2 = 14.29, p = <0.001, 2 df) with few birds than expected observed at rotor height pre-construction although this is mostly likely the result of there being no structures being present within the study area to use as a reference height (i.e. a turbine).

Table 3.43: Proportion of great black-backed gull observed flying at different height bands during the three stages of development.

	Flight band (m)					
	1 (0–5)	**2 (6–25)**	**3 (26–34)**	**4 (35– 125)**	**5 (126–200)**	**6 (200+)**
Pre-construction	27	61	6	6	0	0
Construction	13	59	13	15	0	0
Operation	45	35	7	10	0	0

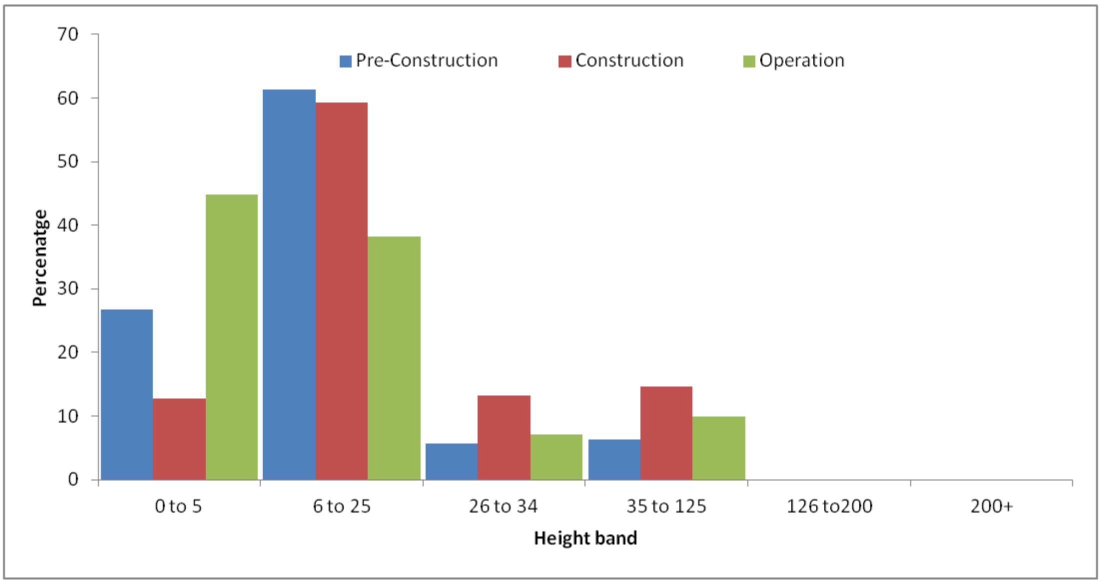


Figure 3.116: Percentage of great black-backed gull recorded in different flight bands during the different stages of the development.

3.13. Results: Guillemot

3.13.1. Summary statistics

The number of guillemot recorded during the three stages of the development can be found in Table 3.44 and Table 3.45. The mean number of guillemot recorded each month is presented in Figure 3. 112 and average group size recorded in each of the three phases in Figure 3.118.

The raw data suggest a decline during the construction phase with a degree of recovery post-construction. Similar numbers of birds were recorded in all operational years with monthly patterns of abundance fairly consistent between of the phases of the development (Figure 3.117). The average group size for each phase suggests a slight decrease in group size during the construction phase (Figure 3.118).

Table 3.44: Raw data for guillemot recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		Construction		Operation years 1-3	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	2192/0.35	262/0.04	3656/0.30	528/0.04	3329/0.32	454/0.04
Total number individuals/IPUE	3797/0.60	355/0.06	5100/0.42	682/0.06	5351/0.51	665/0.06

Table 3.45: Standardised data for guillemot recorded per segment during each phase of the construction of the wind farm and equivalent number per km². SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	Pre-construction				Construction				Operation years 1-3			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	149	1.0	1531	0.64	40	0.25	1193	0.44	204	0.52	3596	0.67
Number per km²	2.80		1.79		0.70		1.23		1.46		1.88	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	12	0.08	191	0.08	6	0.04	197	0.07	16	0.04	567	0.12
Number per km²	0.22		0.22		0.11		0.20		0.11		0.34	

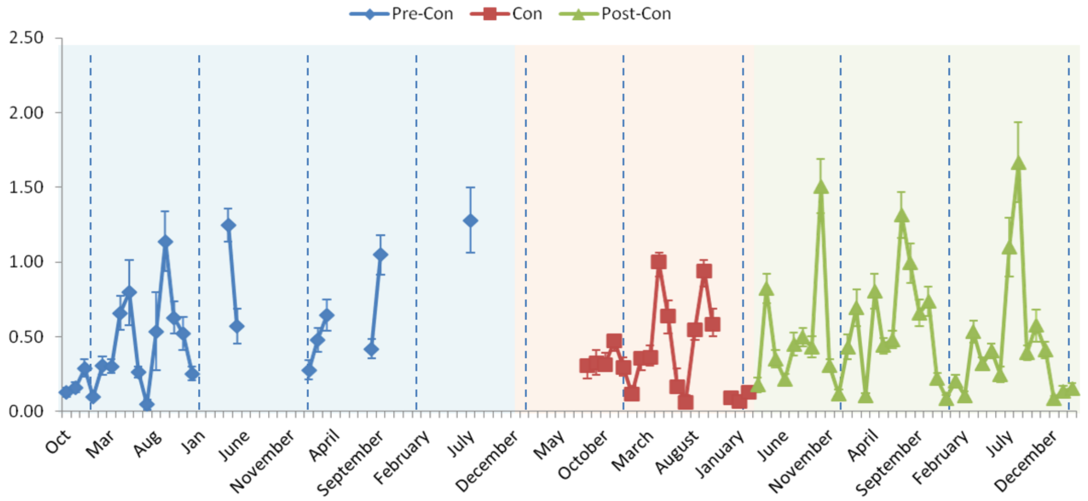


Figure 3.117: Mean number of guillemot observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

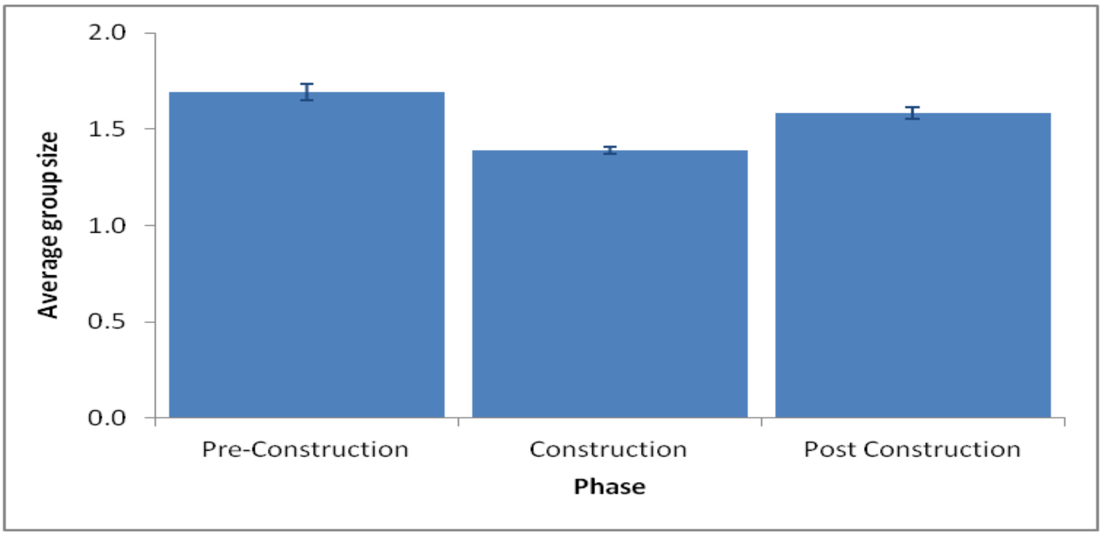


Figure 3.118: Mean group size for guillemot observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.13.2. Distribution and abundance

The standardised raw data for birds on the sea suggest that numbers within the wind farm site and the study area as a whole decrease during the construction phase and increase again during operation. The level of increase was greater outside of the wind farm area (Table 3.45). The model found a highly significant decline in abundance across the entire study area during the construction phase (Table 3.46). The corresponding density plot demonstrates this occurred within the wind farm site and to the south-west (Figure 3.124). Predicted estimates for the wind farm site and buffers (Figure 3.119) suggest avoidance of the wind farm are during the construction phase. During operation, abundance returned to similar levels as observed pre-construction.

The standardised raw data for birds in flight suggest that numbers decrease within the wind farm site during the construction phase but not across the study area as a whole (Table 3.45). The model outputs show no significant difference in abundance or distribution between the three phases however there is some indication of an avoidance of the wind farm site and surrounding 2 km during the construction and operational phases (Figure 3.120).

Table 3.46: Model outputs for guillemots on the sea

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-0.380	0.079	-4.809	1.54e-06 ***
Pre-construction to operation	-0.038	0.065	-0.590	0.555

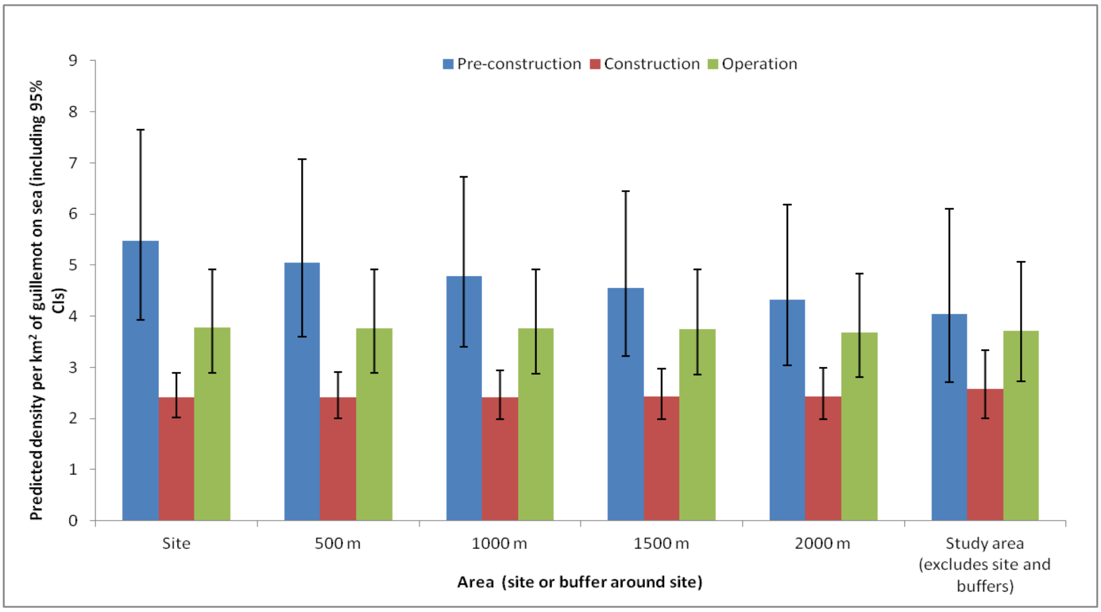


Figure 3.119: Predicted density of guillemot on the sea in July with 95% confidence intervals (95% CI)

Table 3.47: Model outputs for guillemots in flight

Comparison	Parameters estimate	Standard error	t-value	P
Pre-construction to construction	-0.116	0.296	-0.392	0.6949
Pre-construction to operation	-0.329	0.260	-1.266	0.2055

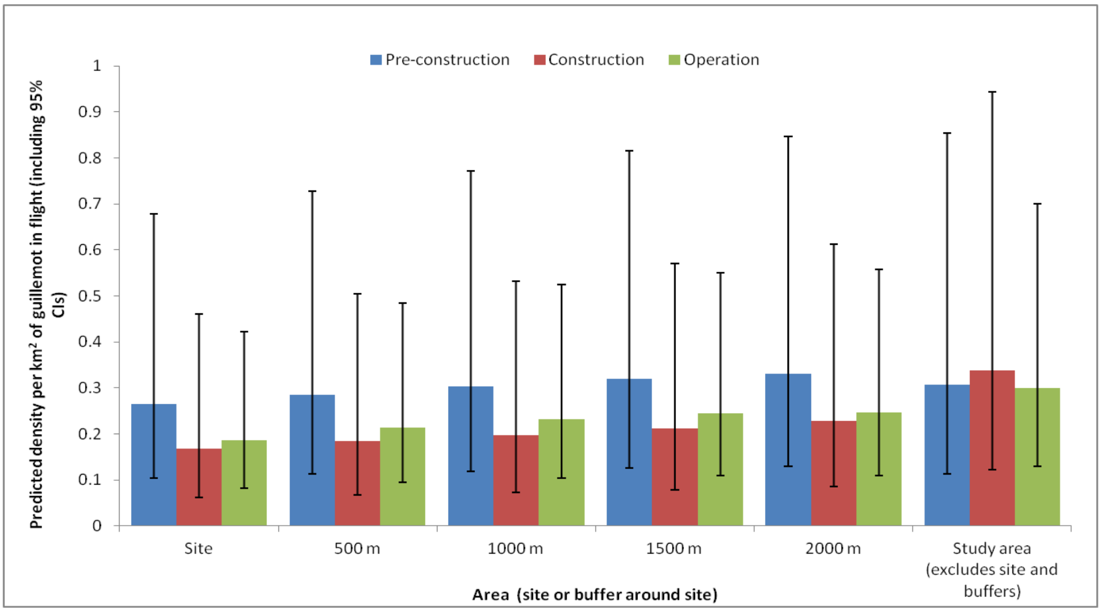


Figure 3.120: Predicted density of guillemot in flight for June with 95% confidence intervals (95% CI)

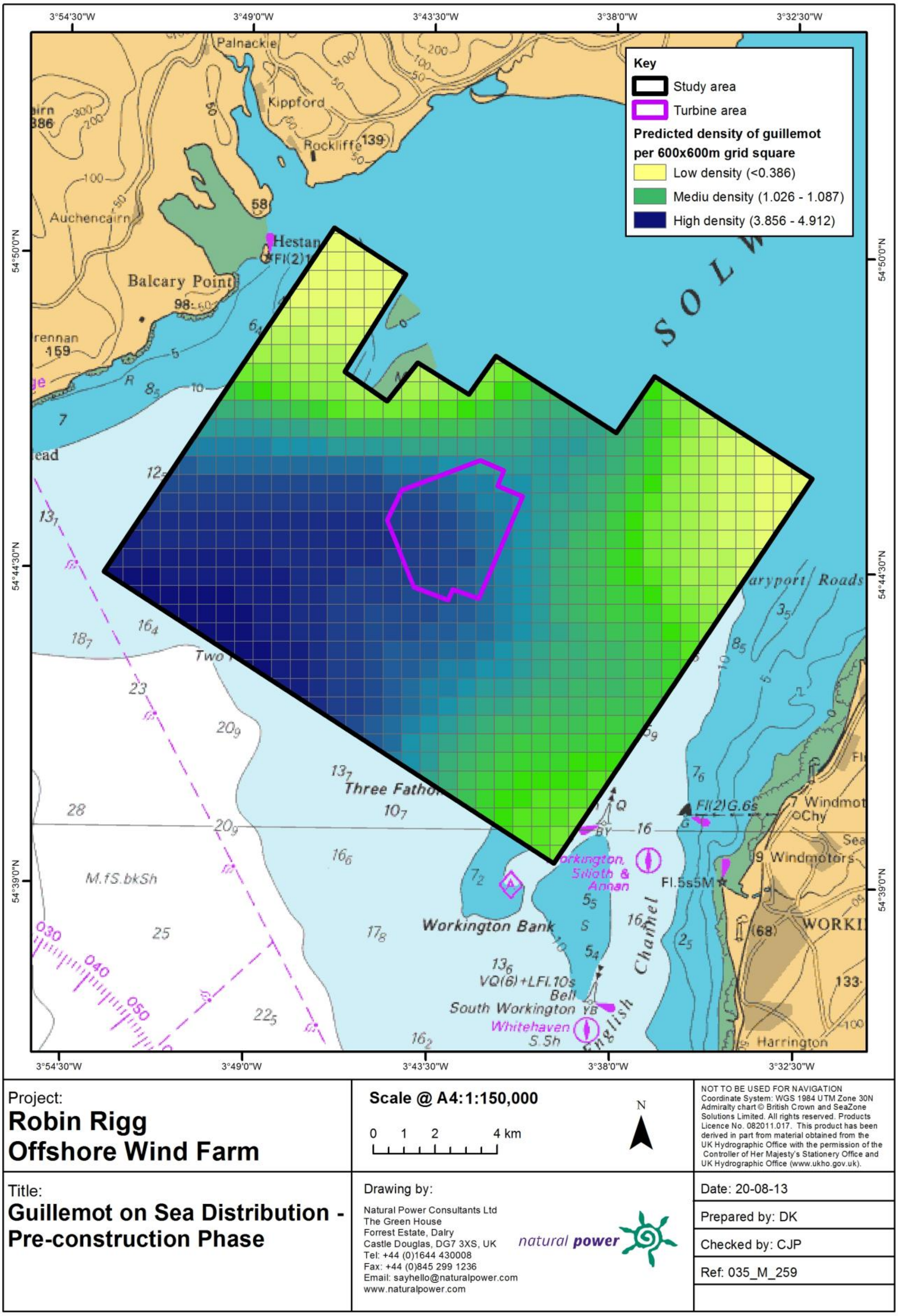


Figure 3.121: Density surface map of the predicted density of guillemot on the sea across the study area during the pre-construction phase of the development

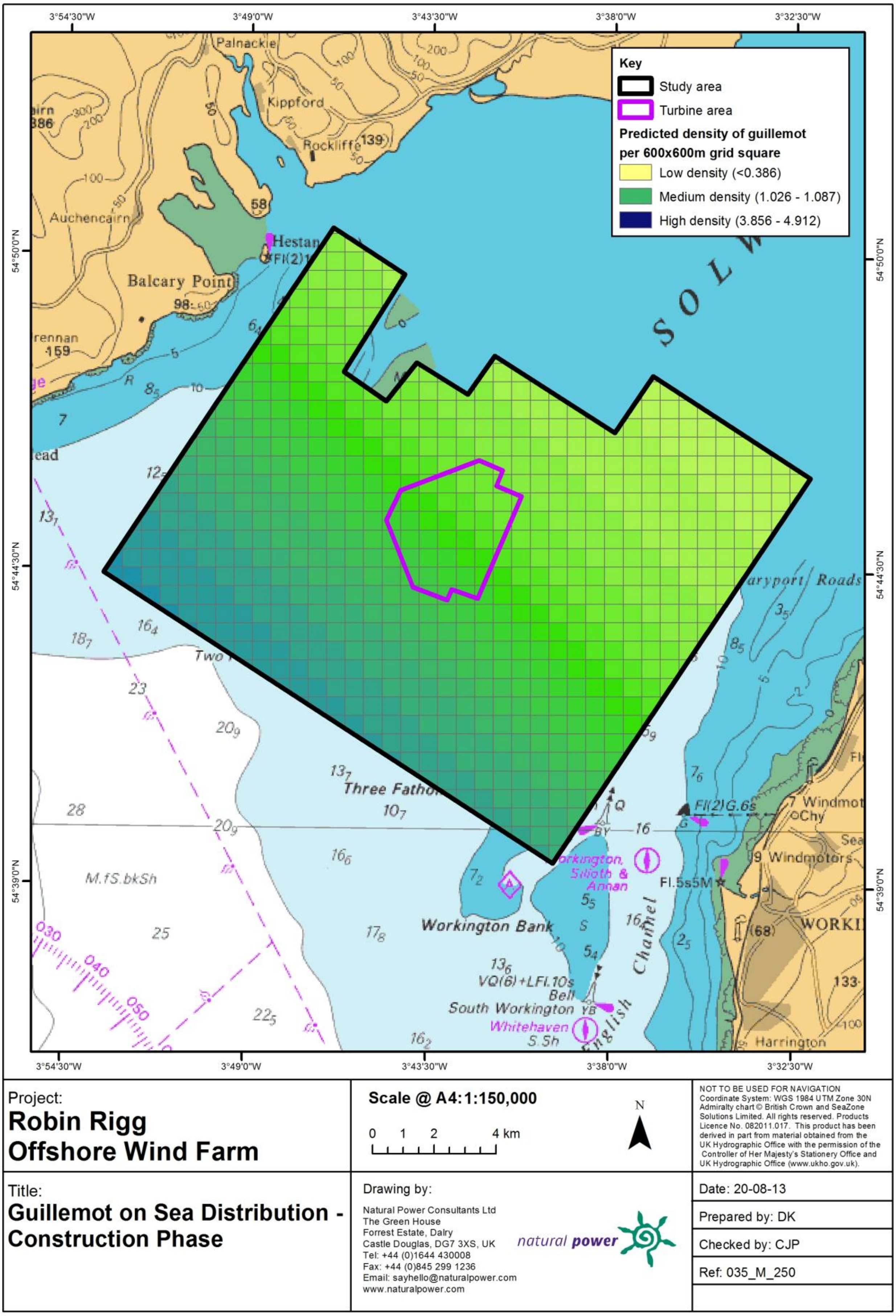


Figure 3.122: Density surface map of the predicted density of guillemot on the sea across the study area during the construction phase of the development

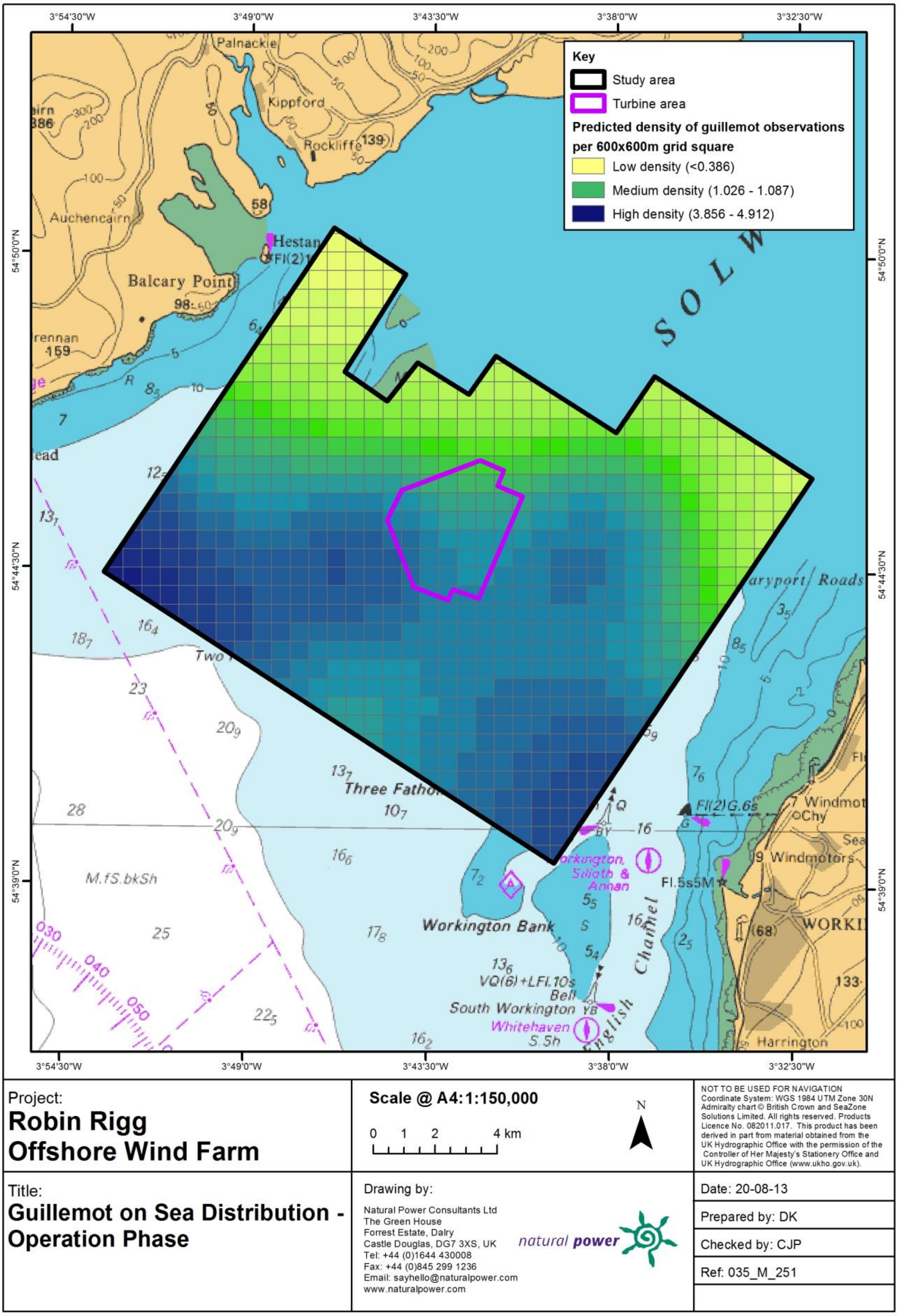


Figure 3.123: Density surface map of the predicted density of guillemot on the sea across the study area during the operational phase of the development

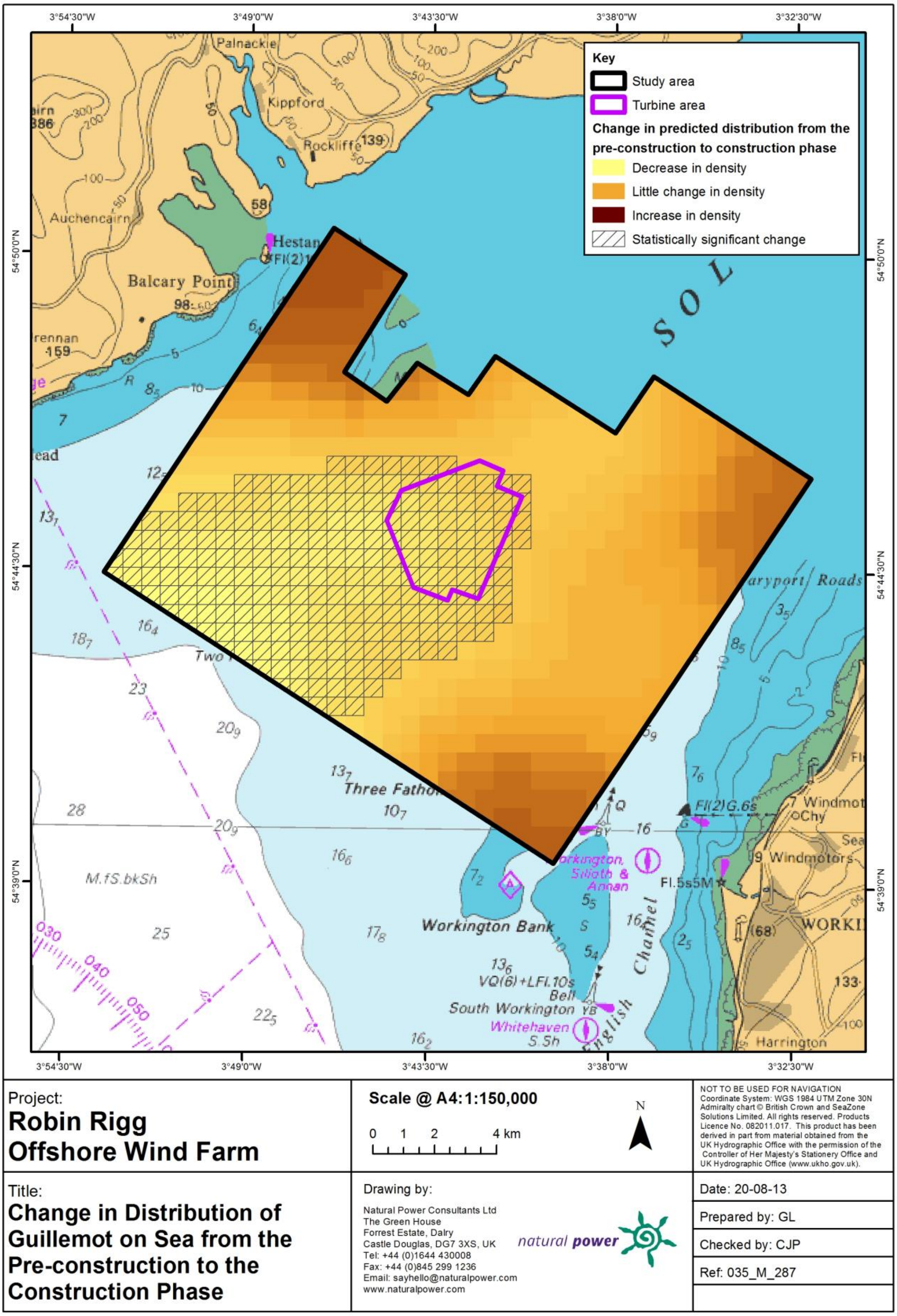


Figure 3.124: Plot of the difference in predicted density of guillemot on the sea between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

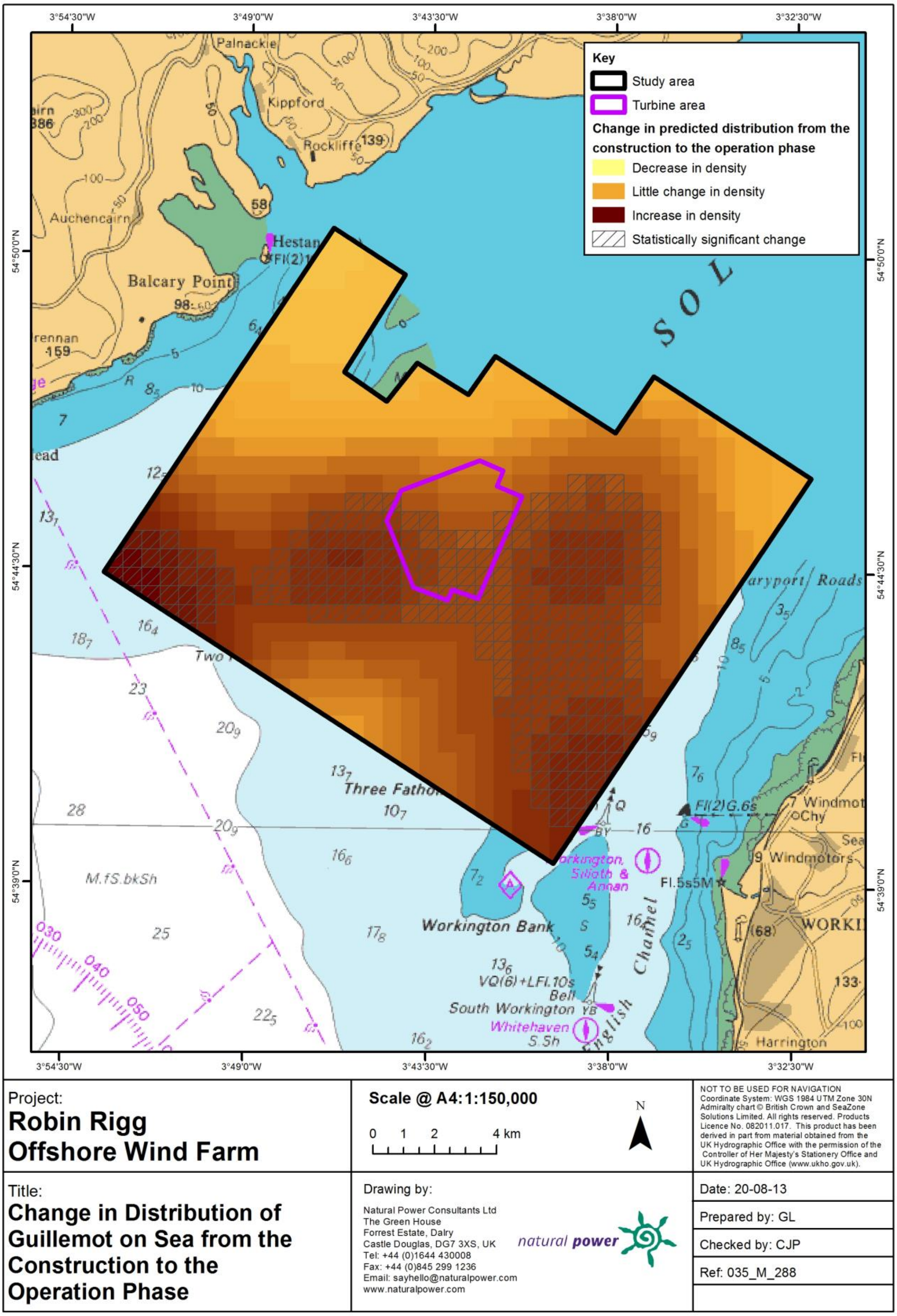


Figure 3.125: Plot of the difference in predicted density of guillemot on the sea between the construction and operational phases of the development. Significant differences are marked with diagonal lines

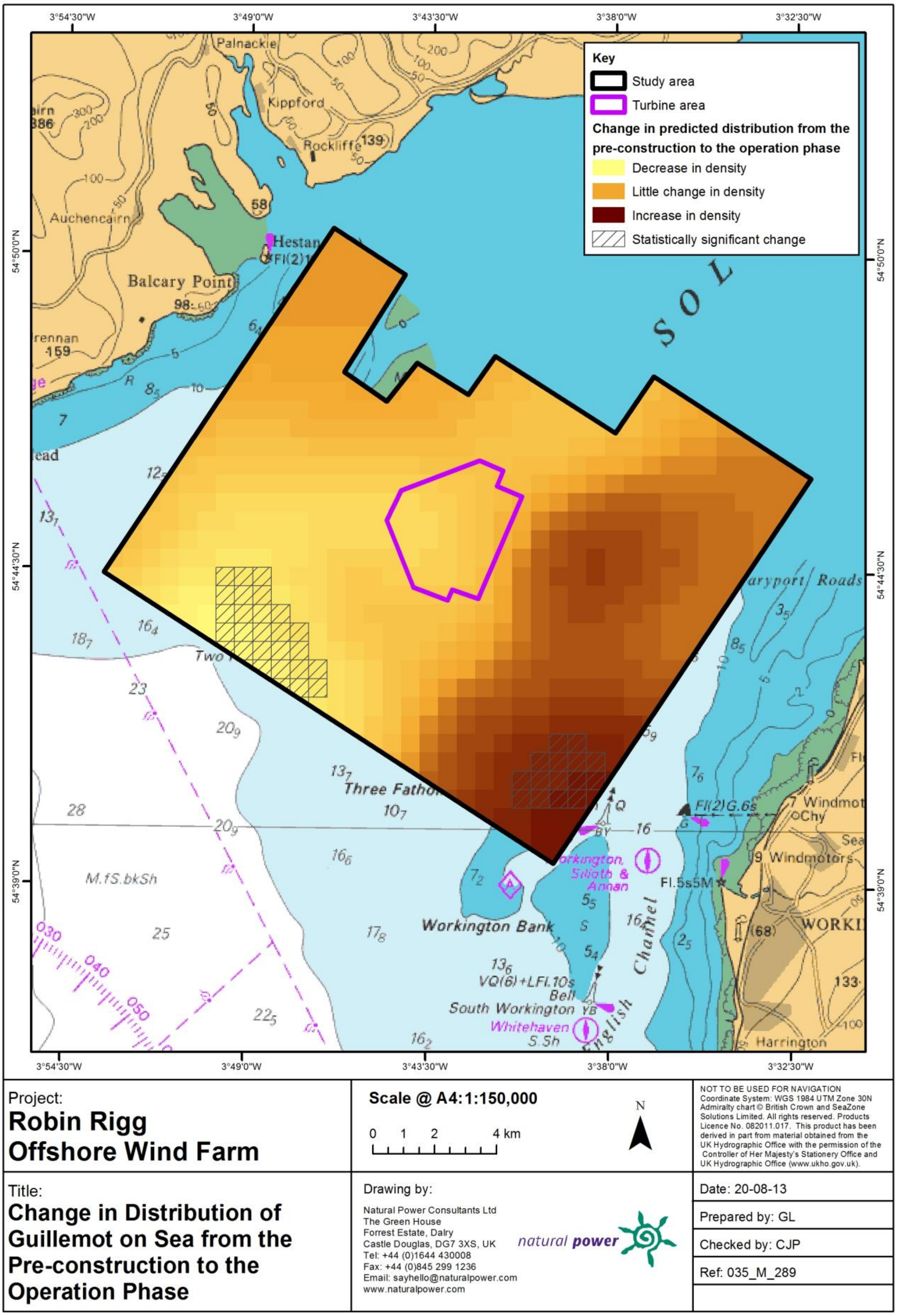


Figure 3.126: Plot of the difference in predicted density of guillemot on the sea between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

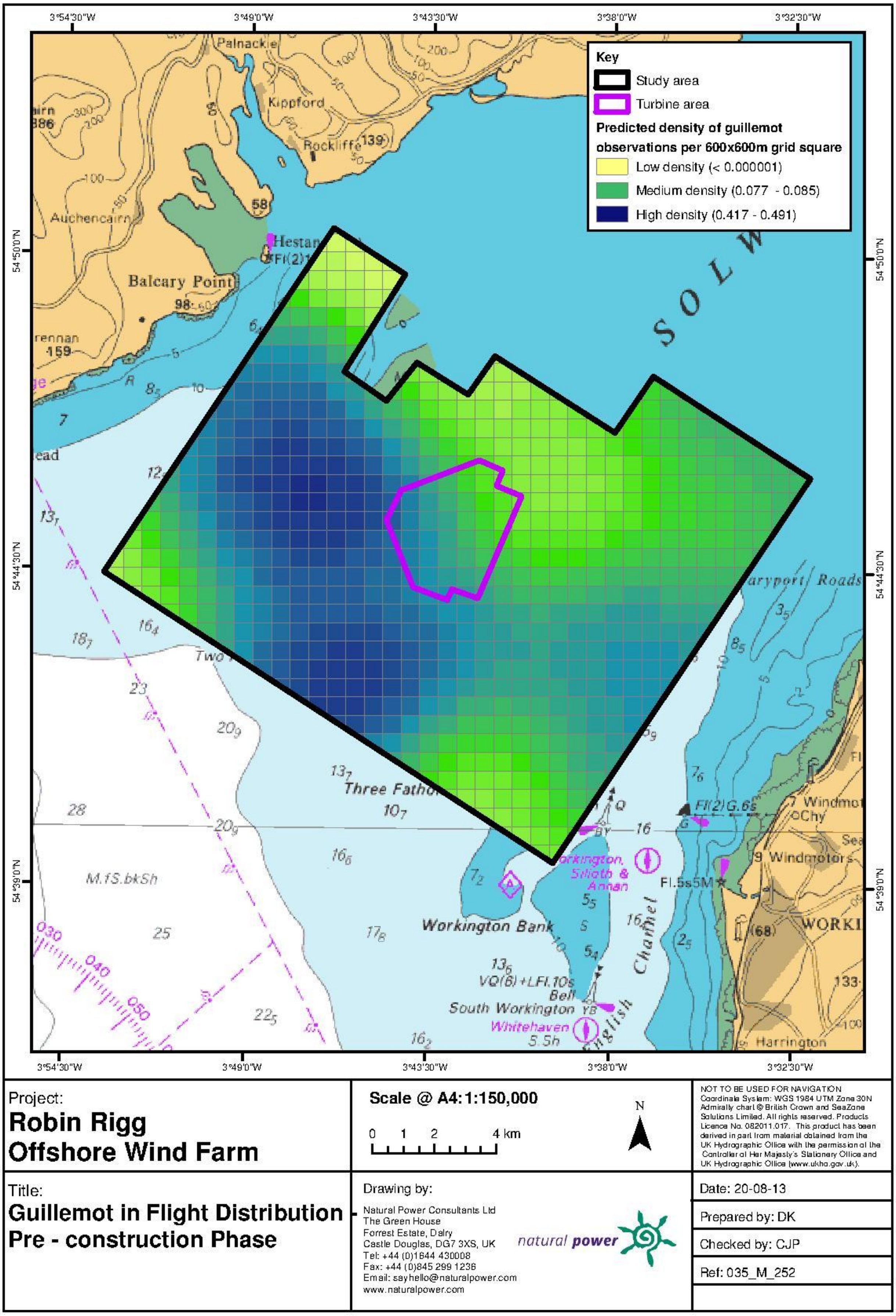


Figure 3.127: Density surface map of the predicted density of guillemot in flight across the study area during the pre-construction phase of the development

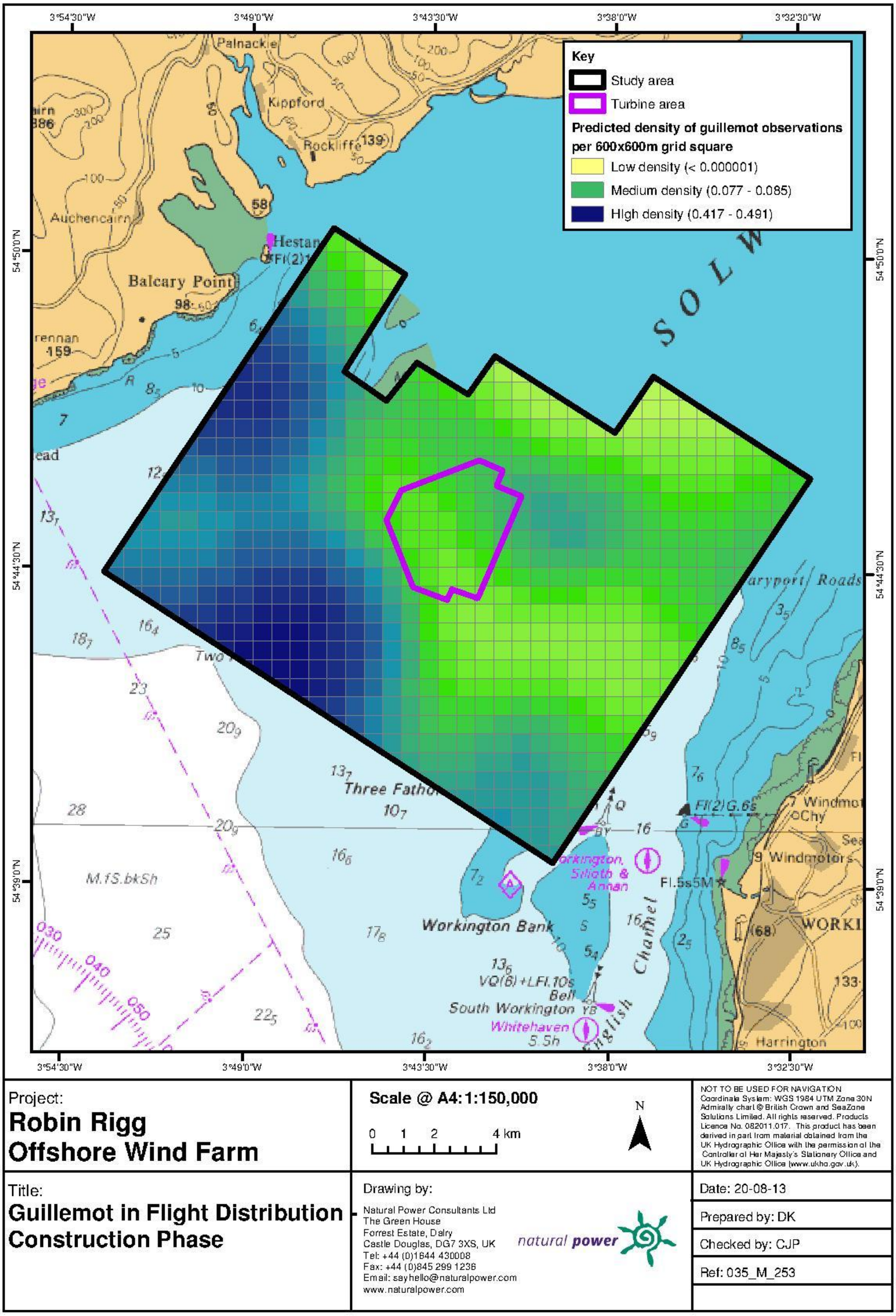


Figure 3.128: Density surface map of the predicted density of guillemot in flight across the study area during the construction phase of the development

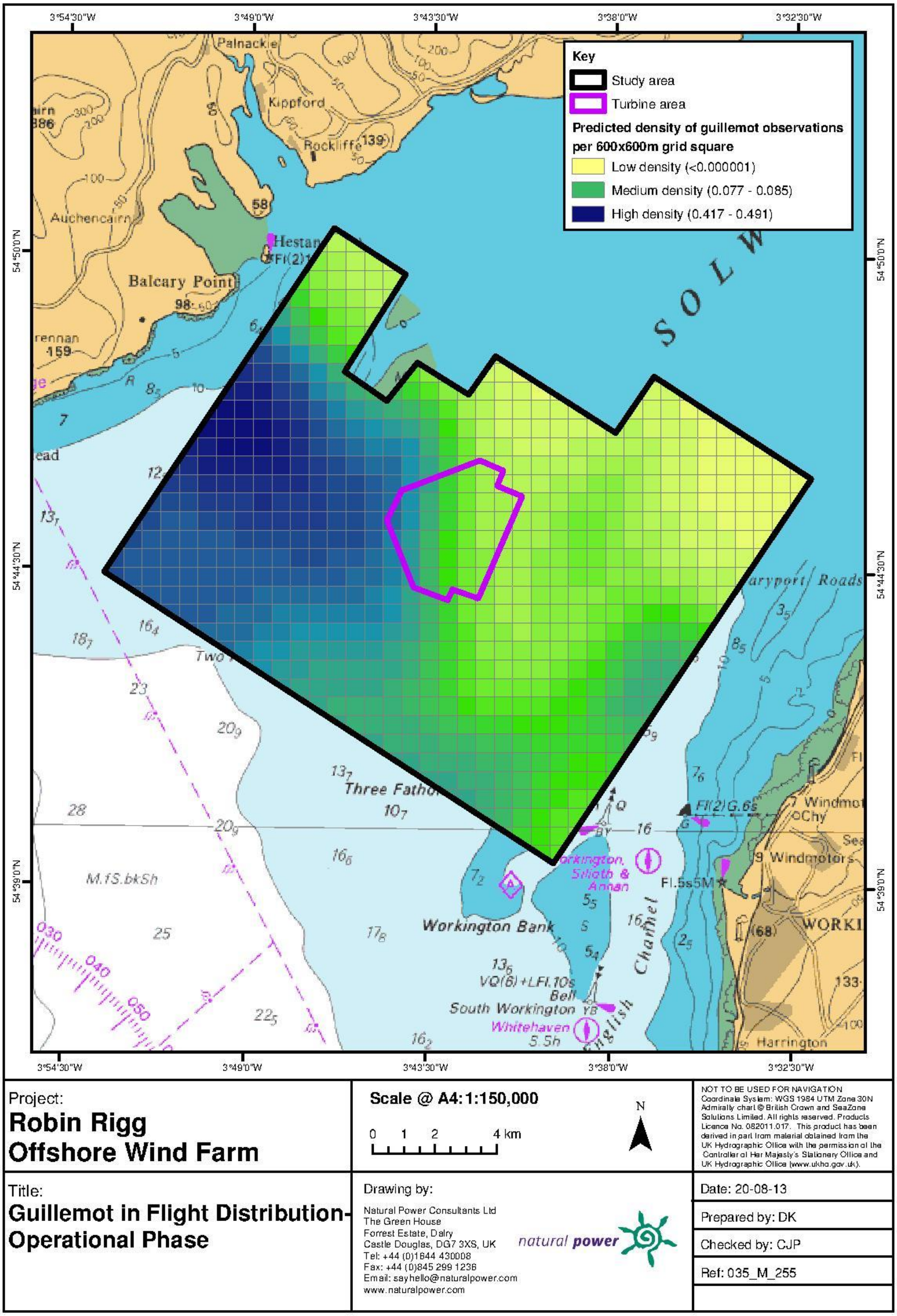


Figure 3.129: Density surface map of the predicted density of guillemot in flight across the study area during the operational phase of the development

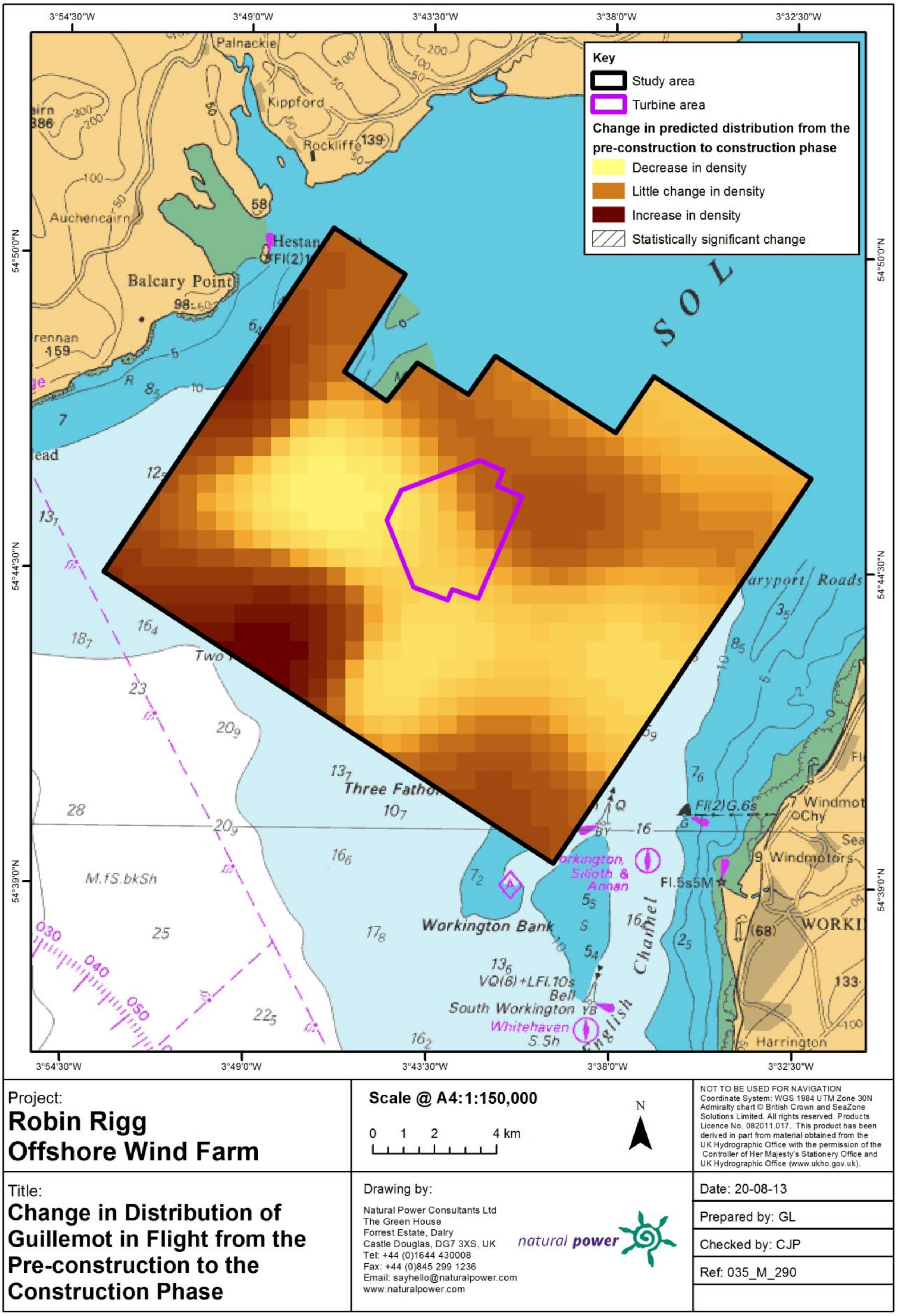


Figure 3.130: Plot of the difference in predicted density of guillemot in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

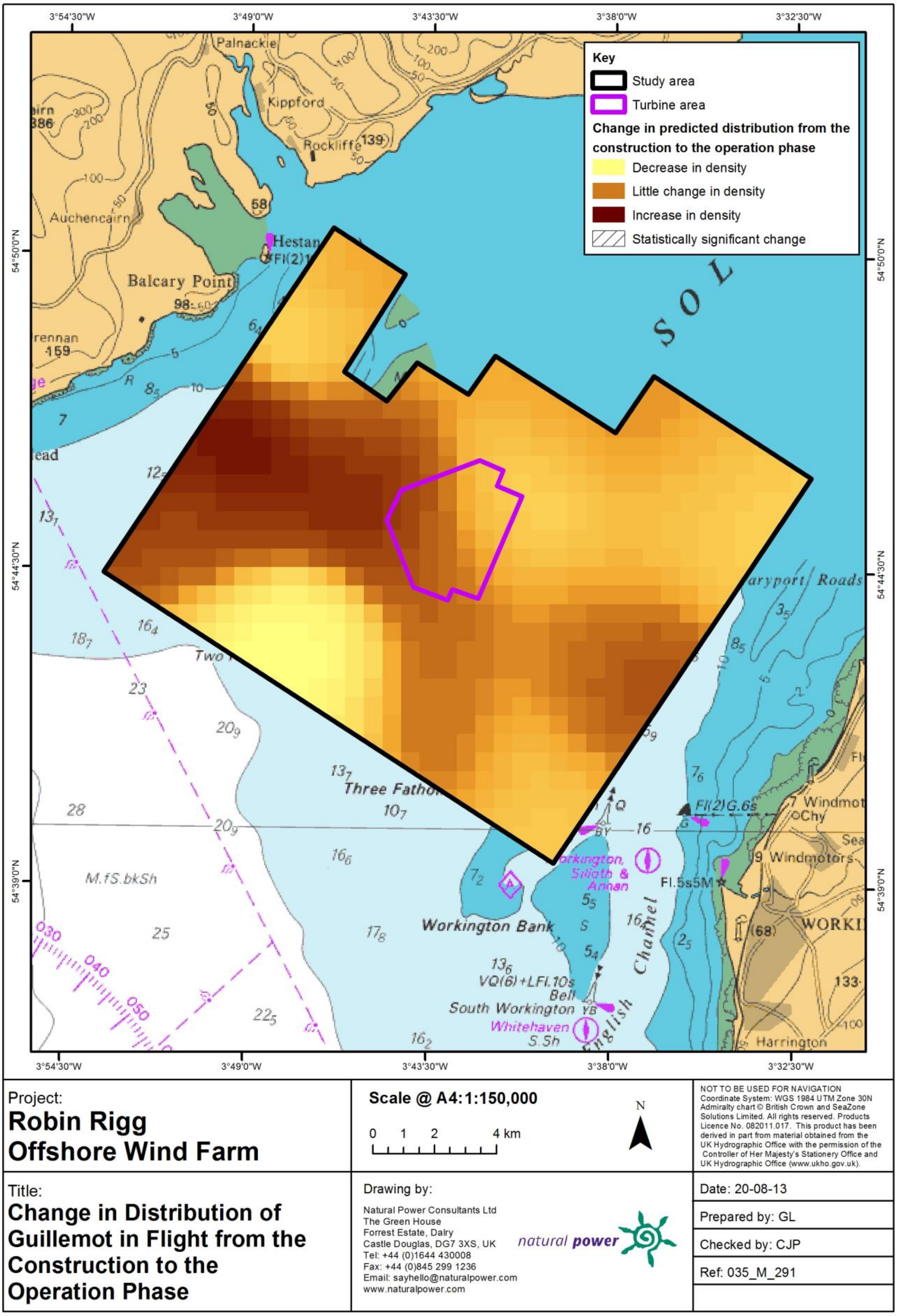
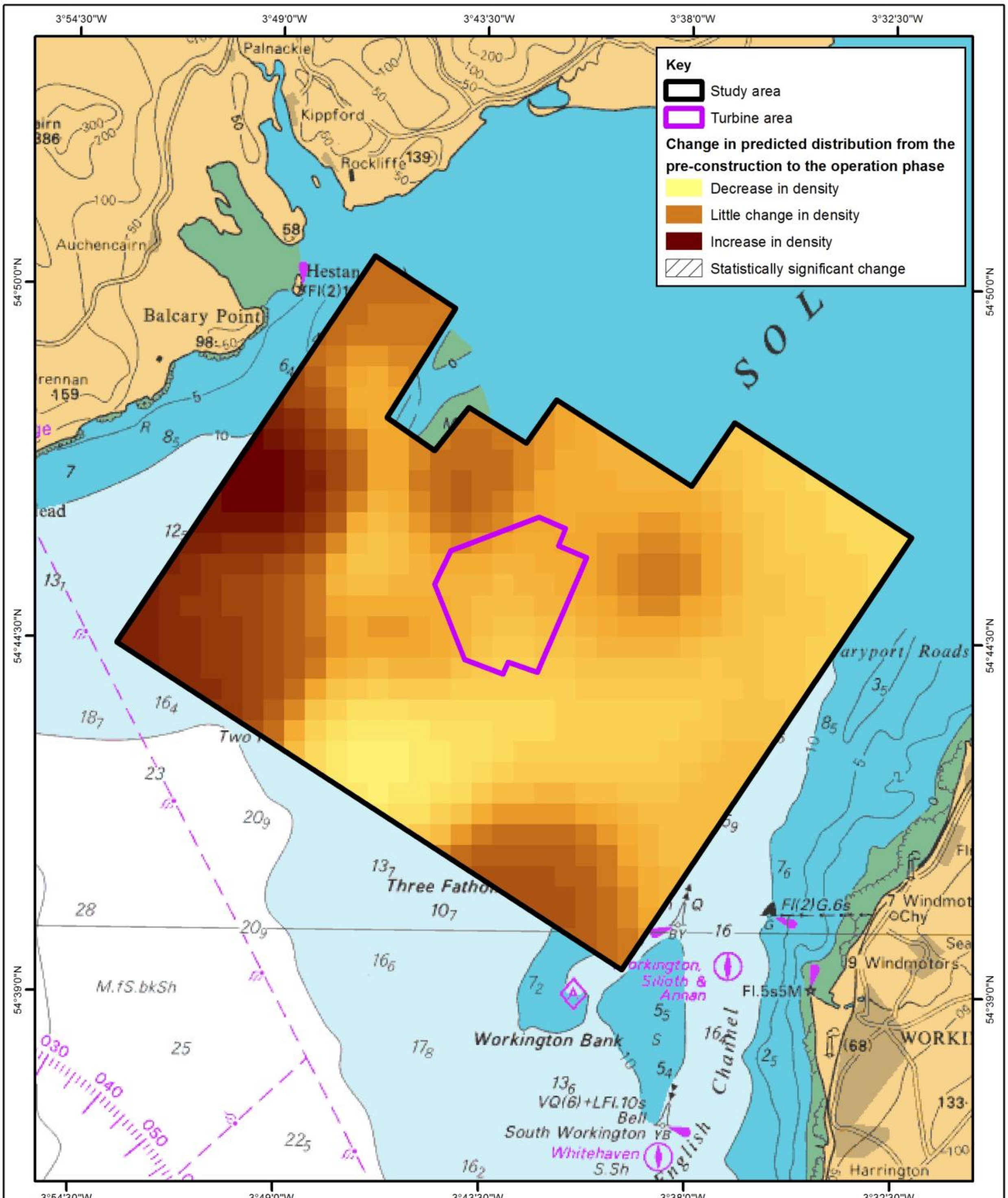


Figure 3.131: Plot of the difference in predicted density of guillemot in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines



Project:
Robin Rigg Offshore Wind Farm

Scale @ A4:1:150,000

0 1 2 4 km

N

NOT TO BE USED FOR NAVIGATION
Coordinate System: WGS 1984 UTM Zone 30N
Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).

Title:
Change in Distribution of Guillemot in Flight from the Pre-construction to the Operation Phase

Drawing by:
Natural Power Consultants Ltd
The Green House
Forrest Estate, Dalry
Castle Douglas, DG7 3XS, UK
Tel: +44 (0)1644 430008
Fax: +44 (0)845 299 1236
Email: sayhello@naturalpower.com
www.naturalpower.com

Date: 20-08-13

Prepared by: GL

Checked by: CJP

Ref: 035_M_292

Figure 3.132: Plot of the difference in predicted density of guillemot in flight between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

3.13.3. Collision risk

The percentage of guillemot recorded in different height bands relative to rotor height can be found in Table 3.48 and Figure 3.133. Band 4 (35-125 m) represents rotor height. No Chi-square test was carried out for this species as less than 1% of observed flights were at turbine rotor height.

Table 3.48: Proportion of guillemot recorded at different height bands through the three phases of development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	99	1	0	0	0	0
Construction	90	9	1	0	0	0
Operation	96	4	0	0	0	0

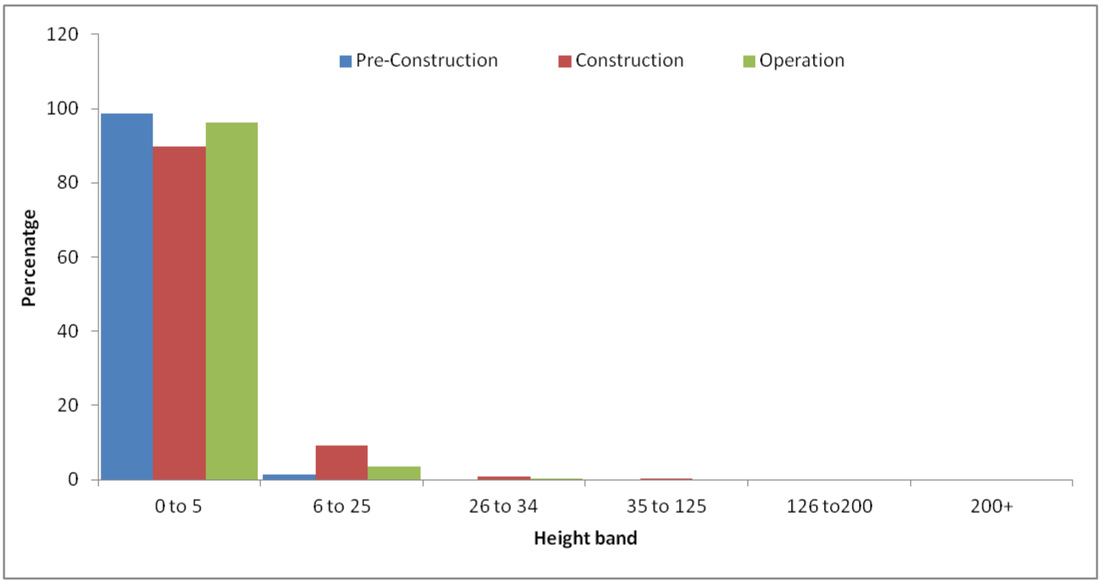


Figure 3.133: Percentage of guillemot recorded in different flight bands during the different stages of the development.

3.14. Results: Razorbill

3.14.1. Summary statistics

The number of razorbills recorded during each phase of the development can be found in Table 3.48 and Table 3.50. The mean number of razorbills recorded each month is presented in Figure 3.134 and average group size recorded in each of the three phases in Figure 3.135.

The raw data suggest a decline in abundance during the construction phase with a degree of recovery post-construction. Overall, the monthly pattern on abundance has remained consistent between phases (Figure 3.134) apart from during September when far more razorbill were recorded pre-construction compared to later years. The average group size recorded in each phase of the development suggests a decline during the construction phase (Figure 3.135).

Table 3.49: Raw data for razorbill recorded per segment during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction		Construction		Operation years 1-3	
	On sea	In flight	On sea	In flight	On sea	In flight
Total number sightings/SPUE	499/0.08	192/0.03	1083/0.09	152/0.01	886/0.08	133/0.01
Total number individuals/IPUE	1275/0.20	921/0.15	2673/0.22	284/0.02	2728//0.26	429/0.04

Table 3.50: Standardised data for razorbill recorded per segment during each phase of the construction of the wind farm and equivalent number per km². SPUE = sightings per unit effort; IPUE = individuals per unit effort

On sea	Pre-construction				Construction				Operation years 1-3			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE	No	IPUE
Total number individuals/ IPUE	54	0.35	492	0.21	19	0.12	561	0.21	46	0.12	1935	0.36
Number per km²	0.98		0.59		0.34		0.59		0.34		1.01	
In flight	**Pre-construction**				**Construction**				**Operation years 1-3**			
	Site		Buffer		Site		Buffer		Site		Buffer	
	No	IPUE	No	IPUE	No	IPUE	No	IPU E	No	IPUE	No	IPUE
Total number individuals/ IPUE	5	0.03	73	0.03	0	0.00	81	0.03	5	0.01	397	0.07
Number per km²	0.08		0.08		0.00		0.08		0.03		0.20	

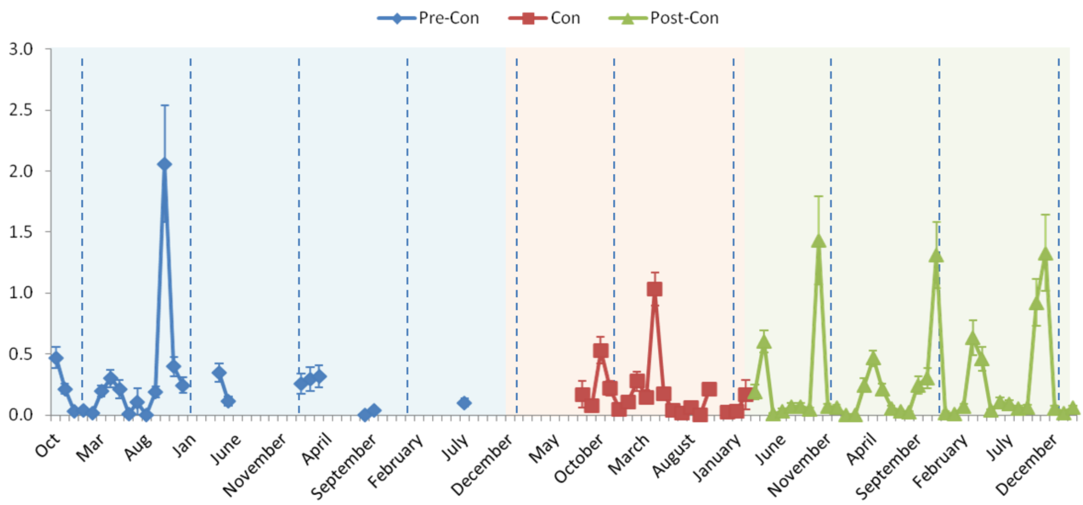


Figure 3.134: Mean number of razorbill observed per segment per month during the pre-construction, construction and operational phase (in flight and on the water) ±standard error

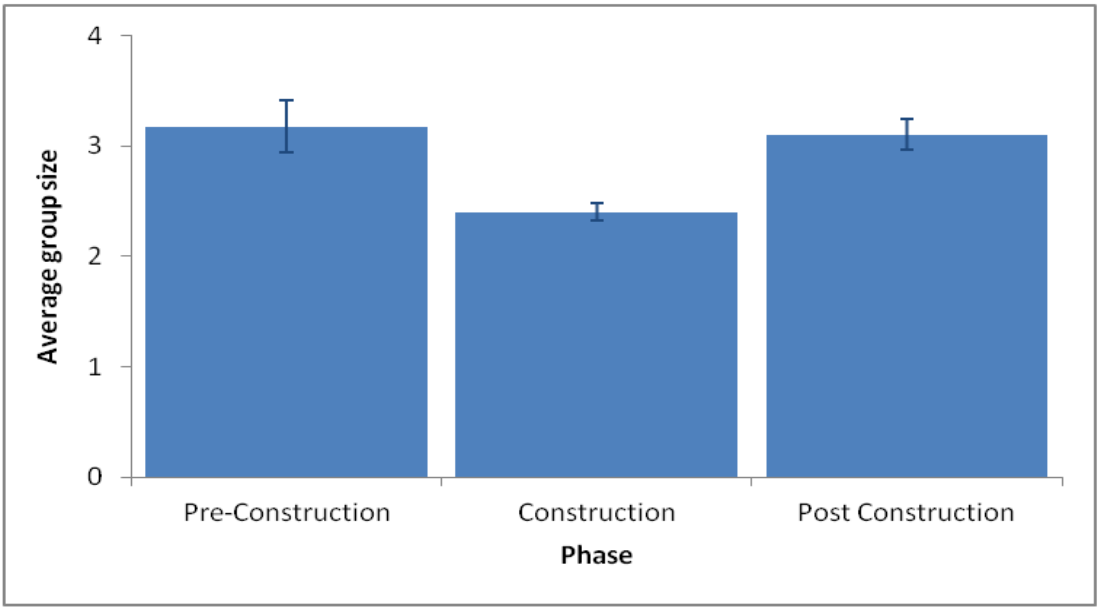


Figure 3.135: Mean group size for razorbill observed per sighting during the pre-construction, construction and operational phases (±standard error).

3.14.2. Distribution and abundance

The standardised raw data for birds on the sea and in flight suggest a possible decline in abundance within the wind farm site during construction and operation (Table 3.50). However numbers on the sea and in flight appear to have increased overall across the three phases (Table 3.50).

The model outputs (both on the sea and in flight) do not support a change in abundance or distribution among the three development phases (Table 3.51 and Table 3.52), except for a potential decrease in numbers of razorbill on the sea in the northern part of the study area during the operational phase (Figure 3.143). Although the predictions for the sites and buffer areas might suggest a degree of avoidance of the wind farm site for birds on the sea during construction and particularly during operation (Figure 3.136 and Figure 3.137).

Table 3.51: Model outputs for razorbill on the sea

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	0.0245	0.4062	0.060	0.952
Pre-construction to operation	-0.0619	0.3629	-0.170	0.865

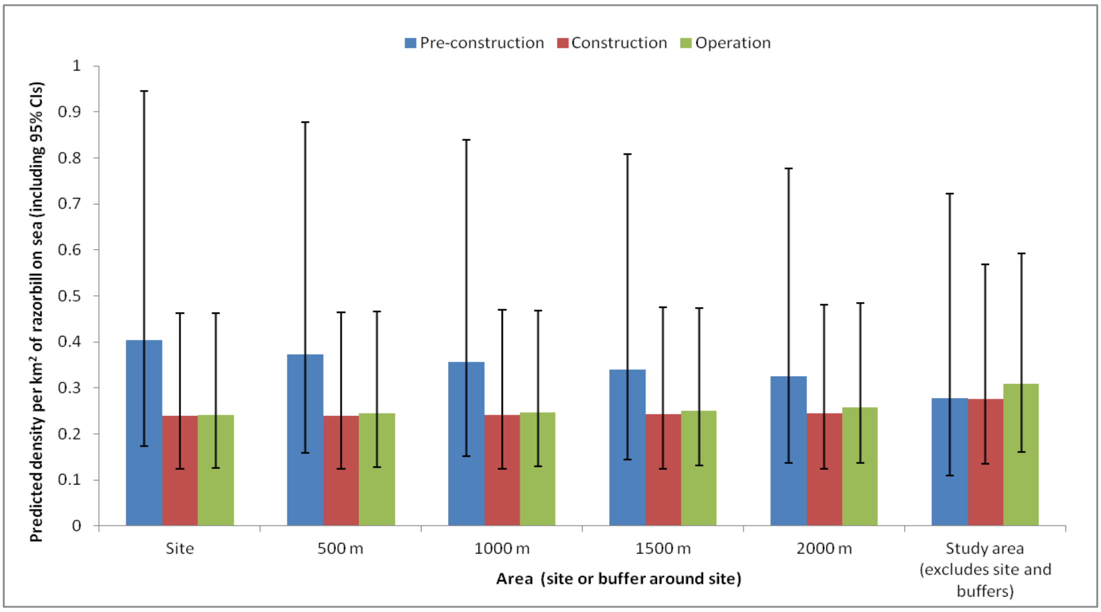


Figure 3.136: Predicted density for razorbill on the sea in the breeding season with 95% confidence intervals

Table 3.52: Model outputs for razorbill in flight

Comparison	Parameter estimate	Standard error	t-value	P
Pre-construction to construction	-0.144	0.614	-0.235	0.814
Pre-construction to operation	0.703	0.465	1.510	0.131

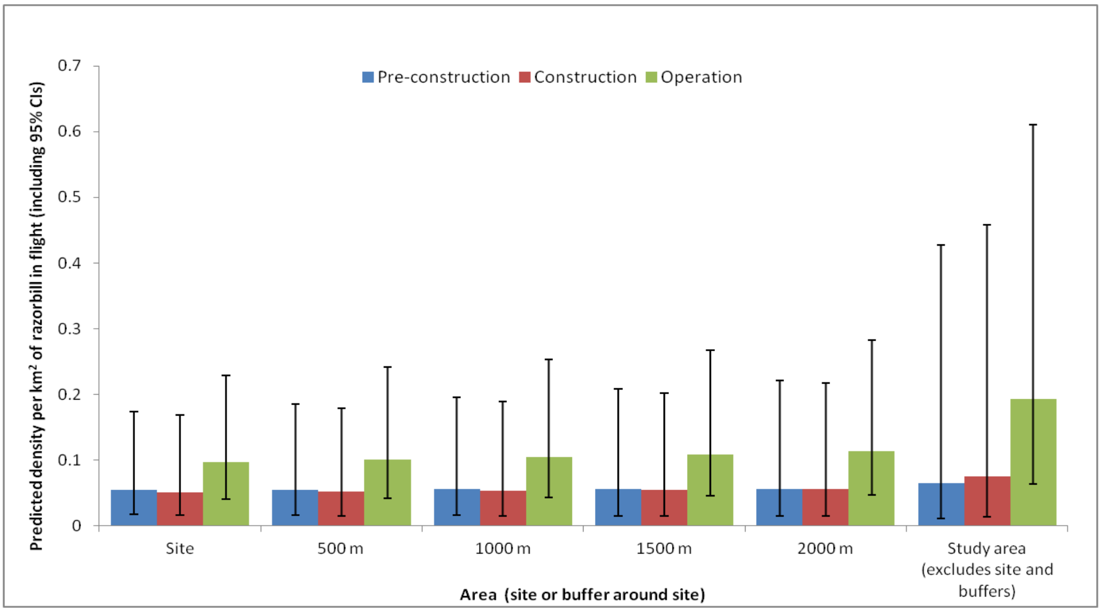


Figure 3.137: Density of razorbill in flight during the non-breeding season with 95% confidence intervals

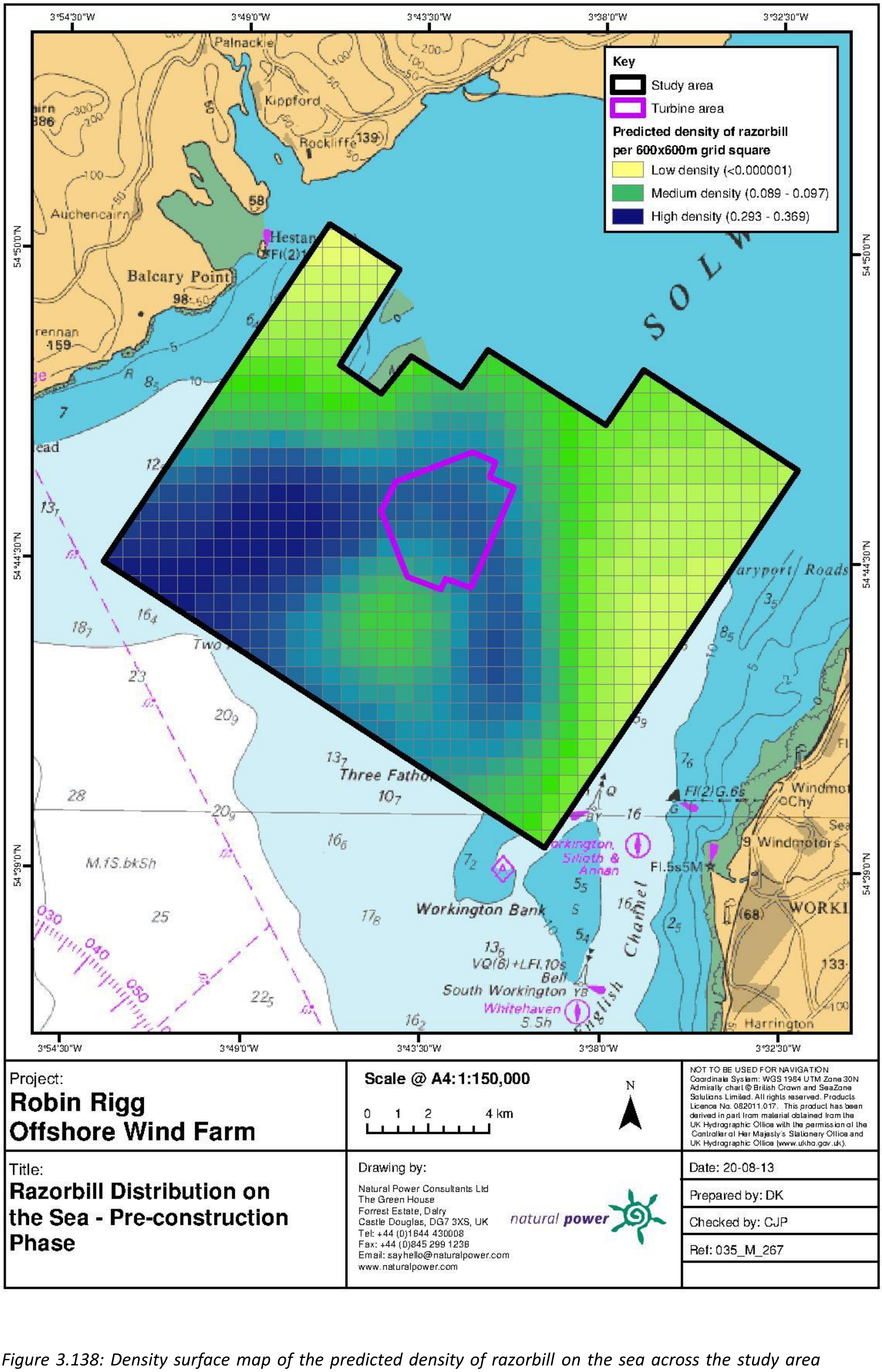


Figure 3.138: Density surface map of the predicted density of razorbill on the sea across the study area during the pre-construction phase of the development

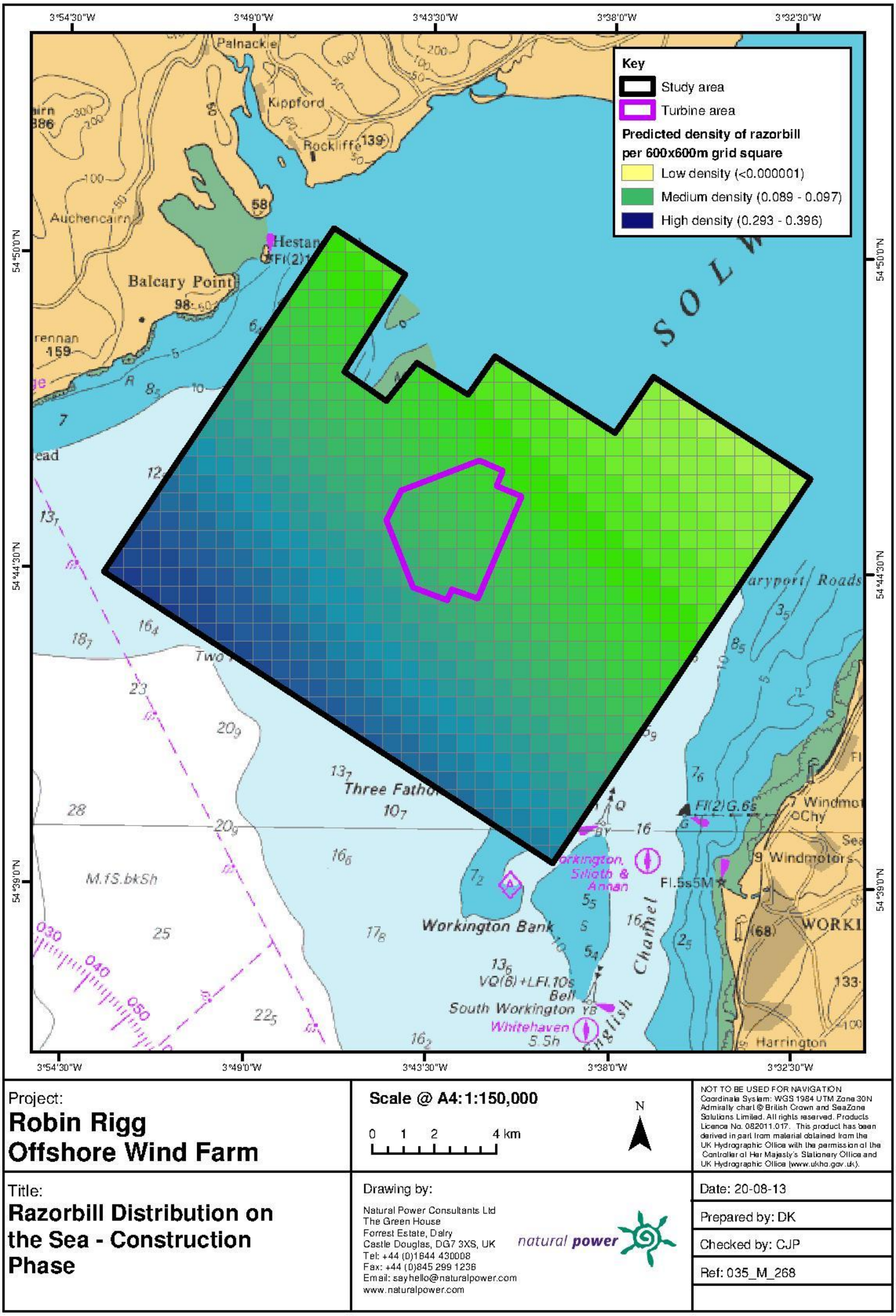


Figure 3.139: Density surface map of the predicted density of razorbill on the sea across the study area during the construction phase of the development

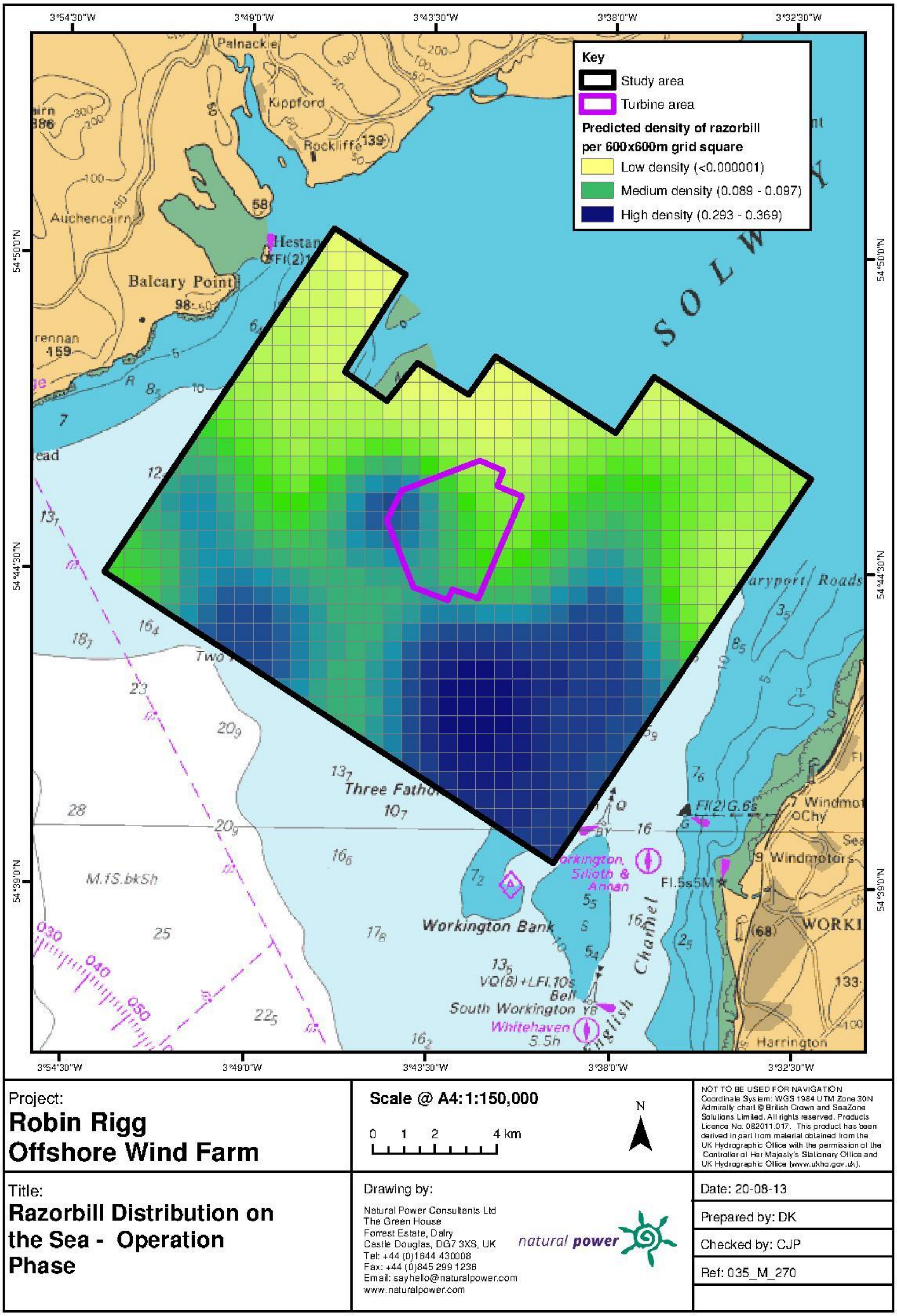
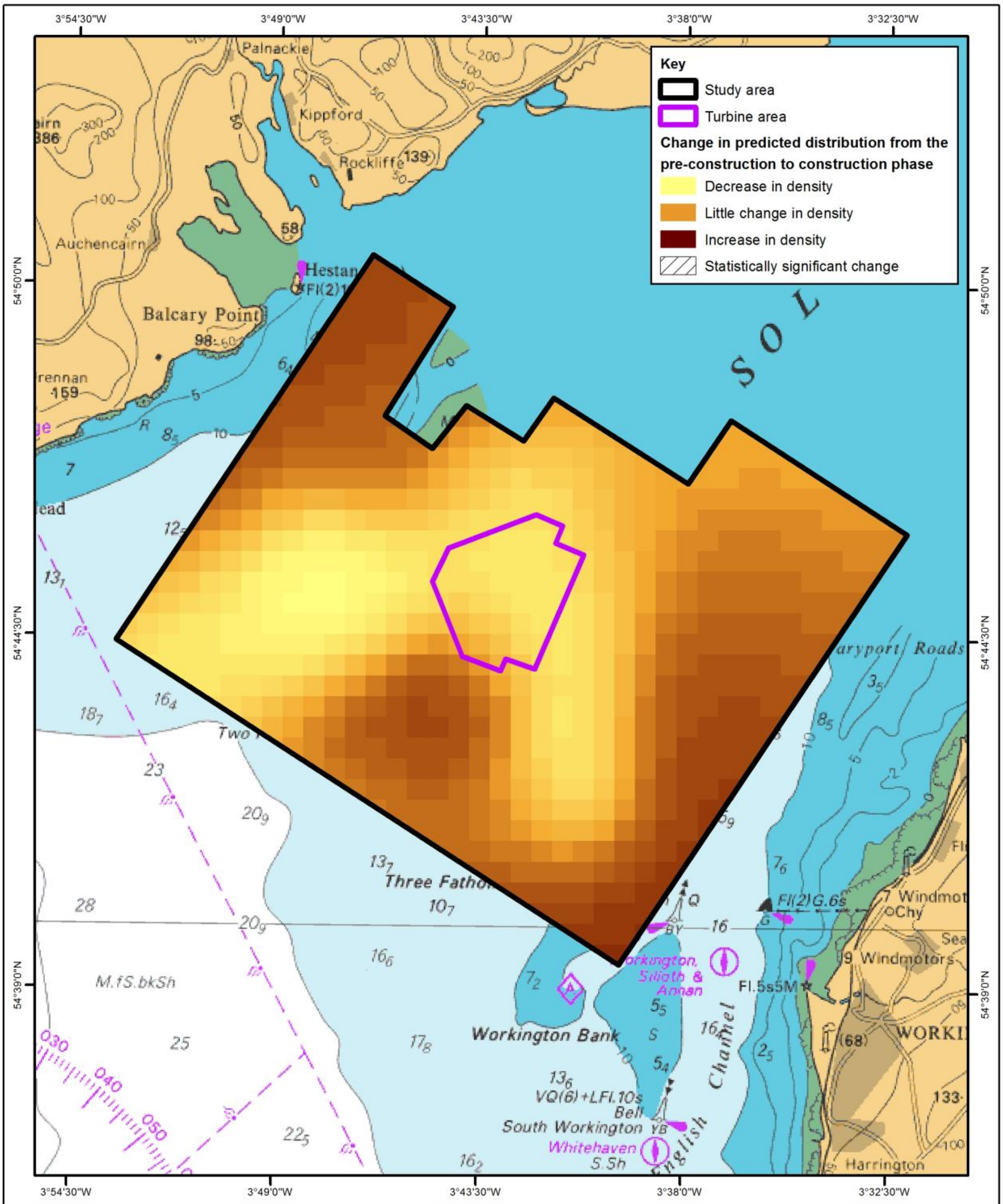


Figure 3.140: Density surface map of the predicted density of razorbill on the sea across the study area during the operational phase of the development



Project: **Robin Rigg Offshore Wind Farm**	**Scale @ A4:1:150,000** 0 1 2 4 km N	NOT TO BE USED FOR NAVIGATION Coordinate System: WGS 1984 UTM Zone 30N Admiralty chart © British Crown and SeaZone Solutions Limited. All rights reserved. Products Licence No. 082011.017. This product has been derived in part from material obtained from the UK Hydrographic Office with the permission of the Controller of Her Majesty's Stationery Office and UK Hydrographic Office (www.ukho.gov.uk).
Title: **Change in Distribution of Razorbill on Sea from the Pre-construction to the Construction Phase**	Drawing by: Natural Power Consultants Ltd The Green House Forrest Estate, Dalry Castle Douglas, DG7 3XS, UK Tel: +44 (0)1644 430008 Fax: +44 (0)845 299 1236 Email: sayhello@naturalpower.com www.naturalpower.com natural power	Date: 20-08-13 Prepared by: GL Checked by: CJP Ref: 035_M_284

Figure 3.141: Plot of the difference in predicted density of razorbill on the sea between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

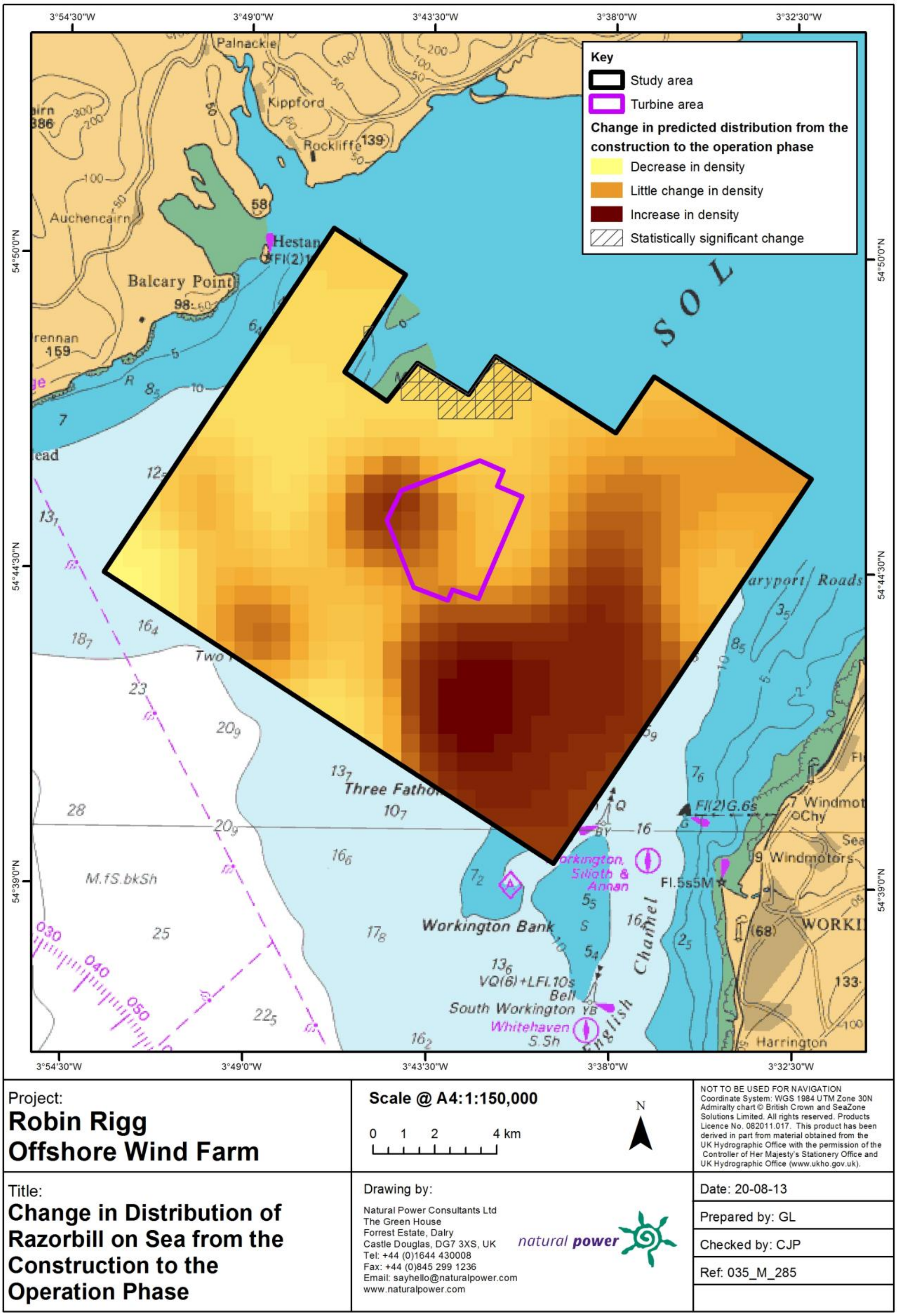


Figure 3.142: Plot of the difference in predicted density of razorbill on the sea between the construction and operational phases of the development. Significant differences are marked with diagonal lines

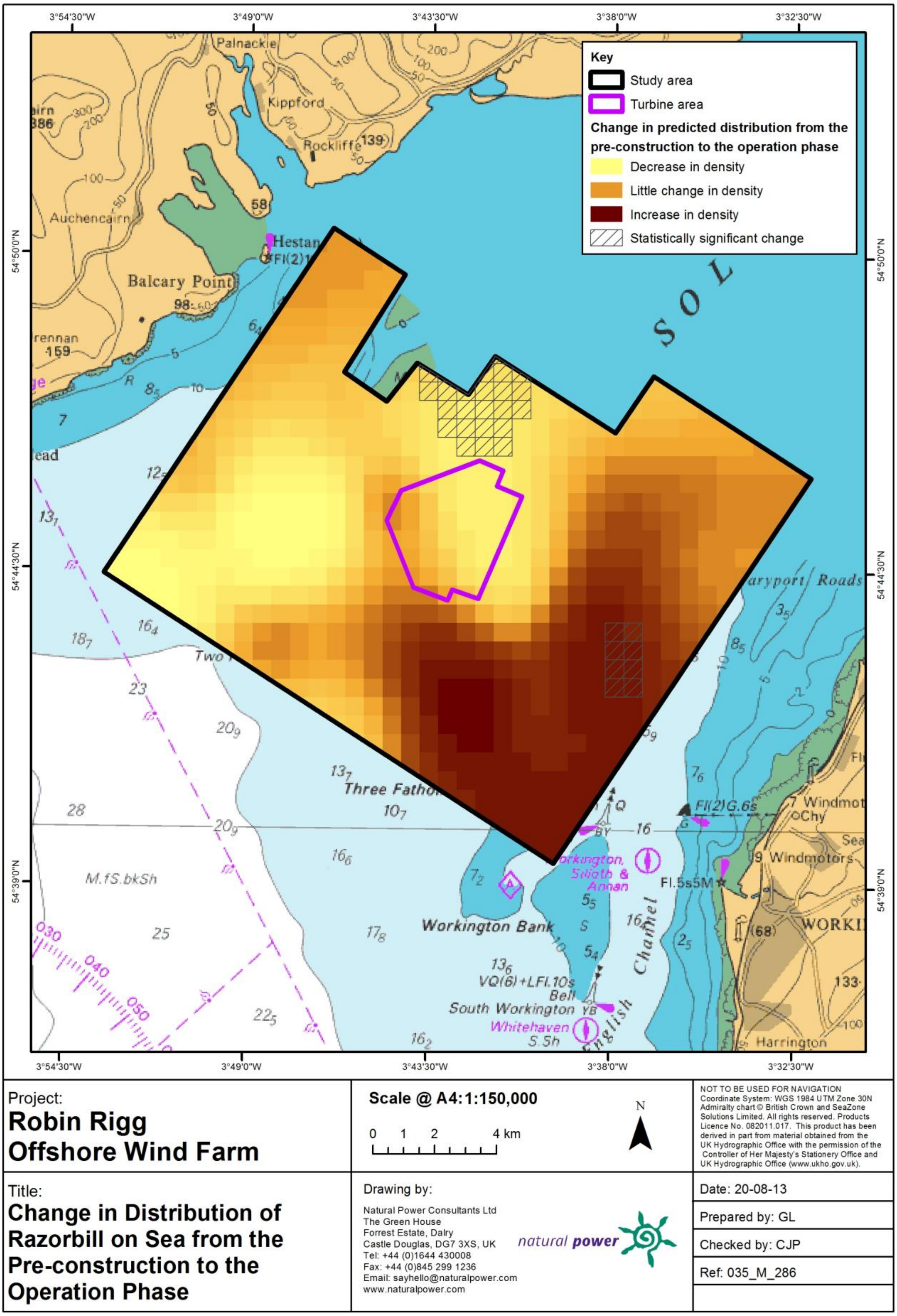


Figure 3.143: Plot of the difference in predicted density of razorbill on the sea between the pre-construction and operational phases of the development. Significant differences are marked with diagonal lines

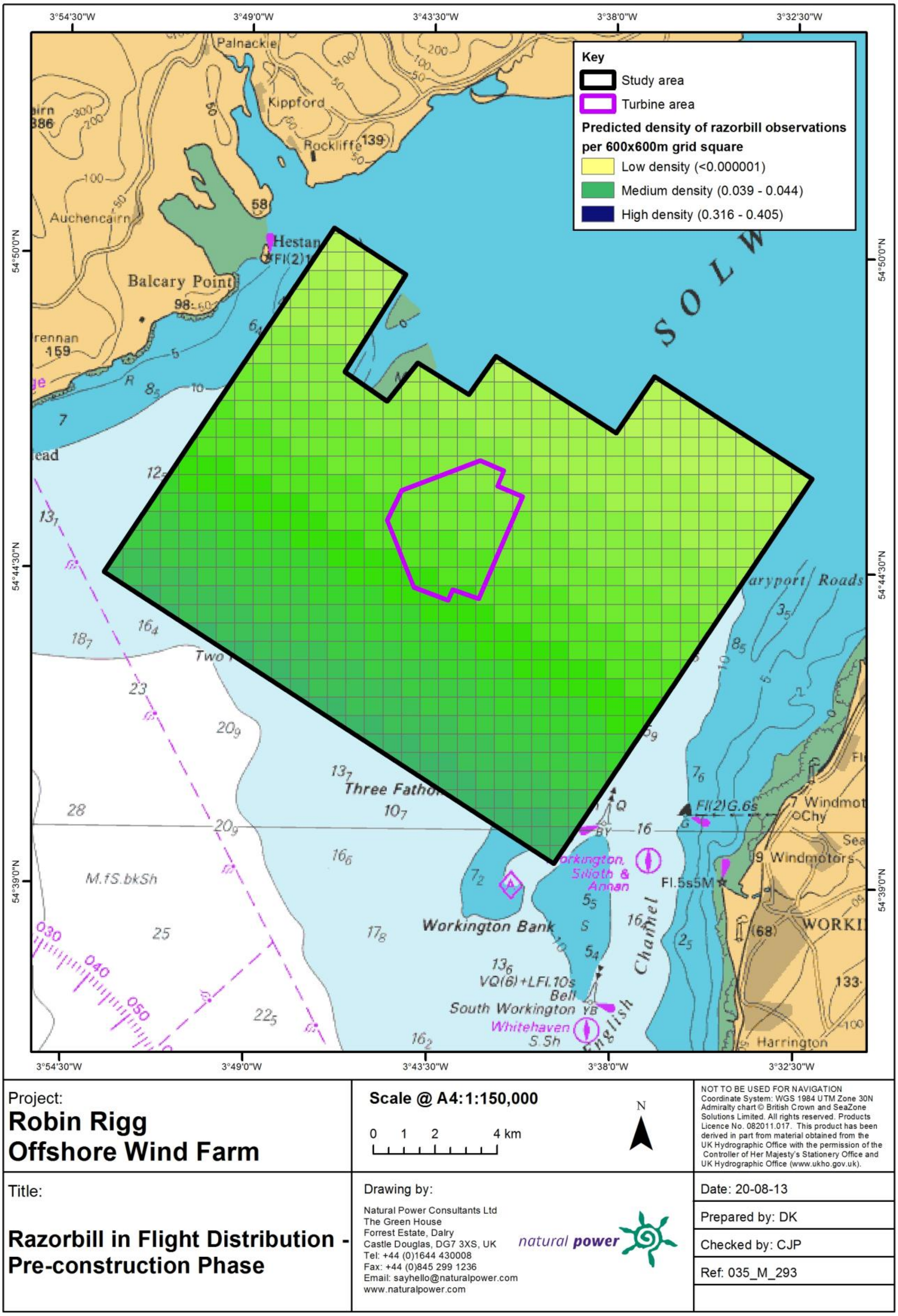


Figure 3.144: Density surface map of the predicted density of razorbill in flight across the study area during the pre-construction phase of the development

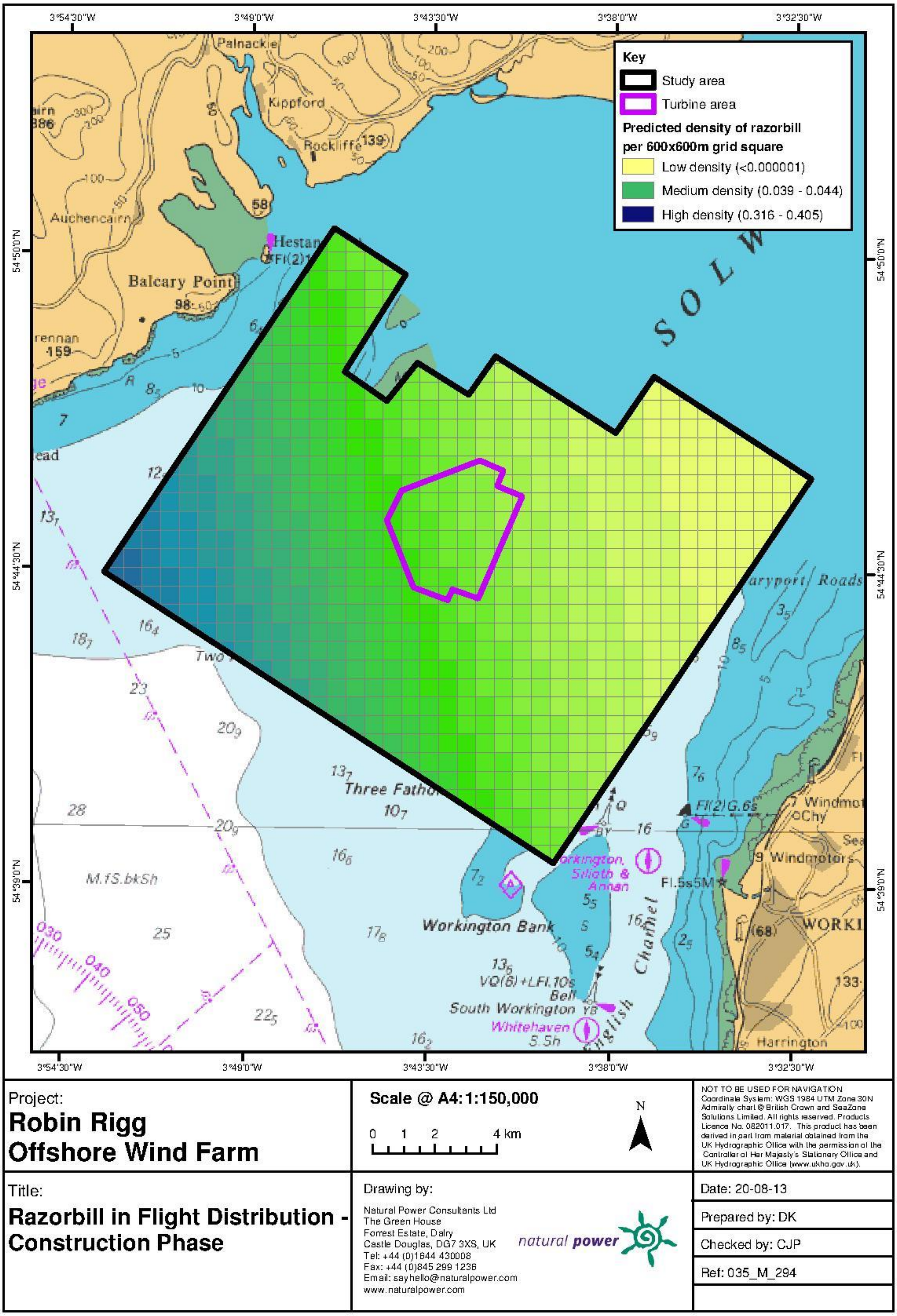


Figure 3.145: Density surface map of the predicted density of razorbill in flight across the study area during the construction phase of the development

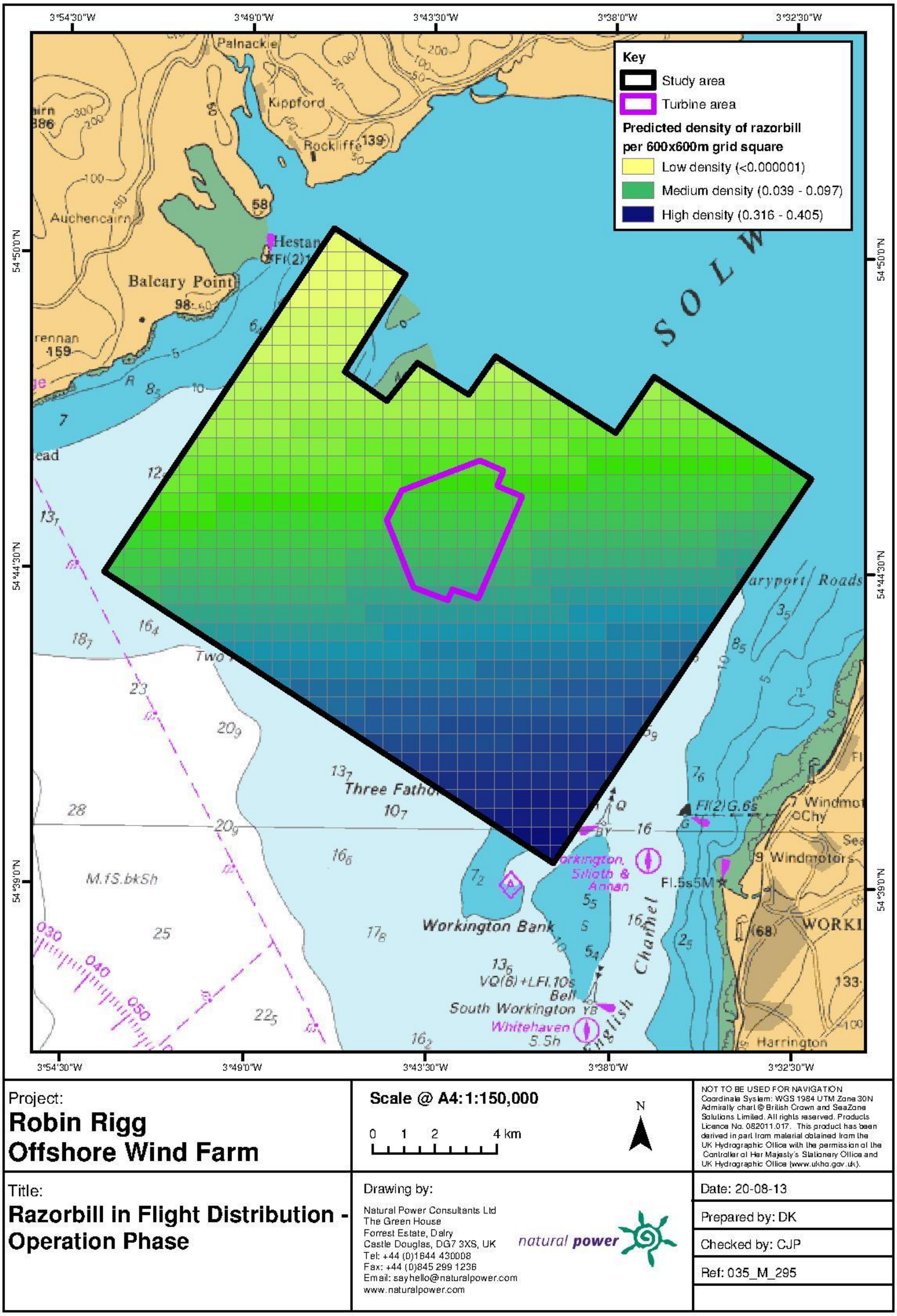


Figure 3.146: Density surface map of the predicted density of razorbill in flight across the study area during the operational phase of the development

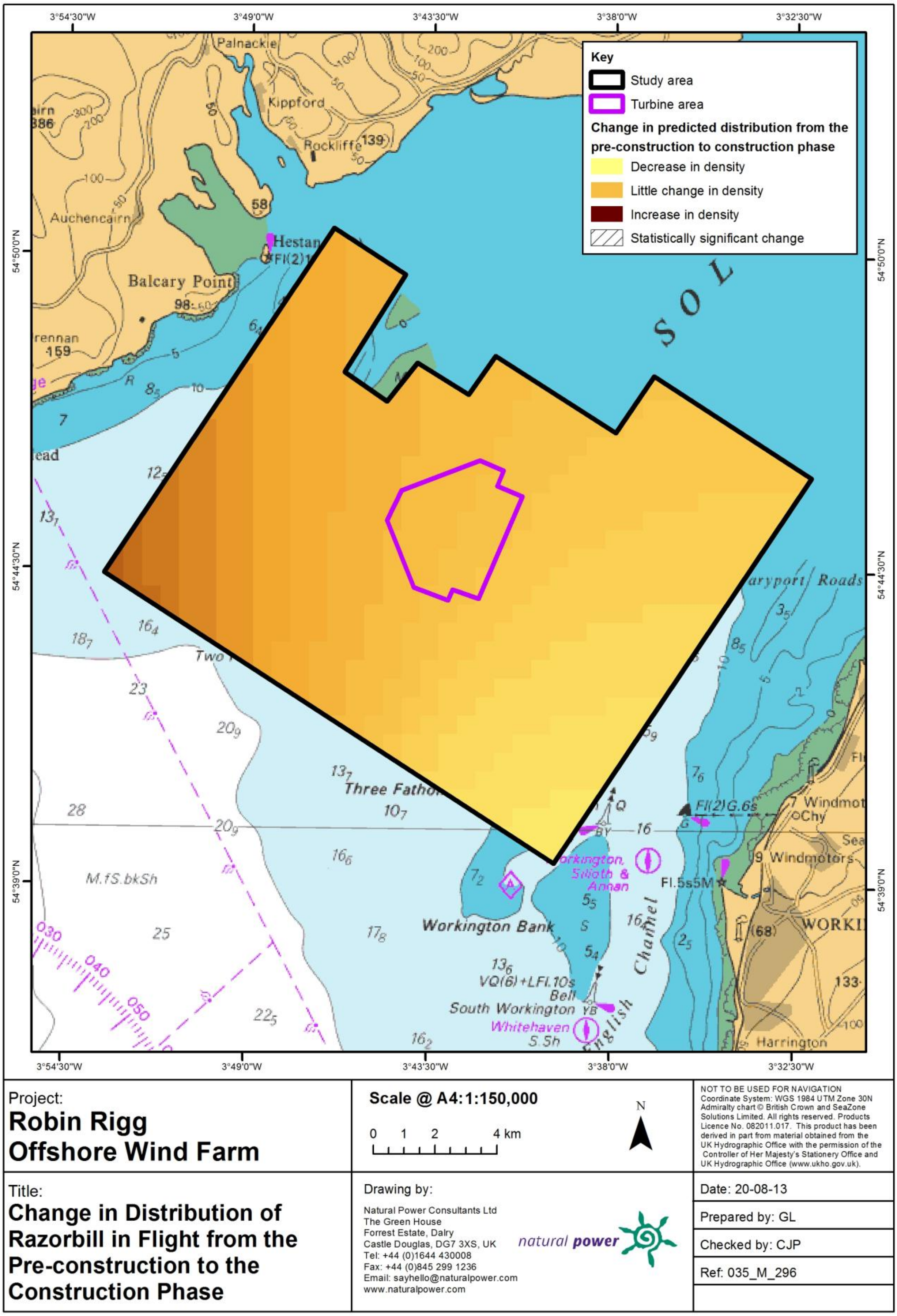


Figure 3.147: Plot of the difference in predicted density of razorbill in flight between the pre-construction and construction phases of the development. Significant differences are marked with diagonal lines

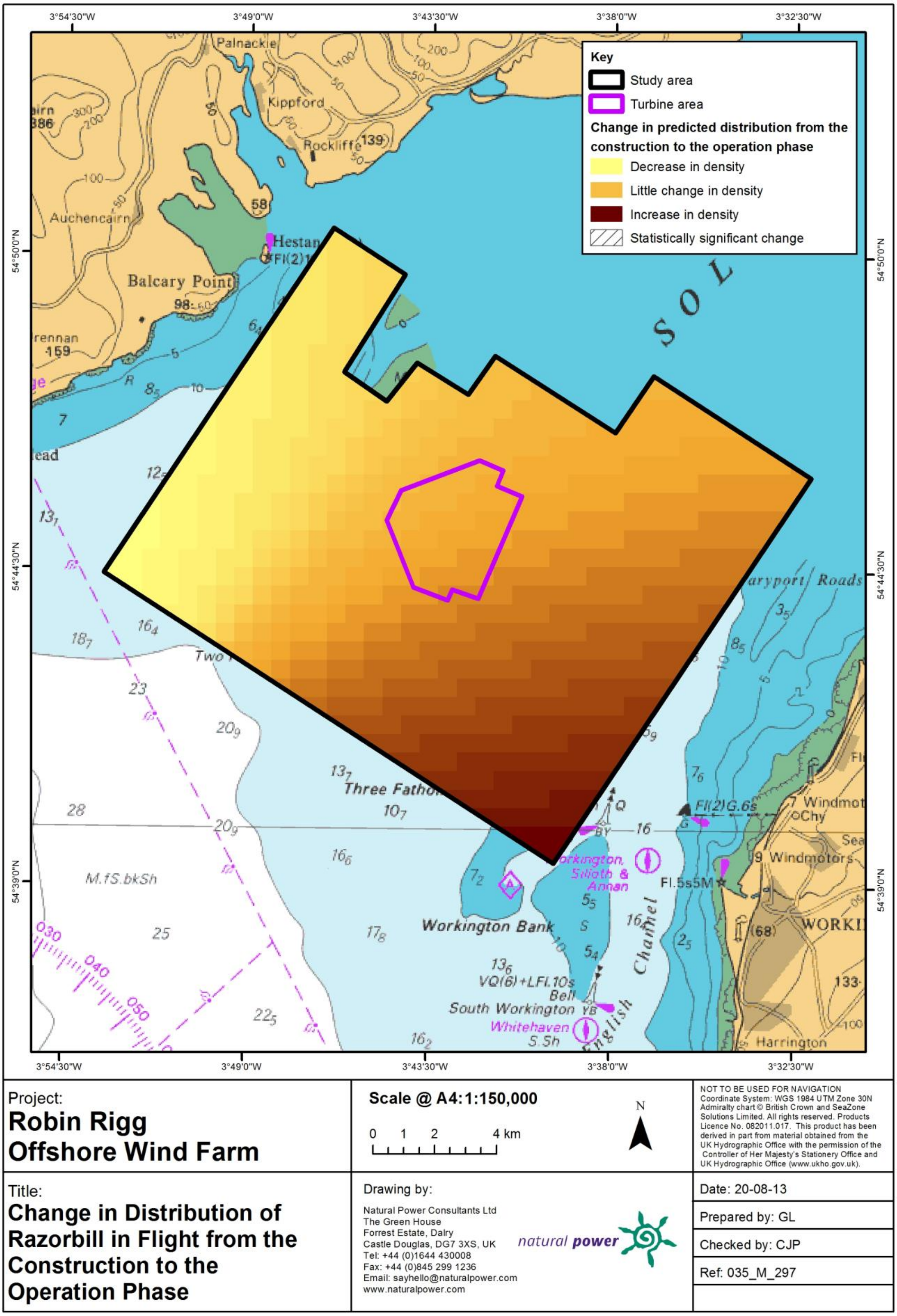


Figure 3.148: Plot of the difference in predicted density of razorbill in flight between the construction and operational phases of the development. Significant differences are marked with diagonal lines

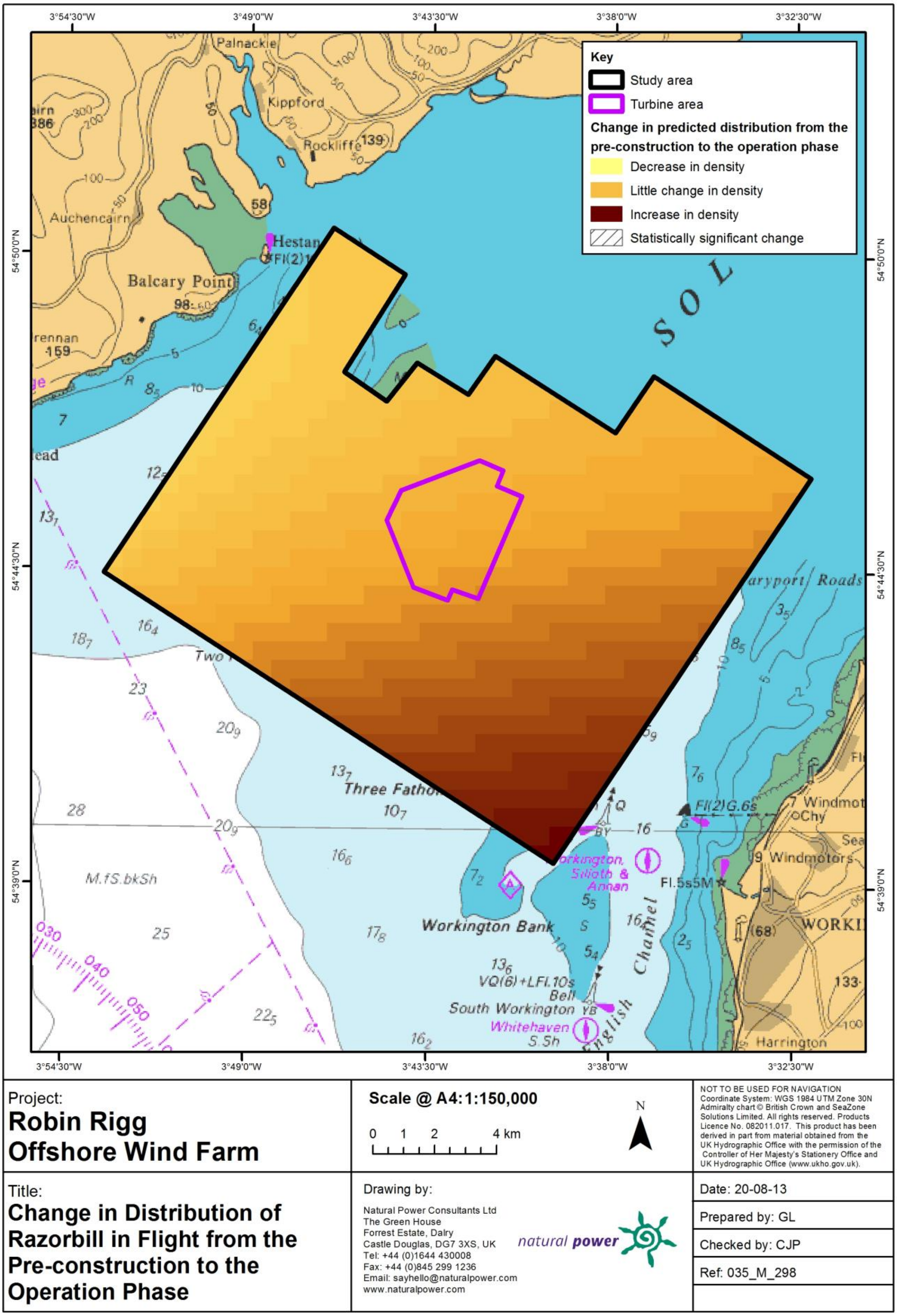


Figure 3.149: Plot of the difference in predicted density of razorbill in flight between the pre-construction and operational phases of the development. Significant differences are marked with

3.14.3. Collision risk

The percentage of razorbill recorded in different height bands relative to rotor height can be found in Table 3.52. Band 4 (35-125 m) represents rotor height. No Chi-square test was carried out for this species as no flights were recorded at turbine rotor height and it was considered that this species is not at risk from collision.

Table 3.53: Proportion of razorbill recorded in different flight height bands through the three phases of the development.

	Flight band (m)					
	1 (0–5)	2 (6–25)	3 (26–34)	4 (35– 125)	5 (126–200)	6 (200+)
Pre-construction	100	0	0	0	0	0
Construction	91	9	0	0	0	0
Operation	95	5	0	0	0	0

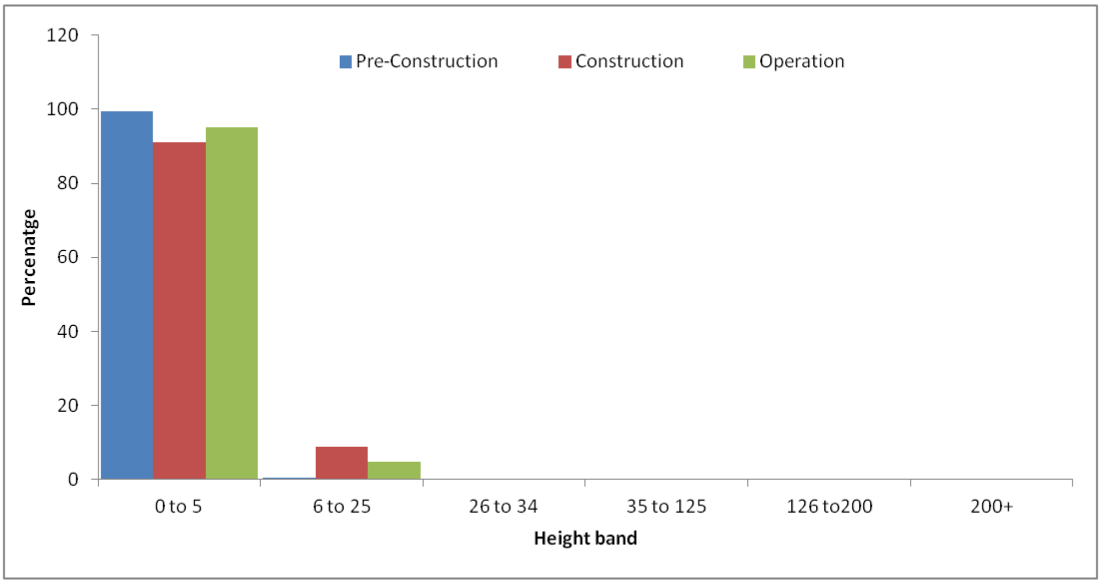


Figure 3.150: Percentage of razorbill recorded in different flight bands during the different stages of the development.

3.15. Comparison of collection methods for birds in flight

In operational year 3, surveyors used two methods of recording birds in flight in order to compare methods traditionally used at Robin Rigg, with methods laid out by ESAS (European Seabirds at Sea) which are now understood as best practise. The difference among the methods is that the original Robin Rigg methodology involves recording all birds continuously along the line transects being surveyed. However, it has since been recognised that this method may lead to double counting of birds flying in and out of the surveyed zone. The ESAS methodology involves recording 'snapshot' data, which involves surveyors recording all birds within a 300x300m window in front of them at a given time to give the equivalent of a series of fixed point surveys along the transect line.

A comparison of data recorded using ESAS methodology versus the original methodology used to record birds in flight for Robin Rigg demonstrates that ESAS methodology results in many fewer observations being recorded as 'in transect' (Figure 3.151). This probably represents the recording of the same birds multiple times as they fly in and out of the surveyed area using the original methodology. The ESAS 'snapshot' methodology has been designed to avoid this by effectively surveying fixed 'snapshots' in time equivalent to a series of point surveys rather than a continuous line.

Since the Robin Rigg methodology has been used consistently across the entire period during which surveys have been carried out, it is still possible to make comparisons among phases (assuming that the rate of double counting remains more or less constant among phases). However, these results indicate that any estimates of abundance and density calculated from bird in flight in this study are likely to be over-estimates. In addition, they illustrate the fact that it is very important that survey methodology is not changed over the course of a monitoring program, as any changes identified may simply be the result of differing data collection techniques.

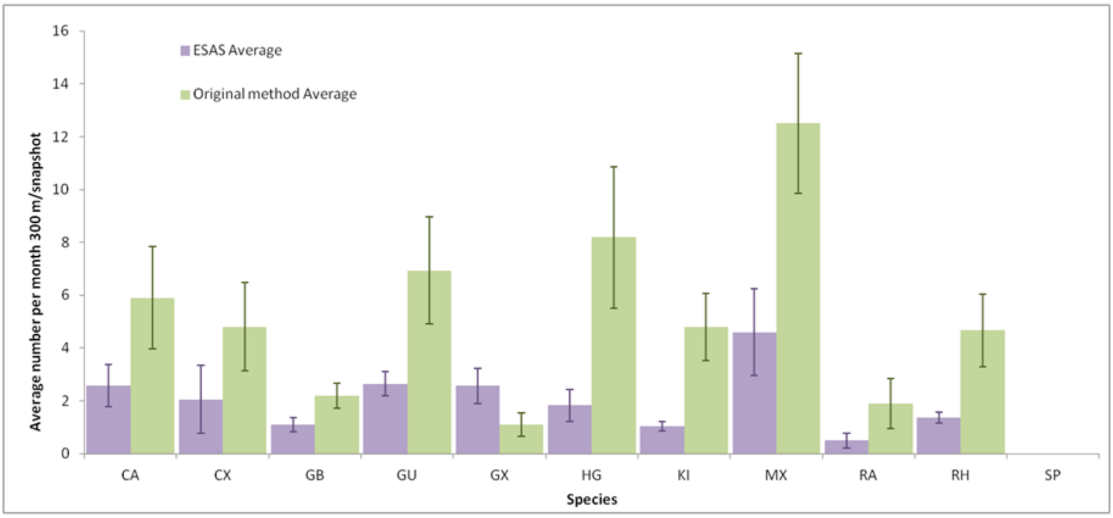


Figure 3.151: Survey average recorded for each species using the two survey methods (±standard error)

3.16. Discussion

For most species, little evidence was found for any changes in abundance and/or distribution attributable to the wind farm.

The only species for which potential negative effects could be identified were red-throated diver and guillemot. Both species appeared to exhibit some degree of avoidance of the wind farm area during the construction phase. However, there is no support for avoidance of the wind farm area during the operational phase suggesting it was associated with construction activity rather than the presence of the wind farm itself. The return of these species in numbers equal or greater than those prior to construction is encouraging, suggesting that any long-term impacts of this brief avoidance of the wind farm area are negligible.

Herring gull and gannet also appear to have declined since the wind farm has been present in the Solway Firth. However, there is no evidence for changes in distribution of gannet with respect to the wind farm and herring gull appear to have increased within the wind farm area, which suggest that this decline is likely to represent a population wide effect rather than an effect of the wind farm itself.

Cormorant may have increased within the study area since the wind farm has been constructed and the usage of the study area by this species has certainly changed, with many more 'birds on the sea' having been recorded within the wind farm area. Surveyors and other workers at the wind farm have reported the presence of a lot of cormorant perching on wind farm structures at the site. It seems that the wind farm structures provide perches from which the cormorant fish. Since birds using the site in this way would be recorded as 'birds on sea', this is the most likely explanation for the observed increase in abundance of this species in the wind farm site. Measures are being implemented to try to modify this behaviour as it leads to fouling of the turbines. It will be interesting to see whether the cormorant distribution returns to those recorded during pre-construction if the birds are discouraged from this behaviour.

Other birds which may have increased within (or show some degree of attraction to) the wind farm area include herring gull, kittiwake and possibly great black-backed gull. Herring gull may be using turbine structures in a similar way to cormorant. Kittiwake are not expected to respond in this way, but it is possible that the presence of other gulls within the wind farm site are attracting the kittiwake into the area.

Scaup and Manx shearwater were not found to be abundant within the study area or wind farm area during the pre-construction phase, and these species continued to be present only in very low numbers during construction and operational monitoring.

Most flying birds were recorded below rotor height during the pre-construction phase and this was largely found to be the case during construction and operational monitoring. Gannet, kittiwake, herring gull and great black-backed gull were recorded at rotor height more often during the construction and operational phases than prior to construction. However, it is extremely difficult to judge the flight height of birds at sea with no landmarks and it is likely that these changes reflect an increase in accuracy of the observers due to the presence of landmarks (turbines) rather than changes in the behaviour of the birds. These species are commonly observed at rotor height (26 – 125 m) and if flight height genuinely changed as a result of the wind farm, it would be expected that birds should avoid rotor height rather than flying more often at the level of the rotor blades.

In operational year 3, surveyors used two methods of recording birds in flight in order to compare methods traditionally used at Robin Rigg, with methods laid out by ESAS (European Seabirds at Sea) which are now understood as best practise. The difference among the methods is that the original Robin Rigg methodology involves recording all birds continuously along the line transects being surveyed. However, it has since been recognised that this method may lead to double counting of birds flying in and out of the surveyed zone. The ESAS methodology involves recording 'snapshot' data, which involves surveyors recording all birds within a 300x300m window in front of them at a given time to give the equivalent of a series of fixed point surveys along the transect line. This should reduce the probability of double counting.

A comparison of data collected simultaneously (although on different sides of the boat) using the two methods demonstrates that the ESAS method does indeed result in far fewer records than the method used to record Robin Rigg data, demonstrating that data collected using these two methods are not comparable. We have therefore used only data collected using the old methodology for our analysis and have adjusted for reduced survey effort accordingly. However, it is important to bear in mind that abundances and densities calculated for birds in flight in this report are likely over-estimates and should not be directly compared with values calculated for other sites using ESAS methodology.

Whilst we have concluded that some impacts may be attributable to the wind farm and others are unlikely to be, in reality, it is almost impossible to conclude that any changes are associated with the wind farm versus natural fluctuations in population size and habitat usage. Sites such as the Solway Firth are highly dynamic and it is likely that many of the changes or indications for changes in abundance and distribution presented here are attributed to changes in prey abundance due to sand bank movements or other environmental conditions not measured as part of this study. Similarly some changes are reported as significant whilst others are not, it is important to note that it is very difficult to detect small changes in abundance and distribution from background variation, making it difficult to conclude whether apparent effects are genuine or simply chance changes. The real value of studies such as this are in combination with other studies, and the contribution of this study to the growing body of literature becoming available on responses of seabirds to offshore wind farms is profound.

3.17. Conclusions

- The Robin Rigg dataset is a valuable resource providing an important contribution to our knowledge of the impacts of offshore wind developments.
- This study provides evidence for a range of species-specific responses to the presence of an offshore wind farm.
- There is little evidence for negative effects of the Robin Rigg wind farm on local seabird populations. Whilst guillemot and red-throated diver may avoid the wind farm area during the construction phase their distributions seem to return to pre-construction levels during operation.
- Some species have been found to be attracted to the wind farm area, probably because the turbine structures provide perches from which birds can fish. The main species for which this seems to be the case are cormorant and herring gull.
- Few birds were recorded at rotor height. Although some species (gannet, kittiwake, herring gull, great black-backed gull) appear to be flying more often at rotor height during the construction and operation phases, this is most likely a result of more accurate recording as a result of the presence of the turbines as landmarks. Collision risk for all species is probably very low.
- Comparing data collected using the traditional methodology for recording birds in flight at Robin Rigg with those collected using the currently accepted best practise methodology suggests that the original method may over-estimate bird abundance, demonstrating the importance of consistency of survey methodology during monitoring. Caution must be employed when comparing data collected at Robin Rigg with those collected at other sites using the currently accepted best practise methodology.

A table summarising conclusions from each of the analysis reports produced to date can be found below.

Table 3.54: Summary of conclusions reported in this and previous analysis reports.

Bird species	Predictions from ES	Pre-construction to construction	Pre-construction to operation
Scaup	➢ Only recorded occasionally although in nationally important numbers on two occasions. ➢ Only a single flock recorded within 2 km of wind farm site.	➢No observations within the site, very few across the study area (none in transect). ➢No birds were observed flying at rotor height.	➢No observations within the site, very few across the study area (none in transect). ➢No birds were observed flying at rotor height.
Common scoter	➢ All observations in north-western region of study area . ➢ Very low numbers recorded within 2 km of wind farm area. ➢ Some displacement expected . ➢ Less than 1% observed flying above 20 m, collision impacts predicted to be low .	➢Common scoter rarely recorded within the wind farm site prior to construction. ➢No evidence of a change in usage of the wind farm site. ➢Less than 1% of flying birds were recorded at rotor height.	➢Common scoter rarely recorded within the wind farm site. ➢No evidence of a change in usage of the wind farm site. ➢Less than 1% of flying birds were recorded at rotor height.
Red-throated diver	➢ Widely distributed though study area. ➢ Some displacement expected. ➢ 3% recorded flying above 20 m; collision impacts predicted to be low.	➢Potential decrease in numbers during construction phase. Not significant. ➢Potential avoidance of the wind farm area by birds in flight – significant decrease in numbers to west of site. ➢4% of flying birds recorded at rotor height (26 – 125 m).	➢Potential significant increase in numbers between the pre-construction and operational phase. ➢No obvious avoidance of the wind farm area (although density in the area to the west of the site still lower than pre-construction). ➢7% flying birds recorded at collision height.
Manx shearwater	➢ Only recorded in the spring-summer months to south and west of study area. ➢Numbers in wind farm area low.	➢Numbers of observations too low to allow meaningful modelling. ➢Numbers in wind farm area remain low. ➢No birds observed at rotor height during pre-construction or construction.	➢Numbers of observations too low to allow meaningful modelling. ➢Numbers in wind farm area remain low. ➢No birds observed at rotor height during operation.

Bird species	Predictions from ES	Pre-construction to construction	Pre-construction to operation
Gannet	➢ Most abundant during summer, distributed evenly across study area apart from shallow areas to north-west. ➢ Numbers in wind farm area low; 3% recorded flying above 20 m.	➢ Little change in abundance from the pre-construction to construction phase. ➢No evidence for a change in distribution. ➢12% of flying birds recorded at rotor height (26 – 125 m).	➢Possible decline in numbers from the pre-construction to the operational phase. ➢No change in distribution across the windfarm site suggesting that the wind farm is not responsible for any decline. ➢11% flying birds recorded at rotor height.
Cormorant	➢Numbers generally low with peak in summer, distribution greater in the north-west close to known breeding colonies. ➢ Low numbers within wind farm area; 5% recorded flying above 20 m.	➢Potential increase in numbers during construction phase. Not significant. ➢Significant change in distribution with an increase in birds using the wind farm site. ➢3% of flying birds recorded at rotor height (26 – 125 m).	➢Potential increase in numbers from the pre-construction to the operational phase. Not significant. ➢Significant change in distribution with an increase in birds using the wind farm site. ➢6% of flying birds recorded at rotor height.
Kittiwake	➢ Highest numbers recorded in spring and summer, widely distributed across study area. ➢ Use of wind farm area expected; less than 1% observed flying greater than 20 m.	➢ Little change in abundance from the pre-construction to construction phases. ➢Little evidence for changes in distribution. ➢25% of flying birds recorded at rotor height (26 – 125 m).	➢Little change in abundance of birds in flight, potential (non-significant) increase in birds on the sea. ➢Evidence for increase in number of kittiwake on sea within the wind farm site compared to the study area as a whole. ➢4% of flying birds recorded at rotor height.

Bird species	Predictions from ES	Pre-construction to construction	Pre-construction to operation
Herring gull	➢ Not discussed in detail within ES. ➢ 8% observed flying greater than 20 m.	➢Significant decline between the pre-construction and construction phases. ➢No change in distribution suggesting decline is not associated with the wind farm. ➢15% of flying birds recorded at rotor height (26 – 125 m).	➢Significant decline between the pre-construction and operation phases. ➢Increase in usage of the windfarm site versus the remainder of the study area. ➢19% of flying birds recorded at rotor height (26 – 125 m).
Great black-backed gull	➢Not discussed in detail within ES. ➢ 16% observed flying greater than 20 m.	➢ Weakly significant decline in birds in flight during construction. ➢Numbers within the wind farm area remain constant. ➢28% of flying birds recorded at rotor height (26 – 125 m).	➢Non-significant decline in birds in flight during operation. ➢Numbers within the wind farm area remain constant. ➢17% of flying birds recorded at rotor height (26 – 125 m).
Guillemot	➢ Observed in high numbers in summer, predominantly in the relatively deeper waters of the outer Solway. ➢ Numbers within wind farm area lower in comparison.	➢ Strongly significant decline in abundance of birds on the sea. ➢Significant decline of birds on the sea within the wind farm and to the southwest of the wind farm area. Potential avoidance of the wind farm area by birds in flight. ➢1% of flying birds recorded at rotor height (26 – 125 m).	➢Abundance of birds on sea similar to birds on sea. ➢Little evidence for avoidance of the wind farm site. ➢No birds recorded at rotor height.
Razorbill	➢ Less abundant than guillemot but distribution more evenly. ➢ Greater numbers observed within the wind farm area compared to guillemots.	➢ No evidence for change in abundance from pre-construction. ➢Possible drop in usage of the wind farm area and nearby areas by birds on sea. ➢No birds recorded at rotor height.	➢Possible drop in usage of the wind farm and nearby areas compared with the remainder of the study area. ➢No birds recorded at rotor height.

3.18. References

Austin, J.E., Afton, A.D., Anderson, M.G., Clark, R.G., Custer, C.M., Lawrence, J.S., Pollard, J.B. and Ringelman, J.K. 2000. Declining scaup populations: Issues, hypotheses, and research needs. Wildlife Society Bulletin 28: 254-263.

Austin, J.E., Afton, A.D., Anderson, M.G., Clark, R.G., Custer, C.M., Lawrence, J.S., Pollard, J.B. and Ringelman, J.K. 2000. Declining scaup populations: Issues, hypotheses, and research needs. Wildlife Society Bulletin 28: 254-263.

Baker , H., Stroud, D.A., Aebischer, N.J., Cranswick, P.A., Gregory, R.D., McSorley, C.A., Noble, D.G. & Rehfisch, M.M. 2006. Population estimates of birds in Great Britain and the United Kingdom. British Birds 99: 25-44.

Benn, S., Webb, A., Burton, C.A., Tasker, M.L., Murray, S. & Tharme, A. 1987. Studies of seabirds at North Rona and Sula Sgeir, June 1986. Nature Conservancy Council, CSD Report No. 736

Birdlife International : http://seabird.wikispaces.com

Birdlife International. 2000. The Development of Boundary Selection Criteria for the Extension of Breeding Seabird Special Protection Areas into the Marine Environment. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. Vlissingen (Flushing).

BirdLife International. 2000. The Development of Boundary Selection Criteria for the Extension of Breeding Seabird Special Protection Areas into the Marine Environment. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. Vlissingen (Flushing).

Blake B. F., Dixon T. J., Jones P. H., & Tasker M. L. 1985. Seasonal changes in the feeding ecology of guillemots *Uria aalge* off north and east Scotland. Estuarine, Coastal and Shelf Science 20: 559–568.

Blake B.F., Tasker M.L., Jones P.H., Dixon T.J., Mitchell R. & Langslow D.R. 1984. Seabird distribution in the North Sea. Huntingdon, Nature Conservancy Council

Blake, B. F. 1983. A comparative study of the diet of auks killed during an oil incident in the Skagerrak in January 1981. J. Zool. Lond., 201, 1-12.

Bradstreet, M.S.W. & Brown, R.G.B. 1985. Feeding ecology of the Atlantic *Alcidae*. In Nettleship, D.N. & Birkhead T.R. (Eds.) The Atlantic *Alcidae*. Academic Press, London.

Brown, L. H., Urban, E. K. and Newman, K. 1982. The birds of Africa vol I. Academic Press, London.

Brown, R.G.B., Barker, S.P., Gaskin, D.E. & Sandeman, M.R. 1981. The Foods of Great and Sooty Shearwaters *Puffinus Gravis* and *P. Griseus* in Eastern Canadian Waters. Ibis 123: 19–30.

Cabot, D. 2009 Wildfowl. Collins, London.

Camphuysen, C. J. 1995. Herring gull *Larus argentatus* and lesser black-backed gull *L. fuscus* feeding at fishing vessels in the breeding season: competitive scavenging versus efficient flying. Ardea 83: 365–380.

Cook, A.S.C.P., Johnston, A., Wright, L.J. & Burton, N.H.K. 2012. A review of flight heights and avoidance rates of birds in relation to offshore wind farms. British Trust for Ornithology report on behalf of The Crown Estate.

Cramp, S., & Simmons, K. E. L. (Eds.). 1985. The birds of Western Palearctic. Vol. 4 – Oxford University Press.

del Hoyo, J., Elliot, A. and Sargatal, J. 1992. Handbook of the Birds of the World, vol. 1: Ostrich to Ducks. Lynx Edicions, Barcelona, Spain.

del Hoyo, J., Elliot, A. Sargatal, J. 1992. Handbook of the Birds of the World, vol. 1: Ostrich to Ducks. Lynx Edicions, Barcelona, Spain.

del Hoyo, J., Elliott, A., Sargatal, J. 1996. Handbook of the Birds of the World, vol. 3: Hoatzin to Auks. Lynx Edicions, Barcelona, Spain

Eaton, M.A., Brown, A.F., Noble, D.G., Musgrove, A.J., Hearn, R.H., Aebischer, N.J., Gibbons, D.W., Evans, A. & Gregory, R.D. 2009. Birds of Conservation Concern 3: the population status of birds in the United Kingdom Channel Islands and the Isle of Man. British Birds 102: 296–341.

Forrester, R.W., Andrews, I.J., McInerny, C.J., Murray, R.D., McGowan, R.Y., Zonfrillo, B., Betts, M.W., Jardine, D.C. and Grundy, D.S. (eds) 2007. The Birds of Scotland. The Scottish Ornithologists' Club, Aberlady.

Forrester, R.W., Andrews, I.J., McInerny, C.J., Murray, R.D., McGowan, R.Y., Zonfrillo, B., Betts, M.W., Jardine, D.C. and Grundy, D.S. 2007. The Birds of Scotland. Scottish Ornithologists' Club, Aberlady.

Furness, R.W & Wade, H.M. 2012. Vulnerability of Scottish seabirds to offshore wind turbines. Marine Scotland Commisioned Report. MacArthur Green Ltd.

Garthe, S. & Hüppop, O. 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41: 724–734.

Garthe, S. 1997. Influence of hydrography, fishing activity, and colony location on summer seabird distribution in the southeastern North Sea. ICES Journal of Marine Science 54: 566–577.

Garthe, S., Gremillet, D. & Furness, R.W. 1999. At-sea activity and foraging efficiency in chick-rearing northern gannet *Sula bassana*: a case study in Shetland. Marine Ecology Progress Series 185: 93-99.

Gremillet, D. 1997. Catch per unit effort, foraging efficiency, and parental investment in breeding great cormorants (*Phalacrocorax carbo carbo*). ICES Journal of Marine Science 54(4): 635-644.

Gremillet, D., Liu, H., Le Maho, Y. and Carss, D.N. 2003. Great cormorants and freshwater fish stocks: a pragmatic approach to an ecological issue. Cormorant 13(2 (supplement no.58)): 131-136.

Guilford, T.C., Meade, J., Freeman, R., Birdo, D., Evans, T., Bonadonna, F., Boyle, D., Roberts, S. & Perrins, C.M. 2008. GPS Tracking of the foraging movements of Manx Shearwaters *Puffinus puffinus* breeding on Skomer Island, Wales. Ibis 150(3): 462-473.

Hamer, K.C., Humphreys, E.M., Garthe, S., Hennicke, J., Peters, G., Gremillet, D., Phillips, R.A., Harris, M.P. & Wanless, S. 2007. Annual variation in diets, feeding locations and foraging behaviour of gannets in the North Sea: flexibility, consistency and constraint. Marine Ecology Progress Series 338: 295-305.

Hamer, K.C., Phillips, R.A., Wanless, S., Harris, M.P. & Wood, A.G. 2000. Foraging ranges, diets and feeding locations of gannets in the North Sea: evidence from satellite telemetry. Marine Ecology Progress Series 200: 257-264.

Harris, M.P. & Riddiford, N.J. 1989. The food of some young seabirds on Fair Isle in 1986–1988. Scottish Birds 15: 119–125.

Harris, M.P. & Swann, R.L. 2002. Guillemot. In The Migration Atlas: Movements of the Birds of Britain and Ireland (eds Wernham, C.V., Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R.), pp 397-400. T. & A.D. Poyser, London.

Harris, M.P. & Wanless, S. 1985. Fish fed to young guillemots, *Uria aalge*, and used in display on the Isle of May Scotland. Journal of Zoology, London 207: 441–458.

Harris, M.P. and Wanless, S. 1986. The food of young razorbills on the Isle of May and a comparison with that of young guillemots and puffins. Ornis Scandinavica 17: 41-46.

Harris, M.P. and Wanless, S. 1990. Moult and autumn colony attendance of auks. Br Birds 83:55–66

Harrison, N.M., Webb, A. and Leaper, G.M. 1994. Patterns in seabird distribution west of Scotland. Aquatic Conservation: Marine and Freshwater Ecosystems 4: 21-30.

Hatchwell, B.J. 1991. The feeding ecology of young Guillemots *Uria aalge* on Skomer Island, Wales. Ibis 133: 153–161.

JNCC 2011

JNCC. 2001. Stroud, DA, Chambers, D, Cook, S, Buxton, N, Fraser, B, Clement, P, Lewis, P, McLean, I, Baker, H & Whitehead, S (eds). 2001. The UK SPA network: its scope and content. JNCC, Peterborough.

Jones, J.J. & Drobney, R.D. 1986. Winter feeding ecology of scaup and common goldeneye in Michigan. Journal of Wildlife Management 50: 446-452.

Jones, J.J. and Drobney, R.D. 1986. Winter feeding ecology of scaup and common goldeneye in Michigan. Journal of Wildlife Management, 50: 446-452.

Kershaw, M. & Cranswick, P.A. 2003. Numbers of wintering waterbirds in Great Britain, 1994/95-1998/99: I. Wildfowl and selected waterbirds. Biological Conservation 111: 91-104.

Klein, R. 1994 .Herring Gulls *Larus argentatus* and Yellow-legged Gulls *Larus cachinnans* on garbage dumps in Mecklenburg (NE Germany) analysis of ringing recoveries. Vogelwarte 115: 267 - 286.

Kober, K., Webb, A., Win, I., Lewis, M., O'Brien, S, Wilson, L.J & Reid, J.B. 2010. An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs, JNCC Report 431, ISSN 0963-8091.

Leaper, G.M., Webb, A., Benn, S., Prendergast, H.D.V., Tasker, M.L., & Schofield, R. 1988. Seabird studies around St Kilda, June 1987. Nature Conservancy Council, CSD Report, No. 804

Leopold, M.F., Van Damme, C.J.G. & Van der Weer, H.W. 1998. Diet of cormorants and the impact of cormorant predation on juvenile flatfish in the Dutch Wadden Sea. Journal of Sea Research 40 (1-2): 93-107.

Lloyd, C., Tasker, M.L. and Partridge, K. 1991. The Status of Seabirds in Britain and Ireland. T&D Poyser, London.

MacLean, I.M.D., Wright, L.J., Showler, D.A. & Rehfisch, M.M. 2009. A review of assessment methodologies for offshore wind farms. Report commissioned by COWRIE Ltd.

Mitchell, P.I., Newton, S.F., Ratcliffe, N., & Dunn, T.E., 2004. Seabird populations of Britain and Ireland. T. and A.D. Poyser; London.

Monaghan, P., Shedden, C.B., Ensor, K., Fricker, C.R. & Girdwood, R.W.A. 1985. Salmonella carriage by herring gulls in the Clyde area of Scotland in relation to their feeding ecology. J. Appl. Ecol. 22**:** 669-680

Monaghan, P., Walton, P., Wanless, S., Uttley, J. & Burns, M. 1994. Effects of prey abundance on the foraging behaviour, diving efficiency and time allocation of breeding Guillemots *Uria aalge*. Ibis 136: 214–222.

Moray Firth Environmental Statement, Technical Appendix 4.5C. http://morayoffshorerenewables.com Home.aspx

Musgrove, A., Aebischer, N., Eaton, M., Hearn, R., Newson, S., Noble, D., Parsons, M., Risely, K. & Stroud, D. 2013. Population estimates of birds in GB and the UK. British Birds 106: 64-100

Musgrove, A.J., Austin, G.E., Hearn, R.D., Holt, C.A., Stroud, D.A. & Wotton, S.R. 2011. Overwinter population estimates of British Waterbirds. British Birds 104: 364–397.

Nilsson, L. 1970. Food-seeking activity of south Swedish diving ducks in the non-breeding season. Oikos 21: 145-154.

Nogales, M., Zonfrillo, B. & Monaghan, P. 1995. Diet of adult and chick herring gulls *Larus argentatus* on Ailsa Craig, south-west Scotland. Seabird 17: 56-63.

Ouwehand, J., Leopold, M.F. & Camphuysen, K.C.J. 2004. A comparative study of the diet of guillemots *Uria aalge* and razorbills *Alca torda* killed in the south-eastern North Sea in January 2003. Atlantic Seabird 6: 147-157.

Parnell, M., Walls, R. J., Brown, M. D. & Brown, S. 2005. The remote monitoring of offshore avian movement using bird detection radar at Weybourne, North Norfolk. Central Science Laboratory, York, UK.

Pedersen, M.B. & Poulsen, E. 1991. Impact of a 90m/2MW wind turbine on birds/Avian responses to the implementation of the Tjaereborg wind turbine at the Danish Wadden Sea. Danske Vildtunders. 47. 44 p. (Danish, Engl. summ.)

Petersen, I.K., Christensen, T.K., Kahlert, J., Desholm, M., Fox, A.D. 2006. Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark. National Environmental Research Institute, Denmark.

Platteeuw, M. & Beekman, J.H. 1994. Disturbance of waterbirds by ships on lakes Ketelmeer and Ijsselmeer. Limosa 67: 27-33

Ratcliffe, N., Phillips, R. A., & Gubbay, S. 2000. Foraging ranges of UK seabirds from their breeding colonies and its implication for creating marine extensions to colony SPAs. Unpublished Report to BirdLife International, RSPB, Sandy.

Sadoti, G., Allison, T., Perkins, S. & Jones, A. 2005. A survey of tern activity within Nantucket sound, Massachusetts, during the 2004 breeding period. Final Report for Massachusetts Technology Collaborative. Massachusetts Audubon Society, Lincoln, MA, USA.

Snow, D. W. and Perrins, C. M. 1998. *The Birds of the Western Palearctic vol. 1: Non-Passerines*. Oxford University Press, Oxford.

Snow, D.W. & Perrins, C.M. 1998. The birds of the western Palearctic, Concise edition. Oxford University Press.

Spaans, A.L. 1971. On the feeding ecology of the Herring Gull *Larus argentatus* Pont. in the northern part of The Netherlands. Ardea 55: 73-188.

Stone, C.J., Harrison, N.M., Webb, A. & Best, B.J. 1992. Seabird distribution around Skomer and Skokholm Islands, June 1990. JNCC, Report No. 30

Stone, C.J., Webb, A. & Tasker, M.L. 1994. The distribution of Manx Shearwaters *Puffinus puffinus* in north-west European waters. Bird Study 41: 170-180.

Stone, C.J., Webb, A. & Tasker, M.L. 1995. The distribution of auks and Procellariiformes in north-west European waters in relation to depth of sea. Bird Study 42: 50-56.

Tasker, M.L., Webb, A., Hall, A.J., Pienkowski, M.W. & Langslow, D.R. 1987. Seabirds in the North Sea. Final report of phase 2 of the NCC seabirds at sea project, November 1983–October 1986. Nature Conservancy Council, Aberdeen.

Thaxter, C.B., Daunt, F., Hamer, K.C., Watanuki, Y., Harris, M.P., Grémillet, D., Peters, G. & Wanless, S. 2009. Sex-specific food provisioning in a monomorphic seabird common guillemot *Uria aalge*: Nest defence, foraging efficiency, or parental effort. J. Av. Biol. 40: 75-84.

Thaxter, C.B., Wanless, S., Daunt, F., Harris, M.P., Benvenuti, S., Watanuki, Y., Gremillet, D. & Hamer, K.C. 2010. Influence of wing loading on the trade-off between pursuit diving and flight in common guillemots and razorbills. The Journal of Experimental Biology 213: 1018-1025.

Walls, R.J., Brown, M. B., Budgey, R., Parnell, M. & Thorpe, L. 2004. The remote monitoring of offshore avian movement using bird detection radar at Skegness, Lincolnshire. Central Science Laboratory, York, UK.

Wanless, S., Harris, M.P. & Greenstreet, S.R. 1998. Summer sandeel consumption by seabirds breeding in the Firth of Forth, southeast Scotland. ICES J. Marine Science 55: 1141-1151.

Webb, A., Tasker, M.L. & Greenstreet, S.P.R. 1985. The distribution of guillemots (*Uria aalge*), razorbills (*Alca torda*) and Puffins (*Fratercula arctica*) at sea around Flamborough Head, June 1984. Nature Conservancy Council, CSD Report No. 590

Wernham, C.V., Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R. (eds). 2002. The Migration Atlas: movements of the birds of Britain and Ireland. T & A.D. Poyser, London

Witt, H.H., Crespo, J., de Juana, E. & Varela, J. 1981. Comparative Feeding Ecology Of Audouin's Gull *Larus audouinii* and the Herring Gull *L. argentatus* in the Mediterranean. Ibis, 123: 519–526

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A., & Smith, G.M. 2009. Mixed effects models and extensions in Ecology with R. Springer, USA.