Hebridean Whale and Dolphin Trust

Research - Education - Conservation

Report on passive acoustic monitoring of cetacean distribution north-west of the Hebrides 1997-1998, for Conoco UK.

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Summary

- This report summarises the passive-acoustic monitoring of cetacean distribution north-west of the Hebrides, carried out in conjunction with the JNCC SAST (Joint Nature Conservation Committee Sea Birds and Cetaceans at Sea Team), by the HWDT (Hebridean Whale and Dolphin Trust) for Conoco (UK) Limited.

- Licensed blocks T36, T37, T38, T43, T44, T47, T48, T52 and T53 were surveyed between December 1997 and March 1998. Some additional acoustic data were collected in blocks T32, T33, T39, T40, T41, T42, T45, T46, T49, T50, T51 and T54 and for an area north of blocks T52 and T53. Acoustic effort was highest in blocks T44, T47, T48, T52 and T53.

- Acoustic data were collected using two different monitoring systems – ‘Medium Frequency’ (bandwidth 200 Hz - 22 kHz) and ‘High Frequency’ (30 kHz - 150 kHz), with data being recorded to DAT (Digital Audio Tape) or logged automatically to computer respectively.

- Species identification and classification of vocalisation categories was carried out onshore and onboard ship. Detection rates per unit effort (number of detections / number of monitoring stations or number of detections / nautical mile) were calculated for ¼ ICES squares.

- Dolphins, pilot whales and sperm whales were the most frequently detected cetaceans during surveys. Acoustic detection rates were higher than visual detection rates for odontocetes, especially for porpoises and sperm whales.

- Acoustic monitoring was carried out in conjunction with JNCC's standard visual monitoring procedures. Acoustic monitoring did not compromise the effectiveness of the visual survey in any way. The overall effect of employing this dual survey approach was to increase detection rates and the effectiveness of the survey.

- Acoustic data and recordings collected during this project could usefully be analysed further to give absolute abundance estimates for sperm whales and an improved picture of dolphin distributions.

- Improvements in acoustic techniques and species recognition that are foreseen for the near future will further enhance the effectiveness of a dual survey approach.

1 Introduction

Information on the distribution, abundance, status and ecology of cetaceans in the north-east Atlantic (Atlantic Frontier) is limited (Moscrop, 1997). Historical whaling records (Thompson, 1928; Brown, 1976), stranding records (Sheldrick, 1989), recent dedicated sightings surveys (e.g. NASS-87, NASS-89, SCANS 1995) and other sightings surveys (e.g. JNCC, SeaWatch Foundation, Hebridean Whale and Dolphin Trust) suggest that the Atlantic Frontier is an important area for at least 22 species of mysticete (baleen) and odontocete (toothed) cetaceans. Several of these are listed as endangered in the IUCN Red Data Book.

Table 1 summarises the seasonal occurrence and status of cetaceans in waters west of the UK and indicates those species for which acoustic monitoring is likely to be most effective. Many of these species are vocally active for most or part of their lives. Vocalisations extend over a wide range of frequencies, from the infrasonic moans of large baleen whales (e.g. blue whale 10 – 15 Hz) to the ultrasonic pulses of small odontocetes (e.g. harbour porpoise 130 kHz) (Gordon, 1996). In recent years, passive acoustic methods have increasingly been used to study cetacean behaviour and distribution (Clark and Ellison, 1988; Leaper *et al.*, 1996; Gillespie, 1996; Goold, 1996; Chappell *et al*., 1996; Clark *et al*., 1997). In fact it has been suggested that the use of passive acoustic methods could provide "a quantum leap" in the quality and quantity of information available about cetaceans in the Atlantic Frontier (Ferguson *et al*., 1997). Passive acoustic surveys offer several advantages when compared to traditional visual surveys, especially for those species such as the harbour porpoise, which are small and inconspicuous, and the sperm whale, which spends approximately 75% of its time below the surface. Acoustic surveys can be conducted around the clock and can continue in weather conditions that limit the effectiveness of, or even prohibit, visual surveys. Acoustic surveys also require fewer personnel and allow scope for automated data collection and analysis (Gordon, 1996; Notarbartolo di Sciara and Gordon, 1997).

Buckland (1996) stated that the ideal option is an integrated survey design that builds on the strengths of both acoustic and sightings surveys. The work undertaken for Conoco, in collaboration with the JNCC SAST, west of the Hebrides, integrated both visual and acoustic techniques. Preliminary results from both this work and work carried out for Shell UK (Iliad Tranche and Brendan's Dome projects) show that generally, odontocete detection rates using acoustic methods are substantially higher than for visual surveys. Acoustic monitoring is now playing an increasingly important role in ensuring compliance with government guidelines for minimising acoustic disturbance to cetaceans during seismic exploration (Gordon *et al*., 1997).

Table 1 Seasonal occurrence and status of cetaceans in waters west of the UK.

SPECIES	SEASONAL OCCURRENCE	STATUS	IUCN STATUS	ACOUSTIC DETECTION POSSIBLE			REFERENCES
ARRAY				**SOSUS**	**CONOCO / HWDT**		
FREQUENCY				**LF**	**MF**	**HF**	
BALEEN WHALES							
Family *Balaenidae*							
Northern right whale †	Summer.	Very rare. Very occasional sightings – off Hebrides	E	**?**	✓	✗	1, 2
Family *Balaenopteridae*							
Blue whale	Summer.	Very rare. Occasional sightings in deep water west of Ireland.	E	✓	✗	✗	1, 2, 3, 4, 29
Fin whale	June – Dec. All year?	Mainly deep water. Sightings appear quite common.	V	✓	✗	✗	2, 3, 4, 5, 6, 7, 8, 29
Sei whale	June – Dec.	Rare. Occasional sightings off continental shelf edge, west coast of Scotland & Ireland.	V	**?**	**?**	✗	2, 3, 9, 10, 29
Minke whale	All year. Summer Peak?	Widely distributed around Scotland, particularly in west and north.	IK	✓	✓	✗	3, 4, 5, 8, 11, 12, 13, 14, 15, 29
Humpback whale	April – Sept. All year?	Rare. Mainly deep water. Sightings seem to be increasing in recent years.	V	✓	✓	✗	2, 3, 4, 11, 16, 17, 29
TOOTHED WHALES							
Family *Ziphiidae*							
Sowerby's beaked whale	All year?	Rare. Deep water. Distribution may centre off Ireland.	IK	✗	**?**	**?**	2, 18
Cuvier's beaked whale	All year?	Rare. Deep water species. Distributed west of Ireland and Scotland.	IK	✗	**?**	**?**	1, 2
True's beaked whale	All year?	Rare. Deep water. Mainly occur west of Ireland.	IK	✗	**?**	**?**	2
Northern bottlenose whale	All year. Summer peak.	Fairly common? Deep water distribution in north and west of Scotland.	IK	✗	**?**	**?**	2, 5, 29
Family *Physeteridae*							
Sperm whale	All year. July – Nov. Peak.	Rare, but sightings / stranding increasing? Distributed in deep water along Atlantic coast, particularly west and north of Scotland.	IK	✗	✓	✗	2, 3, 5, 6, 8, 19, 20, 29, 31
Family *Monodontidae*							
Beluga	June – Nov.	Very rare.	IK	✗	✓	✗	2, 21
Narwhal	?	Arctic vagrant. Not sighted since 1949.	IK	✗	✓	✗	2, 22
Family *Phocoenidae*							
Harbour porpoise	All year.	Common, wide distribution, coastal and offshore. Concentrations around Hebrides and offshore.	IK	✗	✗	✓	3, 6, 8, 12, 13, 15, 23, 29

SPECIES	SEASONAL OCCURRENCE	STATUS	IUCN STATUS	ACOUSTIC DETECTION POSSIBLE			REFERENCES
ARRAY				SOSUS	CONOCO / HWDT		
FREQUENCY				LF	MF	HF	
Family *Delphinidae*							
Killer whale	All year.	Widespread between Scotland and Faeroes. Fairly common.	IK	✗	✓	✓	3, 5, 8, 12, 15, 20, 26, 29
False killer whale	?	Very rare.	IK	✗	✓	✓	1, 2
Long-finned pilot whale	All year. Aug.-Oct. peak?	Common. Wide spread distribution offshore continental shelf. Sightings increasing since 1970's.	IK	✗	✓	✓	1, 2, 6, 8, 15, 20, 26, 29, 31
Risso's dolphin	All year. May–Sept. peak.	Fairly common and widely distributed in coastal and offshore waters.	IK	✗	✓	✓	2, 3, 6, 8, 11, 12, 15, 27, 29
Common dolphin	All year. Summer peak.	Common. Increasing off western Scotland and northern North Sea.	IK	✗	✓	✓	2, 3, 6,12,15,29, 31
White-beaked dolphin	All year. Summer peak.	Common around Hebrides, Shetland and Orkney. Less pelagic than White sided,	IK	✗	✓	✓	3, 6, 8, 11, 12, 13, 29
Atlantic white-sided dolphin	All year. Summer peak. Winter offshore?	Common around Hebrides, Shetland and Orkney. Mainly pelagic.	IK	✗	✓	✓	2, 3, 8, 11, 15, 29
Striped dolphin	July-Dec.	Rare, but increasing off western Scotland?	IK	✗	✓	✓	3, 28, 31
Bottlenose dolphin	All year.	Locally common but rare in Shetland or Orkney.	IK	✗	✓	✓	2, 3, 8, 29

IUCN Status: *E* - Endangered, *V* – Vulnerable, *IK* – Insufficiently Known, ✝ Highly vulnerable or endangered species which were common in British and Irish waters prior to over-exploitation and which may occasionally be seen in traditional habitat / migration routes west of Britain, and Ireland.

Acoustic detection possible: ? – Not known, ✓ - Yes, ✗ - No

References: 1 Evans, 1980a; 2 Evans, 1991; 3 Stone, 1997; 4 Clark *et al*., 1997; 5 Gunnlaugsson and Sigurjónsson, 1990; 6 Mayer *et al*., 1993; 7 Buckland *et al*., 1992; 8 Bloor *et al*., 1996; 9 Evans, 1992; 10 Cattanach *et al*., 1993; 11 Evans, 1995; 12 Evans *et al*., 1993; 13 Northridge *et al*., 1995; 14 Øien, 1991; 15 Hammond *et al*., 1995; 16 Sigurjónsson and Gunnlaugsson, 1990; 17 Christensen *et al*., 1992; 18 Evans, 1980a; 19 Sigurjónsson and Gunnlaugsson, 1989; 20 Sigurjónsson *et al*., 1991; 21 Anon., 1996; 22 Fairweather, 1976; 23 Bjørge and Øien, 1990; 24 Evans, 1988; 25 Bloch and Lockyer, 1988; 26 Buckland *et al*., 1993; 27 Gill and Atkinson. T, 1996; 28 Bloch *et al*., 1996; 29 Stone, 1997; 30 Gordon *et al*., 1997; 31 Swift, 1998.

2 Survey Area

Surveys were conducted to the north-west of the Hebrides in the Malin Sea (Charts 1 and 2). The survey area lay between latitudes 58° N and 60.5° N and longitudes 6° W and 9° W, covering parts of the Hebridean Shelf (continental shelf), Wyville-Thompson Ridge and Faeroes-Shetland Channel. The area was subdivided into ¼ ICES square survey blocks (Chart 3).

Licensed and offered oil exploration blocks north-west of the Hebrides area and survey coverage are summarised in Table 2, and shown in Chart 4. Licensed blocks T36, T37, T38, T43, T44, T47, T48, T52 and T53 were surveyed between December 1997 and February 1998. Some additional acoustic data were collected in blocks T32, T33, T39, T40, T41, T42, T45, T46, T49, T50, T51 and T54 and for an area north of blocks T52, T53. Acoustic effort was highest in blocks T44, T47, T48, T52 and T53.

Table 2 Licensed and offered blocks in the survey area.

Block	**Offered**	**Licensed**	**Company/ Companies**	**Acoustic Coverage**	**Stations per km^2**
T26	✓			✗	0.00
T27	✓			✗	0.00
T28	✓			✗	0.00
T29	✓			✗	0.00
T30		✓	Fina	✗	0.00
T31	✓			✗	0.00
T32	✓			✓	0.02
T33	✓			✓	0.17
T34	✓			✗	0.00
T35	✓			✗	0.00
T36		✓	Texaco / UTP / Murphy / Pedeco	✓	0.04
T37		✓	Marathon / Phillips / Pancan	✓	0.08
T38		✓	Enterprise / Mobil / Statoil	✓	0.14
T39	✓			✓	0.13
T40	✓			✓✓	0.31
T41	✓			✓	0.17
T42	✓			✓	0.04
T43		✓	Statoil / Mobil / Enterprise	✓✓	0.26
T44		✓	Phillips / AGIP / OMV / Petrobas / Ranger	✓✓	0.27
T45	✓			✓✓	0.21
T46	✓			✓✓	0.22
T47		✓	Enterprise / Mobil / Statoil	✓✓✓	0.40
T48		✓	Conoco	✓✓✓	0.44
T49	✓			✓✓✓	0.41
T50	✓			✓	0.14
T51	✓			✓	0.05
T52		✓	Conoco / Arco	✓✓✓	0.49
T53		✓	Elf / BG / ESSO / N. Power	✓✓	0.39
T54	✓			✓	0.07
T55	✓			✗	0.00

Key to Acoustic Coverage: ✗ No data, ✓ Low Coverage, ✓✓ Medium Coverage, ✓✓✓High Coverage.

3 Methods

Surveys were conducted north-west of the Hebrides between December 1997 and February 1998. Survey protocols were designed around the JNCC SAST sightings survey protocols, to ensure that acoustic surveys did not interfere with the work of the JNCC.

3.1 Equipment

The equipment used was based on designs developed on the IFAW (International Fund For Animal Welfare) research vessel *Song of the Whale* (Chappell *et al*., 1996) and by IFAW scientists for surveys of the Southern Ocean Sanctuary (Gillespie, 1996; Leaper and Scheidat, in prep.). This equipment was designed to be deployed from any platform of opportunity by a non-specialised crew. Although more sophisticated monitoring systems, covering a wider range of frequencies, have been used successfully in the field (Gordon *et al*., 1997; Gordon *et al*., 1998a), time, space and budget constraints dictated the use of a simple system in this case. The system was fully automated which allowed two trained personnel to operate the equipment 24 hours a day throughout the survey period.

Acoustic data were collected using two different acoustic monitoring systems (*Medium* and *High frequency*) and using two different survey protocols (*Day* and *Night*). Environmental variables that affected detectability were recorded every half-hour at night.

3.1.1 Medium frequency system (200 Hz – 20 kHz)

This system was used to detect vocalisations from a number of different species, especially the broadband impulsive clicks of sperm whales and the narrow band whistles of smaller odontocete (toothed) whales, e.g. killer whales, pilot whales and dolphins. Additionally, the low frequency sounds of humpback and minke whales would have been audible on this system. An acoustic range of 3 to 5 nautical miles either side of the survey line is normal for sperm whales, and a 1 nautical mile range is usual for smaller odontocetes. Two hydrophone elements are used to detect vocalisations. The stereo output from these can be used to calculate the range and angle to vocalising whales. Figure 1 is a schematic representation of the monitoring equipment.

3.1.1.1 Hydrophone streamer

A "passive" array, built and supplied by IFAW, was used throughout this survey, and was identical to that used by Leaper and Scheidat (in prep.) for surveys of the Southern Ocean Sanctuary. The array was towed on a 400 m Kevlar-reinforced cable and consisted of a 10 m long, 30 mm diameter, oil-filled, polyurethane tube containing 2 Benthos AQ-4 (medium frequency) elements 3 m apart. Each element was linked to a separate Magrec HP-01 pre-amplifier with a bandwidth of 200 Hz - 40 kHz.

3.1.1.2 Recording System

Signals in the audible range, 200 Hz - 22 kHz, were routed through a junction box into the balanced line inputs of a Sony-DC10 Pro-DAT recorder (Automated Recording System) and a Sony PCMR-500 DAT-recorder (Monitor and Manual Recording System). The Sony-DC10 Pro-DAT remote control was modified so that its controls were connected to relay switches controlled by an Amplicon PC14AT card within a PC. This enabled specially written software (*Autorec*) to switch the Sony-DC10 Pro-DAT on and off at an interval specified by the monitor. *Autorec* was configured to make a 30 s recording every 3 minutes (see Fig. 1). All recordings were made to HHB DAT 125 tapes.

3.1.2 High frequency system (30 kHz – 150 kHz)

This system was used to detect the echolocation clicks of the harbour porpoise and several species of dolphin. Detection equipment ran continuously, and detections were logged automatically to the hard disk of a laptop computer. This system has been recently enhanced to cover the frequencies used by beaked whales; however these improvements were not available for this survey.

Figure 1(a) Medium and high frequency monitoring system

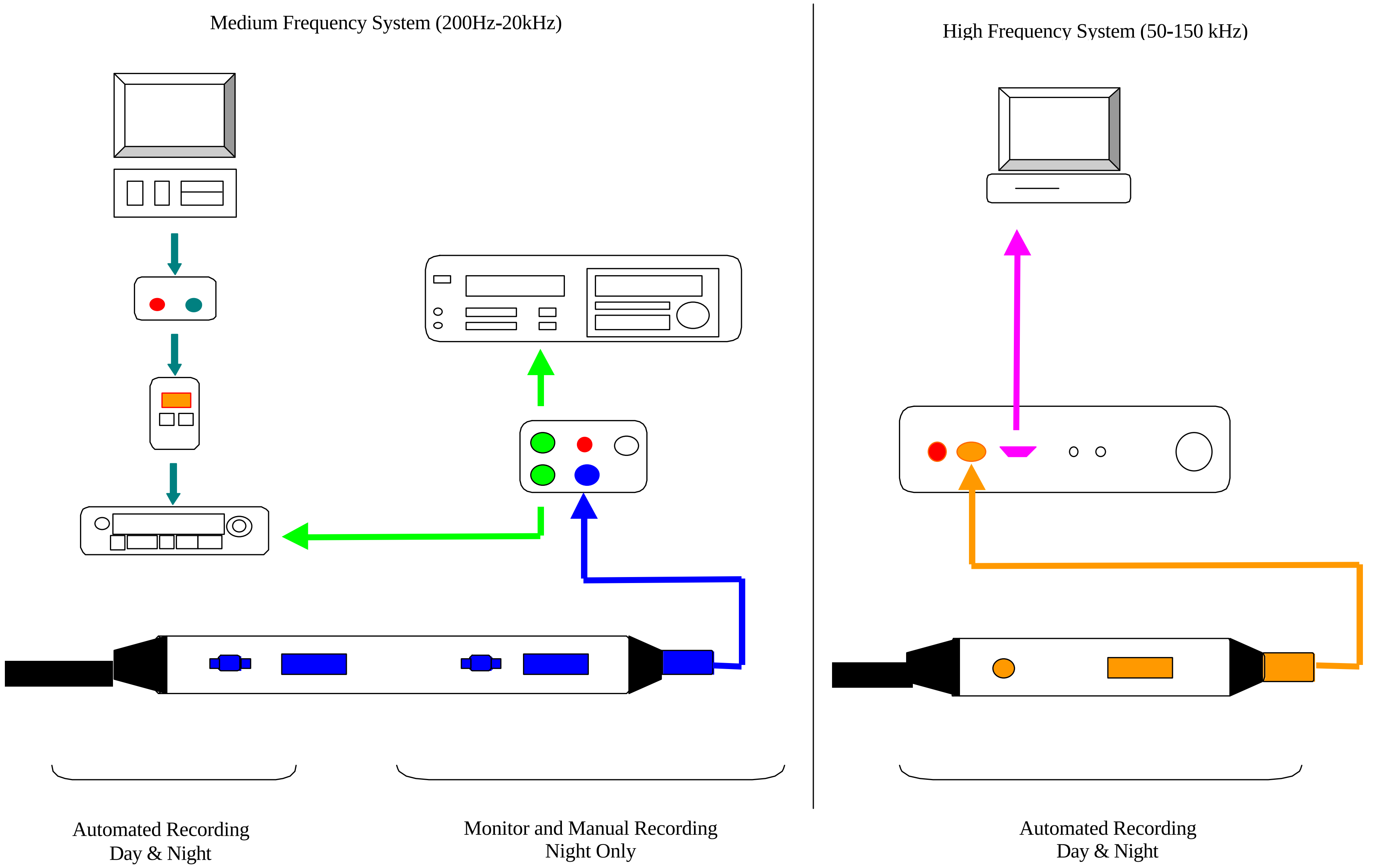


Figure 1(b). Key to equipment for medium frequency monitoring system

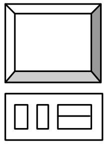
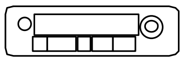
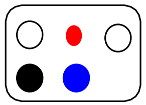
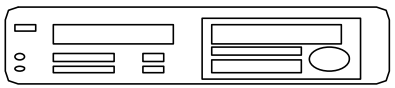
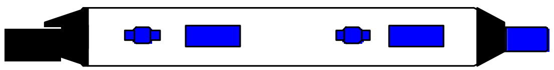
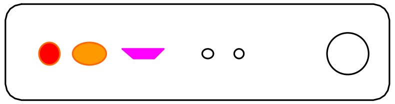
KEY	
	**PC (Personal Computer)** • Function: Run *Autorec.* • Specifications: Intel 386 CPU, SVGA Colour Monitor, Windows 3.1, DOS V 6.0, PC14AT Card. • Power: 240 V. • Modified by Doug Gillespie and Oliver Chappell (*Chappell Hydrophone Equipment*).
AUTOREC	**Autorec Program** • Function: Initiate remote recordings. • Specifications: C++ for DOS. • Designed and written by: Doug Gillespie.
	**Sony TCD-10 DAT Recorder** • Dynamic Range: 200 Hz – 24 kHz. • Line Inputs: Balanced left and right channels. Input from front (left channel) and rear (right channel) hydrophone elements. • Power: 9 volts.
	**Signal Junction Box** • Function: Signal Routing, Amplification and Filtering. • Amplifier: Differential (300 Hz – 24 kHz). • Filters: High Pass (300 Hz). • Power: 12 volts. • Designed and built by Doug Gillespie.
	**Autorec Junction Box and Sony TCD-10 DAT Remote Control** • Function: Route Autorec signals from PC to DAT remote • Function: Initiate remote recording (30 seconds every 2 minutes). • Designed and built by Doug Gillespie.
	**Sony PCMR-500 DAT Player & Recorder** • Operated manually. • Record a 1- minute cut every 15 minutes or any sounds of interest.
	**400 m Towed Hydrophone**  Benthos AQ-4 Elements, separated by 3M.  *Magrec* HP-01 Pre-amplifier. Bandwidth 200 Hz- 200kHz, gain 30 dB, supply 12 v DC. Built and designed by: *International Fund for Animal Welfare (IFAW).* • 400 m Kevlar reinforced cable.

Figure 1(c). Key to equipment for high frequency monitoring system

KEY	
	**Laptop** • Function: Run Automated High Click Detection Software and Log High Frequency Clicks Detections. • Specifications: Intel Pentium CPU, SVGA Colour Monitor, Windows 95/ NT, DOS V 6.0. • Modified by Doug Gillespie and Oliver Chappell (*Chappell Hydrophone Equipment*).
PORPOISE	**High Frequency Click Detection Software (Porpoise Software)** • Function: Click detection and data logging. • Operates under Windows 95. • Designed and written by: Oliver Chappell (*Chappell Hydrophone Equipment*) and Doug Gillespie.
	**Porpoise Box** • Designed and built by Oliver Chappell (*Chappell Hydrophone Equipment*).
	**200 m High Frequency Towed Hydrophone**  HS150 HF Ball hydrophone.  Pre-amplifier. • 200 m Kevlar reinforced cable. Screened 6 core. • +/- 12 Volt power supply.

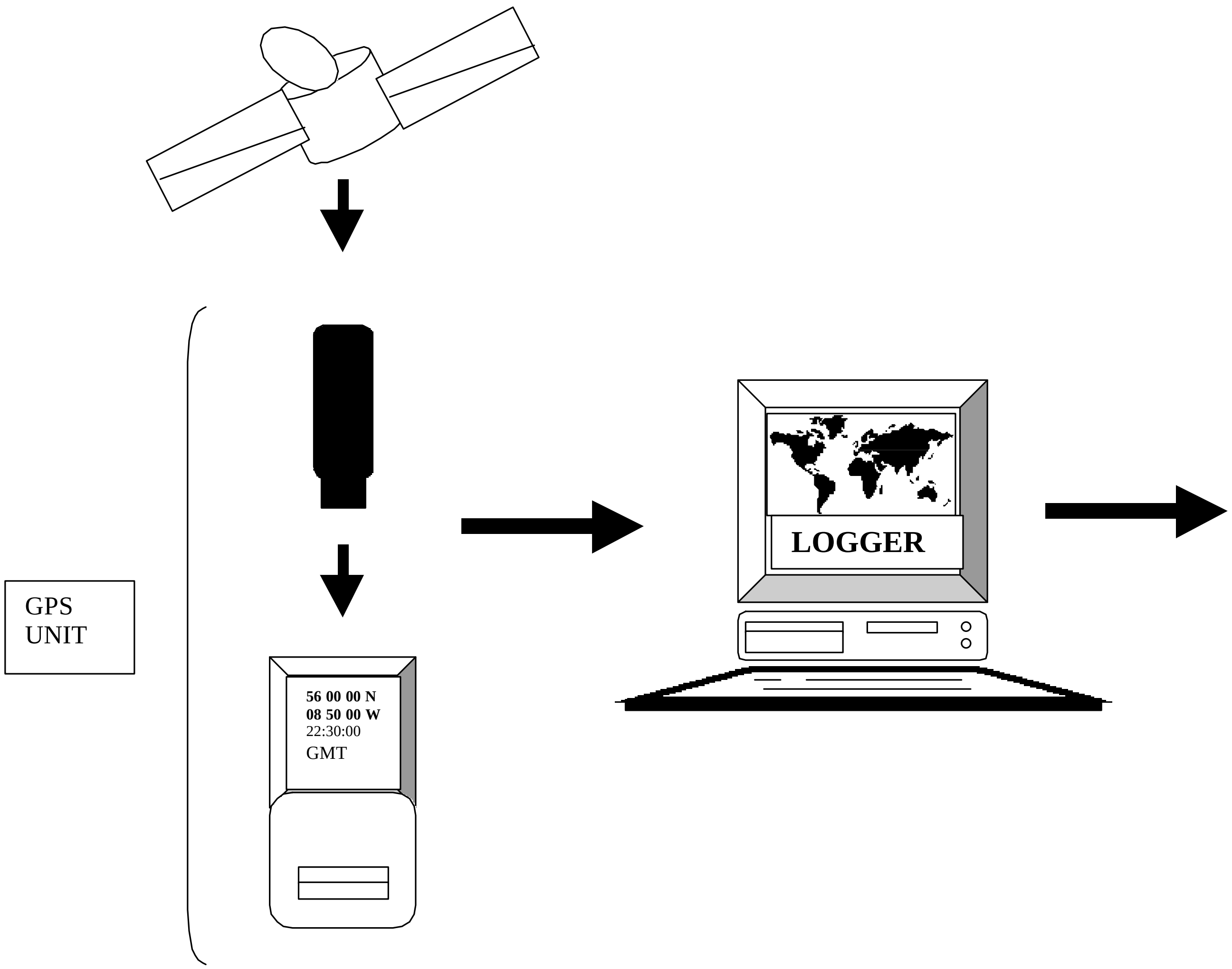
Signal pathways

KEY	
	MF (Medium Frequency) Input from MF Hydrophone
	Differential Input to DAT
	Autorec signal
	HF (High Frequency) Input from HF Hydrophone
	Digital input from Porpoise Box to Laptop

3.1.3 Position and data logging

Logger, an environmental database program, was run continuously throughout the survey on a laptop computer connected to an external GPS (Garmin-120 XL Navigator). Position, SOG (speed over ground) and COG (course over ground) were downloaded automatically from the GPS every minute. Additional information on environmental conditions (e.g. swell height, wave height and presence or absence of vessels) were entered by hand every half-hour. Acoustic monitoring information was also entered every 15 minutes (see section 3.2.2). This system is depicted schematically in Figure 2.

Figure 2. ***Logger*** **environmental database**



LOGGER **ENVIRONMENTAL DATABASE**

ACOUSTIC DATABASE

- Species (dolphin, pilot whale, sperm whale)
- Vocalisation category (whistle or click)
- Vocalisation strength
- Remote ship noise
- Self-made noise
- Water noise
- Tape no., cut no., start and end time.

EFFORT DATABASE

- GPS position data
- Type of monitoring (MF & LF, day or night)
- Start and end times of transects
- Time and date

ENVIRONMENTAL DATABASE

- Swell height
- Wave height
- Wind speed
- Weather
- Presence or absence of other vessels etc.

SIGHTINGS DATABASE

- Species
- Number and pod size
- Behaviour

3.2 Monitoring procedures

Different monitoring procedures were followed during the day and at night (see Appendix 3 for monitoring protocols).

3.2.1 Day Surveys

Day surveys ran in conjunction with the JNCC SAST sightings surveys between 6 am and 6 pm. These surveys were typically conducted at a speed of 10 knots along transects predetermined by the JNCC SAST.

Automated recording equipment (*Autorec*) was used to make a thirty-second cut (tape recording) every 3 minutes to the Sony-DC10 Pro-DAT from the medium frequency system. This resulted in a single 2-hour DAT tape of recordings every 12 hours. No manual monitoring of the medium frequency system occurred during the day. This was to allow monitors to rest and to keep sightings and acoustic data sets independent. The high frequency system ran independently of the medium frequency system and data was logged automatically to its computer continuously, both day and night.

3.2.2 Night Surveys

Night surveys were conducted between the end of one day's visual transects and the start of the next (6 pm - 6 am). Where possible, transects ran perpendicular to (across) the continental shelf, and the hydrophone was typically towed at a speed of 5 knots to minimise boat and water noise. Transects were designed by acoustic monitors after consultation with both the crew of the *MV Neptune* and JNCC SAST.

Night surveys were completed by two operators, working alternate three-hour shifts. The *medium frequency* system was monitored continuously and any detections were logged and interpreted when made.

Opportunistic recordings of (1) unknown sounds, or (2) good examples of vocalisations from known species, were also made.

Every 15 minutes, standard 1 minute recordings were made and details of the acoustic environment were noted in the *Logger* program. Automated DAT recordings were also made, just as for *day surveys*, and the *high frequency* system ran continuously, downloading data automatically to the computer.

3.2.3 *Logger* survey database

3.2.3.1 Acoustic database

Information about vocalisation strength was scored on a scale of 0 (nothing heard) to 5 (very loud), for vocalisation categories (whistles or clicks) for different species (sperm whale, killer whale, pilot whale and dolphins). Levels of remote ship noise, self-made noise and water noise, were also scored on the same scale. Additional information about the start and end time of each tape cut, duration of cuts, cut ID and recording levels were also logged.

3.2.3.2 Effort database

At the start and end of each monitoring session, monitors were required to log information about the time and date of each monitoring station and the systems used. This data was used correct the collected data for differences in monitoring duration on different days.

3.2.3.3 Environment database

At night, monitors were required to enter information about environmental variables (e.g. wind speed, swell height, wave height, weather, presence or absence of other vessels) every half-hour. This information can be used to investigate the effects of environmental factors on detection probability. Previous studies have shown that co-variates, such as wind speed, sea state and background noise levels, affected striped dolphin detection rates in the Ligurian Sea (Gordon *et al*., 1998c). Sea state and wind speed are known to affect ambient noise conditions in the ocean (Urick, 1986); this in turn masks signals such as cetacean vocalisations, making them harder to detect.

3.3 Analysis

Acoustic monitoring resulted in three different analysis tasks at the end of the survey: (1) the analysis of the *auto-recorded* tapes, (2) the data from shipboard monitoring, and (3) the *high frequency* detection files.

3.3.1 Medium frequency monitored data

Sounds noted as unknown were played and identified using cetacean vocalisation databases. No further analysis of these tapes or data was required on shore.

3.3.2 Medium frequency auto-recorded data

Auto-recorded tapes were analysed onshore by listening to them using headphones in a quiet environment. The intensity of acoustic contacts was scored on a scale of 0 (nothing heard) to 5 (very loud)[1] for each species/species group (sperm whale, killer whale, pilot whale, killer/ pilot whale and dolphin) and vocalisation category (whistles & clicks). Assessments of background noise levels were made by ear and scored on a scale of 0 to 5. Background noises were categorised as (1) water noise, (2) self-made noise, and (3) remote vessel noise. Other sources of noise were also noted; e.g. *electrical hum* and *hydrophone knocking*. Data were entered into a relational database, (Microsoft Access), where it was combined with data from *Logger*.

During this phase of analysis, sample sound cuts were also digitally recorded to hard disk. Four categories of cut were made: background noise, unknown sounds, whistles, very good examples of known species. These can be used to assess the effects of co-variates on detection ability and to develop automated detection software for the petroleum industry. The protocols followed during tape analysis are presented in Appendix 4.

For many periods, both *auto-recorded* and shipboard-recorded data were available for analysis. Data from the *auto-recorded* tapes were considered more reliable for a number of reasons. All the *auto-recorded* tapes were scored by a single operator in a quiet environment where sounds could be replayed several times if necessary and where species reference tapes were to hand. Thus, when available, the *auto-recorded* data was used. *Monitored* data was only utilised to cover periods when data from the *auto-recording* system was not available.

An estimate of the number of sperm whales heard was made on the *monitored* data. No estimates were made for *auto-recorded* data, as more objective estimates could be made by processing the data with the *Rainbow Click* program if required. However, the timescale required for this type of analysis is beyond the current study and could be considered as a separate, subsequent, research project.

The positions of stations with or without a detection of a species could thus be plotted and a detection rate within any area calculated:

$$\text{detection rate} = \frac{\text{number of stations with detections}}{\text{total number of stations}}$$

This detection rate can be usefully plotted for subdivisions of the survey area such as ¼ ICES squares or oil exploration blocks. As this measure is a rate, it will be largely independent of the station spacing and duration.

[1] The human ear is extremely sensitive to transient noise (Gabor, 1947), and the regularly repeated clicks of sperm whales can be detected at very low signal-to-noise levels (Leaper and Scheidat, *in prep*.).

3.3.3 High frequency click data

Signal amplitudes were recorded at 50, 75 and 125 kHz, if the amplitude at any one of these frequencies exceeded a threshold value, specific to the vessel, and set by the monitors. The equipment was originally designed to detect harbour porpoise vocalisations, and thus data interpretation is based on the fact that porpoises produce narrow-band clicks in the range 115-145 kHz (Chappell *et al*., 1996). Other impulsive noises, e.g. propeller cavitation, clicking shrimps, other cetaceans, sonar and depth sounding equipment, have broader bandwidths, and porpoise clicks are easily distinguished from these as they possess high amplitudes at 125 kHz with relatively low amplitudes at 50 and 75 kHz.

A new Windows-based high frequency click interpretation program, *Porpoise*, was written to analyse this data. *Porpoise* displays the data graphically and allows detections and other events (such as periods of noise) to be identified, highlighted, annotated and stored in a linked database.

During preliminary analysis of these data, detections where background noise levels exceeded acceptable levels were removed from the effort database.

Porpoises can be detected at ranges of up to 400 m from the hydrophone and a series of acoustic detections typically occurs when a vocalising porpoise pod passes within range of the hydrophones. Porpoise detections were assessed and given a percentage (%) confidence score. The score is related to an ideal porpoise detection, which is characterised by the following:

- High amplitudes at 125 kHz, low at 50 kHz and 75 kHz.

- Increase in trigger rates caused by porpoise clicks triggering the 125 kHz detector - indicating buzz vocalisations (typical porpoise click rates are 0.5 – 900 clicks per second). Ideally, several pulses of rapid clicks (click trains).

- Amplitude at 125 kHz rises to a peak over time then falls away, as the ship approaches then passes by the porpoise pod.

The percentage (%) confidence scores and their criteria are:

100% **Perfect Detection**: 125 kHz signal rises well above background noise, rapid trigger rate with clear click trains, amplitude rises to a peak then drops away.
90% **Near Perfect Detection:** Maybe some noise.
80% **Clear Detection:** Signal rises above background noise, less clear rise and fall of 125 kHz amplitudes.
70% **Detection:** Signal rises above background noise, no clear click trains, no clear rise and fall of 125 kHz amplitudes.
60% **Poor Detection:** Amplitude of 125 kHz signal just rises above noise level.
50% **Marginal Detection**: Noise amplitudes (i.e. 50 and 75 kHz) similar to signal amplitudes, maybe increases triggering rate.
<50% **Possible Detection:** 125 kHz signal amongst noise, maybe increased trigger rate, for the purposes of this survey these were not considered to be porpoises.

Positions of porpoise detections were derived from the record of the ship's survey track by linear interpolation.

4 Results

4.1 Effort

Poor weather conditions limited the time that the *MV Neptune* spent at sea. In the three months (December 1997 – February 1998) a total of 17 days and 24 nights were spent at sea. The ship's track is plotted on Chart 5. The monitoring effort achieved during this time, on the different hydrophone systems, is detailed below.

Unfortunately, we were only permitted to deploy the hydrophone in the Minch on a limited number of occasions. Within the Minch the captain is required to gain permission from the coastguard to undertake operations which could reduce the ship's manoeuvrability. On the occasions when permission was sought, it was given unreservedly.

The distribution of acoustic effort was determined by several factors:

1. When on passage between JNCC's survey area and port, the track and speed of the ship were chosen by the skipper to make the most efficient passage.
2. The daytime track and speed of the survey ship were governed by the requirements of the JNCC survey. JNCC had a target track length of visual survey to be completed in each ¼ ICES square per month. These tracks were surveyed at about 10 knots.
3. The nighttime track of the ship was also influenced by JNCC's survey. The night-time track started where JNCC's visual survey had finished and ended where they needed to start the following morning.
4. The direction of the prevailing swell influenced the direction of both day and night transects. The ship, an ex-Baltic tug, had a shallow draught and tended to roll uncomfortably when the swell was on her beam. Consequently the track was selected so that the ship either travelled into or with the swell.

Within these constraints we chose night tracks so that:

i. Good acoustic coverage over the licensed oil exploration blocks was achieved.
ii. Tracks crossed the bathymetric contours to give good depth coverage.
iii. Doubling back over track lines, and therefore potential duplication, was avoided.
iv. The area surveyed was extended.

4.2 Medium frequency

4.2.1 Effort

Table 3 summarises the monitoring effort achieved each month. The positions of all acoustic stations and the number of acoustic stations per ¼ ICES square are shown in Charts 6 to 9 and Chart 10 shows the number of acoustic stations by oil block. Charts 6 and 10 cover the whole survey period, while charts 7 to 9 show the acoustic effort by month.

Table 3 Summary of medium frequency monitoring effort

Period	Dec	Jan	Feb	Total
***Monitored* stations**	246	507	91	844
Period covered (hours)	61.50	126.75	22.75	211.00
***Auto-recorded* stations**	0	3964	1020	4984
Period covered (hours)	0.00	198.20	51.00	249.20

- Chart 6 shows that over the whole survey period most acoustic effort was concentrated in those ¼ ICES squares that coincide with the target oil blocks and also along the course that the ship took on passage between the survey area and Stornoway.

- Chart 7 shows the acoustic coverage in December. Unfortunately, due to problems with the *auto-recording* system, useful acoustic data were only collected at night.

- Chart 8 shows the acoustic coverage for January. Periods of good weather towards the end of the month resulted in excellent coverage.

- Chart 9 shows the acoustic coverage for February. Poor weather throughout the month meant that the ship only completed two short surveys, giving poor acoustic coverage.

- Chart 10 shows the distribution of acoustic monitoring effort for the whole survey period by oil exploration block. The oil exploration block number, the licensees (if licensed), the number of acoustic stations within the block and the number of acoustic stations per km² are also shown. These data are summarised in Table 2. The greatest acoustic effort was concentrated in blocks T52 and T48. All licensed blocks had some acoustic coverage except T30, which was geographically isolated to the west.

4.2.2 Species distributions

4.2.2.1 Sperm whale detections (Charts 11-14)

Chart 11 shows the distribution of sperm whale detections over the entire survey period. Sperm whales were detected at 25% of all acoustic stations. Detection rates were highest in offshore waters (> 500 m) whereas there were only two geographically distinct detections in water < 200 m deep. This chart also shows the estimates of the number of sperm whales made at the *monitored* acoustic stations (these data were not scored for the *auto-recorded* cuts). Chart 11 indicates that the basin extending into the Wyville-Thompson Ridge (around ICES square 59°30' N, 7° W, oil exploration block T53) is an area of particularly high abundance, though this has not been tested statistically.

Further analysis of these recordings using the *Rainbow Click* and *Cartwheels* programs (Gillespie, 1997) would allow absolute abundance estimates to be made for sperm whales.

The distribution of sperm whale detections is plotted by month in charts 12 to 14. The limited coverage in December and February, due to poor weather, does not allow seasonal changes, if any, in the distribution patterns to be investigated.

4.2.2.2 Pilot whale detections (Charts 15-18)

Chart 15 shows the distribution of pilot whale detections over the entire survey period. Pilot whales were heard at 1% of all monitoring stations. All detections were made in water > 600 m in depth, with a notable concentration of detections close to the 1000 m contour. The distribution of detections by month is plotted on Charts 16 to 18. Again, poor and uneven coverage in December and February does not allow seasonal changes in distribution patterns to be investigated.

4.2.2.3 Killer whales (Chart 19)

One definite detection of a killer whale was made; its position is shown on Chart 19. This was made at 05:00 on 31 January, in 700 m of water.

4.2.2.4 Killer or pilot whales (Chart 20)

Distinguishing between killer and pilot whale vocalisations is sometimes difficult. Some detections have therefore been classified as killer or pilot whale. There were five geographically distinct detections, four in water deeper than 1000 m and one at 250 m.

4.2.2.5 Dolphins (Charts 21-24)

For these analyses, no attempt has been made to distinguish between the vocalisations of different dolphin species; the relative sighting rates of different species in the JNCC data give the best indication of the species detected acoustically in the area. Dolphins were detected at 21% of all acoustic stations. Chart 21 shows the distribution of dolphin detections over the entire survey period. Detections were generally higher offshore, in waters greater than 500 m deep. During some offshore legs acoustic contacts with dolphins were made at almost every listening station. Oil blocks T47 and T46 appear to be areas of highest density.

The distribution of detections by month is plotted on charts 22 to 24. Again, poor and uneven coverage in December and February does not allow seasonal changes in distribution patterns to be investigated.

4.3 High frequency (porpoise) data

4.3.1 High frequency monitoring effort

The ship's track while the porpoise detector was on, and where background noise levels remained acceptably low, is plotted on Chart 25. The total length of track surveyed within each ¼ ICES square is also shown and the squares shaded proportionately. Table 4 summarises *high frequency* survey effort.

Table 4 Summary of *high frequency* monitoring effort for harbour porpoises

Total track length with porpoise detector on	1201.91 nautical miles
Number of ¼ ICES squares with coverage	32
Average track length per ¼ ICES square	37.81 nautical miles
Months with coverage	January & February

During the survey, significant levels of high frequency electrical noise were introduced through the ship's earthing system. According to the ship's engineer, there were several pieces of electrical equipment on the ship where the live was leaking to earth - making it electrically noisy. This problem was mitigated to a large extent in January and February by the use of a modified porpoise detector. However, all the data from December and some from January and February were judged to be too noisy for consistent analysis. Consequently, there is less survey track coverage for the *high frequency* than for the *medium frequency*. These problems were specific to the *MV Neptune* and should not occur again. In addition, a modified version of the porpoise equipment has just been developed which is less susceptible to this type of problem.

4.3.2 Species distributions

4.3.2.1 Porpoises (Chart 26)

Positions of detections for the whole survey period, where the confidence level was greater than 50%, are shown on Chart 26. Symbols were used to indicate the percentage (%) confidence level for each detection. Detection rates were calculated for each ¼ ICES square as the number of distinct detections (where confidence >50%) per nautical mile of surveyed track.

The highest detection rates occurred in the ¼ ICES squares adjacent to the Isle of Lewis with the square that included the Butt of Lewis headland (enlargement inset) having the highest rate (0.535 detections per nautical mile). Further offshore the detection rates were much lower or zero. There were only 9 detections in water deeper than 200 m.

5 Discussion

Significant concentrations of odontocetes were detected within the oil exploration blocks surveyed in the course of this work. The relatively high number of sperm whales in these areas may be a cause for particular concern as they are a species that makes long, deep feeding dives and, without acoustic equipment, they can be very difficult to detect. Thus, although sperm whales are not seen at the surface before the start of seismic surveys, they may be within range, and may actually be in the most vulnerable position, directly below the seismic guns, at start up. Porpoises were detected less frequently than sperm whales, but have a much shorter detection range. Similarly porpoise are another species that were detected within the survey area, and are typically more difficult to detect without acoustic equipment.

Acoustic monitoring was conducted during a project designed principally to be a sightings survey without compromising or inconveniencing the sightings team at all. Acoustic data were collected at the same time as the sightings surveys, augmenting detections, especially of sperm whales and harbour porpoises. Acoustic surveys were also conducted at night and during passages, resulting in an increased area of coverage.

By making the best use of the available ship time, which represents a substantial financial investment, the use of passive acoustic monitoring enhanced the overall efficiency and effectiveness of the survey.

The acoustic monitoring effort was compromised by two equipment failures that have already been mentioned. Problems like this are to be expected in what is essentially a new system, but both were easily identified and have been remedied.

One shortcoming of the acoustic data at the moment is uncertainty about the identity of the vocalisations of some species, especially among the dolphins. It is likely that our ability to identify dolphins from their vocalisations will increase as research on automatic detection and classification of whistles continues (e.g. Chappell and Gillespie, 1998). Current research, in which whistle parameters were measured from spectrograms by hand (e.g. Steiner, 1981), suggests that dolphin whistles are sufficiently varied to allow species to be identified acoustically.

During this project, all identifications were made by ear. Recent advances in automatic detection algorithms (e.g. Chappell and Gillespie, 1998) suggest that efficient acoustic detection will soon be possible using standard PCs. This will clearly increase the efficiency with which small field teams can monitor for cetaceans using field techniques and will serve to eliminate inter-observer variability in detection rates.

More work is still required on the best techniques for using acoustic cues to provide accurate and unbiased indications of cetacean abundance. For some species, e.g. sperm whales (Leaper *et al.*, 1992) and harbour porpoises (Gordon *et al.*, 1998b) techniques have already been developed to determine absolute abundance from acoustic cues.

6 Conclusions

The oil exploration blocks to the north-west of the Hebrides surveyed during this project contain substantial concentrations of odontocetes. If seismic surveys are to be conducted in these areas, then efforts should be made to implement rigourously the UK Government guidelines to reduce disturbance to marine mammals. As some of the species detected are very difficult to detect using visual techniques alone, consideration should be given to incorporating acoustic monitoring during seismic surveys as well.

Any future extraction of oil from these areas should be undertaken in ways that minimise disturbance of cetacean populations that inhabit these waters.

This work has shown that passive acoustic techniques can be used alongside visual methods to increase the overall efficiency of offshore surveys for cetaceans without inconveniencing visual monitoring teams.

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Appendices

Appendix 1 The Hebridean Whale & Dolphin Trust

The Hebridean Whale and Dolphin Trust (HWDT) is a dynamic young charity which has been conducting pioneering research into cetacean distribution and abundance within the Hebrides since 1989. We are committed to using only benign research techniques that neither harm nor seriously disturb the animals being studied. Biological monitoring programmes undertaken by the HWDT provide managers with the information necessary to decide on the most appropriate course of action required for effective conservation. In addition, the information obtained from these programmes provides materials and opportunities to educate and raise public awareness. Over the past few years the HWDT has contributed widely to both local education programmes and the scientific community. We focus our studies on cetaceans (whales, dolphins and porpoises) for a number of reasons:

- Cetaceans are usually predators at the top of their respective food chains, and as such they are excellent indicators of the health of the entire ecosystem.

- Little is known about the distribution, abundance, reproductive and behavioural ecology of these species.

- These large charismatic mammals can command tremendous public interest, and are an excellent way of generating public awareness, and concern for, the wider marine environment.

HWDT management and staffing structure

The HWDT is a registered charity (Scottish Charity No. SCO22403) and a limited company (Scottish Company No. SC172338) run under the auspices of the Chairman and his board of Trustees. The Trust currently has 3 permanent members of staff and several research associates.

The Chairman

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Appendix 2 Common and scientific names of cetacean species reported for the Atlantic Frontier

Toothed Whales (odontocetes)

Sub-order ODONTOCETI

Super-family Delphinoidae (Dolphins and small toothed whales)

Family Monodontidae (Narwhal and Beluga)

Narwhal *Monodon monoceros*
Beluga (White Whale) *Delphinapterus leucas*

Family Delphinidae (Dolphins)

Subfamily Globicephalinae

False Killer Whale *Pseudorca crassidens*
Killer Whale *Orcinus orca*
Long-finned Pilot Whale *Globichephala melas (=melaena)*

Sub-family Delphininae

White-Beaked Dolphin *Lagenorhynchus albirostris*
Atlantic White-sided Dolphin *Lagenorhynchus acutus*
Common Dolphin (Short-Beaked) *Delphinus delphis*
Risso's Dolphin (Grampus) *Grampus griseus*
Bottlenose Dolphin *Tursiops truncatus*
Striped Dolphin *Stenella coeruleoalba*

Family Phocoenidae (Porpoises)

Harbour Porpoise *Phocoena phocoena*

Super-family Physeteroidea (Sperm Whales)

Sperm whale *Physeter catadon (=Physeter macrocephalus)*

Super-family Ziphioidea (Beaked Whales)

Northern Bottlenose Whale *Hyperoodon ampullatus*
Cuvier's Beaked Whale *Ziphius cavirostris*
Sowerby's Beaked Whale *Mesoplodon bidens*
True's Beaked Whale *Mesoplodon mirus*

Baleen Whales (mysticetes)

Sub-order MYSTICETI

Family Balaenidae (Right Whales)

Northern Right Whale *Balaena glacialis*

Family Balaenopteridae (Rorquals)

Blue Whale *Balaenoptera musculus*
Fin Whale *Balaenoptera physalus*
Sei Whale *Balaenoptera borealis*
Minke Whale *Balaenoptera acutorostrata (=B. bonaerensis)*
Humpback Whale *Megaptera novaeangliae*

Appendix 3 Project protocols

A.3.1 Aim

The aim of the project is to carry out acoustic surveys north-west of the Hebrides, over the continental shelf in an area that encompasses the Wyville-Thomson Ridge and the Bryony Bank. Several tranches are to be surveyed for a consortium of oil companies, including Conoco and Enterprise Oil. Conoco have contracted the Hebridean Whale and Dolphin Trust to conduct acoustic surveys, while the JNCC (Joint Nature Conservation Committee) Seabirds at Sea Team conduct visual surveys.

A.3.2 Night surveys

Acoustic surveys at night to be carried out between 6pm and 6 am (i.e. 12 hours monitoring). It is envisaged that monitors will work in 2-hour shifts from 6 pm to 6 am. This should allow a passage time of 2 hours at the beginning and end of each acoustic transect for the vessel to reach the new sightings transect.

Acoustic transects should be conducted at a speed that keeps noise levels at a minimum: suggested speed 5 knots. To determine the most appropriate speed you may need to spend several hours surveying at different speeds. During these tests keep accurate notes of water noise, remote vessel noise, background noise and boat speed. It would also be a good idea to make continuous recordings during these tests so that noise levels can be determined later.

Recordings will be made on two systems. The first "*Autorec* " system will run 24 hours a day during both day and night. The second "*monitored*" system will be operated at night by individual monitors when they hear something of interest. *Autorec* will work in the background and tapes will be analysed at a later date.

A.3.3 Transects

Transects should be selected so that they are perpendicular to the continental shelf, i.e. move inshore across the shelf, or move offshore across the shelf. Looking at the map these should be east to west, west to east or south east to north west, or north west to south east.

Ensure that transect lines are spaced evenly so that you cover the area evenly. You don't want to do all your transects in one area during one month, and then move to cover a different area the next month, i.e. you also need an even coverage in time. You should not need to cover the same transects made during the day as *Autorec* will collect data for these.

Discuss transects with the crew and JNCC each day if necessary.

A.3.4 *Autorec* system

- Desktop PC and monitor running *Autorec* program- see equipment set-up and *Autorec* protocol.
- *Autorec* relay box
- Sony TCD-ProDAT remote control
- Sony TCD-ProDAT

Autorec will make a 30 second recording every 3 minutes. This means a tape change every 12 hours, so 2 tapes a day. We suggest that tape changes are made at the beginning and end of the night monitoring sessions. The system clock on the *Autorec* computer may need to be re-synchronised at every tape change, following the procedure in the *Autorec* protocol. It's important that clocks are kept synchronised throughout the study and if there are any problems that these are noted clearly and accurately.

A.3.5 Monitor system

- Sony PCM-R500 desktop DAT
- Hydrophone relay box.

This system will only be operated during the night. The monitors will monitor the hydrophone in 2 hour shifts at night, making the following recordings:

- **1 Minute every 15 minutes:** To ensure consistency with data collected from *Song of the Whale.*, a one minute recording should be made every 15 minutes and data noted in the acoustic database of *Logger*. Note we will be able to compare *Autorec* recordings with those you make every 15 minutes. Again note these in the acoustic log books.

- **Sounds of interest:** If anything interesting is heard, start recording, and keep accurate notes on start and stop times, positions, record levels, background noise, etc. Stop recording after a 5 minute interval during which nothing of interest is heard. Enter notes into the *Logger* acoustic database and duplicate in acoustic logbook. You do not need to record everything (use your initiative).

A.3.6. Environmental data

Logger will prompt you for environmental data every half-hour. It's important that we keep an accurate record of the wind speed (adjusted for boat speed and heading) every half hour, as well as sea state and significant swell height. A note of the Beaufort wind speed from weather forecasts would also be of use. This may involve asking the JNCC or crew members on the bridge to note down these parameters, if they can't be entered into *Logger* immediately (i.e. during the day). If other environmental data is available note it down.

A.3.7. *Logger* problems

If you have any problems with *Logger* or the GPS keep an accurate note of when they started, the precise nature of the problem, how they were solved and when the problem was solved. Synchronising clocks on all equipment and computers is essential- make sure they are accurate to GMT. Keep notes of logger problems or input errors in the acoustic log books.

A.3.8. Other problems

Note down other problems separately.

A.3.9. Day surveys

During the day visual surveys will be made by the JNCC at 10 knots. *Autorec* will record for 30 seconds every 3 minutes during the day while monitors sleep. Should the JNCC wish to listen show them how this is done, but stress that recordings are being made independently of sightings effort so that comparisons can be made at a later date if noise levels allow. Independence of data is critical for this phase, so that's why you'll be operating at night.

A.3.10. Environmental data

Follow the same protocol as night: collect relevant data, wind speed, etc. every half-hour. You'll need to ask the JNCC and Crew for their co-operation. Have sheets available for them to enter data. Logger should be running 24 hours a day, except when you need to back up data or have a problem.

Night surveys checklist

- Ensure all clocks are synchronised to GMT.
- Ensure GPS and *Logger* are functioning correctly.
- Change *Autorec* tape and ensure that *Autorec* is recording 30 seconds every 3 minutes.
- Ensure record levels are constant.
- Monitor through PCM-R500 DAT. Record any sounds of interest.
- Note time, position, and record levels of recordings in *Logger* acoustic database. Also make a hard copy.
- End recording after 5 minutes if nothing is heard. Note time that recording ends.
- Make a one minute recording every 15 minutes and enter data into the acoustic database of *Logger*. Keep notes in the log books.
- Enter environmental parameters into *Logger* every half-hour. Wind speed, sea state are important variables to note.
- Monitor in 2-hour shifts.
- At the start of your monitoring session select your name from the *Search Status* field of the effort database. Select voyage type AT (*acoustic transect*). Use F1 key to view drop-down menu.
- If you enter notes into the notes field of any *Logger* database, once you have saved the field delete the notes and save again. Instructions on how to save data in different databases are given at the top of the *Logger* screen. If you encounter problems refer to user manual.
- Note down any problems.
- *Autorec* tapes should be labelled with the suffix CN. E.g. CN-001 (first *Autorec* tape). The date, time and position of the beginning and end of recordings should be labelled on the tape covers. CN= Conoco.
- Individual monitor tapes should be labelled with the suffix LW, e.g. LW-001. LW= Lewis. A record of the start time and position, end time and position, record levels for each recording, name of monitor, noise levels and description of the sounds should be kept. See Acoustic Data entry table.
- At the end of the night resynchronise clocks if necessary. Change *Autorec* tape. Back up data from porpoise computer to floppy disk, clearly labelling it with the date. Back up each day’s *Logger* data to Zip disk and label the file with the date.
- Before going to sleep ensure that the *Search Status* field in the *Logger* effort database reads X (off effort).

Appendix 4 *Autorec* tape analysis protocols

A.4.1 Date/time/tape

Date/Time/Tape – Enter date, start and end time of each 30 second cut. Enter tape code.

A.4.2 Species

- Species – score the intensity of vocalisations on a scale of zero (nothing heard) to 5 (very loud).
- Probability (Prob.)
  0 = Nothing Heard (Default Value)
  1 = Definite
  2 = Probable
  3 = Possible
- Killer/Pilot Whale Category – Use this only if you can't distinguish between Killer and Pilot Whale vocalisations.

A.4.3 Noise

- Noise – Score the intensity of noise in each category on a scale of Zero (No Noise) to 5 (Very Loud).
- Water Noise – Noise produced by wind, sea-state, and the flow of water past the hydrophone.
- Self-Made Noise – Noise produced by the vessel towing the hydrophone, e.g. cavitation, engine noise, and platform noise.
- Remote Ship Noise – Engine noise, gear noise etc. produced by another vessel.
- Electrical Hum – Mains hum / interference
- Hydrophone Knocking – Caused by the flow of air bubbles over the hydrophone elements.
- Background Noise (dB) – The average noise level measured from the DAT LCD.
- Other Noise – A description and score of intensity. Examples include sonar, seismic Shot, etc.

A.4.4 Cuts

- Background Noise – Make a 10-second cut every 15 minutes or if background noise levels change. You should try and avoid making cuts that include whistles or clicks. When saving the cut use the pre-fix BN followed by a number. For example, cut number 103 would be labelled as BN-103. Enter a description of the noise, the start and end times, the cut, and the cut ID (BN-103) in the appropriate boxes. The aim of this exercise is to measure background noise levels using a spectrum analyser so that the effects of noise on detectability can be modelled.

- Unknown Sounds – Make a cut of any sounds that you can not identify. Save the cut using the pre-fix U (Unknown) followed by a number. For example, Unknown cut 99 would be labelled as U-99. Enter a description of the sound, the start and end times of the cut, and the cut ID (U-99) in the appropriate boxes. At the end of each day cuts will be listened to by a panel, and the panel will attempt to identify the sound.

- Whistles – During an encounter with dolphins, pilot or killer whales make a 30-second cut every 15 minutes; or when signal strength changes significantly. Save the cut using the pre-fix W (Whistle) followed by a number. For example, whistle cut 116 would be labelled as W-116. Enter a description of the species, e.g. killer whale whistle, or dolphin whistles, the start and end time of the cut, and the cut ID (W-116). The aim of this exercise is to provide cuts to improve signal (whistle) detection software.

- Very Good Sounds – If there are any very good examples of sounds that you feel would be of benefit to the Marine Mammal Sounds database make them. Save the cut using the pre-fix VG (Very Good) and a number. For example Very Good cut number 13 would be labelled as VG-13. Enter a description of the sound, e.g. sperm whale clangs, the start and end time of the cut, and the cut ID (VG-13).

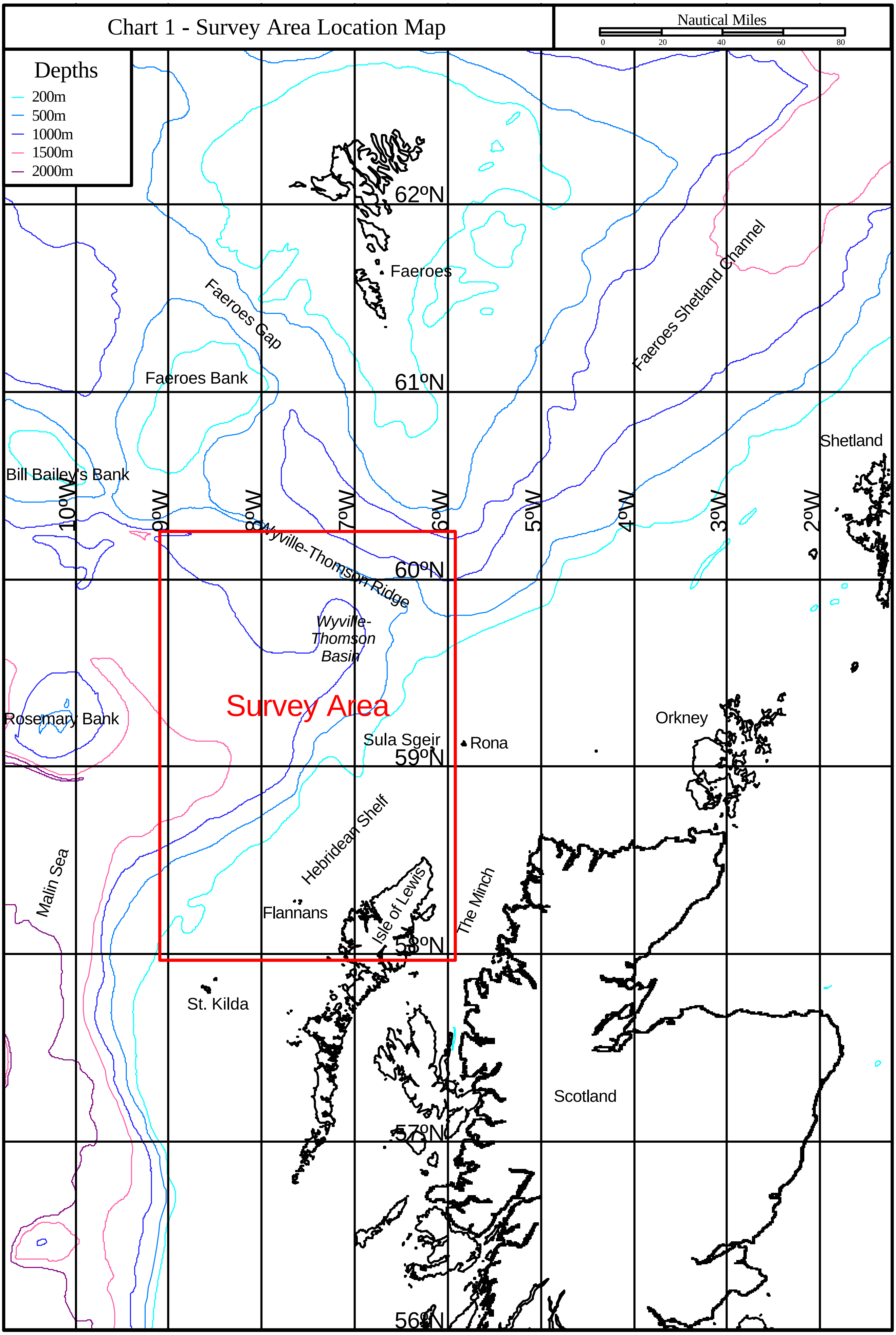
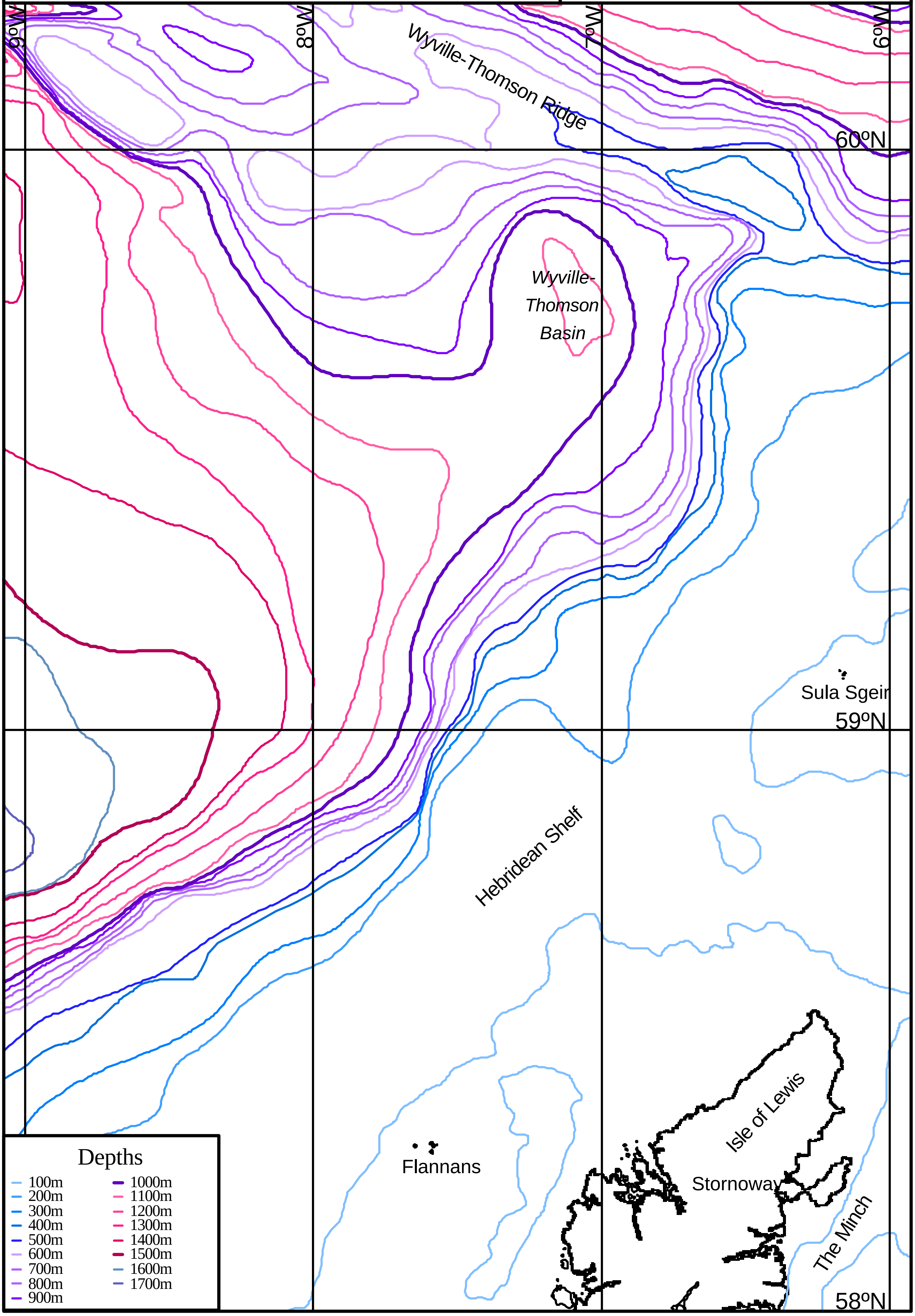


Chart 1 - Survey Area Location Map
Nautical Miles
0
20
40
60
80
Depths
200m
500m
1000m
1500m
2000m
62ºN
61ºN
60ºN
59ºN
58ºN
57ºN
56ºN
10ºW
9ºW
8ºW
7ºW
6ºW
5ºW
4ºW
3ºW
2ºW
Faeroes
Faeroes Gap
Faeroes Bank
Faeroes Shetland Channel
Shetland
Bill Bailey's Bank
Wyville-Thomson Ridge
Wyville-
Thomson
Basin
Survey Area
Rosemary Bank
Sula Sgeir
Rona
Orkney
Hebridean Shelf
Malin Sea
Flannans
Isle of Lewis
The Minch
St. Kilda
Scotland

Chart 2 - Bathymetry



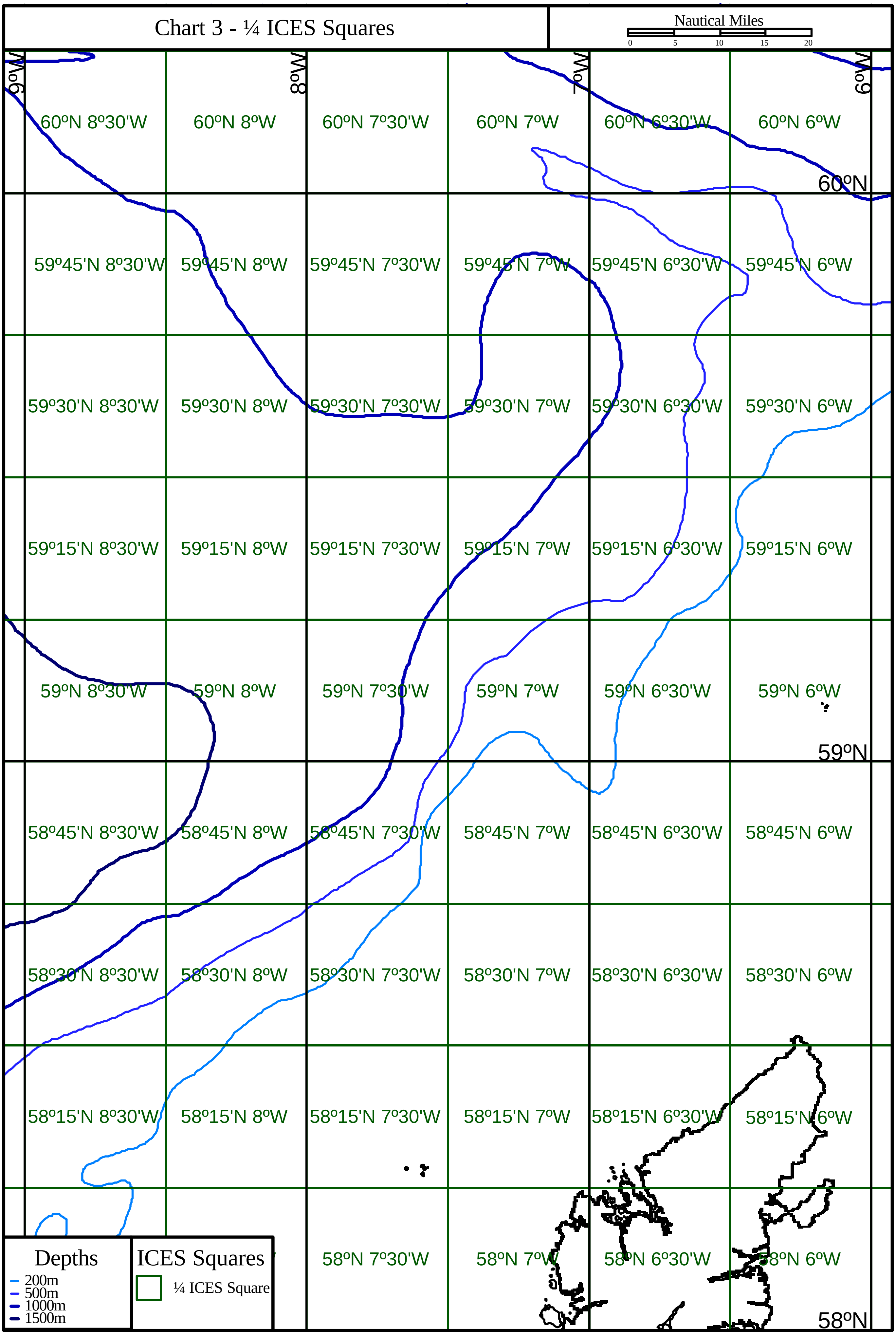
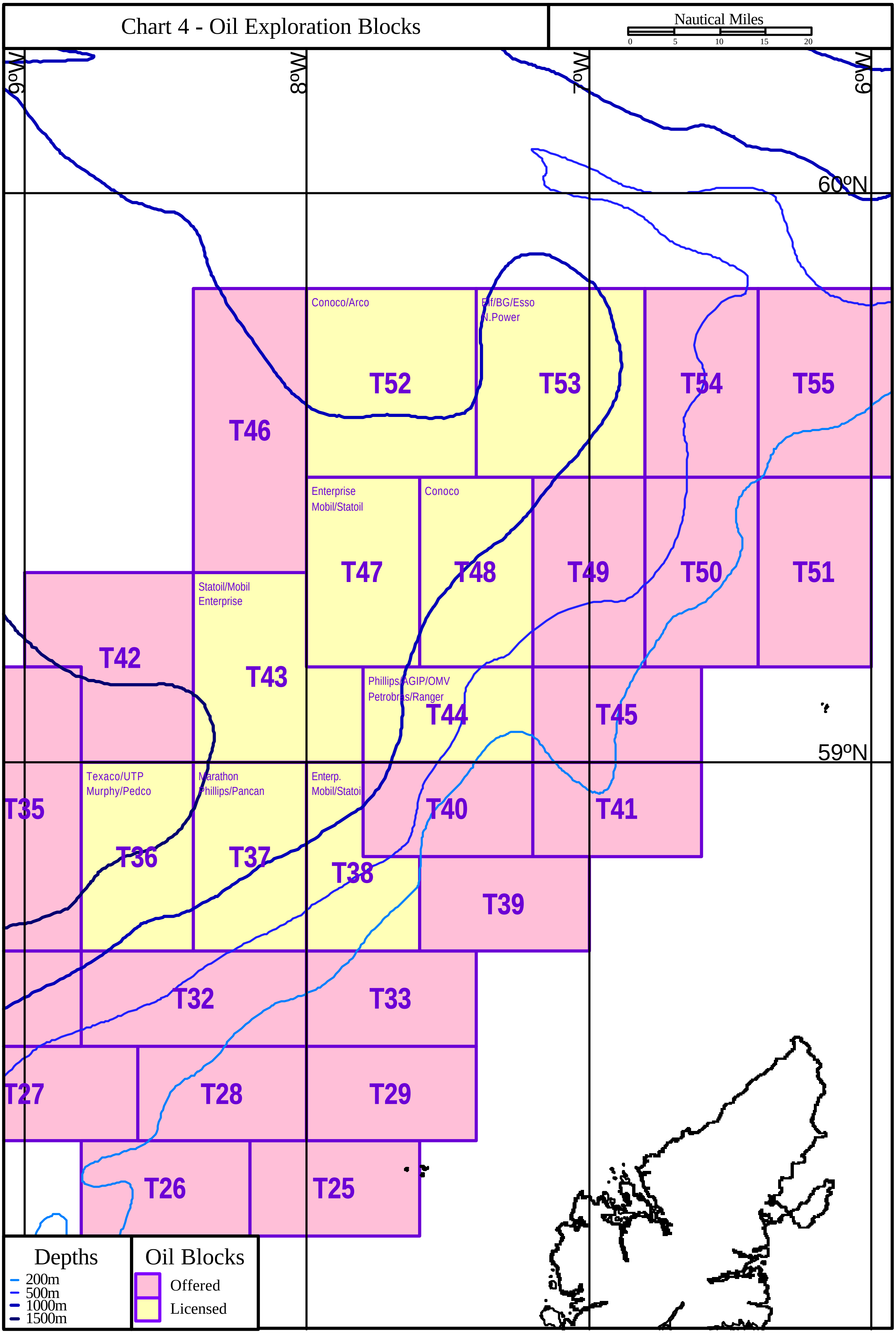


Chart 3 - ¼ ICES Squares
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
60ºN 8º30'W
60ºN 8ºW
60ºN 7º30'W
60ºN 7ºW
60ºN 6º30'W
60ºN 6ºW
59º45'N 8º30'W
59º45'N 8ºW
59º45'N 7º30'W
59º45'N 7ºW
59º45'N 6º30'W
59º45'N 6ºW
59º30'N 8º30'W
59º30'N 8ºW
59º30'N 7º30'W
59º30'N 7ºW
59º30'N 6º30'W
59º30'N 6ºW
59º15'N 8º30'W
59º15'N 8ºW
59º15'N 7º30'W
59º15'N 7ºW
59º15'N 6º30'W
59º15'N 6ºW
59ºN 8º30'W
59ºN 8ºW
59ºN 7º30'W
59ºN 7ºW
59ºN 6º30'W
59ºN 6ºW
58º45'N 8º30'W
58º45'N 8ºW
58º45'N 7º30'W
58º45'N 7ºW
58º45'N 6º30'W
58º45'N 6ºW
58º30'N 8º30'W
58º30'N 8ºW
58º30'N 7º30'W
58º30'N 7ºW
58º30'N 6º30'W
58º30'N 6ºW
58º15'N 8º30'W
58º15'N 8ºW
58º15'N 7º30'W
58º15'N 7ºW
58º15'N 6º30'W
58º15'N 6ºW
58ºN 7º30'W
58ºN 7ºW
58ºN 6º30'W
58ºN 6ºW
Depths
200m
500m
1000m
1500m
ICES Squares
¼ ICES Square

Chart 4 - Oil Exploration Blocks



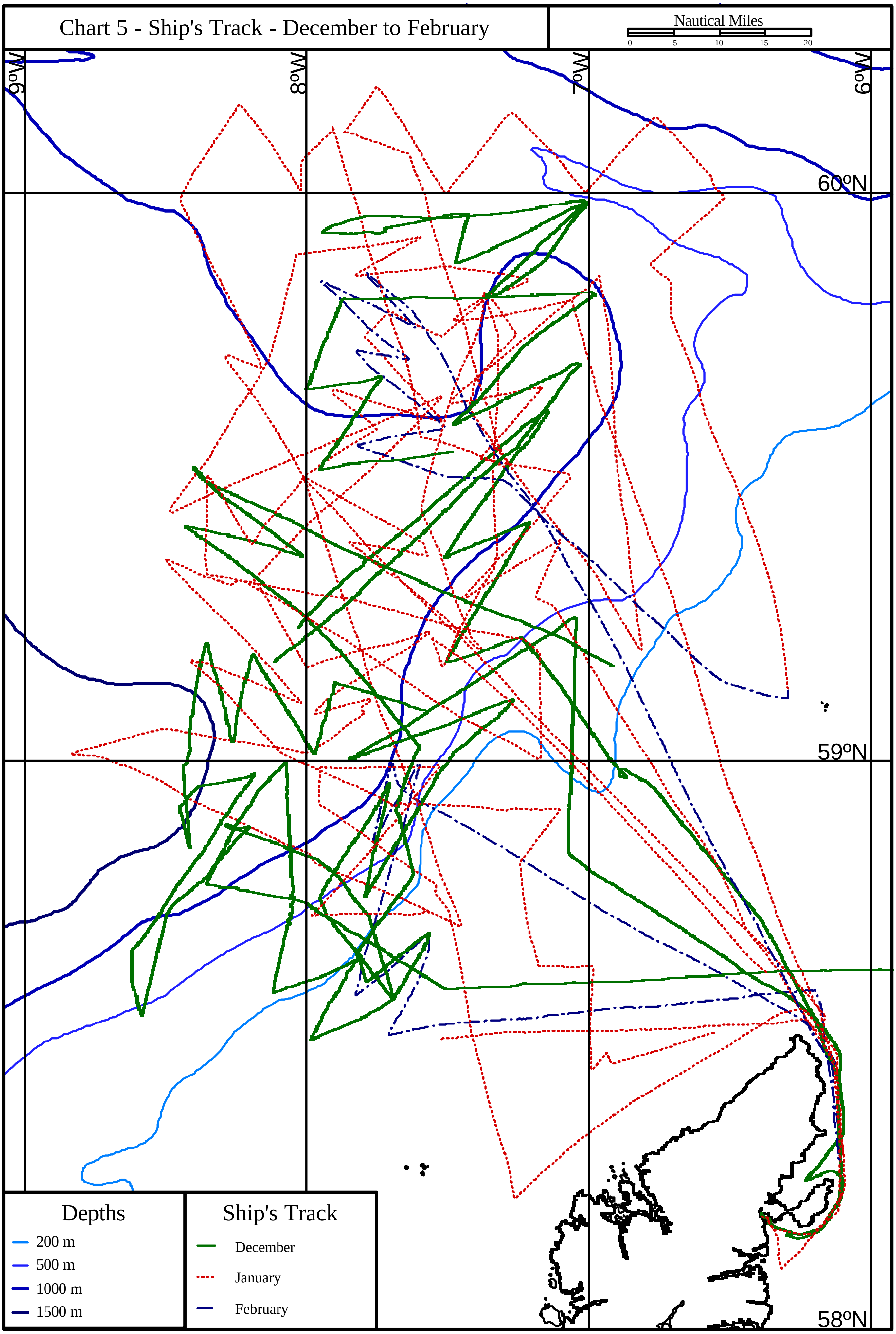


Chart 5 - Ship's Track - December to February
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
Depths
200 m
500 m
1000 m
1500 m
Ship's Track
December
January
February

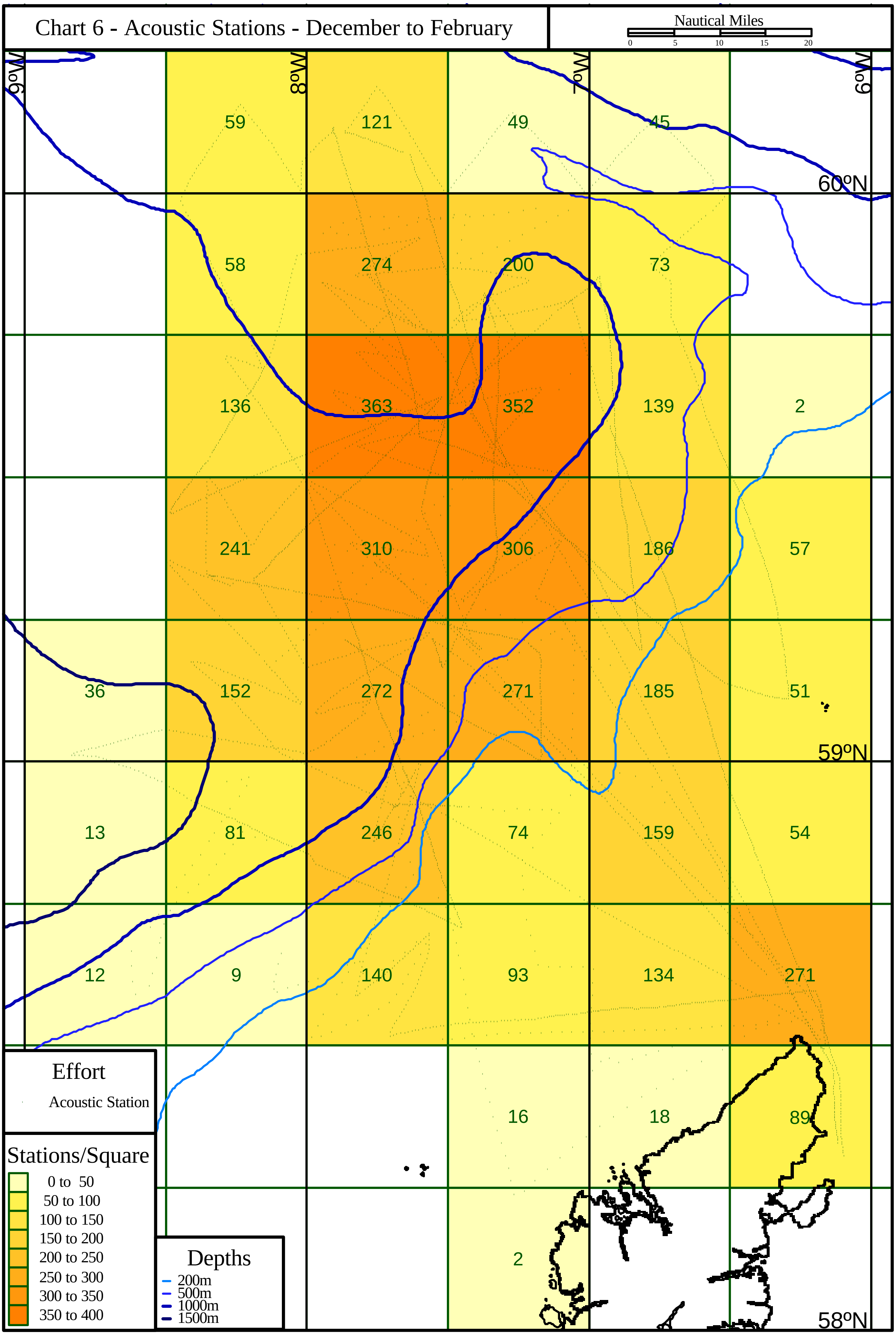


Chart 6 - Acoustic Stations - December to February
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
59
121
49
45
58
274
200
73
136
363
352
139
2
241
310
306
186
57
36
152
272
271
185
51
13
81
246
74
159
54
12
9
140
93
134
271
16
18
89
2
Effort
Acoustic Station
Stations/Square
0 to 50
50 to 100
100 to 150
150 to 200
200 to 250
250 to 300
300 to 350
350 to 400
Depths
200m
500m
1000m
1500m

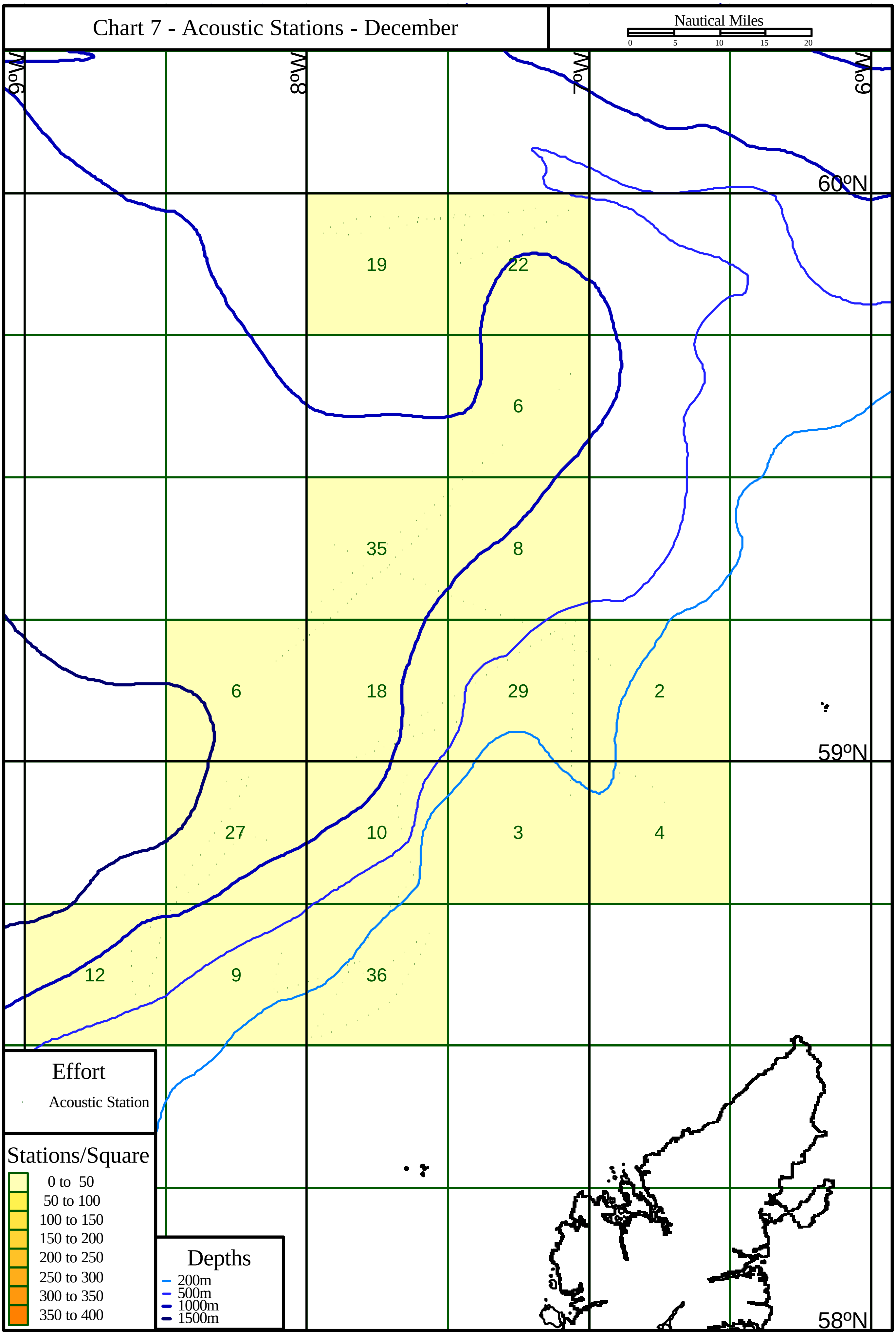


Chart 7 - Acoustic Stations - December
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
19
22
6
35
8
6
18
29
2
27
10
3
4
12
9
36
Effort
Acoustic Station
Stations/Square
0 to 50
50 to 100
100 to 150
150 to 200
200 to 250
250 to 300
300 to 350
350 to 400
Depths
200m
500m
1000m
1500m

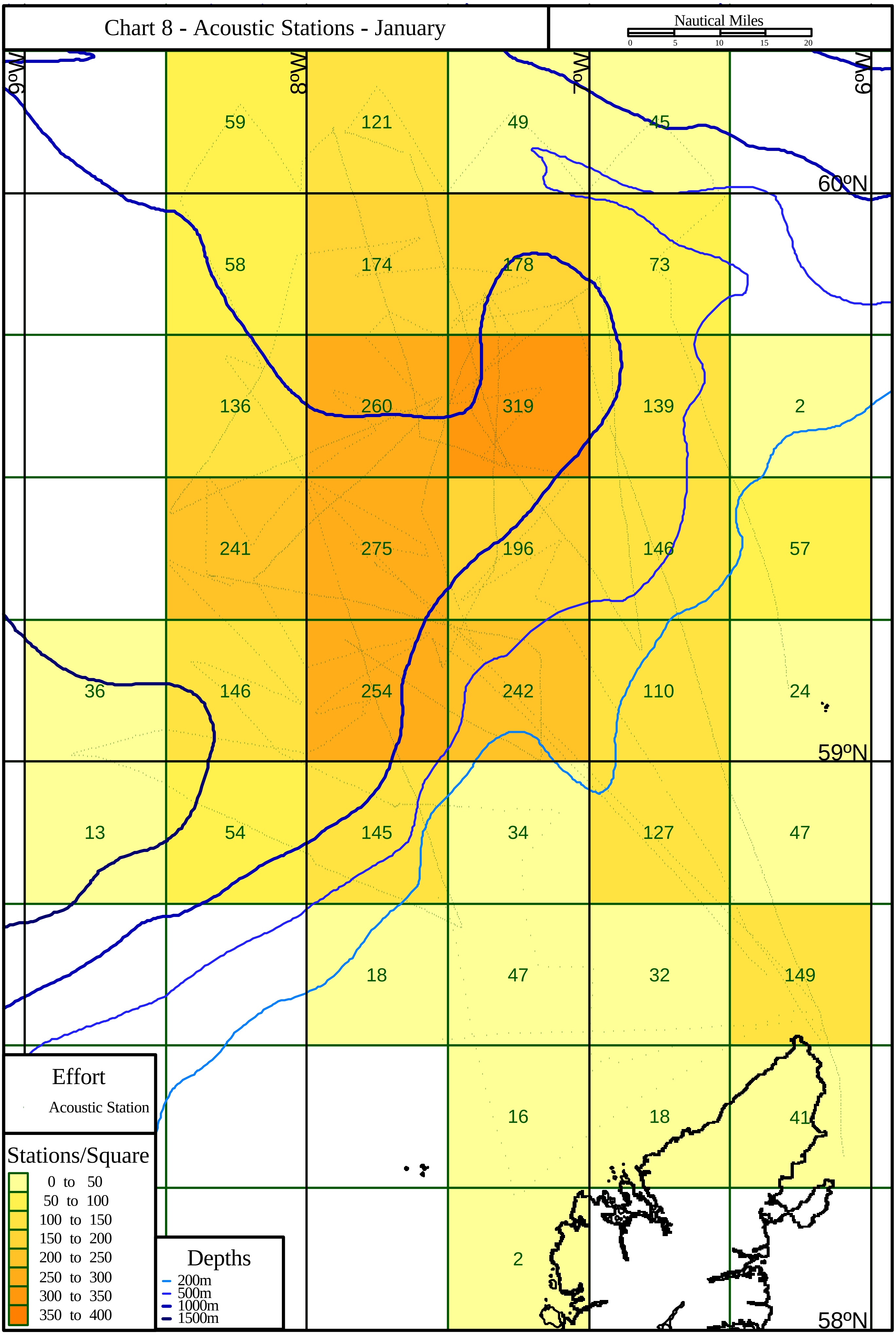


Chart 8 - Acoustic Stations - January
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
59
121
49
45
58
174
178
73
136
260
319
139
2
241
275
196
146
57
36
146
254
242
110
24
13
54
145
34
127
47
18
47
32
149
16
18
41
2
Effort
Acoustic Station
Stations/Square
0 to 50
50 to 100
100 to 150
150 to 200
200 to 250
250 to 300
300 to 350
350 to 400
Depths
200m
500m
1000m
1500m

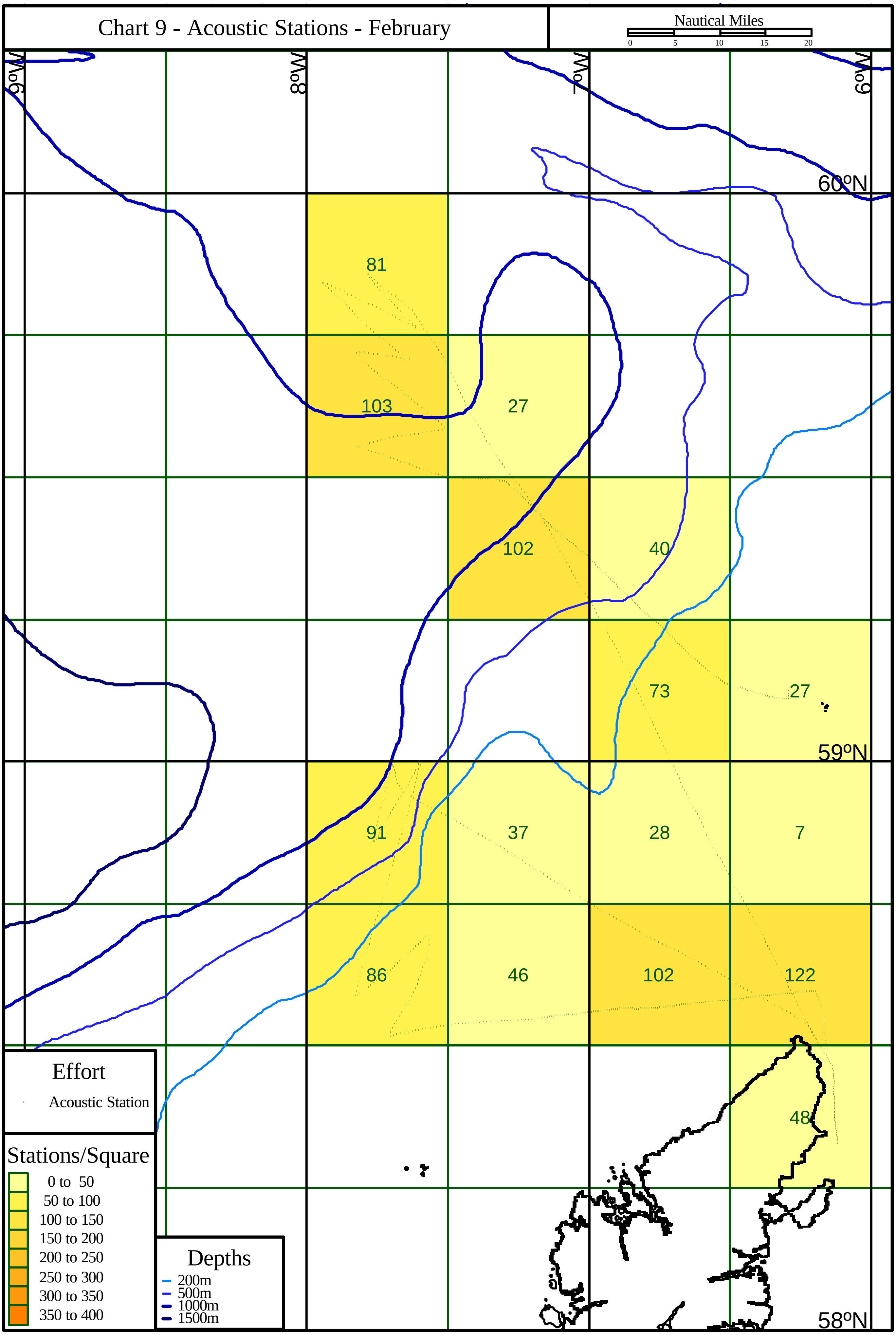
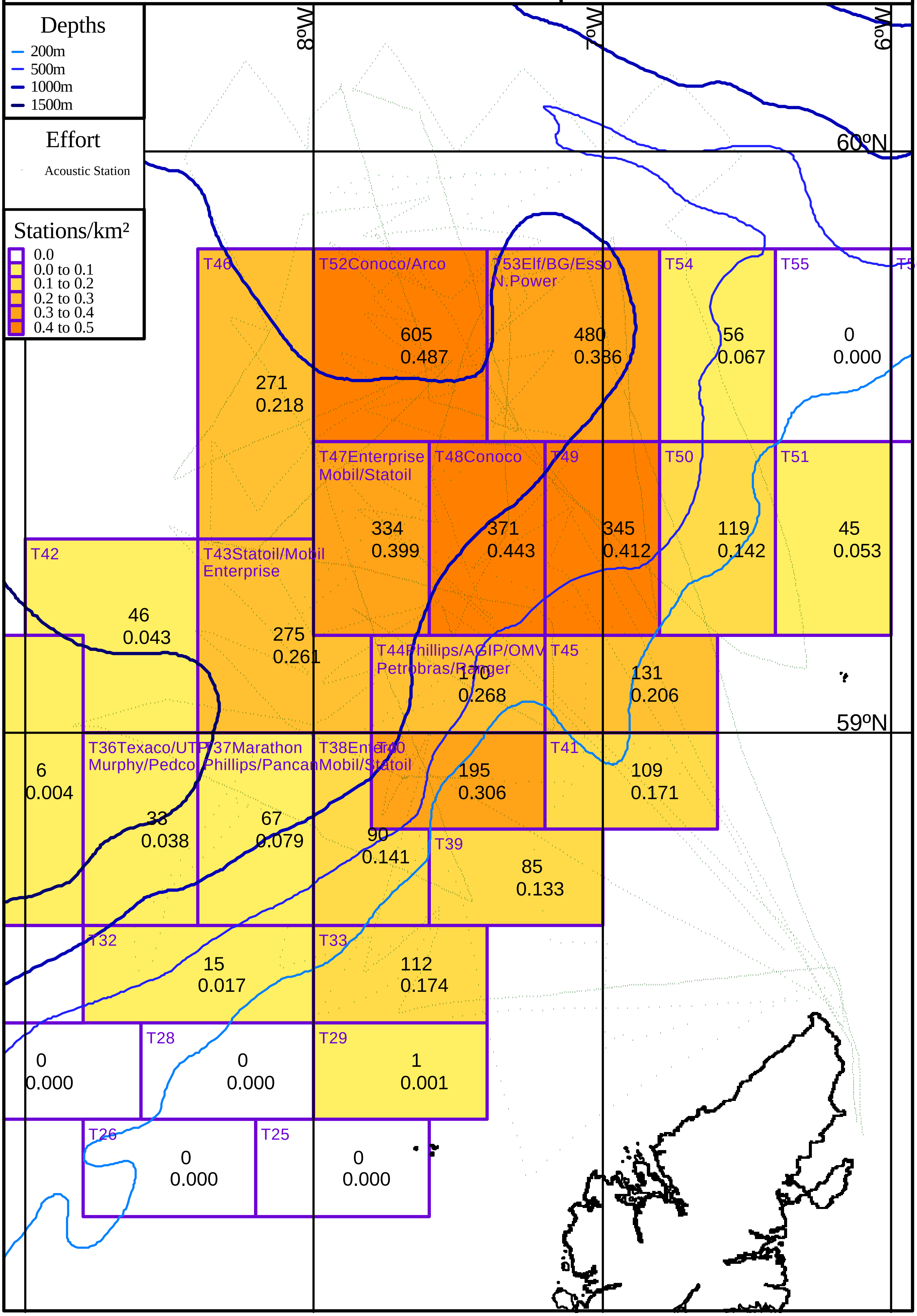


Chart 9 - Acoustic Stations - February
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
81
103
27
102
40
73
27
91
37
28
7
86
46
102
122
48
Effort
Acoustic Station
Stations/Square
0 to 50
50 to 100
100 to 150
150 to 200
200 to 250
250 to 300
300 to 350
350 to 400
Depths
200m
500m
1000m
1500m

Chart 10 - Oil Exploration Blocks & Acoustic Stations

Stations/Block & Stations/km² of Block



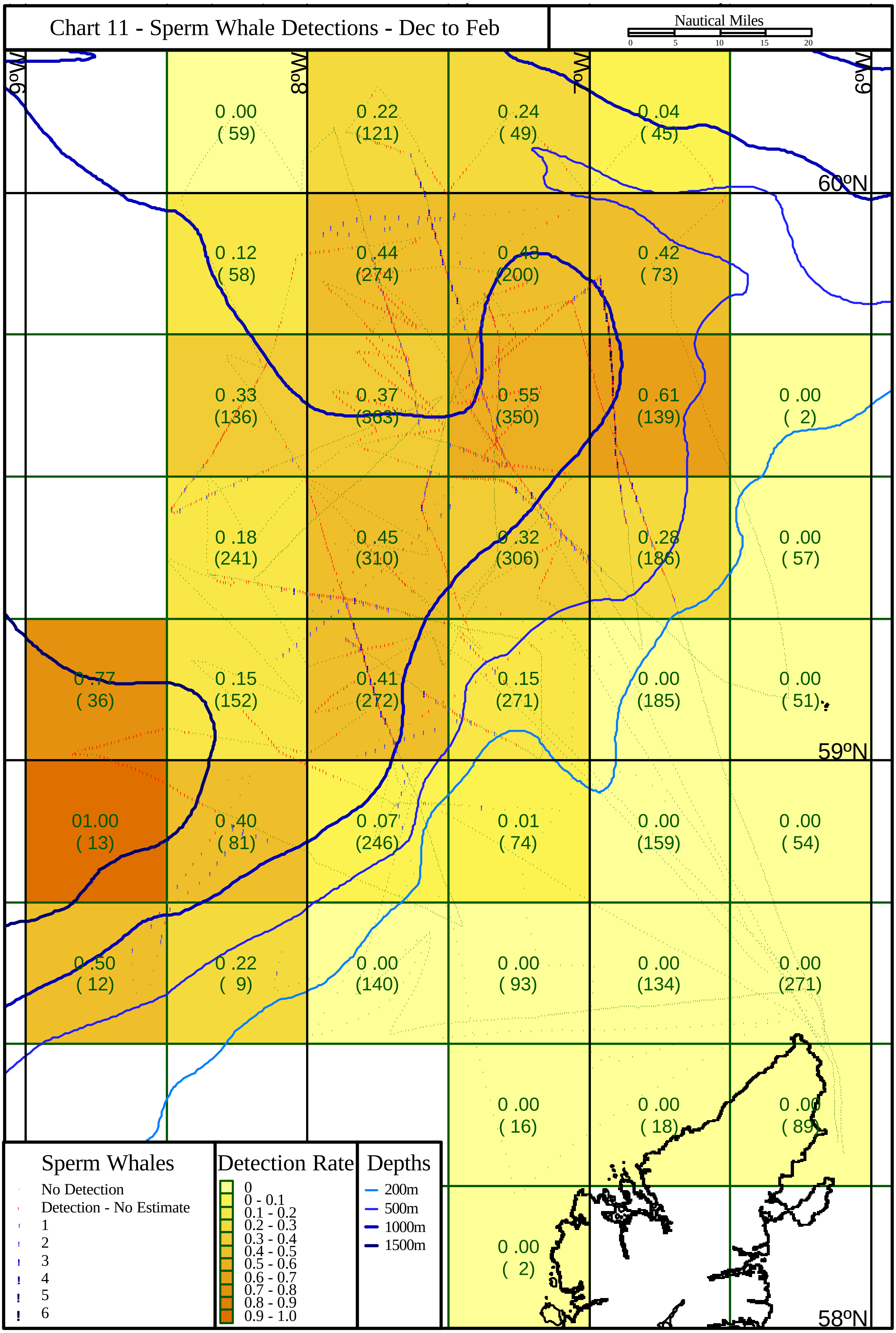


Chart 11 - Sperm Whale Detections - Dec to Feb
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .00 (59)
0 .22 (121)
0 .24 (49)
0 .04 (45)
0 .12 (58)
0 .44 (274)
0 .43 (200)
0 .42 (73)
0 .33 (136)
0 .37 (363)
0 .55 (350)
0 .61 (139)
0 .00 (2)
0 .18 (241)
0 .45 (310)
0 .32 (306)
0 .28 (186)
0 .00 (57)
0 .77 (36)
0 .15 (152)
0 .41 (272)
0 .15 (271)
0 .00 (185)
0 .00 (51)
01.00 (13)
0 .40 (81)
0 .07 (246)
0 .01 (74)
0 .00 (159)
0 .00 (54)
0 .50 (12)
0 .22 (9)
0 .00 (140)
0 .00 (93)
0 .00 (134)
0 .00 (271)
0 .00 (16)
0 .00 (18)
0 .00 (89)
0 .00 (2)
Sperm Whales
No Detection
Detection - No Estimate
1
2
3
4
5
6
Detection Rate
0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

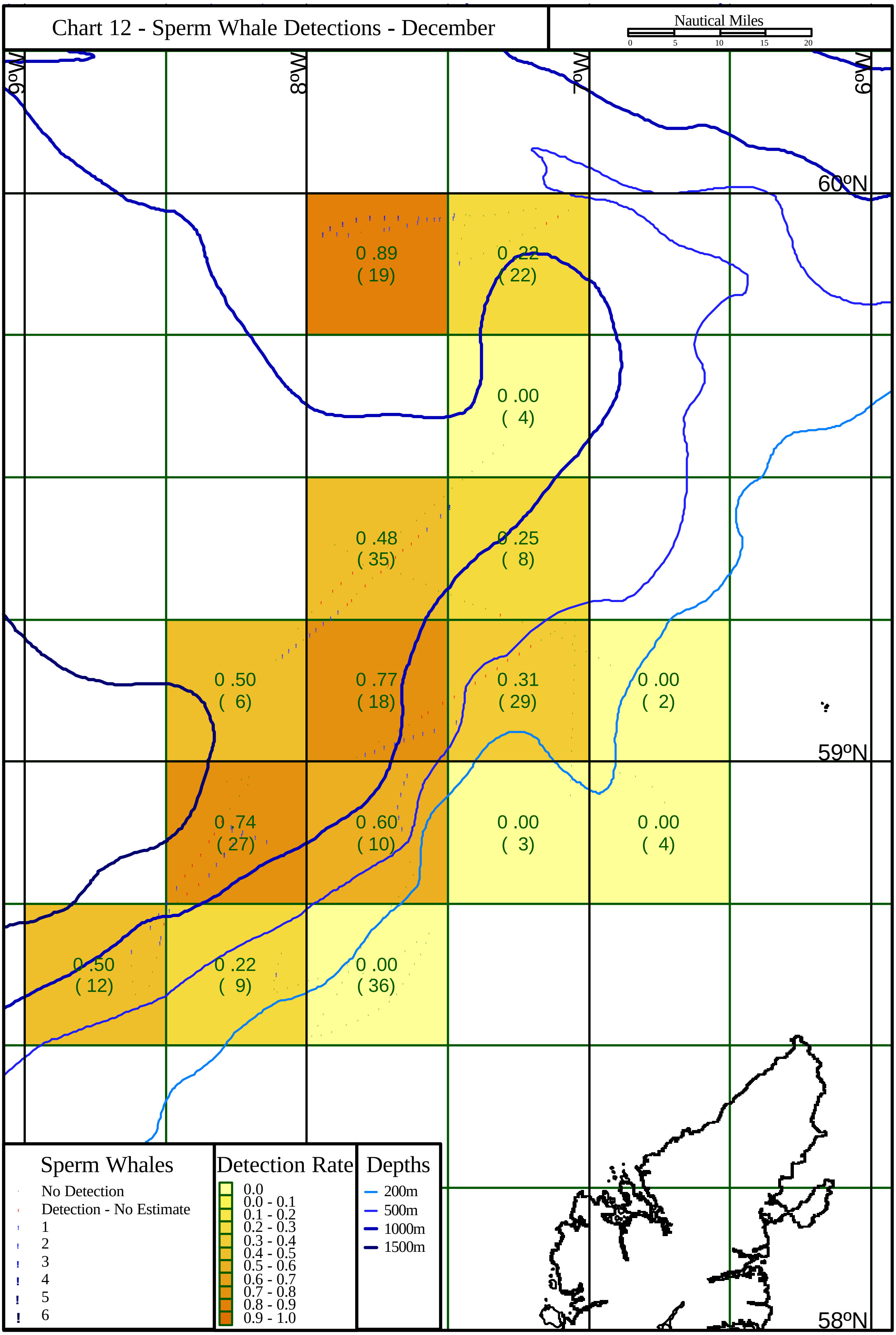


Chart 12 - Sperm Whale Detections - December
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .89
(19)
0 .22
(22)
0 .00
(4)
0 .48
(35)
0 .25
(8)
0 .50
(6)
0 .77
(18)
0 .31
(29)
0 .00
(2)
0 .74
(27)
0 .60
(10)
0 .00
(3)
0 .00
(4)
0 .50
(12)
0 .22
(9)
0 .00
(36)
Sperm Whales
No Detection
Detection - No Estimate
1
2
3
4
5
6
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

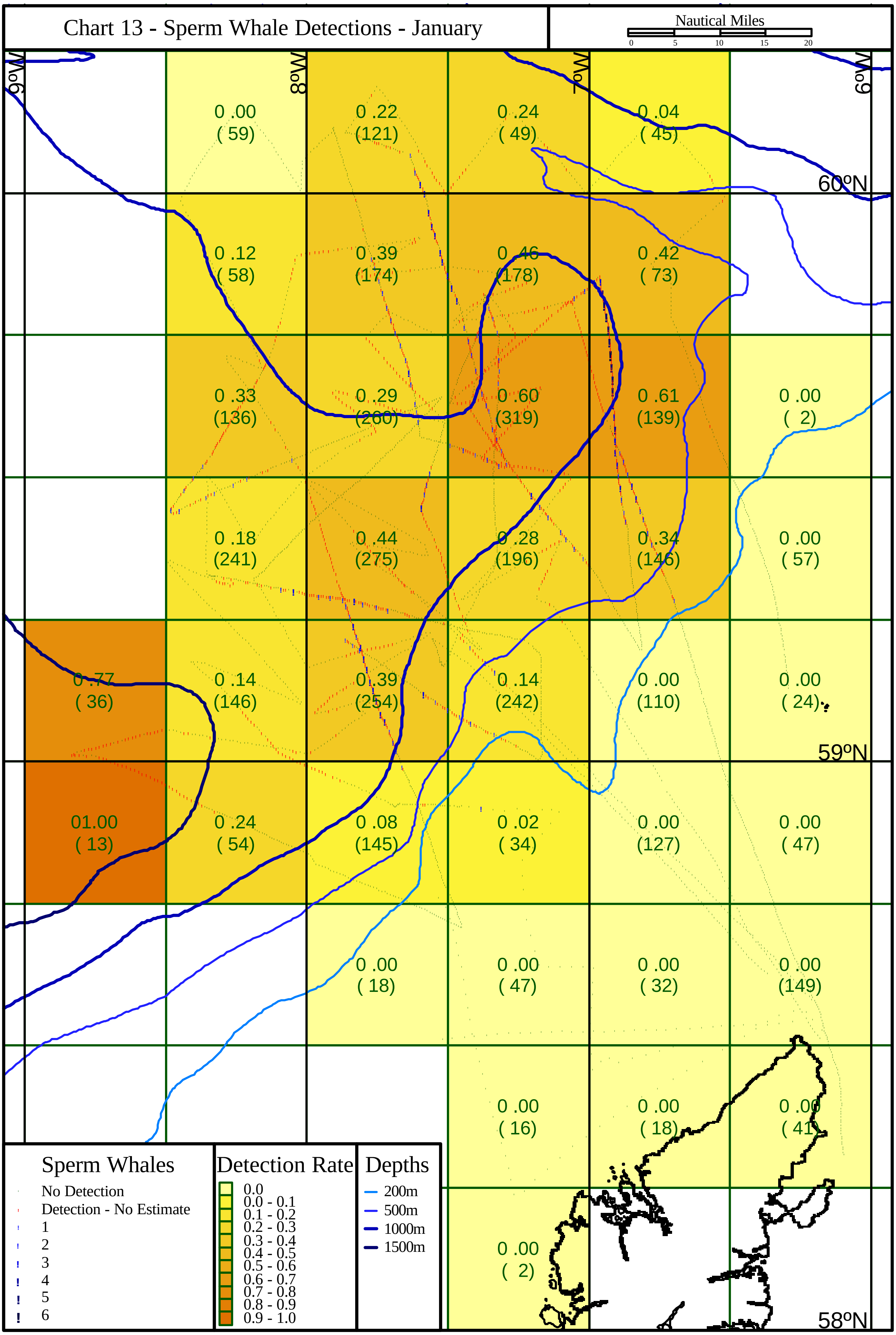


Chart 13 - Sperm Whale Detections - January
Nautical Miles
0 5 10 15 20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .00 (59)
0 .22 (121)
0 .24 (49)
0 .04 (45)
0 .12 (58)
0 .39 (174)
0 .46 (178)
0 .42 (73)
0 .33 (136)
0 .29 (260)
0 .60 (319)
0 .61 (139)
0 .00 (2)
0 .18 (241)
0 .44 (275)
0 .28 (196)
0 .34 (146)
0 .00 (57)
0 .77 (36)
0 .14 (146)
0 .39 (254)
0 .14 (242)
0 .00 (110)
0 .00 (24)
01.00 (13)
0 .24 (54)
0 .08 (145)
0 .02 (34)
0 .00 (127)
0 .00 (47)
0 .00 (18)
0 .00 (47)
0 .00 (32)
0 .00 (149)
0 .00 (16)
0 .00 (18)
0 .00 (41)
0 .00 (2)
Sperm Whales
No Detection
Detection - No Estimate
1
2
3
4
5
6
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

Chart 14 - Sperm Whale Detections - February

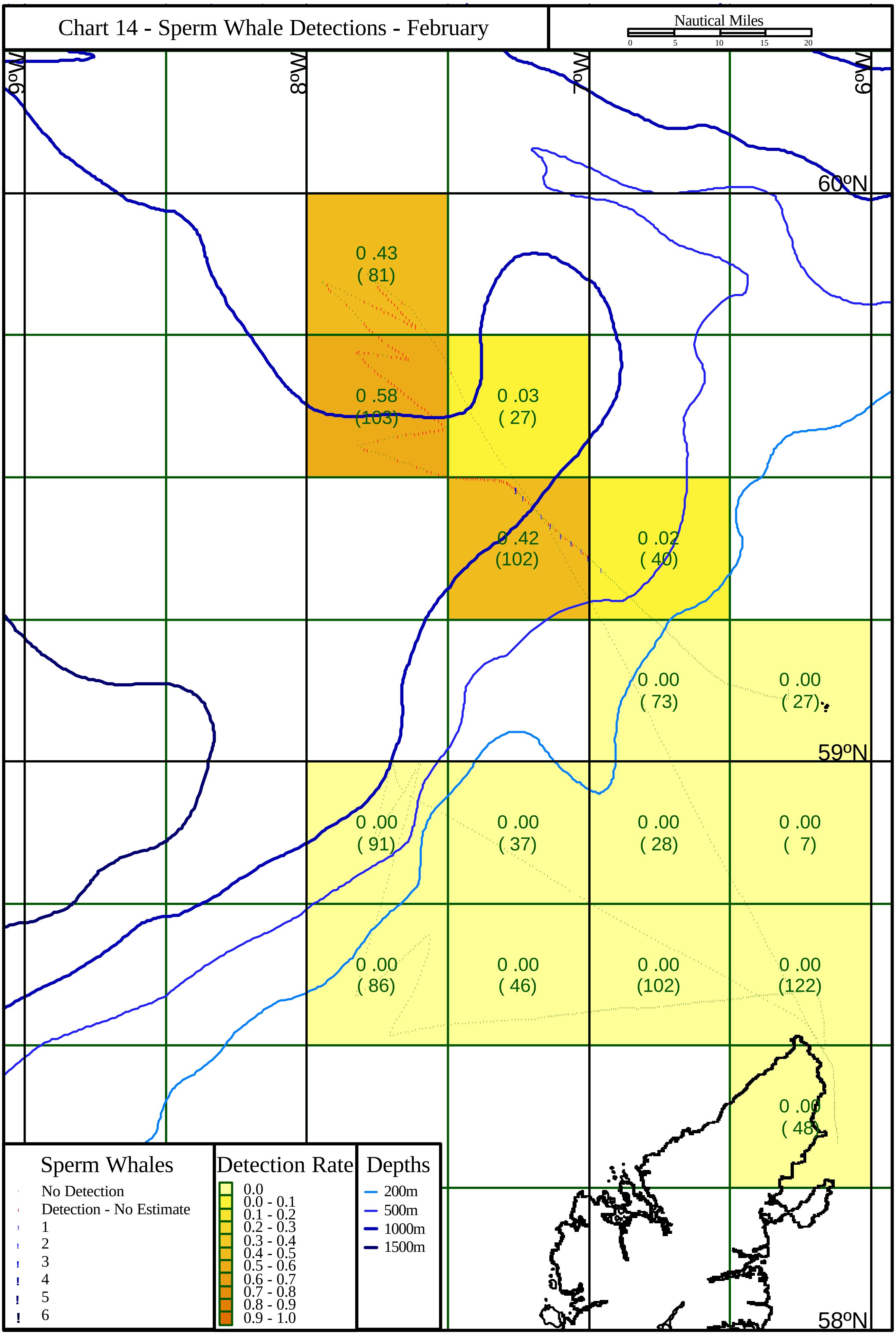


Chart 15 - Pilot Whale Detections - Dec to Feb

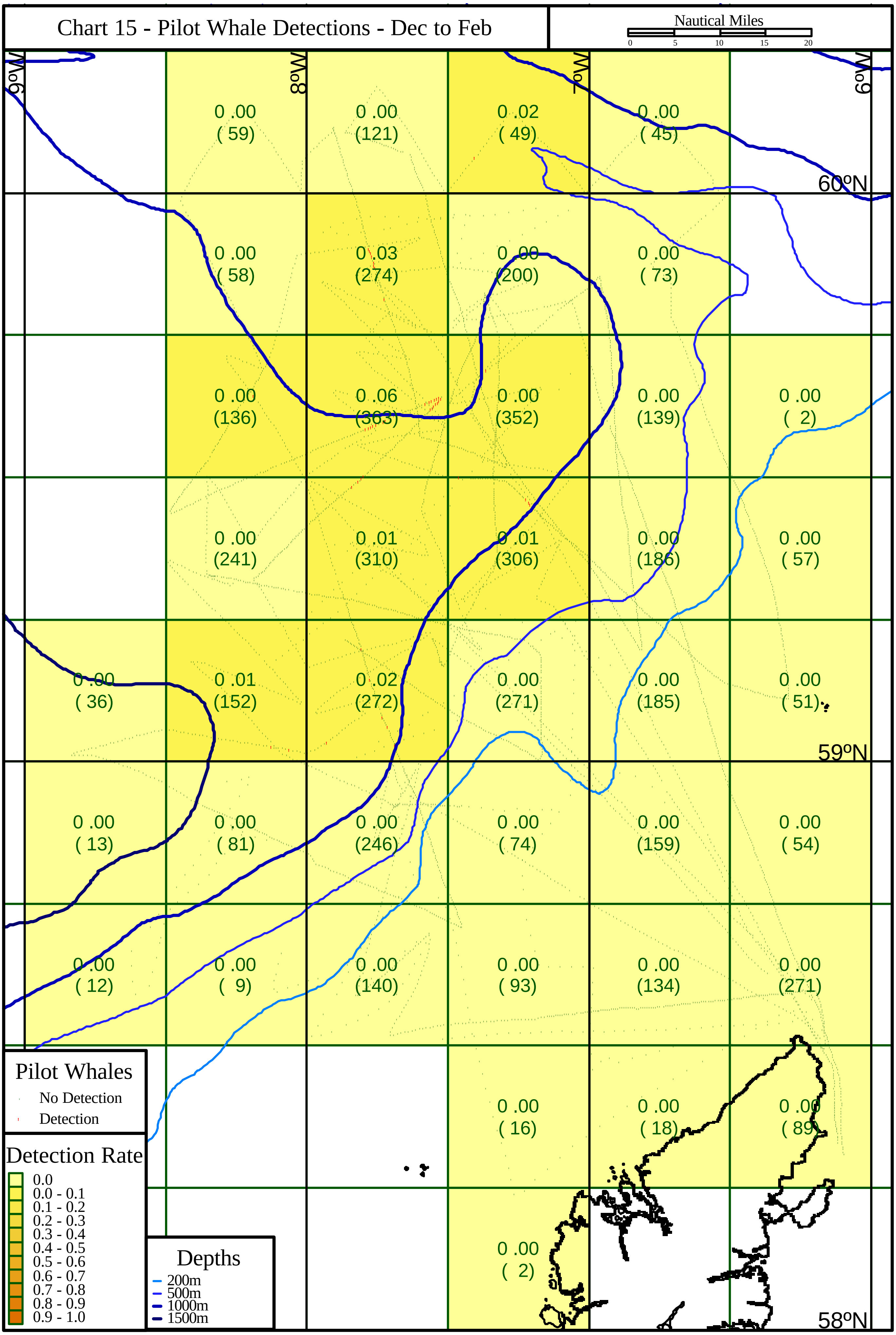
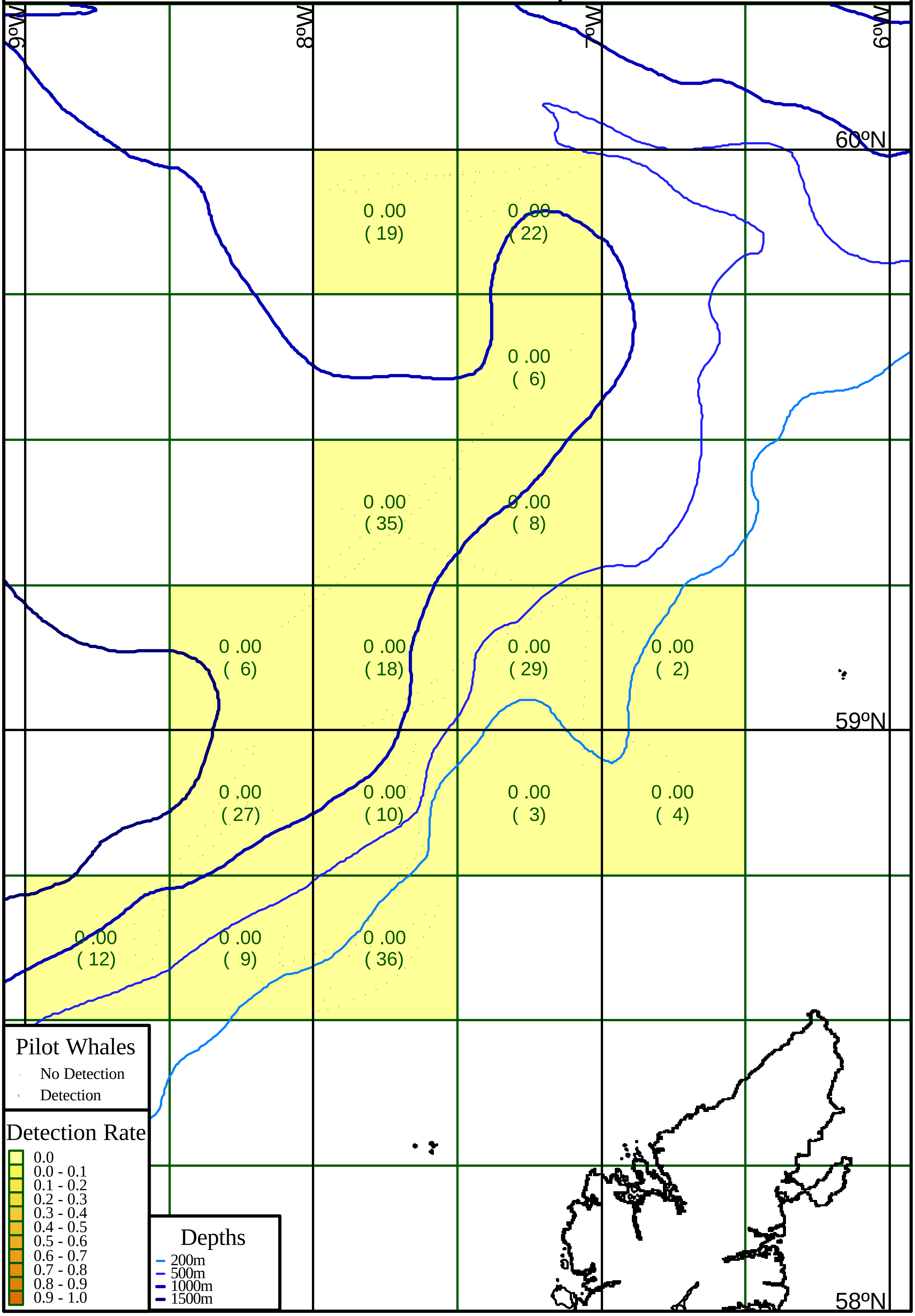


Chart 16 - Pilot Whale Detections - December



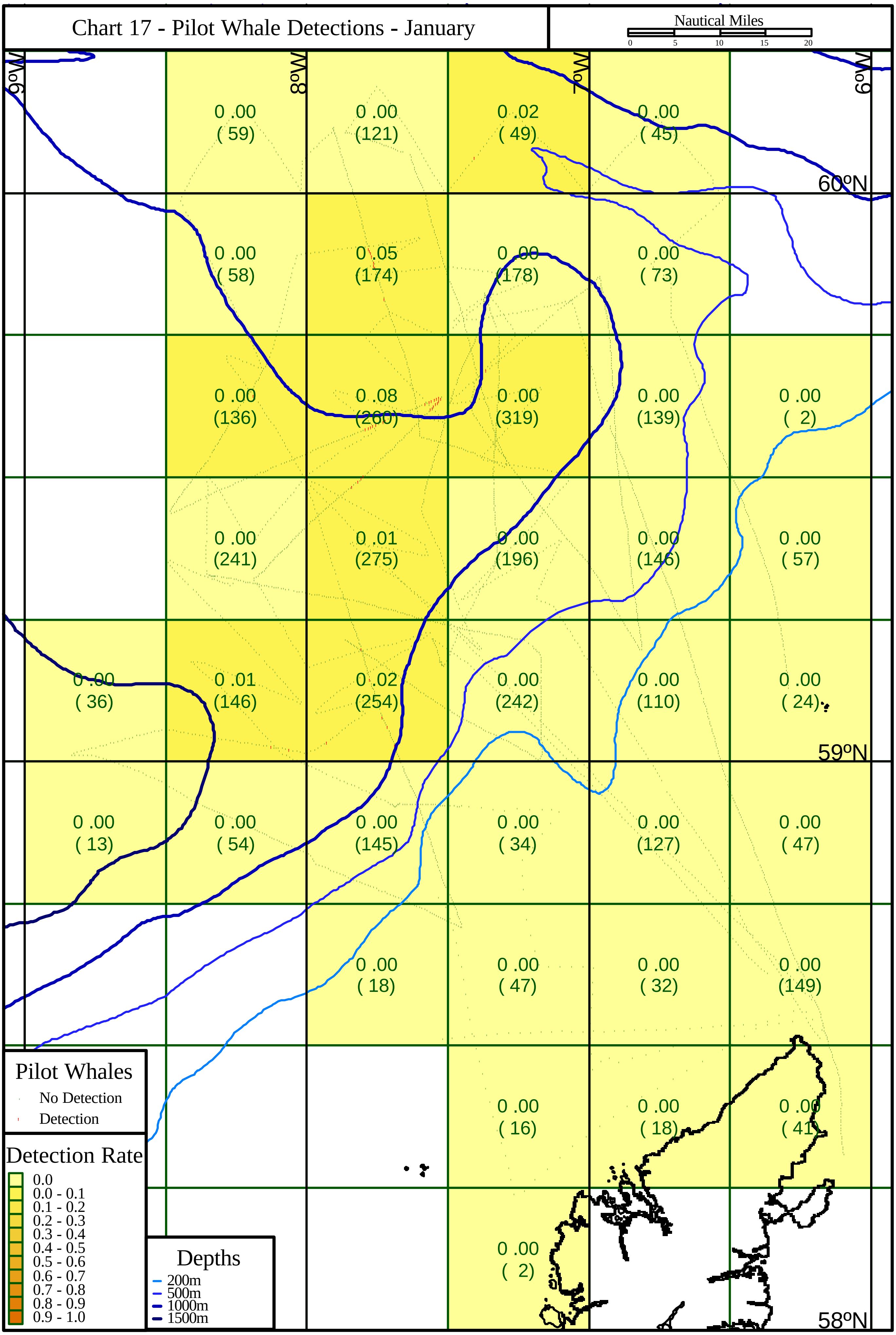
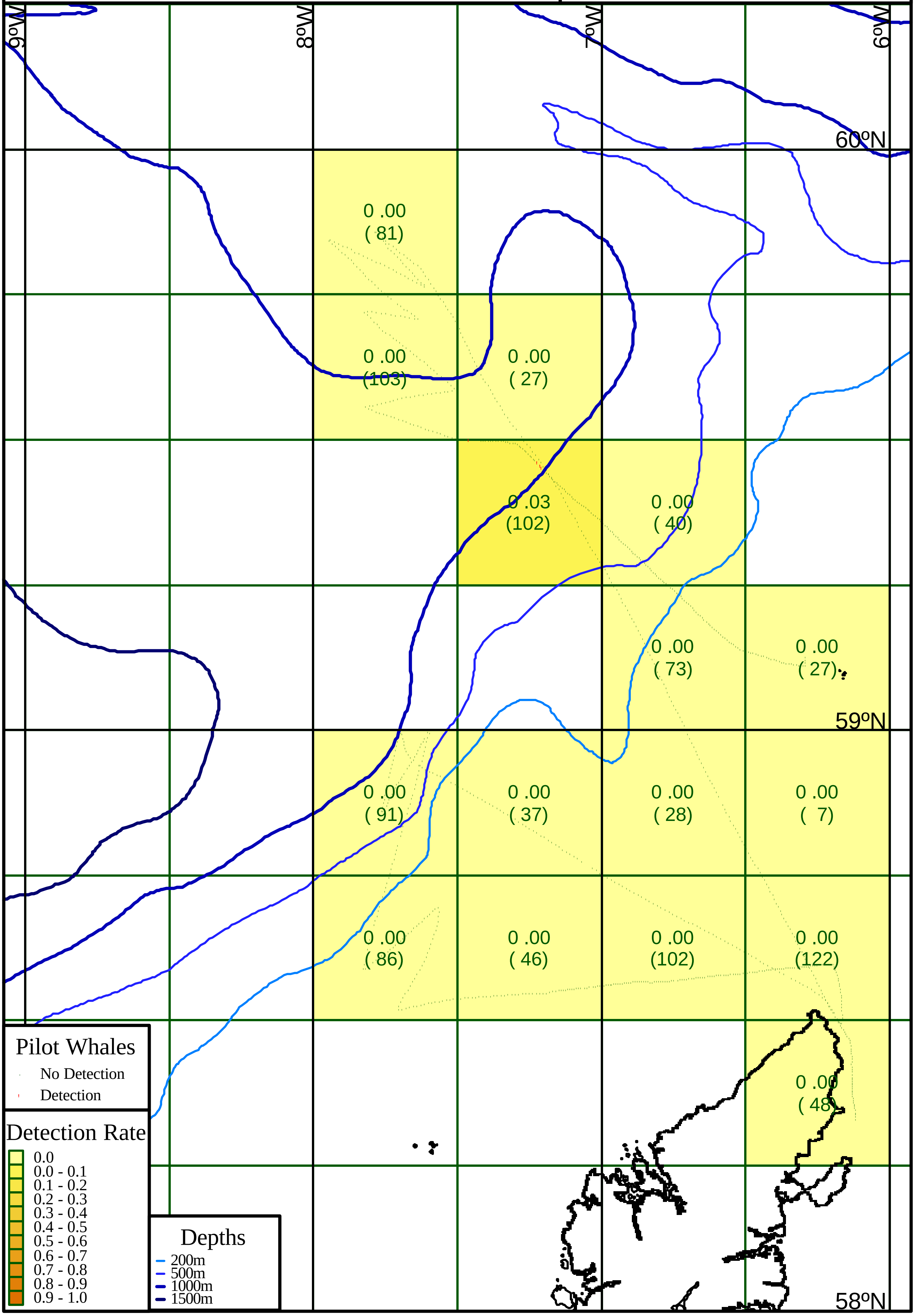


Chart 17 - Pilot Whale Detections - January
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .00
(59)
0 .00
(121)
0 .02
(49)
0 .00
(45)
0 .00
(58)
0 .05
(174)
0 .00
(178)
0 .00
(73)
0 .00
(136)
0 .08
(260)
0 .00
(319)
0 .00
(139)
0 .00
(2)
0 .00
(241)
0 .01
(275)
0 .00
(196)
0 .00
(146)
0 .00
(57)
0 .00
(36)
0 .01
(146)
0 .02
(254)
0 .00
(242)
0 .00
(110)
0 .00
(24)
0 .00
(13)
0 .00
(54)
0 .00
(145)
0 .00
(34)
0 .00
(127)
0 .00
(47)
0 .00
(18)
0 .00
(47)
0 .00
(32)
0 .00
(149)
0 .00
(16)
0 .00
(18)
0 .00
(41)
0 .00
(2)
Pilot Whales
No Detection
Detection
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

Chart 18 - Pilot Whale Detections - February



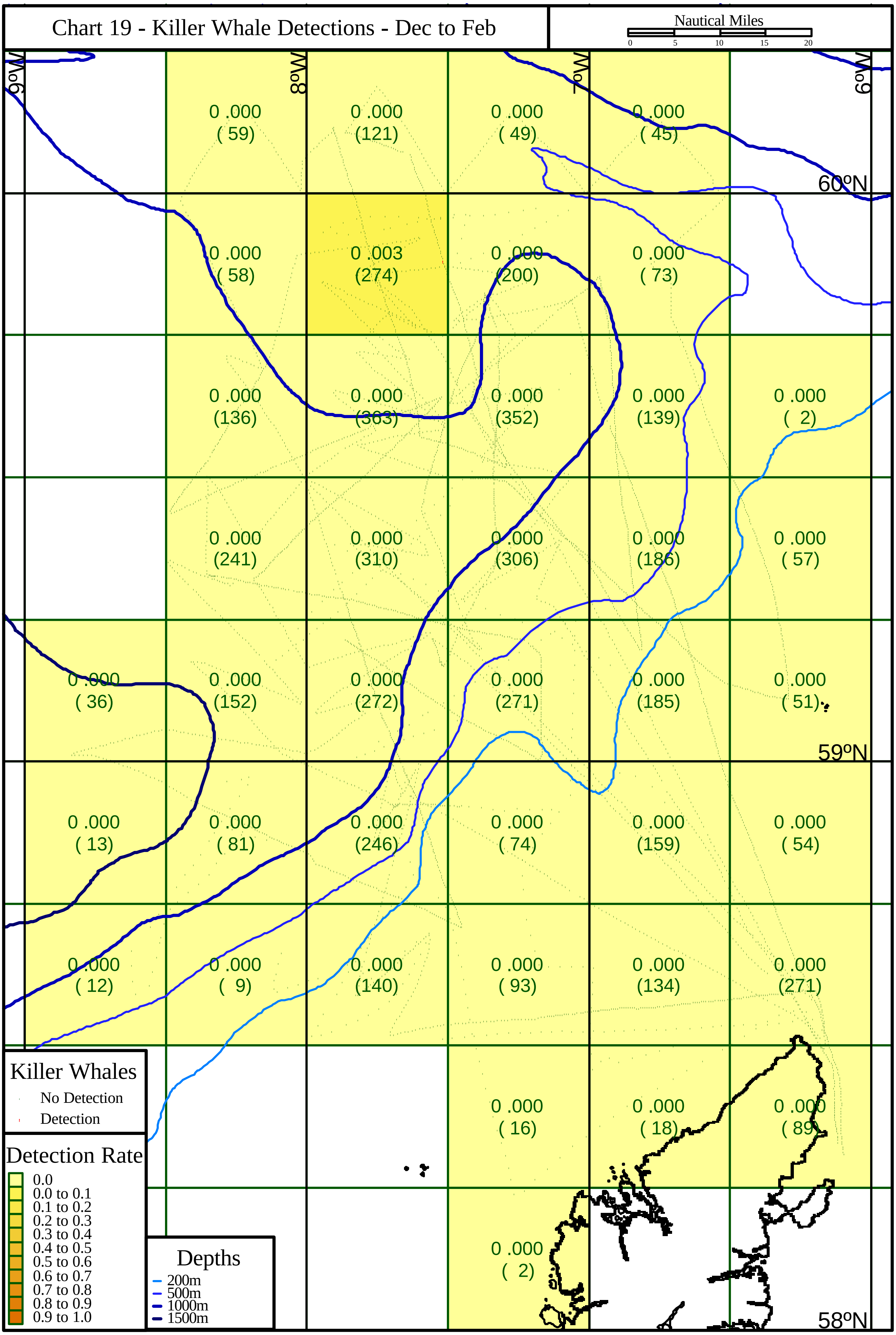


Chart 19 - Killer Whale Detections - Dec to Feb
Nautical Miles
0 5 10 15 20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .000
(59)
0 .000
(121)
0 .000
(49)
0 .000
(45)
0 .000
(58)
0 .003
(274)
0 .000
(200)
0 .000
(73)
0 .000
(136)
0 .000
(363)
0 .000
(352)
0 .000
(139)
0 .000
(2)
0 .000
(241)
0 .000
(310)
0 .000
(306)
0 .000
(186)
0 .000
(57)
0 .000
(36)
0 .000
(152)
0 .000
(272)
0 .000
(271)
0 .000
(185)
0 .000
(51)
0 .000
(13)
0 .000
(81)
0 .000
(246)
0 .000
(74)
0 .000
(159)
0 .000
(54)
0 .000
(12)
0 .000
(9)
0 .000
(140)
0 .000
(93)
0 .000
(134)
0 .000
(271)
0 .000
(16)
0 .000
(18)
0 .000
(89)
0 .000
(2)
Killer Whales
No Detection
Detection
Detection Rate
0.0
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
0.6 to 0.7
0.7 to 0.8
0.8 to 0.9
0.9 to 1.0
Depths
200m
500m
1000m
1500m

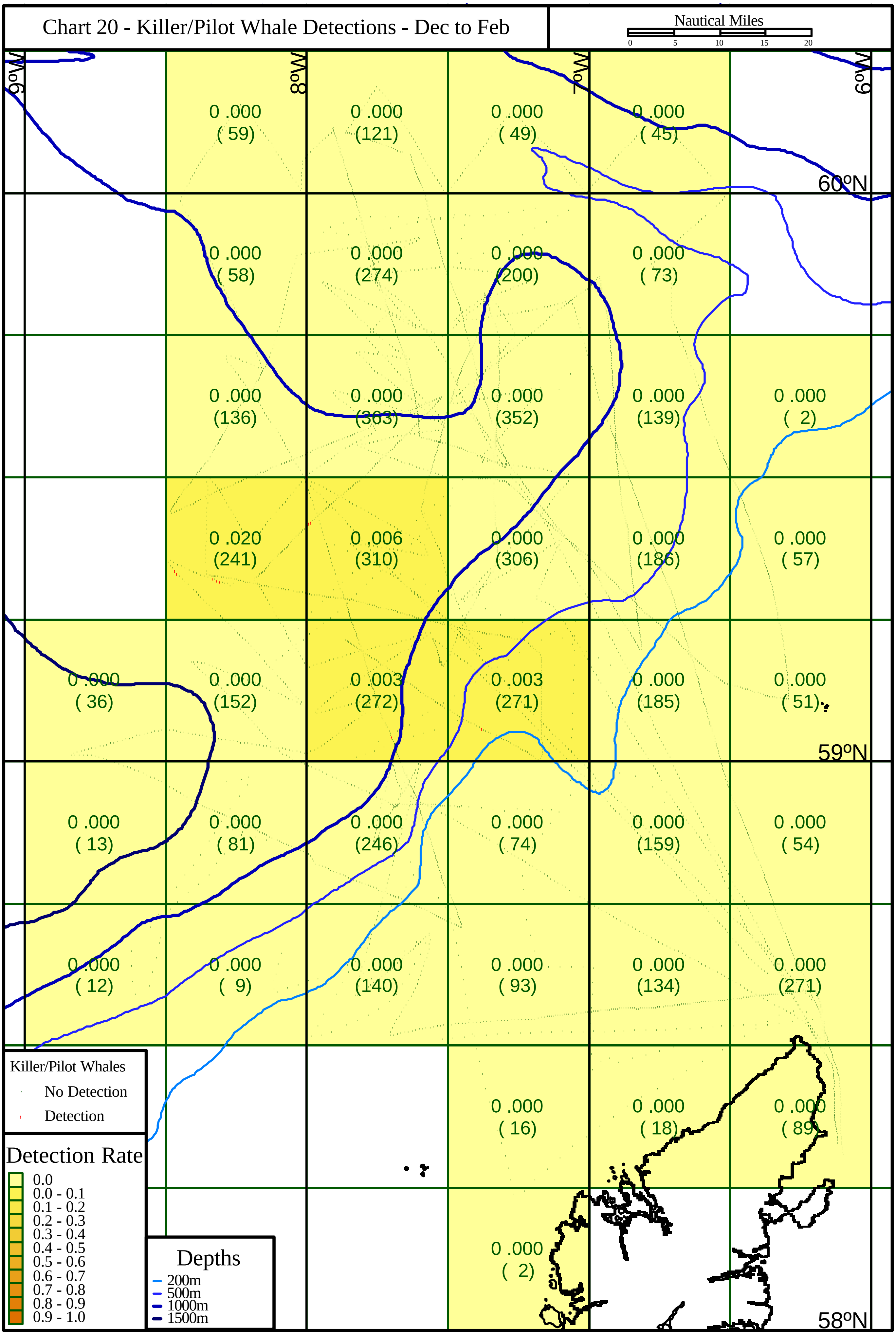


Chart 20 - Killer/Pilot Whale Detections - Dec to Feb
Nautical Miles
0 5 10 15 20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .000 (59)
0 .000 (121)
0 .000 (49)
0 .000 (45)
0 .000 (58)
0 .000 (274)
0 .000 (200)
0 .000 (73)
0 .000 (136)
0 .000 (363)
0 .000 (352)
0 .000 (139)
0 .000 (2)
0 .020 (241)
0 .006 (310)
0 .000 (306)
0 .000 (186)
0 .000 (57)
0 .000 (36)
0 .000 (152)
0 .003 (272)
0 .003 (271)
0 .000 (185)
0 .000 (51)
0 .000 (13)
0 .000 (81)
0 .000 (246)
0 .000 (74)
0 .000 (159)
0 .000 (54)
0 .000 (12)
0 .000 (9)
0 .000 (140)
0 .000 (93)
0 .000 (134)
0 .000 (271)
0 .000 (16)
0 .000 (18)
0 .000 (89)
0 .000 (2)
Killer/Pilot Whales
No Detection
Detection
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

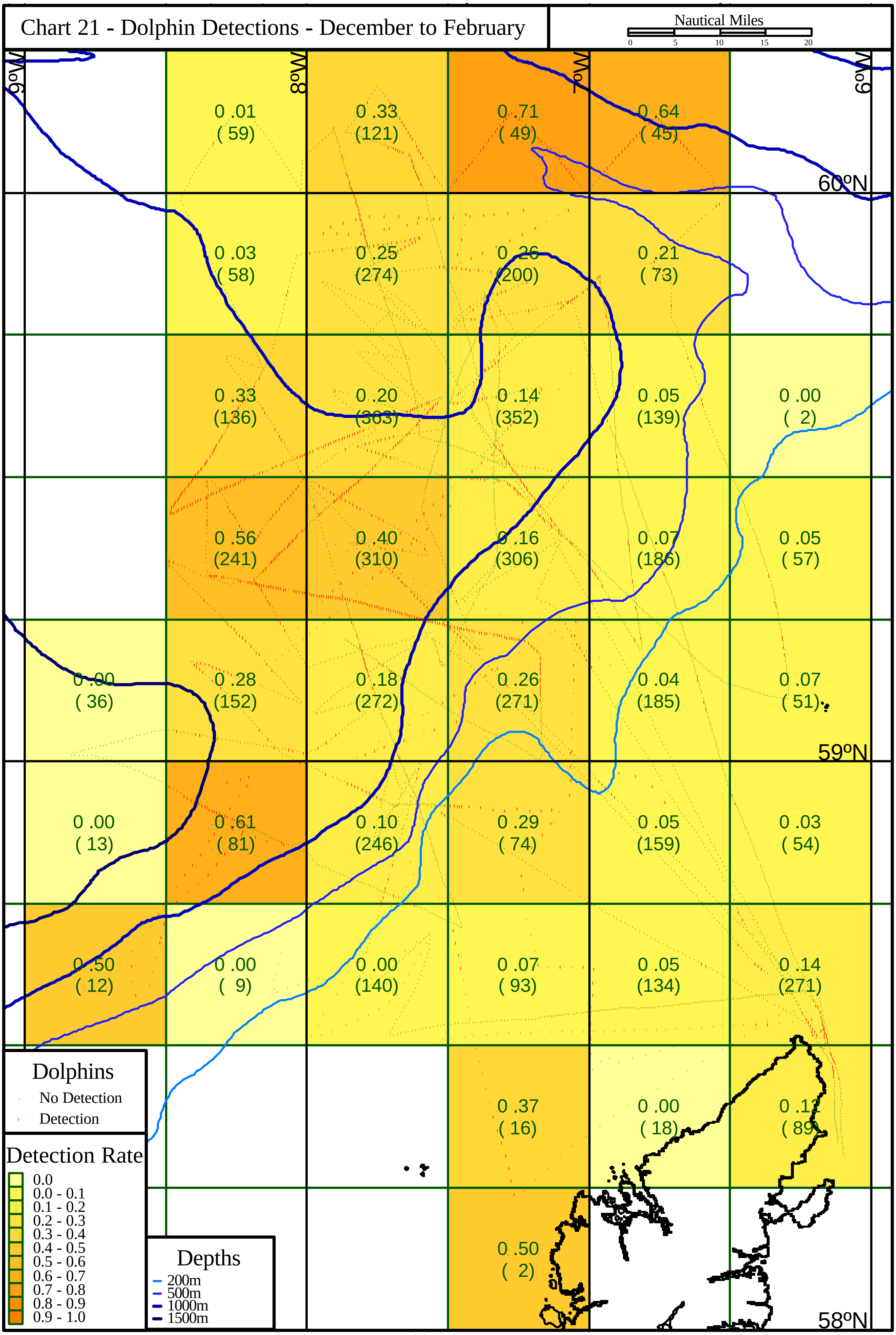


Chart 21 - Dolphin Detections - December to February
Nautical Miles
0 5 10 15 20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .01 (59)
0 .33 (121)
0 .71 (49)
0 .64 (45)
0 .03 (58)
0 .25 (274)
0 .26 (200)
0 .21 (73)
0 .33 (136)
0 .20 (363)
0 .14 (352)
0 .05 (139)
0 .00 (2)
0 .56 (241)
0 .40 (310)
0 .16 (306)
0 .07 (186)
0 .05 (57)
0 .00 (36)
0 .28 (152)
0 .18 (272)
0 .26 (271)
0 .04 (185)
0 .07 (51)
0 .00 (13)
0 .61 (81)
0 .10 (246)
0 .29 (74)
0 .05 (159)
0 .03 (54)
0 .50 (12)
0 .00 (9)
0 .00 (140)
0 .07 (93)
0 .05 (134)
0 .14 (271)
0 .37 (16)
0 .00 (18)
0 .12 (89)
0 .50 (2)
Dolphins
No Detection
Detection
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

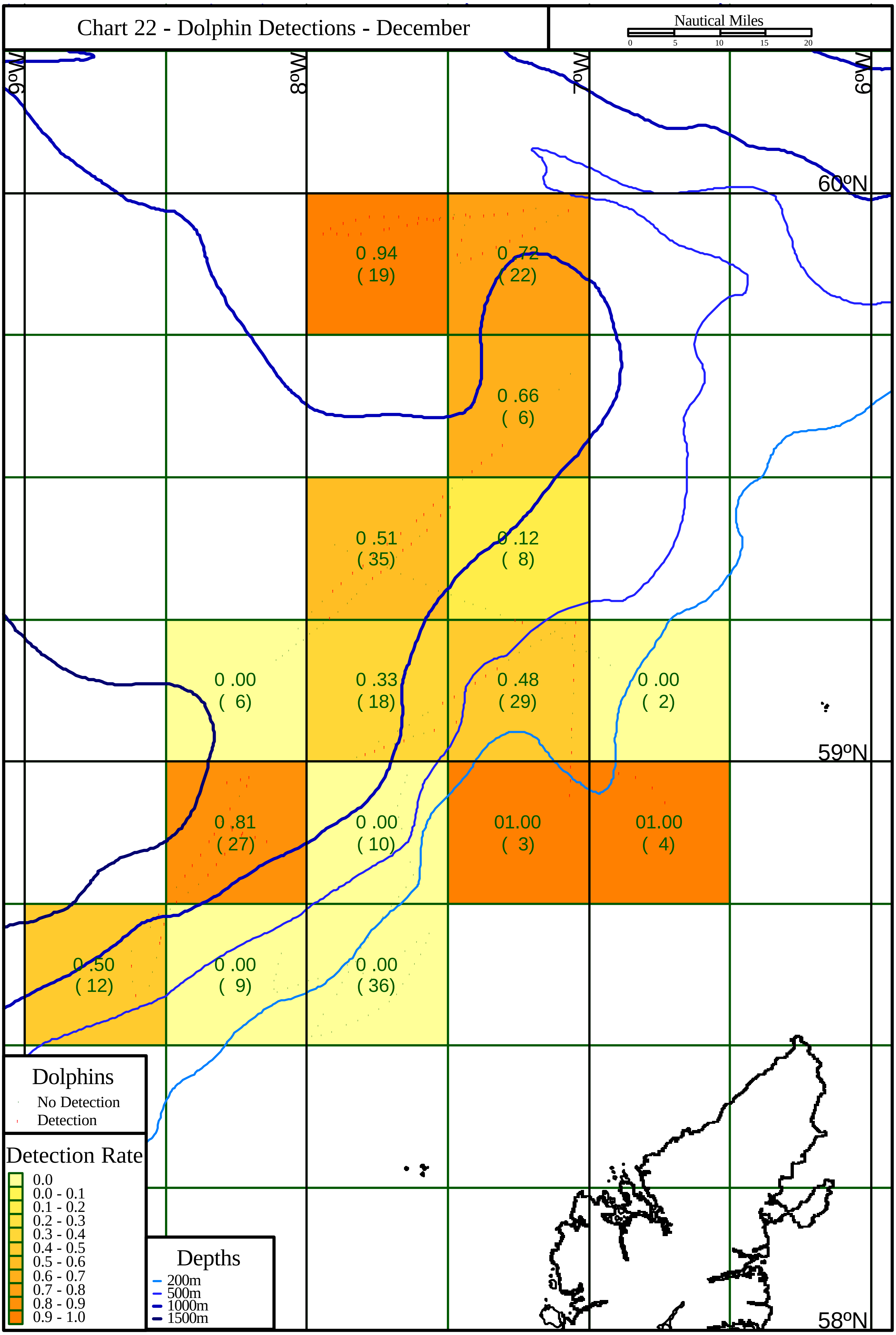
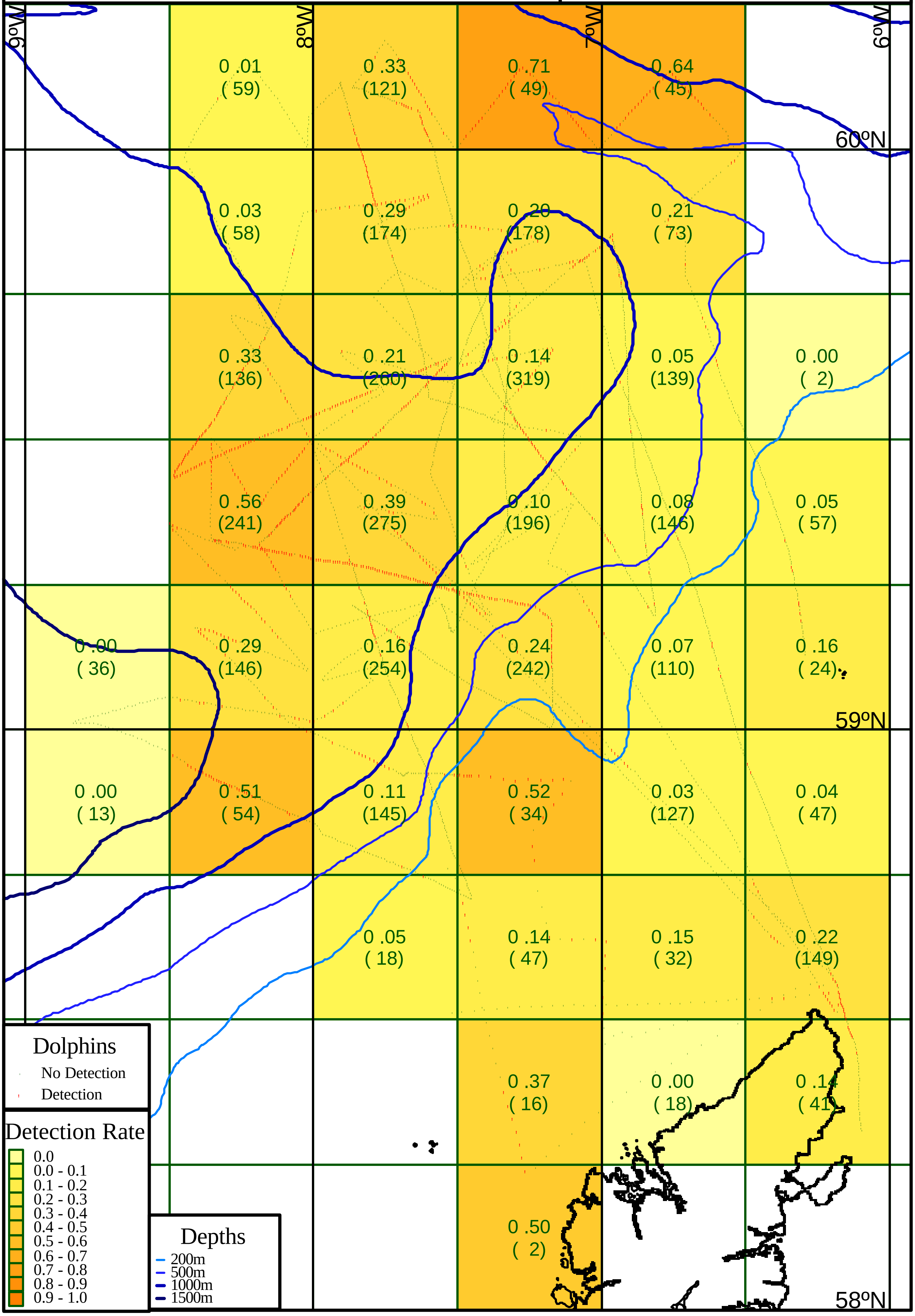


Chart 22 - Dolphin Detections - December
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .94
(19)
0 .72
(22)
0 .66
(6)
0 .51
(35)
0 .12
(8)
0 .00
(6)
0 .33
(18)
0 .48
(29)
0 .00
(2)
0 .81
(27)
0 .00
(10)
01.00
(3)
01.00
(4)
0 .50
(12)
0 .00
(9)
0 .00
(36)
Dolphins
No Detection
Detection
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

Chart 23 - Dolphin Detections - January



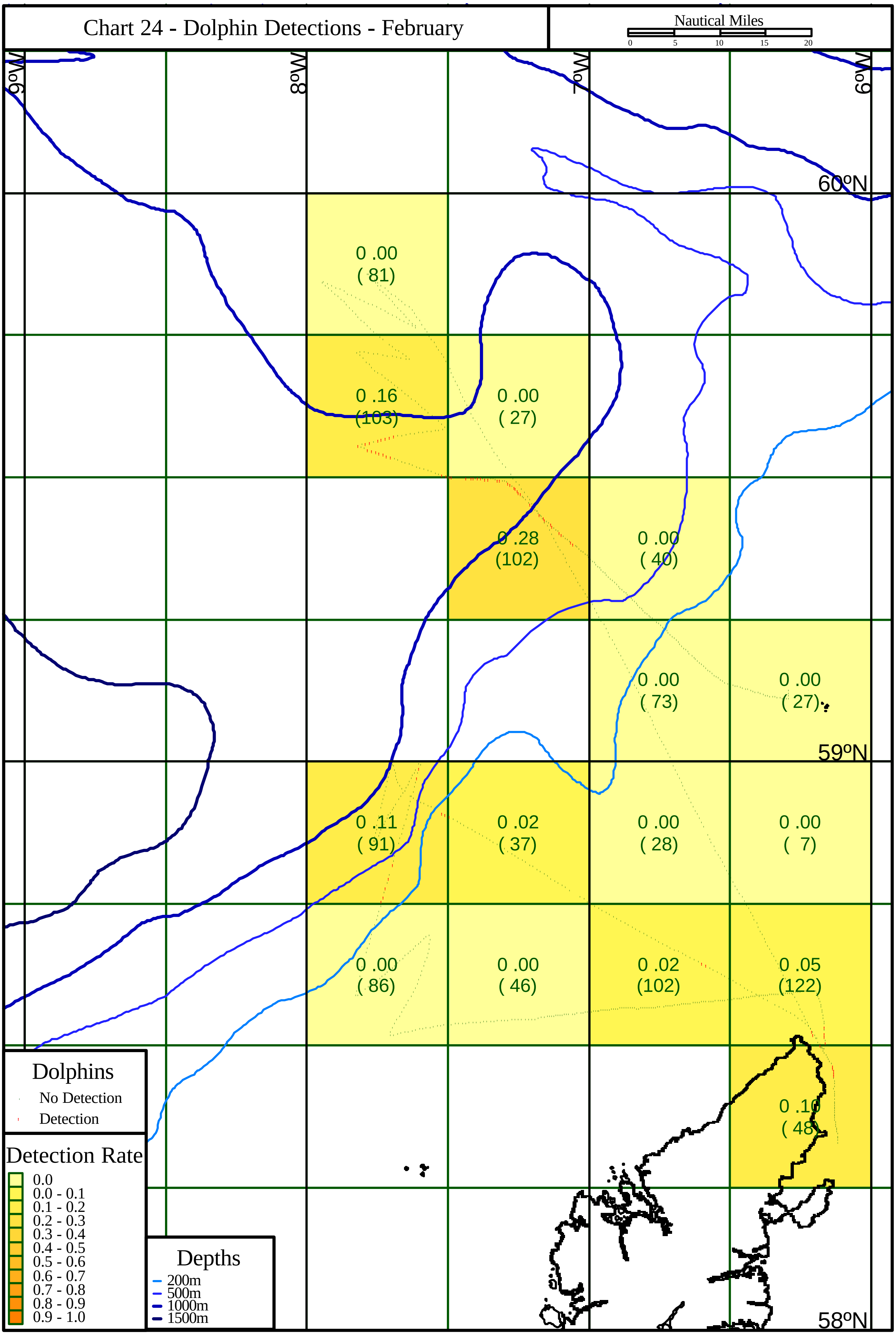


Chart 24 - Dolphin Detections - February
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0 .00
(81)
0 .16
(103)
0 .00
(27)
0 .28
(102)
0 .00
(40)
0 .00
(73)
0 .00
(27)
0 .11
(91)
0 .02
(37)
0 .00
(28)
0 .00
(7)
0 .00
(86)
0 .00
(46)
0 .02
(102)
0 .05
(122)
0 .10
(48)
Dolphins
No Detection
Detection
Detection Rate
0.0
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
Depths
200m
500m
1000m
1500m

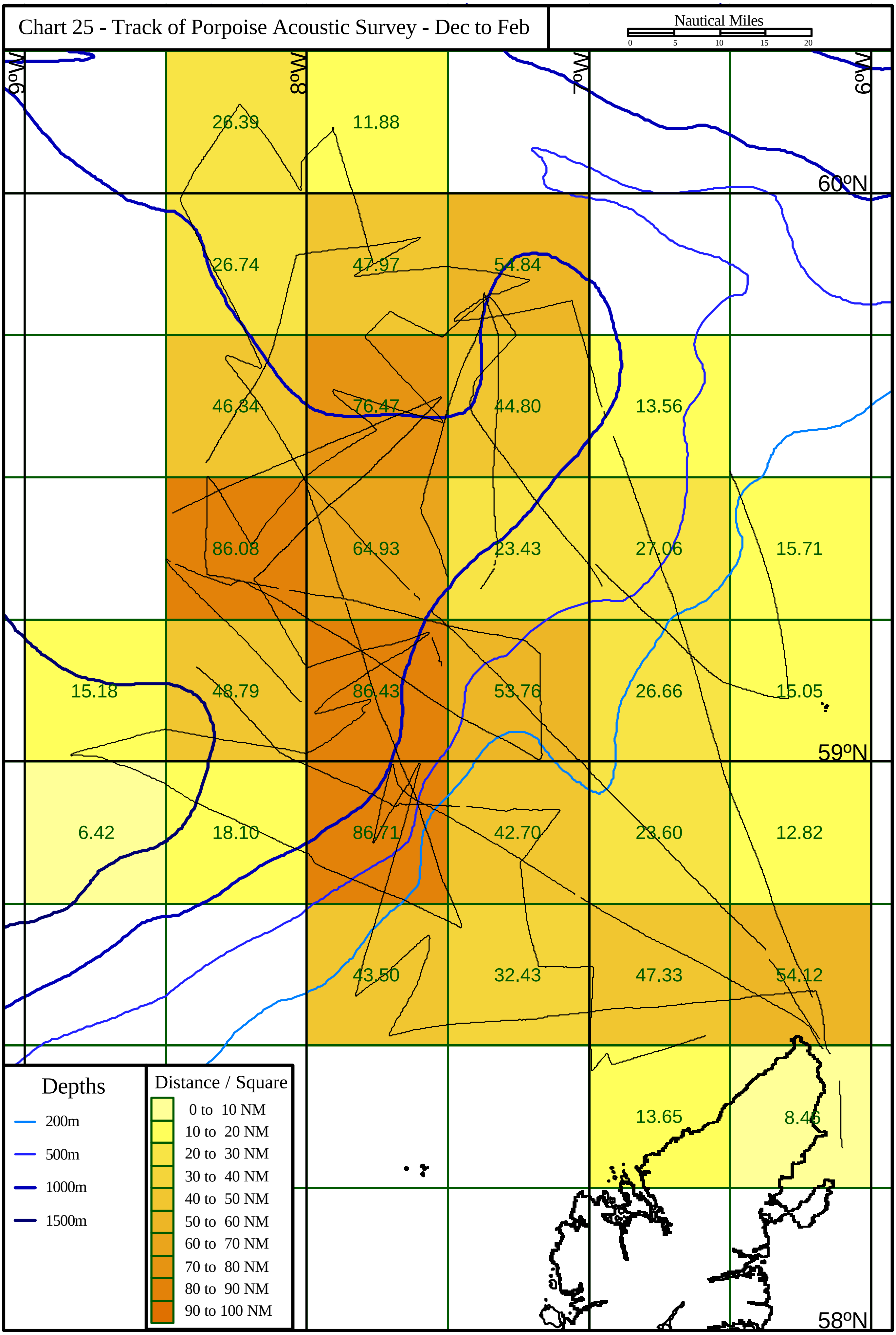


Chart 25 - Track of Porpoise Acoustic Survey - Dec to Feb
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
26.39
11.88
26.74
47.97
54.84
46.34
76.47
44.80
13.56
86.08
64.93
23.43
27.06
15.71
15.18
48.79
86.43
53.76
26.66
15.05
6.42
18.10
86.71
42.70
23.60
12.82
43.50
32.43
47.33
54.12
13.65
8.46
Depths
200m
500m
1000m
1500m
Distance / Square
0 to 10 NM
10 to 20 NM
20 to 30 NM
30 to 40 NM
40 to 50 NM
50 to 60 NM
60 to 70 NM
70 to 80 NM
80 to 90 NM
90 to 100 NM

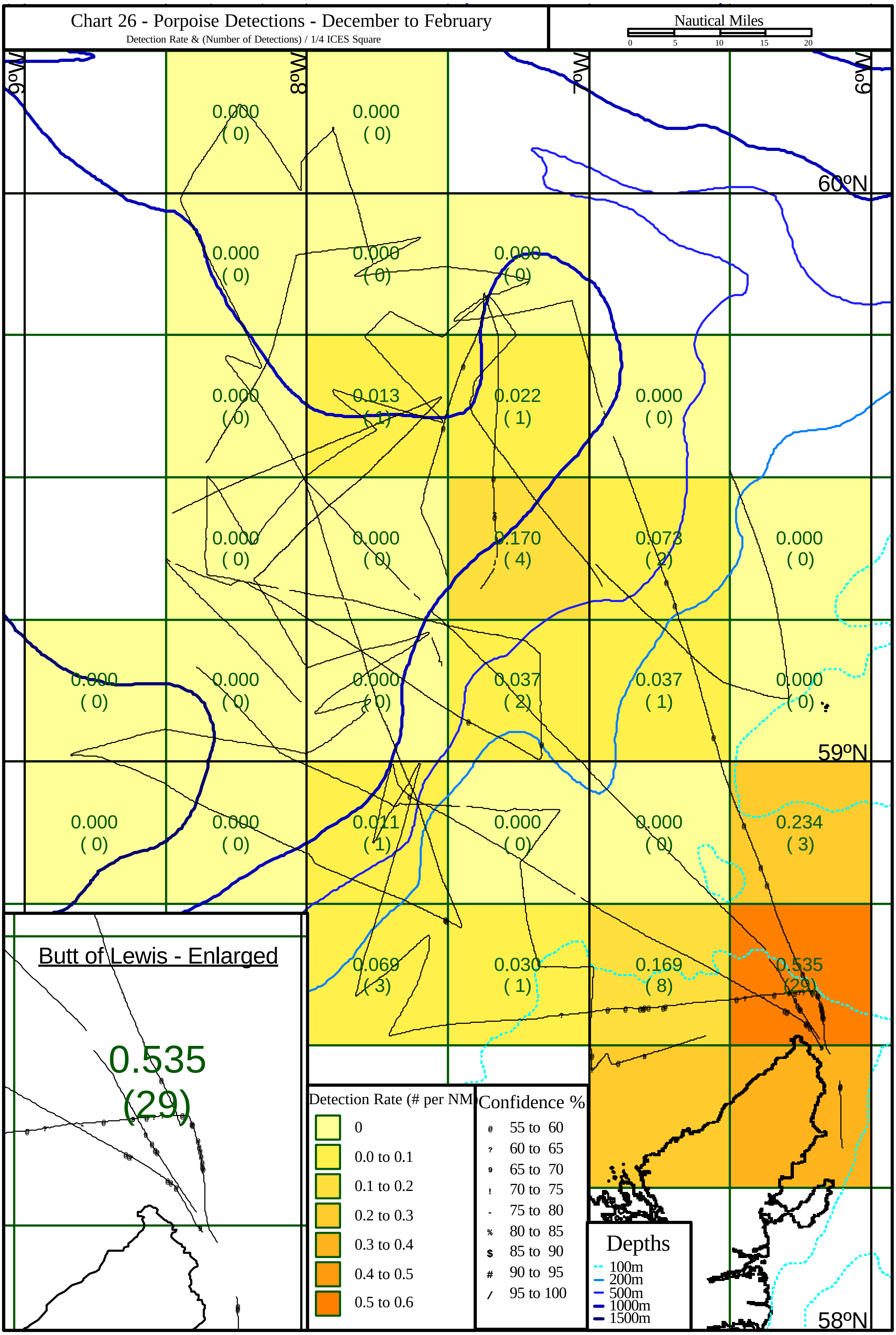


Chart 26 - Porpoise Detections - December to February
Detection Rate & (Number of Detections) / 1/4 ICES Square
Nautical Miles
0
5
10
15
20
9ºW
8ºW
7ºW
6ºW
60ºN
59ºN
58ºN
0.000 (0)
0.013 (1)
0.022 (1)
0.170 (4)
0.073 (2)
0.037 (2)
0.037 (1)
0.234 (3)
0.011 (1)
0.069 (3)
0.030 (1)
0.169 (8)
0.535 (29)
Butt of Lewis - Enlarged
0.535
(29)
Detection Rate (# per NM)
0
0.0 to 0.1
0.1 to 0.2
0.2 to 0.3
0.3 to 0.4
0.4 to 0.5
0.5 to 0.6
Confidence %
55 to 60
60 to 65
65 to 70
70 to 75
75 to 80
80 to 85
85 to 90
90 to 95
95 to 100
Depths
100m
200m
500m
1000m
1500m