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Identification of Western Australian Grey Nurse Shark aggregation sites

Final Report to the Australian Government, Department of the Environment and Heritage

J. Chidlow, D. Gaughan, R. McAuley

Cover photo: Greg Phoebe

Department of Fisheries

Australian Government
Department of the Environment and Heritage

Fish for the future

Fisheries Research Division
Western Australian Fisheries and Marine Research Laboratories
PO Box 20 NORTH BEACH
Western Australia 6920

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Enquiries
Department of Fisheries
3rd floor The Atrium
168-170 St George's Terrace
PERTH WA 6000
Telephone (08) 9482 7333
Facsimile (08) 9482 7389
Website: http://www.fish.wa.gov.au

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The primary function of the Fisheries Research Division is to provide scientific advice to government in the formulation of management policies for developing and sustaining Western Australian fisheries.

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Corresponding Author: Justin Chidlow

Address: Department of Fisheries
Research Division
PO Box 20
North Beach
Western Australia, 6920
Telephone: (08) 9203 0208 Facsimile: (08) 9203 0199

Email: jchidlow@fish.wa.gov.au

Non Technical Summary

The first phase of this project involved a desktop study to broadly identify areas where Western Australian Grey Nurse Sharks potentially aggregate for further investigation with field surveys. These areas were identified from information obtained from commercial shark fishers, previously unpublished research data, as well as anecdotal reports of sightings or captures from recreational divers and fishers, professional dive stores, dive clubs and charter boat operators. A total of 25 survey areas were identified during the desktop study, 16 of which were in depths less than 30m and 9 in depths greater than 30m. During the second phase of the project, visual diver surveys were conducted at 9 sites in the North West Cape area and 5 sites in the Cape Leeuwin area. Although the physical characteristics of diver survey sites were similar to those of Grey Nurse Shark aggregation sites elsewhere, no Grey Nurse Sharks were observed. Remote Operated Vehicle surveys of deep-water sites could not be undertaken due to unfavourable weather conditions and equipment failure. Despite this study being unable to confirm the location of Grey Nurse Shark aggregations off WA, potential aggregation areas identified during the desktop study, provide some guidance for future surveys. Furthermore, the information collected during this project confirms that Grey Nurse Sharks remain widely distributed along the WA coast and are still regularly encountered, albeit with low and indeterminate frequency.

Objectives

1. Identify areas in which aggregation sites may occur
2. Determine if Grey Nurse Shark aggregation sites occur in WA waters, and, if so, the most appropriate method to monitor these sites.

1.0 Introduction

The Grey Nurse Shark, *Carcharias taurus*, has a biennial reproductive cycle and produces only two pups per litter. As a result, this species has one of the lowest intrinsic rates of population growth of all large coastal elasmobranch species and their ability to sustain fishing pressure is consequently very low (Branstetter and Musick, 1994). Populations in eastern Australia and South Africa have shown severe declines as a result of commercial fishing, spearfishing and beach meshing, requiring the introduction of conservation strategies to ensure the species' survival in areas in which they were once plentiful (Reid and Krogh, 1992; Krogh, 1994; Pollard et al., 1996; Parker and Bucher, 2000; Otway and Parker, 2000; Otway et al., 2003). The eastern Australian population of Grey Nurse Sharks is listed as critically endangered under the Environment Protection Biodiversity Conservation Act (1999) (EPBC Act) and by the IUCN Red List (A2abcd+3bc) (Cavanagh et al., 2003).

In southeast Australian and South African waters Grey Nurse Sharks are known to form aggregations at certain locations around inshore rocky reefs and sandy bottom gutters, that may be related to pupping and/or mating activity (Pollard et al., 1996; Otway and Parker, 2000; Otway et al., 2003). An aggregation is considered to be five or more Grey Nurse Sharks present at the same site (Otway and Parker 2000). Divers in southeast Australia have observed this behaviour since the 1950s, and in the 1960s and 1970s large numbers of Grey Nurse Sharks were targeted by spearfishers on the east coast of Australia at known aggregation sites. This, in combination with other forms of mortality (beach meshing and incidental capture by commercial and recreational fishing) has led to a severe decline in east coast populations, with estimates of fewer than 500 individuals (Otway and Parker, 2000). Mortality of Grey Nurse Sharks at aggregation sites is recognised as a major contributing factor to the species' vulnerability. In eastern Australia, 19 aggregation sites were identified as habitat critical to the survival of Grey Nurse Sharks. Five of these sites are in Queensland, twelve in NSW and two in Commonwealth waters (Environment Australia, 2002).

Unlike other regions, Grey Nurse Sharks have never been subjected to targeted fishing in Western Australia (WA). The only significant source of mortality has been from incidental capture by the demersal gillnet fishery that operates between Steep Point and the South Australian border (Figure 1). Data from this fishery is the best available information on the location of aggregation sites for the Grey Nurse Shark in WA waters. Catch and catch rate data from the demersal gillnet fishery, prior to 1997, indicates that Grey Nurse Sharks were relatively abundant in temperate WA waters in the mid-late 1990s and that the population was stable (Cavanagh et al., 2003). The west coast Grey Nurse Shark population has therefore been assessed as near threatened by the IUCN Red List but as vulnerable under the EPBC Act (October 2001). In December 1999, the Grey Nurse Shark was protected in Western Australian waters under the Wildlife Conservation Act (1950).

Following the Australia-wide protection of this species in Commonwealth waters in 1997, commercial reporting of catches in the gillnet fishery ceased, due to fear of prosecution. This resulted in the loss of catch rate (CPUE) data from the fishery, which had provided an established index of abundance. Therefore it was considered necessary to develop an alternative means of monitoring the abundance of Grey Nurse Sharks off WA.

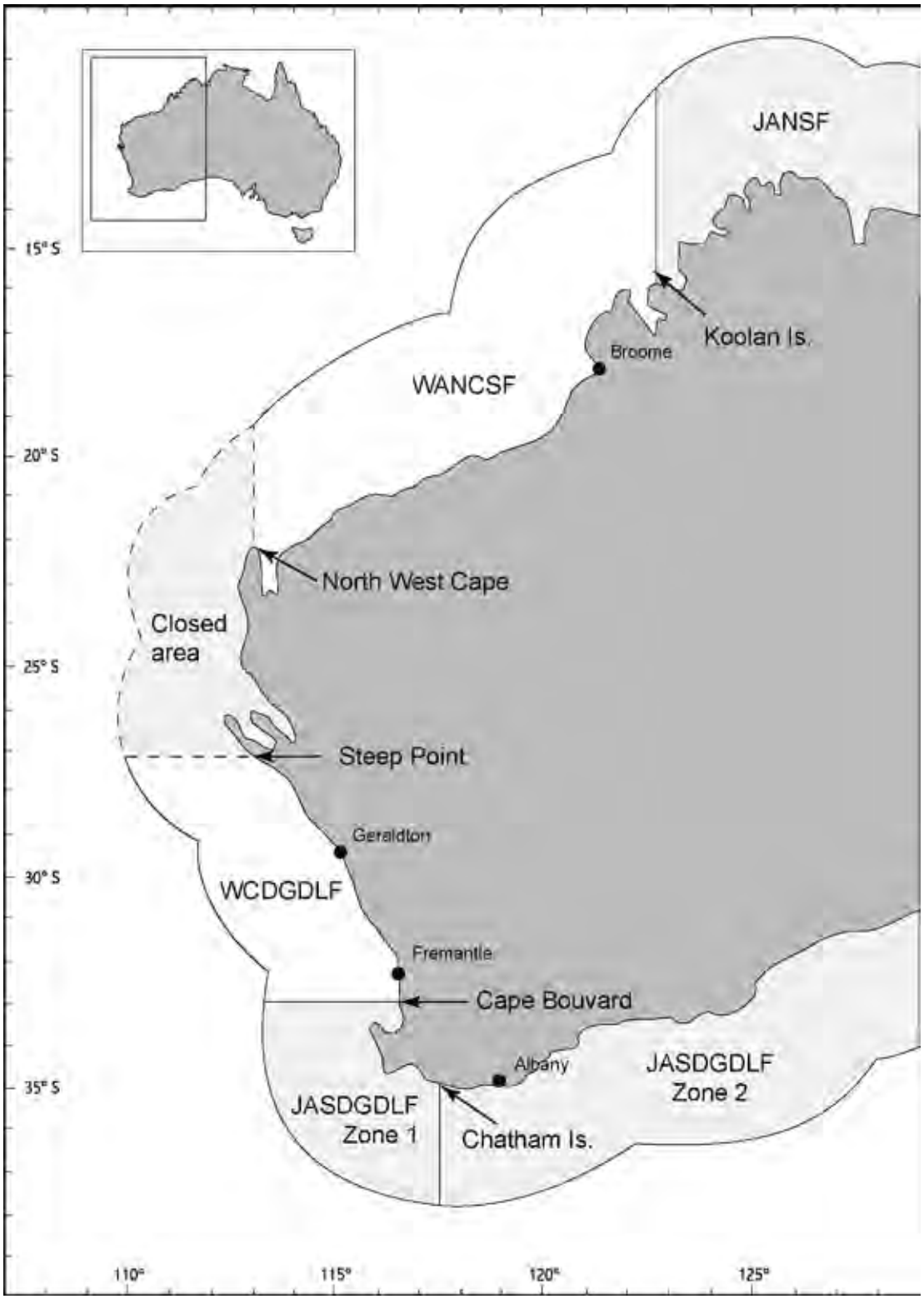

Figure 1. The “shark” fisheries in Western Australia. JASDGDLF - Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery. WCDGDLF - West Coast Demersal Gillnet, Dropline Interim Managed Fishery. WANCSF – WA North Coast Shark Fishery. JANSF – Joint Authority Northern Shark Fishery.

No persistent Grey Nurse Shark aggregation sites have been known to occur in WA and as such Grey Nurse Sharks have not been subjected to targeted spearfishing. There are anecdotal reports that Grey Nurse Sharks were encountered more frequently in the 1960s and 1970s and that there may have been inshore aggregation sites. However, it is not clear whether these 'aggregations' were at specific sites that were visited on a regular basis or represented inshore schooling to take advantage of seasonal prey availability events, such as the annual Australian salmon migration.

Long-term monitoring of Grey Nurse Shark numbers at 'key' aggregation sites potentially offers an alternative means of detecting changes in the species' abundance. Information from the WA demersal gillnet fishery, which is the principal source of reported encounters with Grey Nurse Shark in WA, could provide information on possible aggregation sites. The Western Australian Department of Fisheries catch and effort data supplied by commercial fishers, suggests that aggregation sites may not occur within the functional area of the WA demersal gillnet fishery. Assuming such sites do occur within the fishery's broader geographic boundaries, they are likely to be in areas of heavy reef and/or in deeper coastal waters (>100 m), where commercial gillnet vessels do not regularly operate.

Surveys conducted in NSW have identified 14 (including two in Commonwealth waters) aggregation sites that were utilised by Grey Nurse Sharks for substantial periods of time (Otway et al., 2003). Ten of these sites were declared as Critical Habitat by the NSW Government in 2002. Surveys to monitor the abundance and distribution of populations have been conducted at these and other sites in southeast Australian waters (Pollard et al. 1996; Otway and Parker, 2000; Otway et al., 2003). Five aggregation sites have also been identified in Queensland. However, as no sites have been identified in WA, this monitoring method has not been used.

This study aims to determine if Grey Nurse Shark aggregation sites occur in WA waters and, if so, the most appropriate method to monitor these sites.

2.0 Materials and methods

2.1 Identification of potential aggregation sites

The first stage of this project (Phase 1) was to identify areas in which aggregation sites may occur. This process included a number of components that are outlined below.

2.1.1 Fine-scale geo-spatial identification of demersal gillnet fishing grounds to be excluded from further investigation

As the WA gillnet fishery is the main known source of Grey Nurse Shark encounters in WA, the geographic area of this fishery provides a useful boundary for identifying possible aggregation sites. Commercial fishing catches in WA are reported in 1∞ x 1∞ blocks. This resolution was unsuitable for assessing the presence of Grey Nurse Shark aggregation sites, which based on experience from east coast sites (Otway and Parker, 2000), may only be on a scale of 10 to 100 m. Therefore finer scale resolution was required.

A total of approximately 25% of fishers operating in the WA temperate demersal gillnet and demersal longline fisheries were interviewed by the senior author to determine where fishing grounds are, to identify areas fishers avoid due to the likelihood of gillnet damage

and to identify areas or specific locations of known Grey Nurse Shark captures. The fishers interviewed operated in areas of the fishery that, in total, covered the functional area of the WA demersal gillnet fishery between Steep Point (26º 30'S) and the South Australian border (129ºE). One commercial fisher using demersal longline in the northern WA shark fishery was also interviewed to provide information on the location of Grey Nurse Shark captures. During the interview each fisher was presented with a relevant series of Royal Australian Navy nautical paper charts and requested to shade in areas using different colours according to information required as outlined below.

Each fisher was requested to shade in grey areas where they deploy their demersal gillnets. The cumulative mapping of individual fisher's areas of operation produced a complete map of the functional area of the WA demersal gillnet fishery.

Fishers were then asked to shade in red areas that they avoid due to the risk of net entanglement over unsuitable bottom topography such as heavy (i.e. relatively high relief) reef. These areas are typically shallow reef systems (<4 m deep) that occur close to the mainland or near offshore islands and represent locations that may require further investigation as potential Grey Nurse Shark aggregation sites. Shallow inshore beach zones were also included in the areas that fishers avoid.

Lastly, each fisher was also asked to identify, by shading in green, areas where they have previously caught Grey Nurse Sharks during their years of involvement in the fishery and if possible provide information such as date (month or year), location, approximate length, sex and approximate number of individuals caught at either a specific time or more generally (i.e. per year). In some cases long-term fishers were able to provide an overview of historical Grey Nurse Shark captures. For example, these fishers indicated areas where Grey Nurse Shark were regularly encountered, but were not able to recall specific details. Alternatively, in other cases specific details could be provided for relatively recent captures (e.g. within the past 12 months). All information obtained from each fisher at the completion of the interview was transferred from paper charts onto corresponding nautical charts using Geographic Information System (GIS) software. It was not expected that the information provided by fishers would provide precise locations of Grey Nurse Shark aggregation sites or detailed information on habitat types. Rather, the intention was to obtain approximate locations that may contain suitable habitat for aggregations and then to further investigate these locations by focusing subsequent surveys on reef habitats within the identified locations (i.e. Phase 2 of the project). Other investigations of potential sites were also conducted, and are detailed below.

2.1.2 Identification of the gillnet fishing grounds

Most vessels that operate in the fishery have a limited operational range from their home ports, so there are substantial areas of unfished grounds within the geographic boundaries of the fishery. The available information confirmed that the fleet operates inside the 100 m isobath. Consequently, no data on Grey Nurse Shark captures would be available for depths >100 m, therefore the identification of aggregation sites focused on depths <100 m.

2.1.3 Collation of existing research data and anecdotal reports of Grey Nurse Shark

Information from a variety of sources, including results from the DEH-funded "Western Australian Grey Nurse Shark pop up archival tag project" (McAuley, 2004), was examined

to provide further evidence for the locations of possible aggregation sites. The Grey Nurse Shark PAT tag project provided information on depth profiles, habitat usage and movement patterns of four Grey Nurse Sharks. Grey Nurse Shark capture data collected by Department of Fisheries research staff between 1994 to 2004 from commercial gillnet vessels and during research surveys onboard Department of Fisheries research vessels were also examined, and the locations plotted on appropriate nautical charts using GIS software.

Anecdotal evidence of sightings or captures from recreational divers and fishers, professional dive stores, diving clubs and charter boat operators were also collected and the locations plotted onto nautical charts. A number of these reports from divers and fishers were not specific enough to plot a precise location, so the positions were estimated as a single point. Initial contact with potential interviewees was made by phoning local dive store operators and diving clubs who either provided their own evidence of sightings and/or provided contact information for divers and fishers who could be of assistance. Further contacts and information were gathered from enquiries generated by a media release requesting Grey Nurse Shark sighting or capture details.

The combination of results from Sections 3.1.1 and 3.1.2 enabled a list to be compiled of potential aggregation sites of Grey Nurse Sharks that required further investigation using diver and remotely operated vehicle (ROV) surveys (i.e. Phase 2 of the Project). Survey sites were grouped into two categories based on their suitability for survey by SCUBA equipment (<30 m) or ROV (>30 m). Each potential site was selected based on Grey Nurse Shark captures and sightings as well as suitable benthic habitat and were ranked according to the following criteria;

1. Low (A single Grey Nurse Shark capture or sighting. Unknown or unsuitable habitat).
2. Medium (Two captures in one day or two captures on different days or occasional sightings. Potentially suitable habitat).
3. High (>two captures in one day or >two captures on different days, or regular sightings. Known benthic structure, suitable habitat).

2.2 Sampling sites and protocol

The sites chosen for visual examination in this study were from the most likely Grey Nurse Shark aggregation sites identified in Section 2.1 and based on the suitable benthic habitat and sighting/capture rankings of low, medium or high. Suitable benthic habitat was defined as significant vertical and horizontal reef structures and associated sandy-bottom areas, similar to aggregation sites identified on the east coast of Australia (Pollard et. al., 1996; Otway and Parker, 2000). Grey Nurse Sharks were most commonly sighted in sandy gutters (42% of sightings) and in caves (24% of sightings) in a survey conducted in northern NSW (Otway and Parker, 2000).

This project allowed for seven days of SCUBA and seven days of ROV exploratory work. Sites were carefully selected according to logistical parameters such as weather and when more than one site could be surveyed on the same day or over consecutive days to maximize use of available resources. The aim of the visual surveys was to confirm the locations of potential aggregation sites and to estimate the abundance and distribution of Grey Nurse Sharks at these sites.

2.2.1 Diver survey

The objective of each site survey was to confirm the locations of potential aggregation sites and to record the number of Grey Nurse Sharks observed, their total lengths (TL) estimated and sex. Total lengths were to be recorded in three size-classes according to Otway and Parker (2000) of 1-2 m, 2-3 m and >3 m. The search method adopted for this survey was the U-Pattern (Miller, 1979; Richardson, 1995), which enabled the survey divers to cover a large area with minimal equipment (Figure 2). Diver 1 was responsible for navigating the transect, while Diver 2 was the observer. The vessel's anchor served as the starting point, the location of which was recorded by Geographical Positioning System (GPS). Using a compass, Diver 1 swam in a straight line maintaining a heading for a predetermined number of kick-cycles or time, depending on dive site characteristics and conditions. A kick-cycle is defined as a complete "rotation" of the fins (i.e. one up and one down stroke = one kick cycle). Diver 2 swam beside Diver 1 to maintain buddy contact and ensure that the transect was followed correctly. At the end of the predetermined time or distance for the first transect line, Diver 1 turned 90∞ left or right and swam on the new heading for a short distance, depending on visibility, so that the maximum area was covered in the time available without missing or repeating any area. Diver 1 then swam the 2nd line on the reverse heading as the 1st transect line. This pattern was repeated until the dive site was adequately surveyed or the maximum allowable bottom time reached. The search pattern for each dive site was influenced by the particular topography and environmental conditions found at the site and adjusted accordingly.

Dive site characteristics such as location (latitude and longitude), dive time, maximum depth, visibility, benthic structure and survey search pattern were also recorded. Locations of sampled dive sites were transferred to appropriate nautical charts using GIS software.

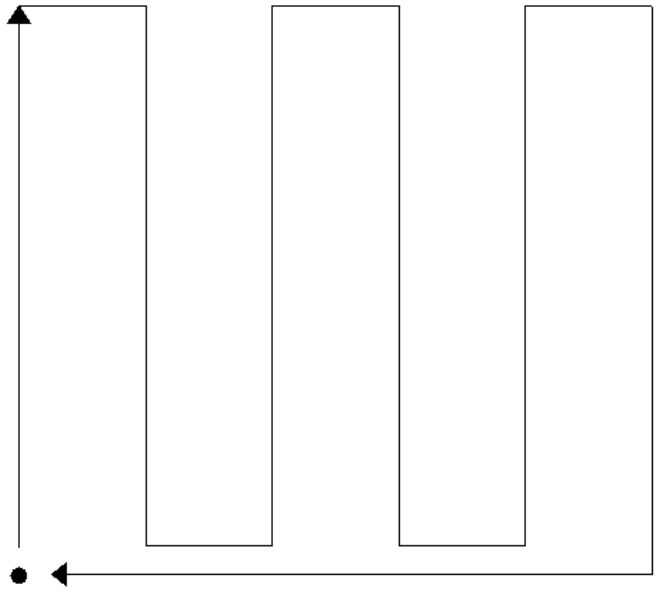

Figure 2. U-Shaped search pattern utilised in diver surveys of potential Grey Nurse Shark aggregation sites.

2.2.2 ROV survey

Visual surveys of dive sites at depths greater than 30 m were attempted using a hired SeaBotix LBV150S ROV and an experienced operator. This particular ROV has the following features:

depth rated to 150 m, 150 m of umbilical, one 570 line/0.3 lux colour camera which has a 270 degree field of vision, 50 watt halogen lamp, 4 thrusters (2 forward, 1 lateral, 1 vertical), and is small enough to be operated by one person (weighs 11 kg in air). The size of the ROV allows the operator to manoeuvre the unit through narrow gullies and under ledges/overhangs of reef systems that may be suitable Grey Nurse Shark habitat. The ROV was tethered via a load-bearing umbilical that interfaced with a console and a live-feed monitor, for viewing by the operator. The video image was recorded using a digital video camera with a 60-minute cassette for later viewing and analysis. Details displayed on screen by video overlay were depth, temperature, compass heading, date and time. This particular ROV unit was chosen over other available systems as it was able to be launched from charter vessels without the need for hydraulic lifting gear and was of sufficient size to be safely manoeuvred around typical Grey Nurse Shark habitat (ledges, overhangs). As this was a study of potential techniques to identify Grey Nurse Shark aggregation sites, cost had to be kept at reasonable levels because any useful techniques identified in this study would potentially be developed into a longer term, cost-effective monitoring system.

The search method for ROV surveys was the same used in diver surveys with adjustments made according to particular environmental conditions and topography. ROV surveys are only limited by the length of umbilical cord, not time, thus allowing the site to be surveyed in greater detail. As for the diver surveys, the number of Grey Nurse Sharks observed, their total length estimate and sex were to be recorded. ROV site characteristics such as location (latitude and longitude) search time, maximum depth, visibility, benthic structure and survey search pattern were also recorded. Locations of sampled ROV sites were transferred to appropriate GIS maps.

Survey of Dive Site 10

On the 24th and 25th of February 2005 an opportunity arose to visually survey Dive Site 10, located south-west of Rottnest Island (see figure 12(c) and 17), with a towed camera system and a ROV. Working together with another Department of Fisheries project, the two forms of survey equipment were trialed onboard the *R.V. Naturaliste*. Dive Site 10 is a shallow water site previously identified from research captures as a potential aggregation site of Grey Nurse Sharks and suitable for survey by SCUBA.

Towed camera

The WA Department of Fisheries towed camera system used to survey Dive Site 10 consists of a digital video camera in a steel housing with a perspex window and two halogen lights. The camera and housing were fixed in position inside a steel frame that has a large weight (approx. 150 kg) attached to the underside. This weight ensures that when towed behind the vessel the camera remains upright, stable and in close proximity to the vessel. The camera's proximity to the vessel, enables an accurate track of the area surveyed to be captured by the vessel's GPS plotter. The camera was attached to the vessel and towed by a winch operated steel cable. An umbilical attached to the camera provided a live video feed that enabled the operator to maintain the camera at a constant position above the sea floor by winching the camera up and down as required. A digital camera recorded the video image onto a 60-minute cassette and footage was then transferred to DVD for further viewing and analysis. The vessel's GPS position was displayed onto the video footage using a Seatrak GPS overlay system by Seaviewer®.

On the 24th of February 2005 the *R.V. Naturaliste* towed the camera across Dive Site 10 at a speed of between 1.5 and 3.0 knots from 11:24 am to 12:25 pm. The time displayed on footage is Coordinated Universal Time (UTC). Depth of site surveyed ranged from 27 to 38 m. Vessel track was plotted using Seaplot® (Geographic Datum WGS 1984) and the data plotted onto the relevant nautical chart using GIS.

ROV camera

The ROV utilised to survey Dive Site 10 and details on the unit are as mentioned previously in this section. The R.V. Naturaliste anchored in 26 m of water at Dive Site 10 (32° 05.24 S, 115° 27.61 E) at 08:15 am on the 25/02/05 and when settled, the vessel was hanging with the bow facing SW. The ROV was deployed over the port side of the vessel at 08:45 am and immediately manoeuvred to the seafloor to begin the survey. The ROV surveyed the site within a 40 m arc of the port aft of the vessel. As the contractor operator had mistakenly failed to calibrate the ROV's compass, the heading data displayed on monitor was incorrect and it was not possible to conduct the survey following directional transect lines. The senior author viewed the live video footage from the ROV and directed the operator to move the ROV to points of interest such as ledges and overhangs in the reef. The ROV was retrieved at 09:30 am. Recorded video footage was transferred from miniDV cassette tape to DVD.

3.0 Results

3.1 Identification of potential aggregation sites

3.1.1 Identification of demersal gillnet fishing grounds

Information collected from fishers operating in the WA demersal gillnet and demersal longline fishery between Steep Point (26° 30' S) and the South Australian border (129° E) indicated that gillnets are deployed along the coast from the inshore zone (>4m depth) to depths no greater than approximately 100 m (Figures 3 - 5). Large areas of unfished regions occur within the boundaries of the fishery.

Areas avoided by the fishers within the 100 m isobath (i.e. the functional area of the fishery) include shallow reef systems and known areas of heavy reef where net entanglement is a possibility (See Figures 3 – 5). These areas represent the types of habitat in which Grey Nurse Shark may aggregate and were included as potential survey sites.

3.1.2 Examination of research data and collation of anecdotal reports

A total of 118 (Male = 64, Female = 45, Unknown = 9) Grey Nurse Sharks were captured and the details recorded by observers whilst onboard commercial gillnet vessels and Department of Fisheries WA research vessels between 1994 and 2004. The locations of these captures are shown in Figure 6, with finer details shown in Figures 7-14 at the end of this report.

Anecdotal information on sightings of Grey Nurse Shark collected from 34 sources encompassing a variety of experiences and covering an area from North West Cape (114∞ 06 E) to 124º E in the south, is shown in Table 1. The majority of these reports were of individual Grey Nurse Sharks observed infrequently. Despite being reported by independent sources over different time periods, a number of these reports were from the same locations, e.g. Muiron

Islands (21° 41.4 S, 114° 17.4 E; Figure 7), West End of Rottnest Island (32° 01.8 S, 115° 25.8 E; Figures 12, 12c), suggesting that Grey Nurse Sharks regularly frequent these areas. Some divers provided photographs and video footage as conclusive evidence of Grey Nurse Sharks for a number of locations. Information obtained from commercial shark fishers indicated that they capture an unspecified number of Grey Nurse Sharks each year at various locations. Precise information on the timing of captures was lacking in most cases.

Table 1. Grey Nurse Shark sightings and capture information collected from commercial and recreational fishers, professional and recreational divers and charter boat operators. 'Various' dates observed were defined as multiple, non-specific instances when Grey Nurse Sharks were encountered. 'Numerous' refers to an estimated number of Grey Nurse Sharks and was defined as more than one encounter, but exact figures were not available. 'Occasional' was defined as infrequent encounters of one Grey Nurse Shark at a particular location.

Site ID No.	Location	Date observed	Estimated No. of GNS	Comments
1	Cape Leeuwin area	Various	Numerous	Commercial shark fisher for 20 years
2	Cape Leeuwin area	Various	Numerous	Commercial shark fisher for 30 years
3	Augusta (Salvation Reef, Bessie Reef, Big Island)	Various	Occasional sightings	Recreational diver/fisher for 40/50 years
4	Cape Naturaliste/ Leeuwin area	Various	Numerous	Commercial shark fisher for 20+ years
5	South West coast	Various	Numerous	Commercial shark fisher for 30 years
6	West coast	Various	Numerous	Commercial shark fisher for 30 years
7	West coast	Various	Numerous	Commercial shark fisher for 20+ years
8	Perth Metro and Rottnest area	Various	Occasional sightings	Dive operator employee
9	Rottnest Island	Unknown	Occasional sightings	Dive operator employee
10	NE of Rottnest Island	Jan 2005	1	Dive operator employee
11	Dirk Hartog Island	Unknown	Occasional sightings	Charter Boat Operator
12	Coral Bay	Various	Occasional sightings	Dive operator employee
13	Exmouth/Muiron Islands	Various	Occasional sightings	Dive operator employee
14	Exmouth/Muiron Islands	Various	Occasional sightings	Dive operator employee
15	Rottnest Island (West Patch)	April 2004, unknown	Occasional sightings	Recreational diver (Underwater Explorers Club)

Table 1. (continued)

16	"Opera House" (off Hillarys) and West End of Rottnest	Unknown	Occasional sightings	Recreational diver
17	Approx 12km off Hillarys	23/03/05	3	Recreational Diver/University researcher
18	North of Rottnest	06/03/05	1	Recreational diver
19	Roe Reef, Rottnest	19/03/05	1	Recreational diver
20	West End, Rottnest	March/ April, 2004	2	Recreational diver
21	Gardner River, near Windy Harbour	Jan 1991	1	Recreational diver
22	Gnarloo Station	Unknown	6-8	Recreational diver
23	Twilight Cove (near Cocklebiddy) off beach	Jan, 2005	2	Abalone diver (saw recreational fisher catch GNS off beach)
24	Garden Island	June, 2005	1	Dive operator employee
25	West of Carnarvon	Various	Occasional captures	Fisheries Research staff
26	West of Quobba Station	Various	Occasional captures	Fisheries Research staff
27	Cathedral Rocks/West End, Rottnest	Various	Occasional sightings	Recreational diver/fisher and shark author
28	Exmouth, Muiron Islands and Coral Bay	2002/03	Occasional sightings	Recreational diver
29	3 Mile Reef, Hillarys	Jan, 2005	Occasional sightings	Recreational diver (Underwater Explorers Club)
30	Albany/Esperance	Various	Numerous	Commercial shark fisher for 20 years
31	West Coast	Various	Numerous	Commercial shark fisher for 10 years
32	Asho's Gap, Coral Bay and Muiron Islands, Exmouth	Various	Occasional sightings	Exmouth Diving Centre employee
33	Gnarloo Station	Various	Occasional sightings	Recreational diver/fisher and ROV operator
34	Exmouth	Various	Occasional sightings	Commercial shark fisher for 15 years.

Using the commercial and fishery-independent sources of information, a total of 25 sites were identified as potential Grey Nurse Shark aggregation sites (Figures 7-14), with 16 of these sites considered suitable for diver survey (Table 2) and 9 for ROV survey (Table 3).

Table 2. Sites identified as suitable for survey using SCUBA. Ranking: 1 = Low, 2 = Med, 3 = High.

Site	Location	Depth (m)	Source	Comments	Ranking
1	28º 06.6 S 113º 28.2 E (NW of North Island, Houtman Abrolhos)	11–30	Research capture data.	Three GNS caught on 14/11/95 and one on 27/08/03.	3
2	30º 54.0 S 115º 0.6 E (Southwest of Wedge Island)	29	Research capture data.	Four GNS caught on four different occasions, close to this location.	3
3	30º 55.8 S 115º 0.6 E (Southwest of Wedge Island)	23-30	Research capture data.	(see site 2 above)	3
4	34º 18.29 S 115º 01.37 E (Minns Ledge, south of Cape Hamelin)	5-15	Fisher reports	Site identified by two demersal gillnet fishers where GNS are occasionally caught.	2
5	34º 13.11 S 114º 59.45 E (West of Hamelin Bay)	2 -15	Fisher reports	(see site 4 above)	2
6	34º 19.29 S 114º 59.64 E (Geographe Reef, SW of Cape Hamelin)	2-15	Fisher reports	(see site 4 above)	2
7	31º 41.4 S 115º 37.8 E (Staggie Reef, west of Quinns Rock)	27	Research capture data and fisher reports	One GNS caught on 11/7/96 and one fisher capture.	2
8	31º 44.7 S 115º 38.4 E (NW of Three Mile Reef)	27	Research capture data	Two GNS caught on 10/07/96 and one on 25/02/97.	3
9	31º 39.6 S 115º 28.2 E (West of Quinns Rock)	29	Research capture data and fisher reports	One GNS caught on 13/06/96 and one fisher capture.	2
10	32º 05.4 S 115º 27.6 E (South of Rottnest Island)	26	Research capture data	One GNS caught 22/03/95 and two nearby on 15/02/03 and 13/05/96	2
11	32º 01.8 S 115º 25.8 E (West Patch, west of Rottnest Island)	20-30	Research capture data and reports from divers	One GNS caught on 16/06/94 and three separate reports of sightings from divers	3

Table 2. (continued)

12	32º 25.2 S 115º 19.8 E (West of Singleton Beach)	27-30	Research capture data	One GNS caught on 09/03/95 and one on 04/03/02 close to this site	2
13	21º 41.4 S 114º 17.4 E (South Muiron Island)	8-15	Reports from divers	GNS sighted occasionally by two dive companies operating in this area	2
14	25º 29.4 S 112º 57.0 E (North of Dirk Hartog Island, St. Madelina wreck)	22	Report from diver	Regular sighting of GNS by dive operator (Les Fewster)	3
15	31º 10.02 S 115º 11.4 E (Southwest of Ledge Point)	30	Research capture data	Four GNS caught on 04/04/02	3
16	31º 09.00 S 115º 16.20 E (Southwest of Ledge Point)	30	Research capture data	Two GNS caught on 16/06/03	2

Table 3. Sites identified as suitable for survey using ROV. Ranking: 1 = Low, 2 = Med, 3 = High.

Site	Location	Depth (m)	Source	Comments	Ranking
1	32º 03.395 S 115º 22.789 E (Wreck southwest of Rottnest Island)	80-90	Report from diver and research capture data	Occasional sighting of GNS at this site by diver and capture of GNS close to this location	2
2	31º 53.4 S 115º 19.8 E (Northwest of Rottnest Island)	80-100	Research capture data	One GNS caught on 15/11/00, one on 10/12/02 and one on 12/12/02 close to this site	2
3	30º 39.0 S 115º 00.0 E to 30º 43.2 S 115º 01.8 E (West of Green Island)	38	Research capture data	Three GNS caught in this area on the 10/04/01 and two caught on 30/04/01	3
4	31º 36.6 S 115º 24.0 E (Southwest of Two Rocks)	37	Research capture data	Two GNS caught on 02/05/96 and two close to this site on 20/03/97	2
5	33º 01.19 S 114º 56.19 E (Northwest of Naturaliste Reef)	44-50	Research capture data and fisher capture	One GNS caught on 22/03/97 and one fisher capture in this area	2
6	30º 20.23 S 114º 54.32 E (West of Jurien Bay)	40-45	Fisher capture	Fourteen GNS caught in one day in this area by fisher	3
7	21º 36.12 S 114º 14.55 E (Northwest of South Muiron Island)	50-100	Research capture data and fisher capture	Two GNS caught on 07/11/01, one on 12/12/02 and occasional capture by fisher in this area	3
8	21º 43.46 S 114º 01.47 E (West of North West Cape)	100	Research capture data	One GNS caught on 13/11/01 also noted to be suitable GNS habitat	1
9	21º 45.33 S 113º 53.59 E (West of North West Cape)	200	Research capture data	One GNS caught on 09/06/02 also noted to be suitable GNS habitat	1

3.2 Diver Survey

Potential aggregation sites identified as suitable for diver surveys in Section 3.1 were further considered based on logistical parameters such as weather and accessibility by available vessels. The visual surveys (Phase 2) were planned to occur following the completion of Phase 1. Weather suitable for undertaking diving surveys did not occur consistently until autumn, which is usually the calmest period during the first half of the year. Consequently Exmouth (Northwest Cape) was selected as the first area to be investigated followed by Augusta (Southwest WA). The Exmouth survey took place between the 4th and 8th of May 2005 and allowed for two dives per day. The Augusta survey took place on the 29th and 30th of May 2005 and allowed two or three dives per day, depending on conditions. Figure 6 shows general locations of surveys. Other survey trips were planned in the Perth area, but were cancelled due to poor weather conditions.

3.2.1 Exmouth

A total of 10 dives (Table 4) were completed at 9 sites between the 4th and 8th May 2005 with a local dive operator (Village Dive) off the coast of Exmouth, Northwest Western Australia (Figure 15). These sites included Dive Site 13 identified in Phase 1 as a potential aggregation site. Other sites surveyed were subsequently recognised by the dive operator employees as areas of known Grey Nurse Shark sightings. Mike Malota (Village Dive) provided various photos and some video footage of individual Grey Nurse Sharks observed at some of the surveyed locations during previous dives over the past year.

Although no Grey Nurse Sharks were observed during this particular survey, each dive site was considered suitable for Grey Nurse Shark habitation based on the physical properties observed at each site. As with known aggregation sites on the east coast of Australia, all Exmouth sites had significant vertical and horizontal reef structure (e.g. fringing coral reef with isolated coral bombies amongst sand/rubble).

Table 4. Details of dive sites surveyed in the Exmouth area between the 4th May 2005 and 8th May 2005 by two divers (Justin Chidlow and Rory McAuley) from the Department of Fisheries WA. All dives were completed between 10:00 am and 1:00 pm.

Dive Number	Site Location	Date surveyed	Max Dive Depth (m)	Dive Time (min)	Visibility (m)	GNS Observed (Y/N)
1	"Jaws" 21° 41.328 S 114° 18.533 E	04/05/05	14	47	8-10	N
2	"Graveyard" 21° 41.477 S 114° 18.401 E	04/05/05	12.8	63	8-10	N
3	"Blizzard Ridge" 21° 47.724 S 114° 08.074 E	05/05/05	13.5	52	15	N
4	"Labyrinth" 21° 47.512 S 114° 08.544 E	05/05/05	11.5	56	10-12	N
5	"The Spit" 21° 37.638 S 114° 22.427 E	06/05/05	19.5	47	15-20	N
6	"East-side Bombies" 21° 41.020 S 114° 20.369 E	06/05/05	8.5	63	10	N
7	"El Dorado" 21° 47.726 S 114° 08.335 E	07/05/05	13.5	56	15	N
8	"Labyrinth" 21° 47.519 S 114° 08.539 E	07/05/05	13	57	15	N
9	"The Maze" 21° 37.554 S 114° 22.792 E	08/05/05	11	58	10-15	N
10	"Whalebone" 21° 39.723 S 114° 20.439 E	08/05/05	11.5	63	10-15	N

3.2.2 *Augusta*

Although no potential Grey Nurse Aggregation sites in the Augusta area were specifically identified in Phase 1 of the project, this area was noted as an area with a number of sightings by local recreational divers and captures by commercial gillnet fishers. Since completion of Phase 1, information on recent and historical sightings/captures provided by a number of local sources became available to suggest that potential sites in this area required further investigation. A detailed examination of this new information relative to reef structure visible on nautical charts revealed that the habitat was suitable for Grey Nurse Shark. The Augusta sites were not identified in Phase 1 because, without prior knowledge of potential Grey Nurse

Shark aggregation sites, it was inevitable that not all sources of information would be captured in the interview process. Furthermore, the Augusta dive location rarely experiences long periods of good weather conditions for diving. As suitable weather conditions at Augusta occurred at a time when it was not possible to launch from the intended boat ramp at Hamelin Bay, diving was undertaken at this location in preference to Dive Sites 4 – 6 in the Cape Leeuwin area identified in Phase 1. Note that the sites accessible from Augusta and Hamelin Bay were nonetheless both within the Cape Leeuwin area.

A total of five dives at five different sites (Table 5) were completed off Augusta in the southwest of Western Australia (Figure 6 and 16) on the 28th and 29th May 2005. Wayne Marshall, a local recreational diver, has personally observed Grey Nurse Sharks at some of these sites and has also heard reports of sightings by other divers over a number of years. Wayne kindly provided his boat and local knowledge to assist in surveying the Augusta sites.

No Grey Nurse Sharks were observed in this particular survey, although it was noted that all sites were suitable Grey Nurse Shark habitat based on the physical properties observed at each site. The dive sites at Augusta were characterised by large granite reefs with caves and ledges, and intermixed with sandy gutters.

Table 5. Details of dive sites surveyed in the Augusta area on the 28th and 29th May 2005 by two divers (Justin Chidlow and Rory McAuley) from the Department of Fisheries WA. All dives were completed between 9:00 am and 12:00 pm.

Dive Number	Site Location	Date surveyed	Max Dive Depth (m)	Dive Time (min)	Visibility (m)	GNS Observed (Y/N)
11	"South East Rocks" 34° 25.291 S 115° 12.867 E	28/05/05	24.5	35	10-15	N
12	"West of South East Rocks" 34° 25.370 S 115° 12.563 E	28/05/05	17	40	10-15	N
13	"Sth East Canyon" 34° 26.416 S 115° 12.293 E	29/05/05	25	35	10-15	N
14	"Nth East Flinders" 34° 24.821 S 115° 12.789 E	29/05/05	18.5	16	10-15	N
15	"Nth Flinders" 34° 24.499 S 115° 12.577 E	29/05/05	14.5	40	10-15	N

3.3 ROV Survey

Due to a variety of factors (Table 6) the investigation of deep-water (>30 m) sites using the ROV camera system was not successful and no surveys of these sites took place. Although the trial of the ROV in surveying Dive Site 10 demonstrated that this particular system had potential for such surveys, the particular ROV unit chosen had some limitations. The ROV is relatively small, which enabled it to be deployed from vessels available for charter, however the unit cannot operate when water currents exceed 1.5 knots and/or the wind strength is above approximately 18 knots. During the planned survey period, water currents and wind strengths were consistently above the ROV's working limit. The ROV obtained for hire experienced a breakdown on the day of a planned survey trip and could not be repaired in time to take advantage of the suitable weather conditions. Due to this delay and the likelihood of unsuitable weather with the onset of winter weather pattern (low pressure systems accompanied by increased swell), no further ROV surveys were undertaken.

Table 6. Schedule for ROV survey.

Date (dd/mm)	Location	Completed	Notes	Reschedule
24 & 25/02	Dive Site 10 – South of Rottnest Island	Yes	Trial of ROV and Towed camera systems	
31/03 & 01/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Cancelled due to unsuitable weather	06 & 07/04
06/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Cancelled due to unsuitable weather and ROV provider losing the services of an operator	13 & 14/04
13 & 14/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Weather not suitable for 13th and vessel not available for 14th	15 & 16/04
15 & 16/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Very strong currents (>1.5knots) in area of planned survey	18 & 19/04
18 & 19/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Currents still too strong and weather not suitable	21 & 22/04
21/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	Weather not suitable for 21st	22 & 23/04
22 & 23/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	ROV breakdown	26 & 27/04
26/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	ROV inoperable	27 & 28/04
27 & 28/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	ROV inoperable and weather not suitable	02 & 03/04
02/04	ROV Site 1 & 2 – SW & NW of Rottnest Island	No	ROV inoperable and weather not suitable	

3.3.1 Survey of Dive Site 10

Towed camera

The angle of the camera was such that it gave a field of view across the top of the reef to the limit of visibility (approximately 10m). The quality of video footage was generally good, although the picture deteriorated when the vessels' speed approached 3 knots, placing strain on the umbilical. Viewing of the footage at the time of recording and subsequent playback revealed that although Dive Site 10 appeared to be suitable habitat (rocky reef intermixed with sandy-bottom areas) for Grey Nurse Shark, no individuals were observed on this particular day.

ROV camera.

The video footage was generally good with high resolution and clear visibility up to approximately 10 m. The ROV was able to investigate areas not accessible by the towed camera system. Viewing of the footage at the time of recording and subsequent playback revealed that although Dive Site 10 appeared to be suitable habitat for Grey Nurse Shark no individuals were observed on the day surveyed.

4.0 Discussion

4.1 Distribution of Grey Nurse Shark off WA

Examination of fishery and research records in combination with detailed interviews of commercial fishers, professional dive operators and members of dive clubs etc. revealed that Grey Nurse Sharks appear to be widely distributed along the WA coast between at least Augusta and Exmouth (Figure 6). This distribution is within the previously recognized range for this species (Last and Stevens, 1994). This species is thought to occur all the way around the Australian mainland (Last and Stevens, 1994) but is rare in the Northern Territory and through the southern extent of its range.

A project that examined movements of few Grey Nurse Sharks using Pop-up archival transmitting tags found that three juveniles moved hundreds of kilometres along the WA mid-west coast between Perth and Kalbarri (McAuley, 2004), suggesting that individual Grey Nurse Sharks may not be restricted to particular localities or habitats. The east coast Grey Nurse Shark population is known to have a complex (i.e. sex and age segregated) seasonal migration pattern (Pollard et al. 1996; Otway and Parker, 2000), while Compagno (1984) suggests this species is migratory throughout much of its distribution. Additionally, movements of tagged Grey Nurse Shark in WA between depths of 20 and 160 m also indicated broad use of the continental shelf (McAuley, 2004). It is clear that Grey Nurse Sharks off the WA coast therefore occur across much of the continental shelf, as has previously been reported by Last and Stevens (1994) for the Australian population as a whole.

This study failed to locate any Grey Nurse Shark aggregations off the western Australian coast. The limited field program precluded any definite conclusions on the occurrence or locations of aggregations. Thus, the lack of verified Grey Nurse Shark aggregation sites in WA from this current study does not indicate that such sites do not exist. Whilst Grey Nurse Sharks in eastern Australia are known to aggregate in depths suitable for recreational diving, it is not known if such aggregations occur at greater depths (e.g. <50 m water) on either the east or

west coasts. Furthermore, as WA has a much smaller human population than the east coast, restricted mainly to discrete metropolitan and regional centres, a lower proportion of the west coast Grey Nurse Shark distributional range has been dived with any frequency. There is also a possibility that west coast Grey Nurse Sharks may not aggregate, to a degree (i.e. numbers, locations, durations), which would result in this behaviour being consistently detectable. Either of these alternatives are possible because the one-off observations employed in this study may have been unsuitable for assessing the presence or lack thereof of Grey Nurse Shark aggregations. However, considering that commercial fishing is the main potential source of incidental mortality of Grey Nurse Shark in WA, and given that the commercial fishing effort over this species' range in WA is decreasing, the status of the stocks previously reported to IUCN (i.e. relatively large and stable) is likely to still hold. Therefore, the failure to detect any Grey Nurse Shark aggregation sites off Western Australia is unlikely to be the result of a seriously overexploited stock. Indeed, although the east coast population of Grey Nurse Shark is listed as Critically Endangered, aggregations are still observed. If the east and west coast populations behaved similarly, then not only would recreational divers off WA have recorded at least a few consistent aggregations, but any such aggregations should still be evident.

In summary, Grey Nurse Shark off western Australia may not

- aggregate to the same degree as in eastern Australia,
- aggregate in depths or areas suitable for recreational SCUBA diving,
- aggregate with sufficient regularity in locations frequented by recreational divers.

4.2 Survey methods to identify Grey Nurse Shark aggregations

Although no Grey Nurse Shark aggregation sites were verified, the study can provide guidelines for potential future surveys.

4.2.1 Tagging

The infrequent occurrence of Grey Nurse Shark captures in commercial fishing gear and general lack of knowledge of where Grey Nurse Shark can reliably be found precludes the use of conventional tagging methods as a means of contributing data that may assist in the identification of aggregation sites. While the archival tags used by McAuley (2004) successfully showed depth and movement patterns, only a small number of sharks were tagged, making this type of tagging an expensive option for identifying aggregation sites.

4.2.2 ROV

ROV surveys appear suitable for surveying limited areas of potential aggregation sites. The towed camera was opportunistically trialled and while it did have some operational advantages over the ROV, the inability to check under ledges or in reef-gutters precludes this method for Grey Nurse Shark visual surveys.

The small ROV system used in this study had the advantage that it could be deployed from relatively small vessels and could be handled without the need for lifting gear (e.g. deck winch). The limitation to working in wind strengths <18 knots could be managed through careful observation of weather forecasts during the planning phase for a trip. However, the limitation imposed by current strengths >1.5 knots could not be managed because there is no system in place to predict currents. These unfavourable environmental conditions could be

compensated for by factoring in or planning several more field days at each site (each potential site would require several trips, each of several days). In terms of planning a sampling strategy, the use of the small ROV therefore poses a risk because days spent at sea can result in no deployment of the ROV but still incur substantial costs. The best way to manage this risk would be to determine which times of the year are likely to have the weakest currents in the depth ranges to be surveyed by ROV.

4.2.3 SCUBA

SCUBA has been used successfully on the east coast to survey Grey Nurse Shark aggregation sites (Otway and Parker, 2000; Otway et al., 2003). There is no doubt that this method works, helped by the relatively inactive nature of Grey Nurse Sharks at particular reefs when divers follow set protocols to minimise shark disturbance. However, SCUBA is not an appropriate method for surveying waters deeper than 30 m. This is particularly the case when volunteers are used in a survey program because the majority of recreational divers will not have the training required for deep-water diving. The approach proposed in this study, which was to visually survey suitable habitats in areas close to where Grey Nurse Shark had previously been observed, appears to be the only practical, low-cost technique.

4.2.4 Sampling Protocols and Experimental Design

Single observations at potential sites are an ineffective means of searching for Grey Nurse Shark aggregation sites. Even if one Grey Nurse Shark had been observed at some of the surveyed sites, this would not have been sufficient evidence to indicate the presence of an aggregation site. Each site selected for survey in this current study was ranked according to the number of sightings/captures and the suitability of the benthic habitat. An aggregation is considered to be five or more Grey Nurse Sharks present at the same site at the same time (Otway and Parker, 2000). The identification of key aggregation sites off eastern Australia was based on knowledge gained over many years (decades) by the recreational diving community. There are undoubtedly reefs off eastern Australia at which Grey Nurse Shark occurs but that would not constitute an aggregation site. Indeed, a comprehensive visual (SCUBA) survey of ~60 sites over nearly two and half year off NSW and southern QLD found that nearly 90% of observed Grey Nurse Shark occurred at only 14 sites (Otway et al., 2003).

A more appropriate strategy to search for aggregation sites off WA would be to survey a reduced number of sites over a greater temporal and spatial scale. However, given the substantial spatial and temporal variability along the entire NSW coast and the concomitant patchiness of key aggregation sites (Otway et al, 2003), selection of Western Australian sites to survey over longer periods remains problematic because of the lack of any means of prioritizing sites beyond that which was undertaken in this project. Even in NSW there has been no clear determination why some habitats are used for aggregation and other apparently suitable habitats are not.

4.2.5 Fixed underwater camera

An alternative visual method of undertaking longer-term sampling might be to use underwater cameras fixed in place for a set period of time (e.g. weeks). The technology is now available to place cameras in situ and take images at predetermined intervals. Baited underwater cameras could initially be used to detect sites that are at least visited by Grey Nurse Shark, while a time series of images (from unbaited cameras to avoid biasing retention of Grey Nurse Shark in an area) could permit quantification of the frequency at which Grey Nurse Shark visit a site.

4.2.6 Community-based survey program

A program of visual surveys by the diving community (dive shops, charter boats, dive clubs, individuals) in eastern Australia was able to undertake 10 surveys over a period of ~2.5 years, with an average of 57 sites sampled on each survey (Otway et al., 2003). This more extensive survey recorded several hundred Grey Nurse Shark sightings. A geographically wide sampling program would be less likely to succeed in WA for two reasons. Firstly, the sites surveyed off eastern Australia were those at which Grey Nurse Sharks were known to aggregate; the aim was to map the sites as well as determine the abundance of Grey Nurse Shark. Grey Nurse Sharks are known to aggregate in very specific locations at particular reefs, whereas in this west coast study such precise spatial information is not available. Secondly, the much lower human population along much of the WA coast would preclude a similar level of diver coverage to that undertaken off eastern Australia. However, recreational divers could carry out longer term monitoring of a few select shallow-water sites off WA. Such a program would require ongoing management (e.g. training, co-ordination, data entry etc) but would nonetheless be a relatively cost-effective method of extending the search for Grey Nurse Shark aggregation sites. This may particularly apply to the Perth and Exmouth regions where there are many divers and many reported sightings of Grey Nurse Shark.

4.3 Management of Grey Nurse Shark in WA

The main source of mortality of Grey Nurse Sharks in WA has historically been commercial gillnet fishing. However, Grey Nurse Shark was never a targeted species. Over the eight years prior to 1997, analysis of catch rate data for WA Grey Nurse Sharks suggests a relatively large and stable population (Pollard et al., 2003). Since 1997, there have been effort reductions in the demersal gillnet fisheries in response to sustainability concerns for other shark species (*Furgaleus macki, Carcharhinus obscurus*). These reductions should benefit western Grey Nurse Shark by reducing their incidental capture. Future management of these fisheries is likely to include an effort ceiling of between 20-50% of the fisheries peak effort levels, which should result in a proportional reduction in captures. Additionally, since it's protection in 1997, fishers no longer retain Grey Nurse Sharks. Given their observed low rates of post-capture mortality (McAuley, 2004) their protection under the EPBC Act (October 2001) and the Wildlife Conservation Act (1950) is likely to have further reduced mortality. This current study identified large unfished areas within the geographic boundaries of the demersal gillnet fishery, which combined with the area closed to shark fishing between NW Cape and Steep Point since 1993 and the recent (2005) 80% reduction in fishing area in the WA North Coast Shark Fishery, potentially offers significant refugia to Grey Nurse Shark in WA.

In response to the increased demand for shark fin and the resultant increased targeting of large shark species, WA now has regulations to prohibit landing of fins without trunks. DNA techniques are also now available as a means of identifying Grey Nurse Shark body parts (McAuley et al., 2005). These measures should deter illegal, unrecorded retention of Grey Nurse Shark.

The level of Grey Nurse Shark mortality from recreational fishing has not been quantified, but this sector is not known to specifically target sharks, preferring scalefish. Anecdotal evidence indicates however that Grey Nurse Sharks are caught and occasionally landed by recreational fishers. Incorrect species identification and the lack of knowledge on the protected status of Grey Nurse Sharks are thought to contribute to ongoing recreational fishing mortality. Although shown in relevant recreational fishing brochures, identification guides and government websites as a

protected species, an increased educational program to ensure correct identification of Grey Nurse Sharks and promote their safe release should reduce recreational fishing related mortality of this species.

4.4 Conclusion

In consideration of the apparent size and stability of the population prior to 1997 and the subsequent decreases in effort in the gillnet fisheries, the current status of the western population of Grey Nurse Shark is likely to be similar to or better than that in 1997.

Despite this study being unable to confirm the presence of any Grey Nurse Shark aggregations off WA, available information suggests that Grey Nurse Sharks are still widely distributed along the WA coast and are still regularly encountered, albeit with little or indeterminate frequency. There is a possibility that Grey Nurse Sharks do not aggregate to the same degree or in the same areas/habitat types as off the east coast. If the west coast population aggregates in deeper waters or in habitat not suitable for setting gillnets, their vulnerability to commercial fishing is unlikely to change, hence the population should remain stable or be able to increase from it's level prior to effort reductions in the temperate gillnet fishery. Given the ongoing increased level of management for all WA commercial fisheries, which in most cases equates to reductions in fishing effort (both for line and net fisheries), it is likely that fishing mortality of Grey Nurse Sharks will decline further. As such, knowledge of whether Grey Nurse Shark aggregation sites exist off WA does not currently appear to provide any potential additional benefits to how this species is currently managed in WA. Thus, there may be little value in continuing to search for aggregation sites given the status of the stock, particularly when more pressing issues relevant to the sustainability of other elasmobranchs have been identified. The commercially exploited elasmobranchs of current concern in WA waters are dusky, sandbar and whiskery sharks (Gaughan and Chidlow, 2005). It was concern for the status of these key commercial species that has driven the ongoing effort reductions in the shark fishery. Other non-targeted elasmobranchs that require more data to clarify their status include sawfish (Family Pristidae) and *Glyphis* sp. A and *Glyphis* sp. C. Outside of Western Australia, the Critically Endangered status for the east coast Grey Nurse Shark indicates that this population be given a significantly higher research priority than western Grey Nurse Shark.

Although the western Grey Nurse Shark population appears to be reasonable stable, the inherent vulnerability of this strongly k-selected species (late maturity, low fecundity and slow growth) warrants that the population status be regularly reviewed. The approach taken here has proven to be risky in terms of obtaining clear results; the project was thus unable to determine whether western Grey Nurse Sharks aggregate or not. As such, considerably more investment in visual surveys would likely be required before this technique could be expected to result in data of sufficient robustness to be confidently used to assess the status of the population.

The most cost-effective long-term method of undertaking regular population assessments would appear to be through careful review of the catch rate data from the commercial fisheries. Because fishers no longer report Grey Nurse Shark catches, this approach is not currently possible. Investment in an education program on the reporting requirements may help to overcome this deficiency in reporting.

5.0 Figures

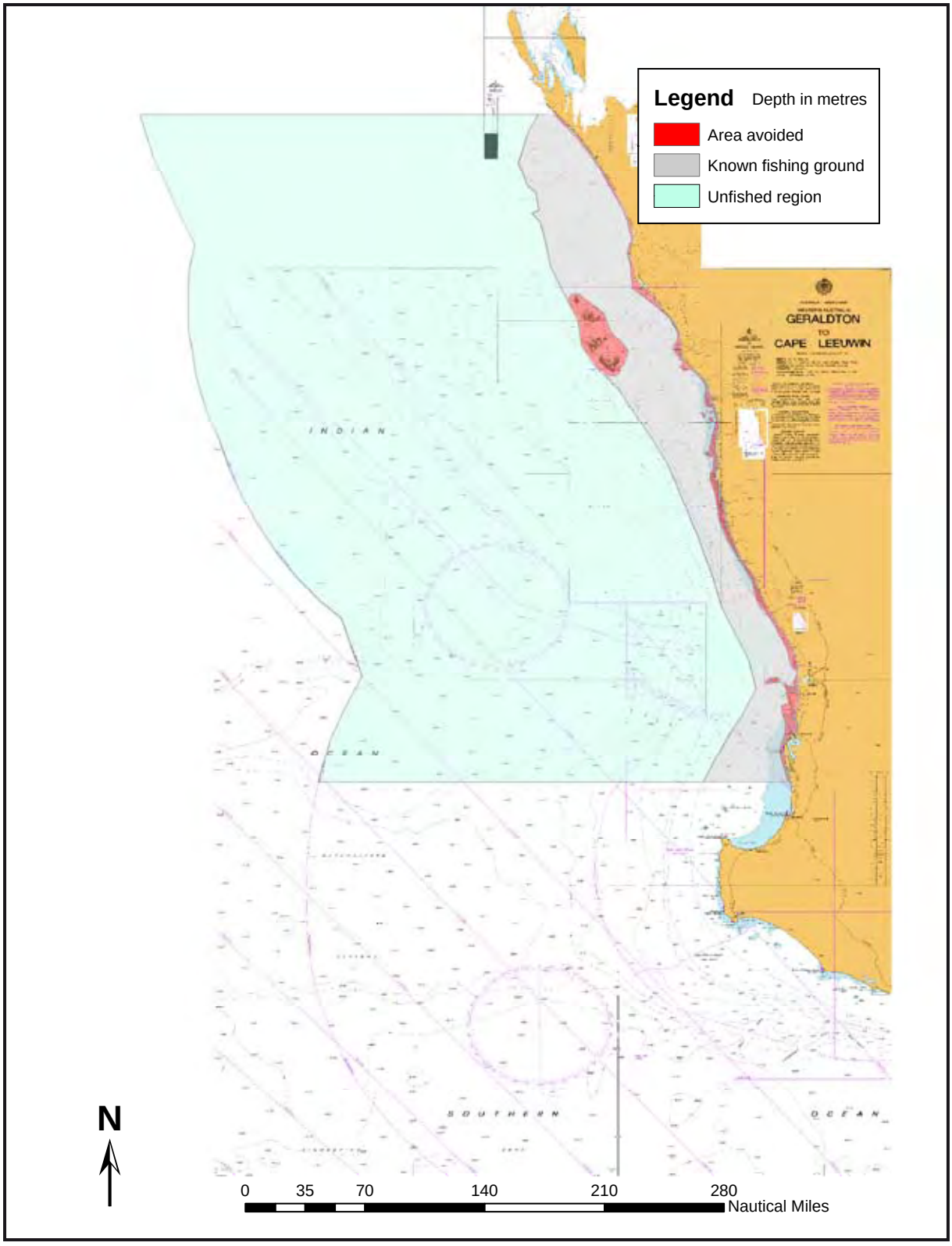

Figure 3. West Coast demersal gillnet and longline fishery.

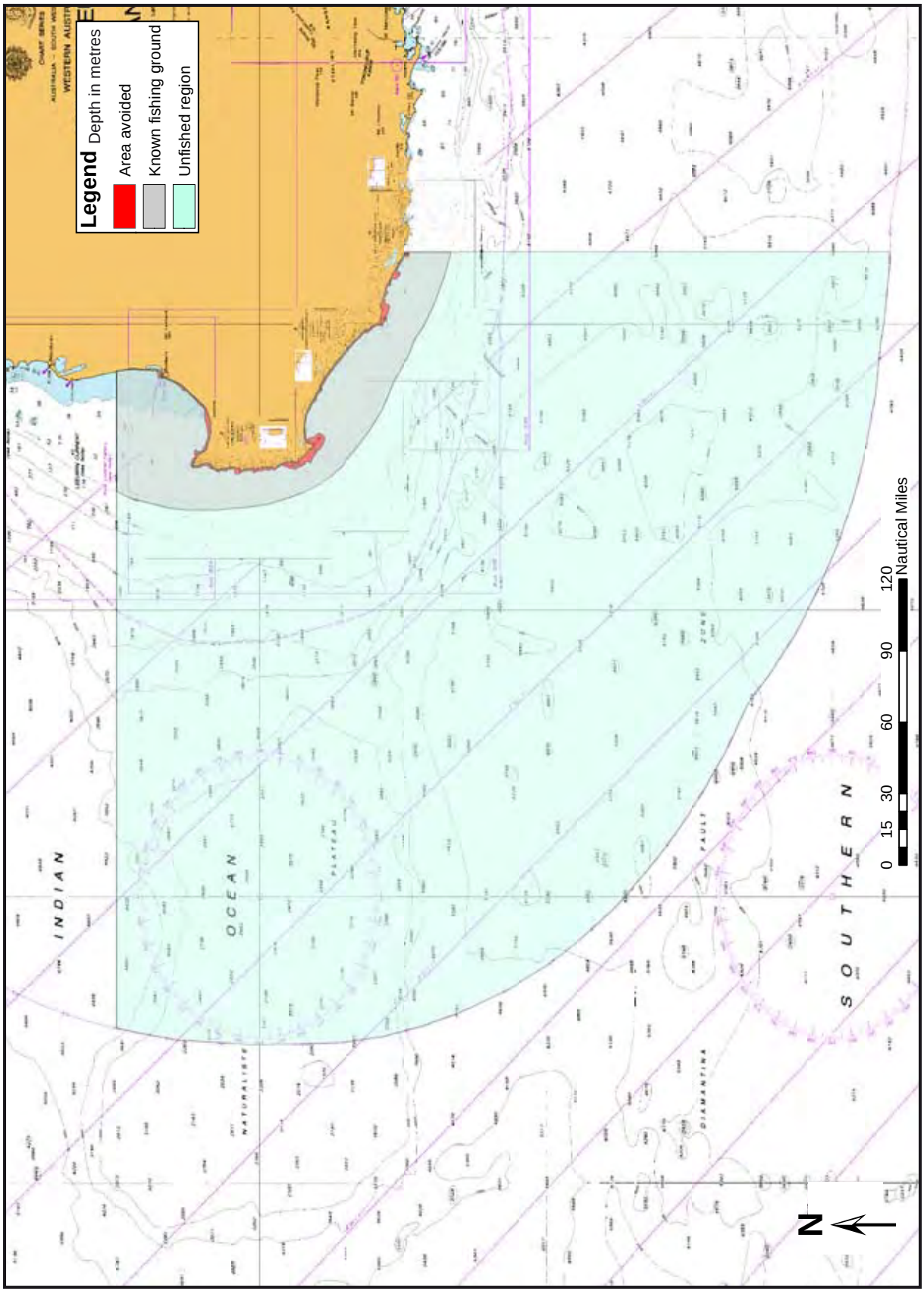

Figure 4. Southern demersal gillnet and longline fishery Zone 1.

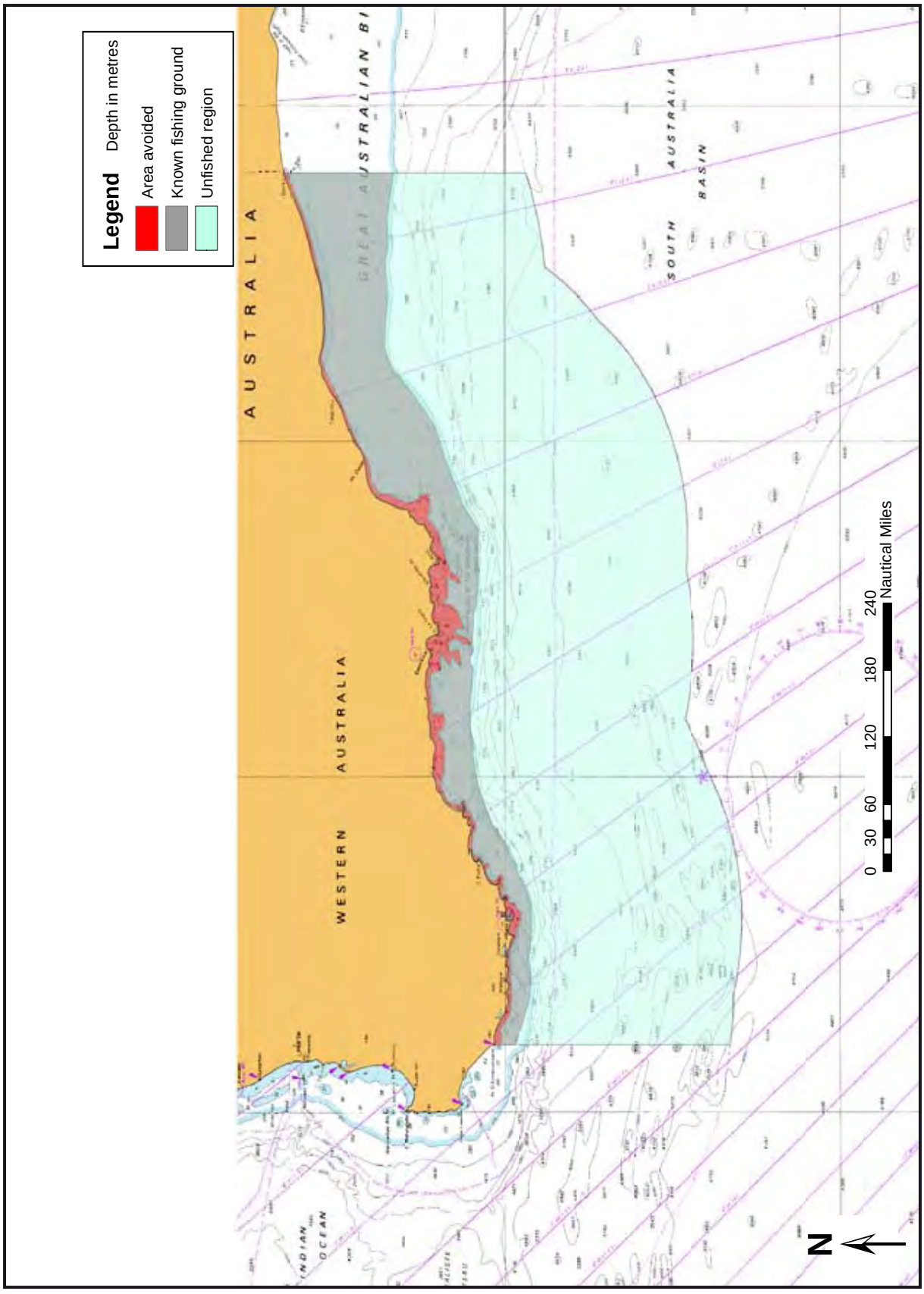

Figure 5. Southern demersal gillnet and longline fishery Zone 2.

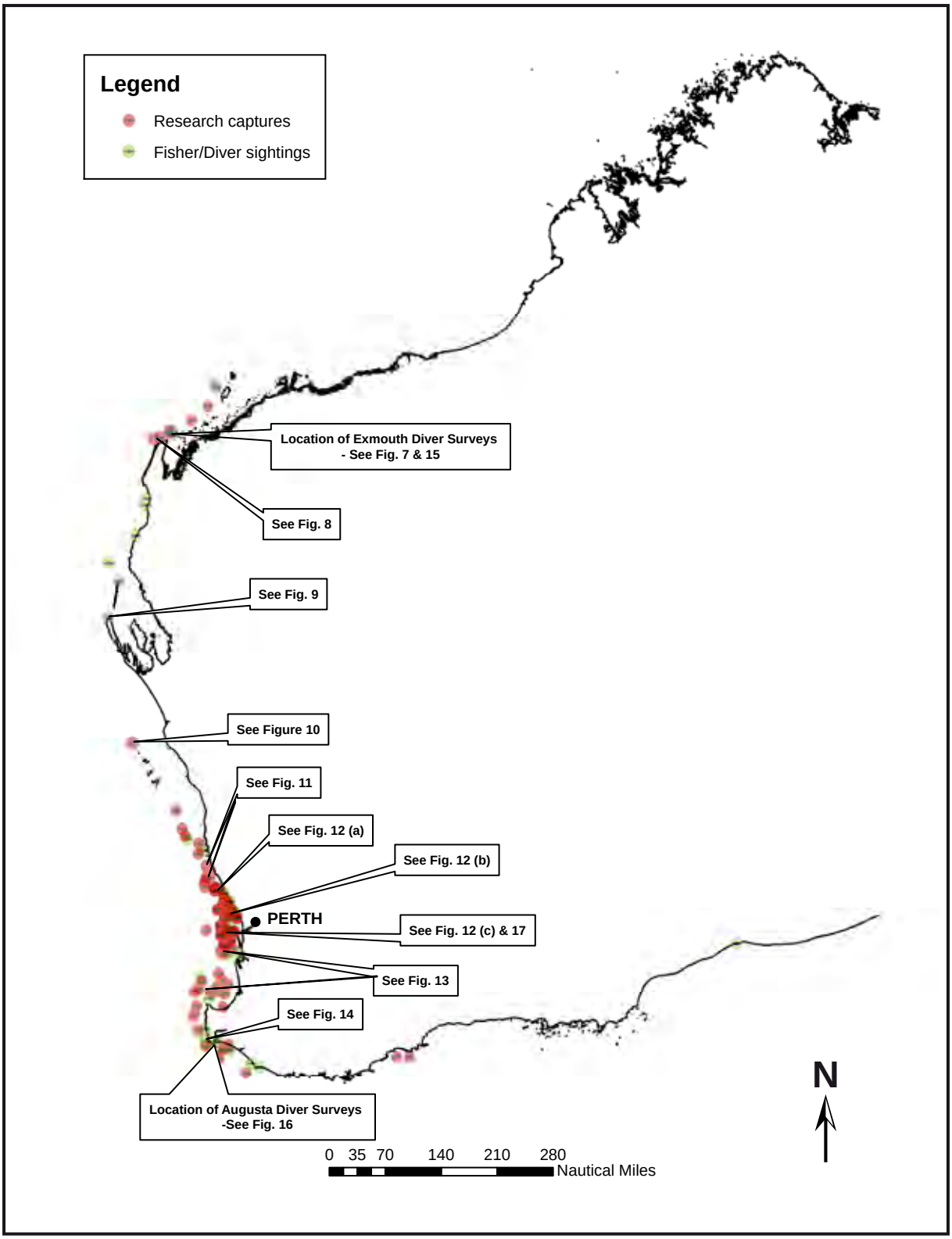

Figure 6. Grey Nurse Shark research captures 1994 - 2004 and fisher/diver sightings (see Table 1).

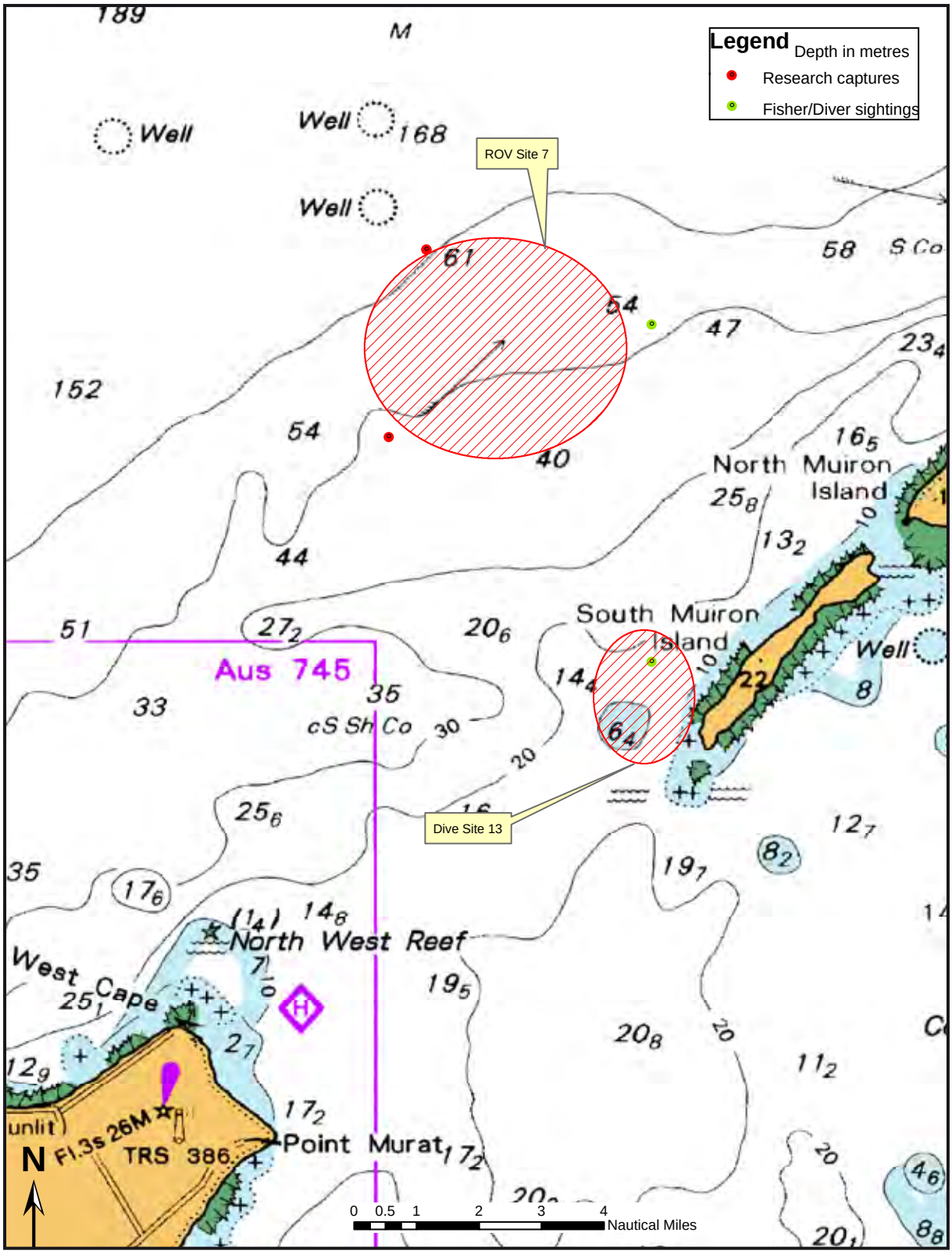

Figure 7. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

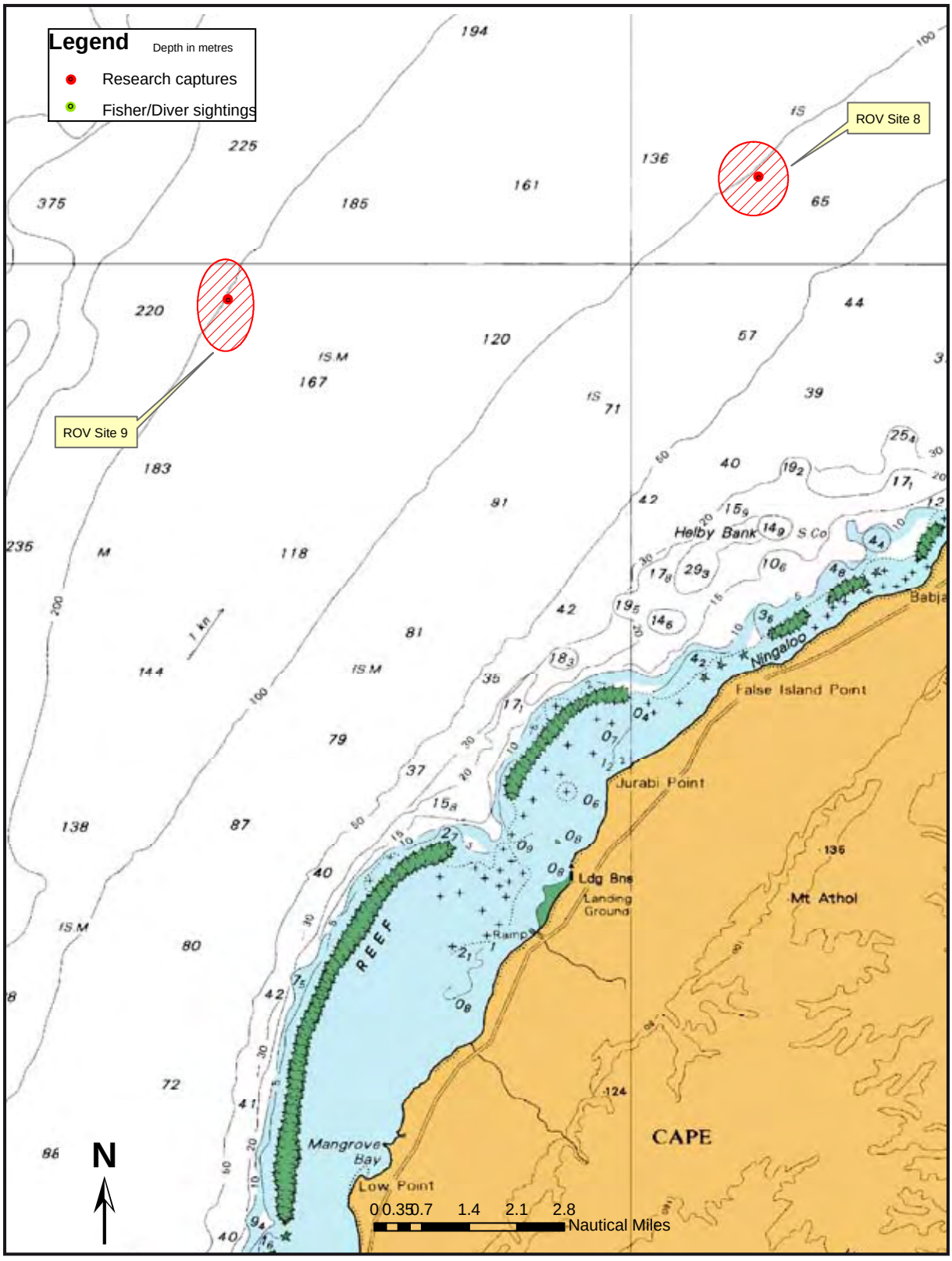

Figure 8. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

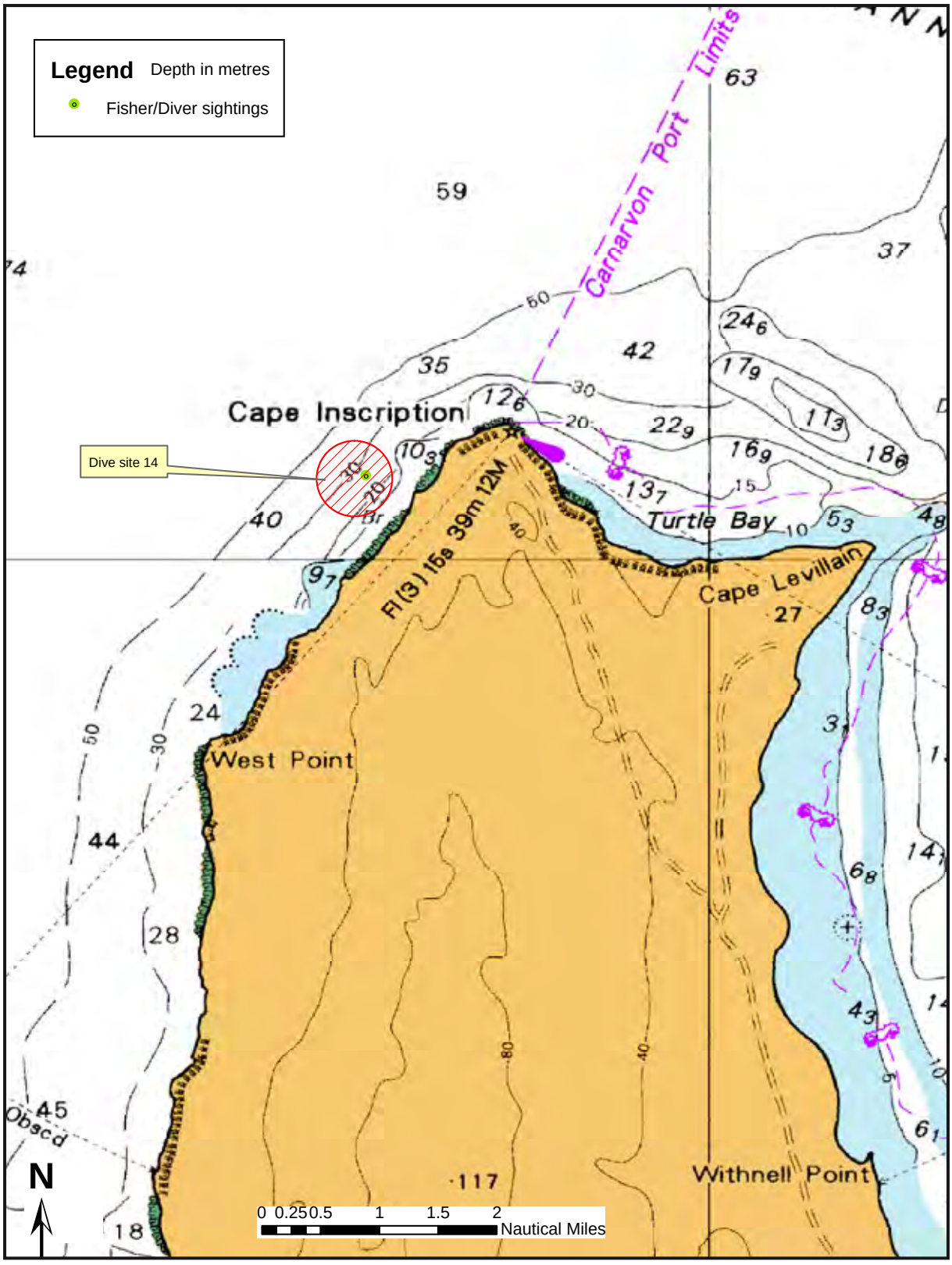

Figure 9. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

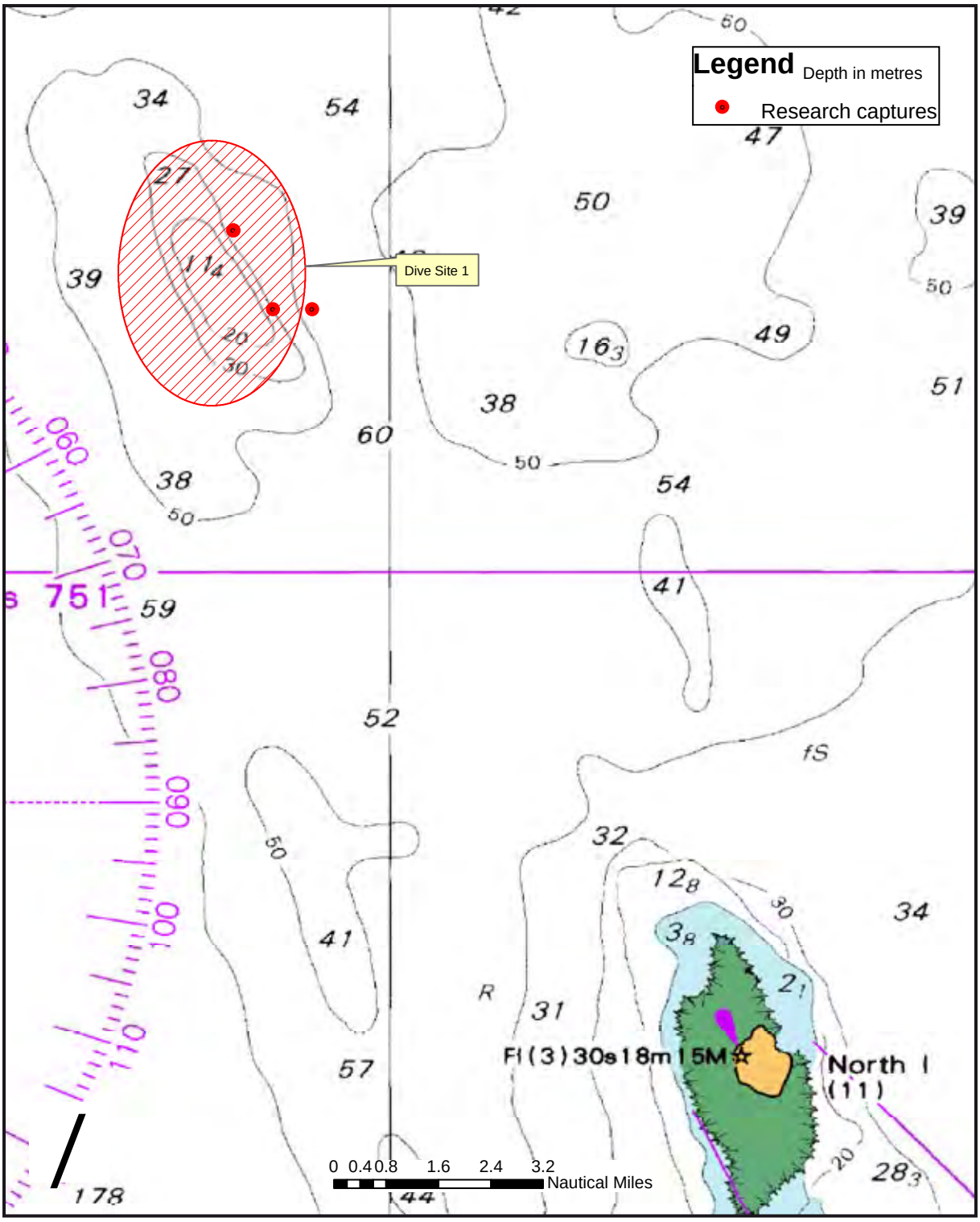

Figure 10. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

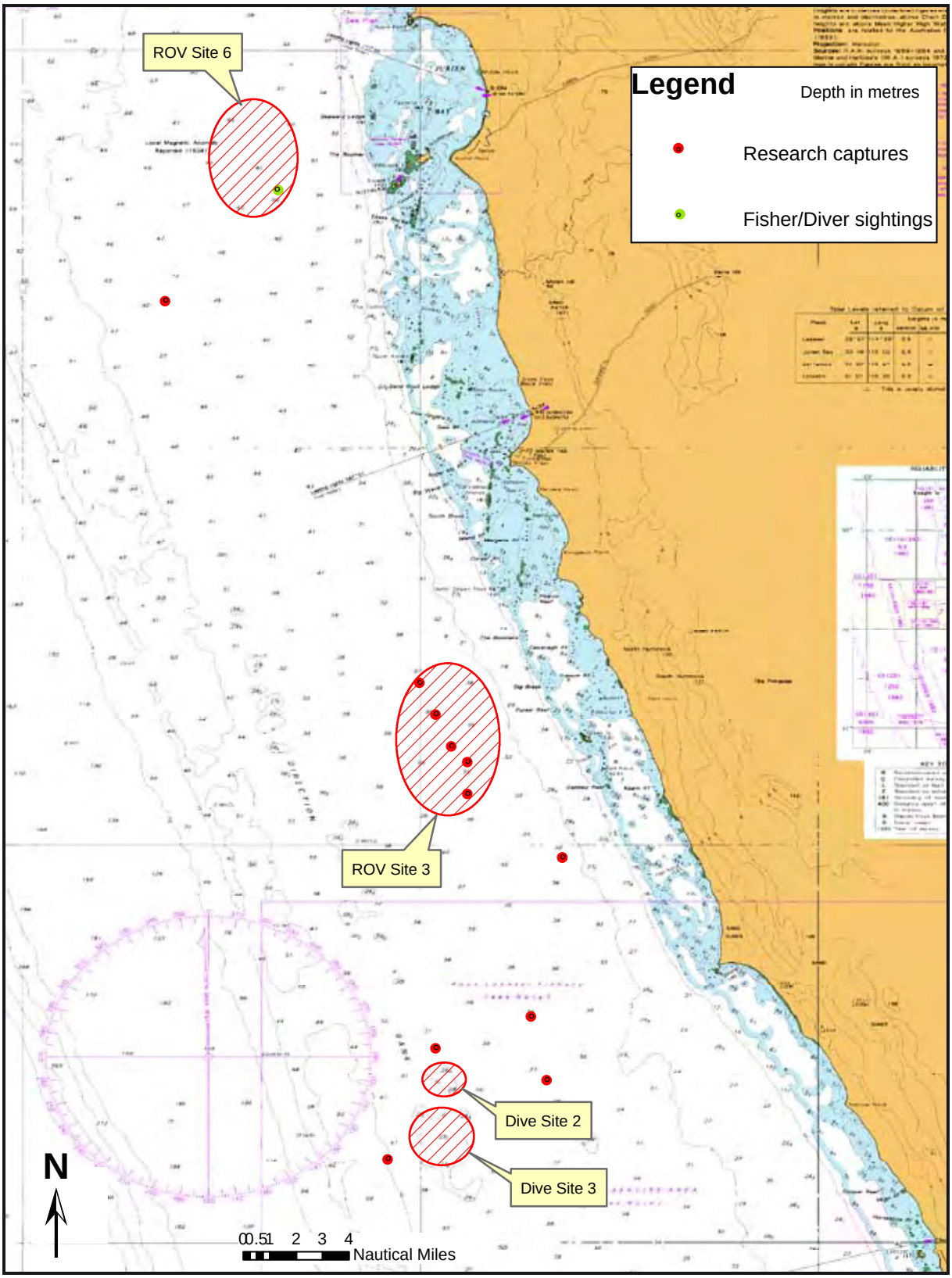

Figure 11. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

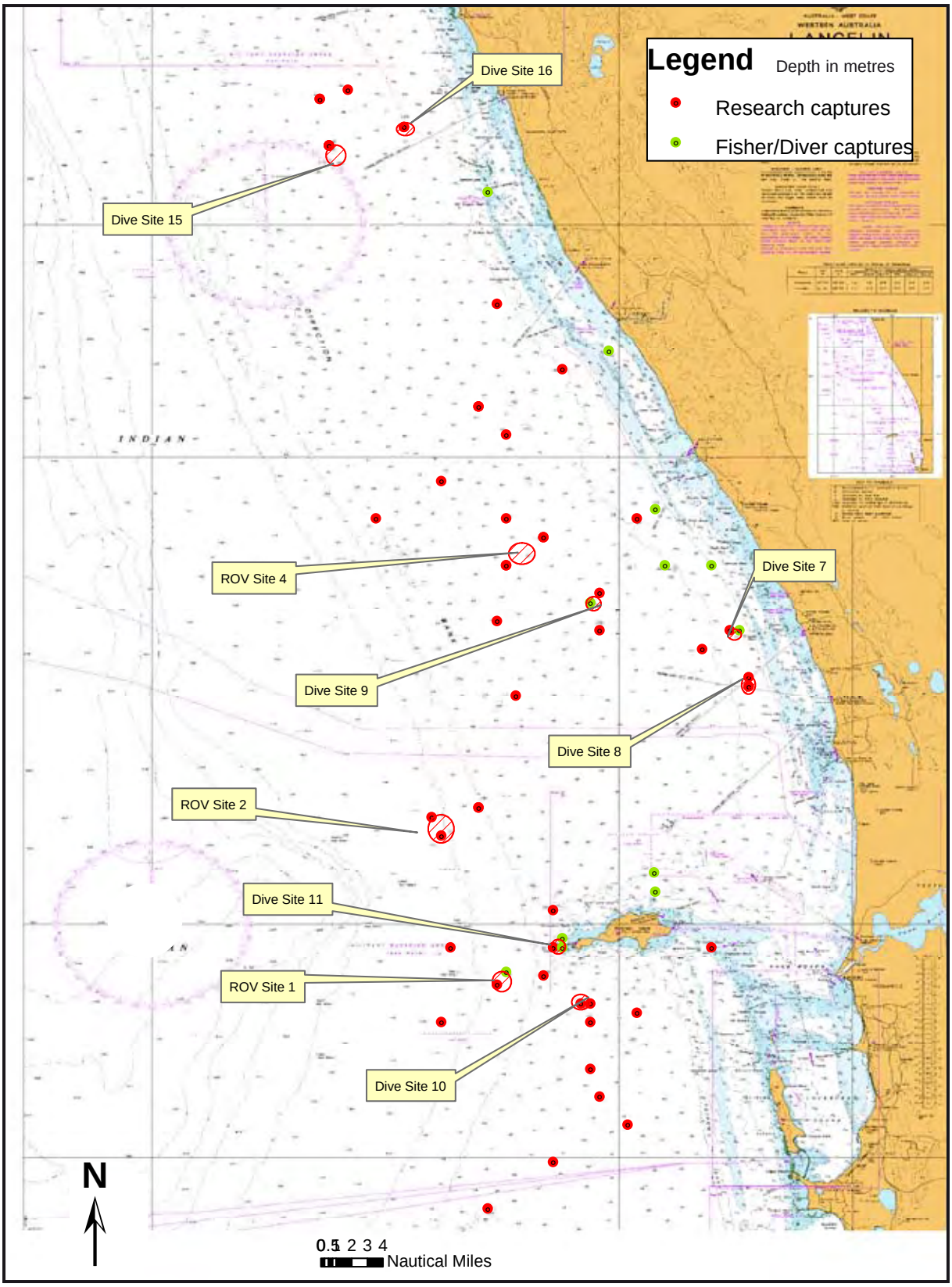

Figure 12. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

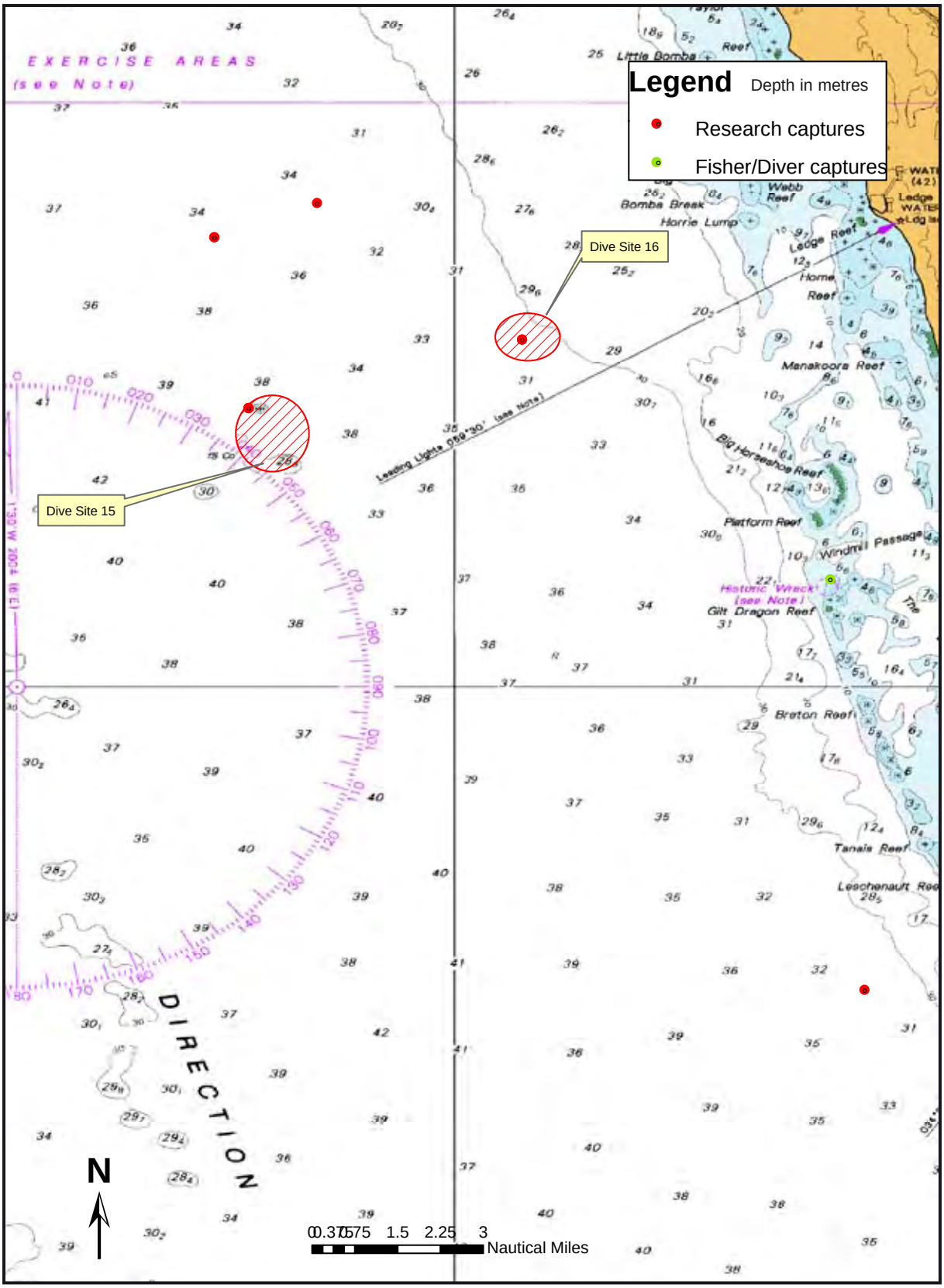

Figure 12(a). Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

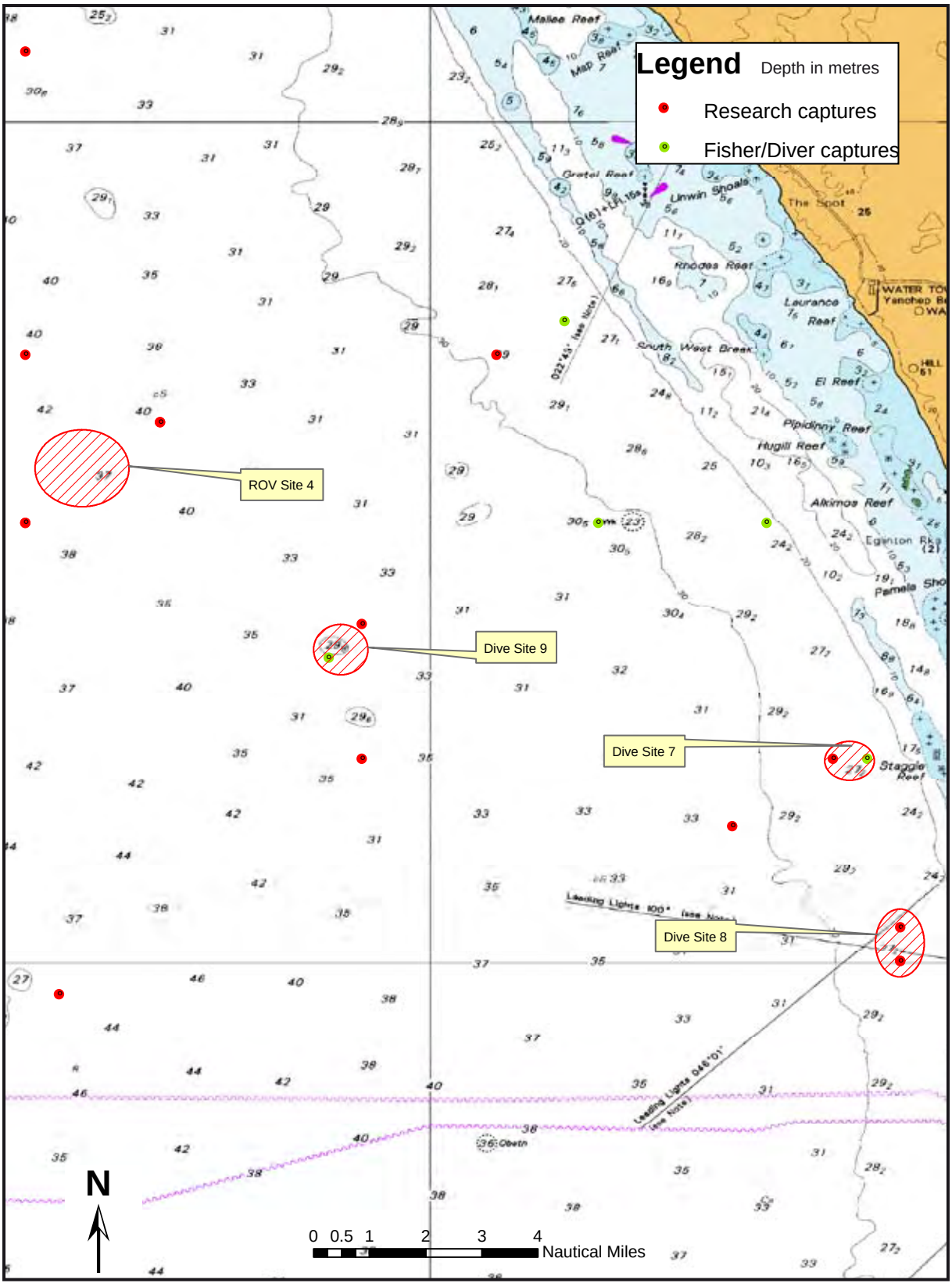

Figure 12(b). Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

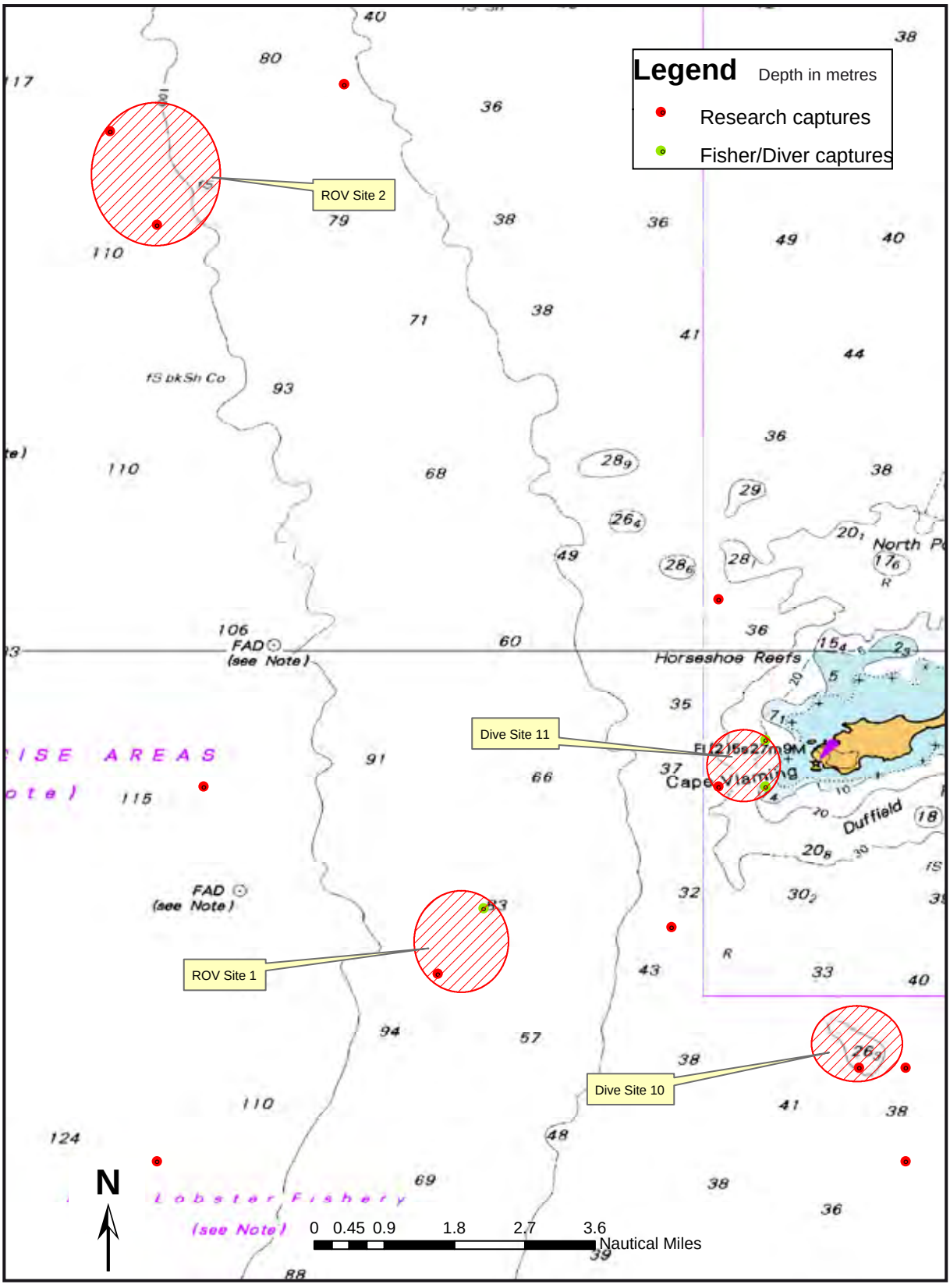

Figure 12(c). Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

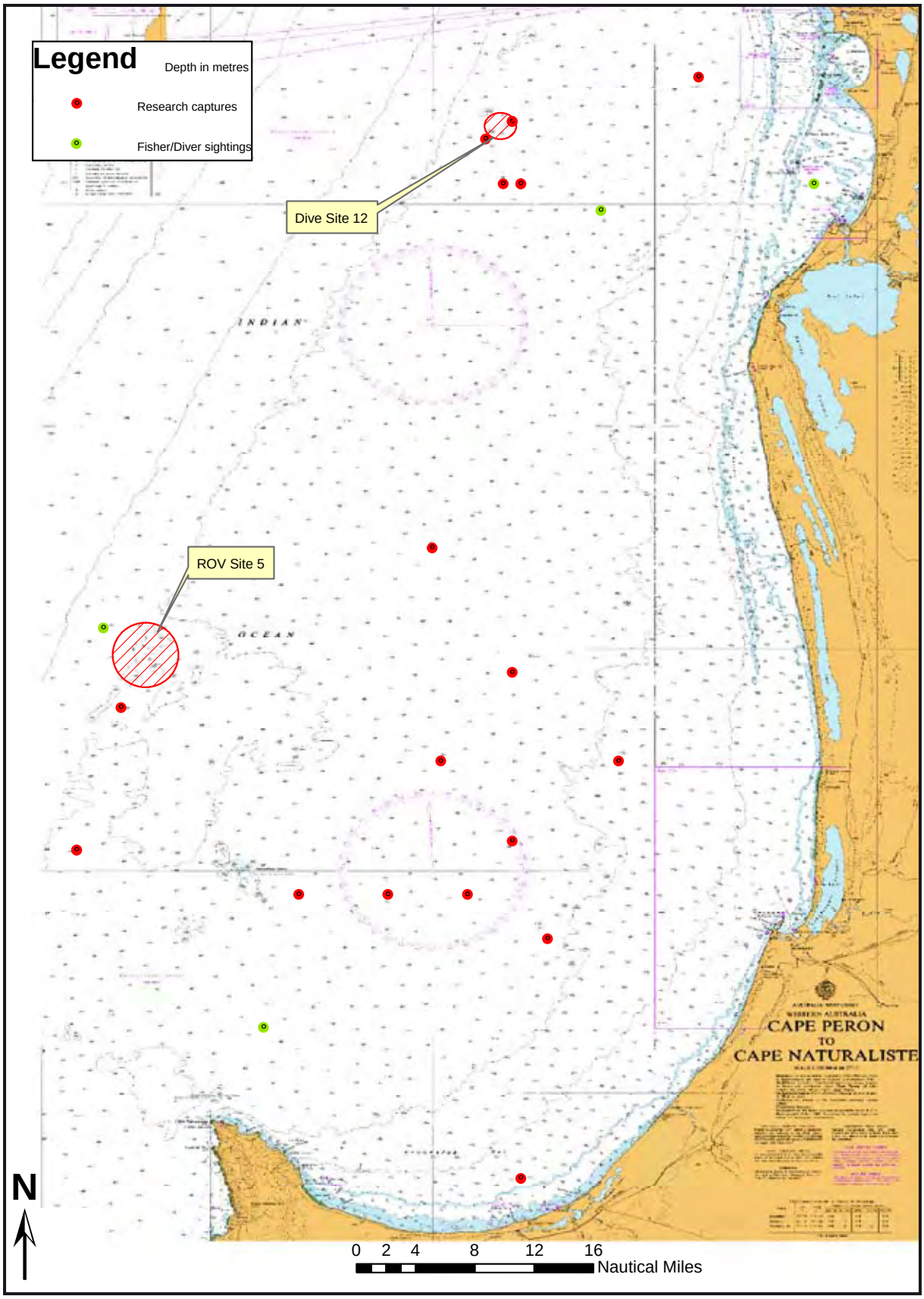

Figure 13. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

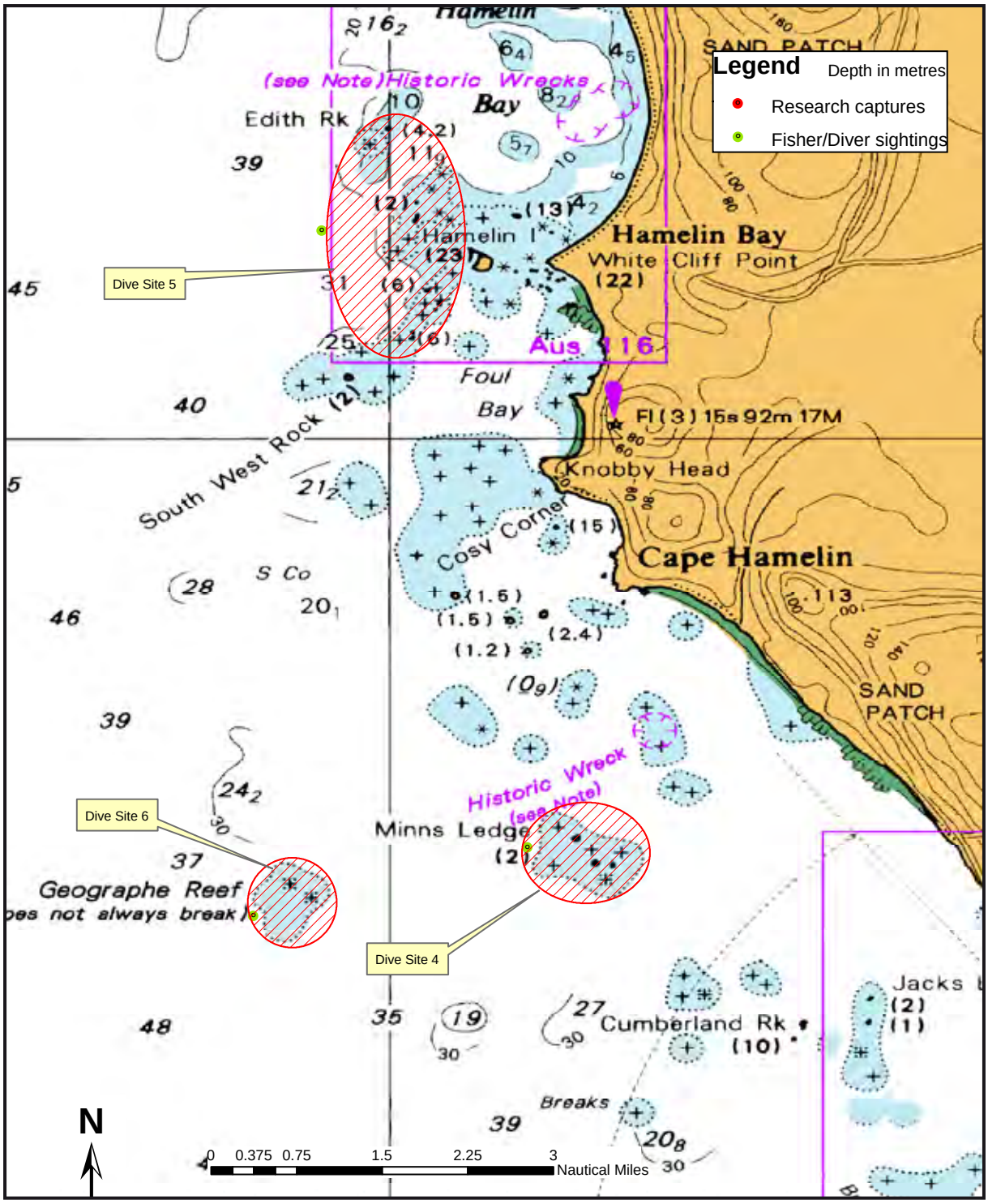

Figure 14. Potential Grey Nurse Shark aggregation sites suitable for diver and ROV survey.

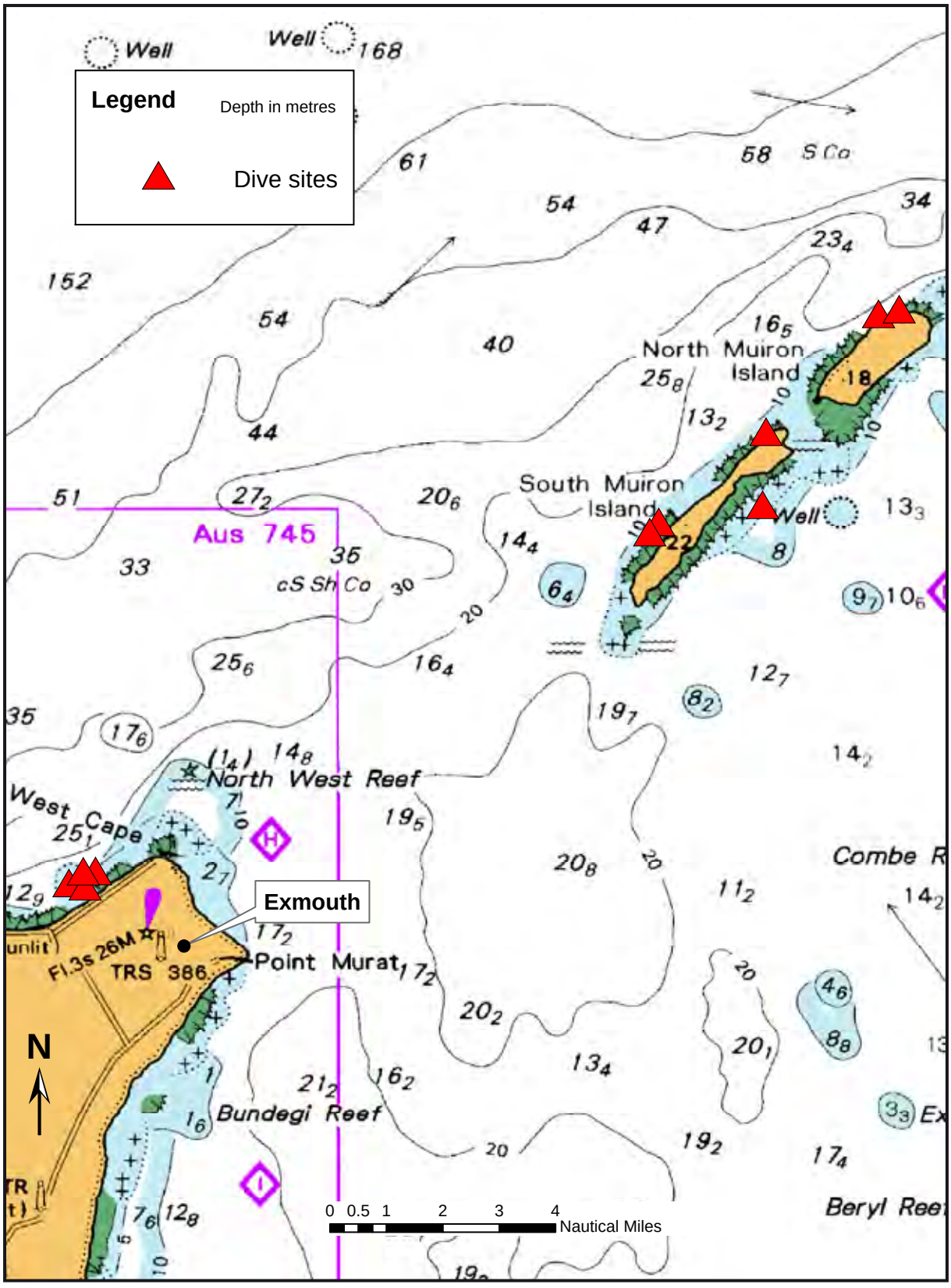

Figure 15. Location of dive sites surveyed in the Exmouth area.

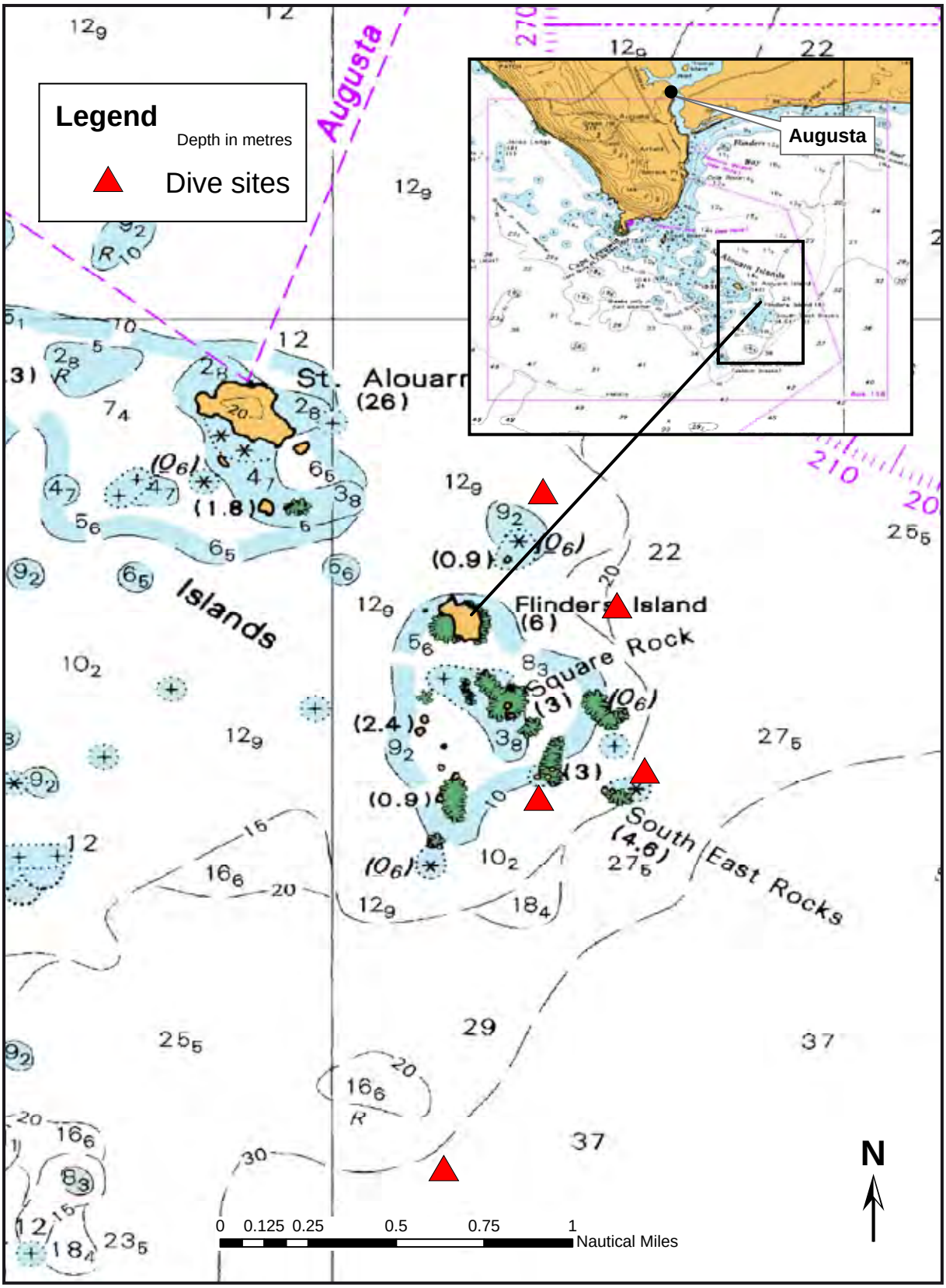

Figure 16. Location of dive sites surveyed in the Augusta area.

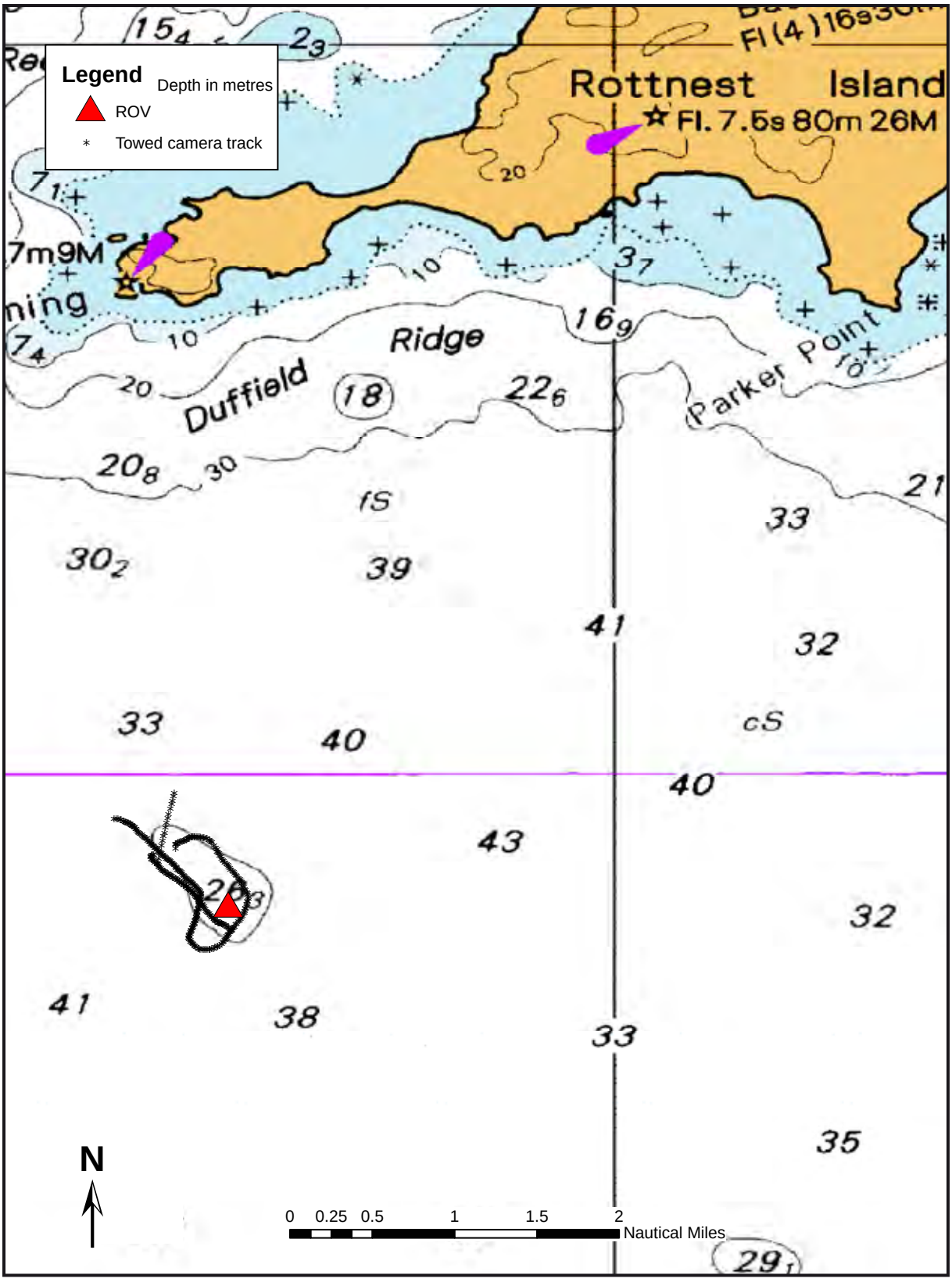

Figure 17. Survey of Dive Site 10.

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