

CHAPTER 4:

**DESCRIPTION OF THE
AFFECTED ENVIRONMENT**

FINAL REPORT



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CHAPTER 4. DESCRIPTION OF THE ENVIRONMENT

The description of the environment contained in this chapter encompasses the Namibian coast and coastal waters around, and immediately adjacent to, Mining Licence 170 and, where appropriate, provides information on the coast between Henties Bay, Namibia and Lüderitz (Figure 4.1) in order to place the ML170 Area in context.

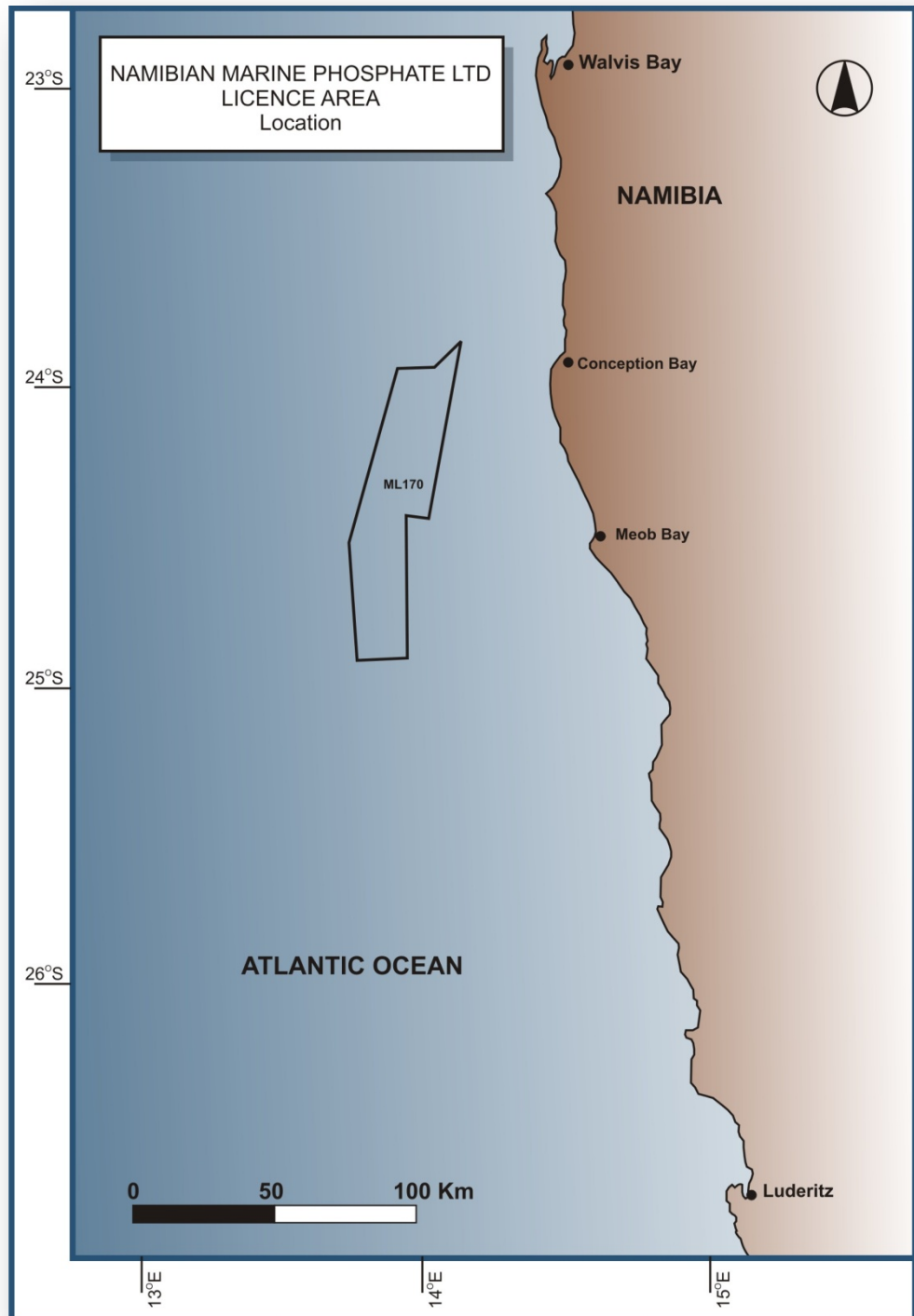


Figure 4.1:
Location of the Mining Licence Area

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4.1 MARINE ENVIRONMENT

The nature of the marine environment is presented as a series of short descriptions of its important constituents and summarised in the following sections.

4.1.1 Geology and Regional Setting

4.1.1.1 Introduction

Namibian Marine Phosphates intends to dredge the phosphate deposit off the coast of Central Namibia. The conditions prevailing in this marine environment has led to the formation of a massive deposit of phosphate-rich (P_2O_5) sediments. The following section discusses the regional geological context, the formation of the deposit, and other sedimentary formations relevant to the proposed dredging operations.

Three main phosphorite types have been identified on the Namibian continental shelf, these deposits are geographically distinct. They are: phosphorite sand, rock phosphorite and concretionary phosphorite. The Phosphorite sand is further subdivided into pelletal phosphorite and glauconitized phosphorite. Both the pelletal and glauconitized pelletal phosphorite varieties are found on the middle and outer continental shelf and have been dated radiometrically as pre-Quaternary, probably Miocene in age. Concretionary phosphorite forms today by slow authigenic growth in the interstitial waters of a Holocene diatomaceous mudbelt centred over the inner and middle continental shelf off Walvis Bay, Rogers and Bremer (1991). The phosphorite sand of Miocene age on the middle continental shelf is the target mineral deposit of this project.

4.1.1.2 Regional Geology and Sea Level Changes

The western shelf is underlain by a complex assemblage of Tertiary (65 to 2.6 Ma) strata (Figure 4.2). The shelf is marked by many planes of erosion, rapid lithological change and, various structural attitudes that provide evidence of the structural activity of this region. The history of major transgressions and regressions is of particular importance with regard to the formation of phosphorites, Coles *et al.* (2002). These transgressions and regressions are summarized as: a major Palaeocene-Eocene (55.5 Ma) transgression was followed by a regression at the end of the Eocene (55.8 to 33.9 Ma) period, eroding a bulk of the early Tertiary on land sediments. A second major transgression occurred in the Mio-Pliocene (5.3 Ma) transgression-regression occurring at the end of the Miocene (23 to 5.3 Ma). Quaternary (2.59 Ma to present) sea-level movement involved the cutting of the Last Interglacial terrace (125 000 BP) approximately 5 m above mean sea level, was followed by the Last Glacial Maximum (18 000 BP) when sea level reached approximately 120 m below present level, Coles *et al.* (2002).

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Era	Period	Epoch	Time Scale	
			Present	
CENOZOIC	QUATERNARY	Holocene	10,000 years ago	
		Pleistocene	1.8 million years ago	
	TERTIARY	NEOGENE	Pliocene	5.3 million years ago
			Miocene	23.8 million years ago
		PALAEOGENE	Oligocene	33.7 million years ago
			Eocene	54.8 million years ago
			Palaeocene	65 million years ago

Figure 4.2: Geological time scale

Ramsay and Cooper 2002 summarise a range of sea-level indicators for emergent and submerged conditions on and off the South African coastline (Figure 4.3). From this a revised Late Quaternary (2.59 Ma to present) sea-level curve from the test Pleistocene (130 000 years) to the Holocene (last 10 000 years) has been established. The curves origin is at 130 000 years ago during the Last Interglacial, when the sea level was approximately 2 m above present. From that point on a highly fluctuating and slow downward trend occurs, until the Last Glacial Maximum lowstand (17 000 years ago) is reached with water depths of -120 m.

The area of interest for the proposed phosphate mining was significantly affected by these (and earlier) major changes of sea level and it is important to understand the shelf dynamics and the resultant development and distribution of these extensive phosphate deposits.

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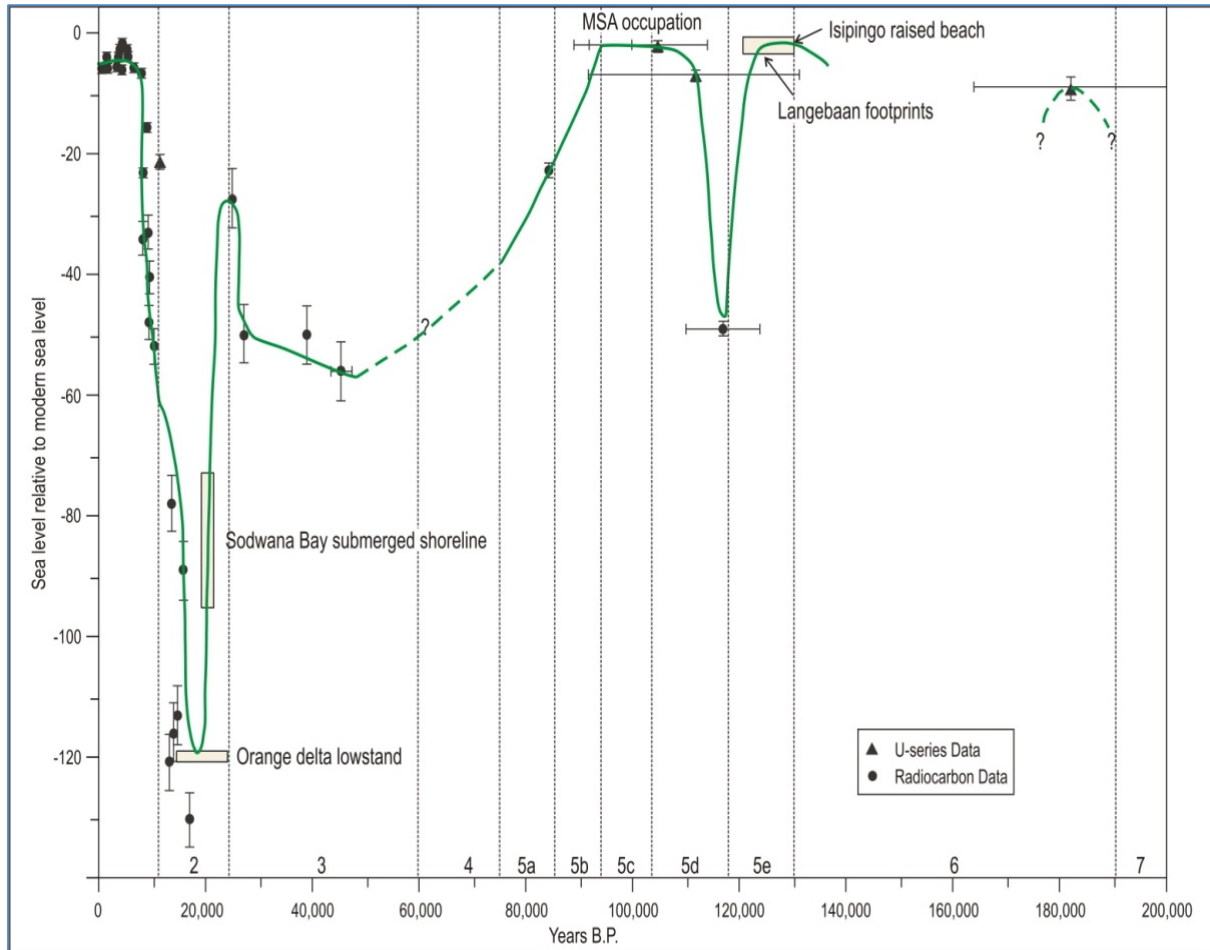


Figure 4.3: Sea-level curve for past 200,000 years, Former shorelines are shown as colour filled blocks (from Ramsay & Cooper 2002).

4.1.1.3 Discovery of Phosphates

The first reports of the presence of phosphate off the southern African west coast were made by Russian geologists such as Baturin (1969), and Emelyanov and Senin (1969). Coinciding with these publications work was undertaken by the Marine Geoscience Unit of the University of Cape Town, which was engaged in detailed exploration of the southern African continental margins, which ultimately led to accurate regional maps of the phosphorite deposits being presented in a number of publications e.g. Rogers (1977), Bremner (1978) and Birch (1971; 1975).

Bremner (1992) undertook a detailed evaluation of the phosphorite deposits off the Namibian coast between Hottentot Bay and Swakopmund in the north. Birch (1975) indicated that rocks on the mid and outer shelf were most likely to be phosphatic, with > 5% P₂O₅.

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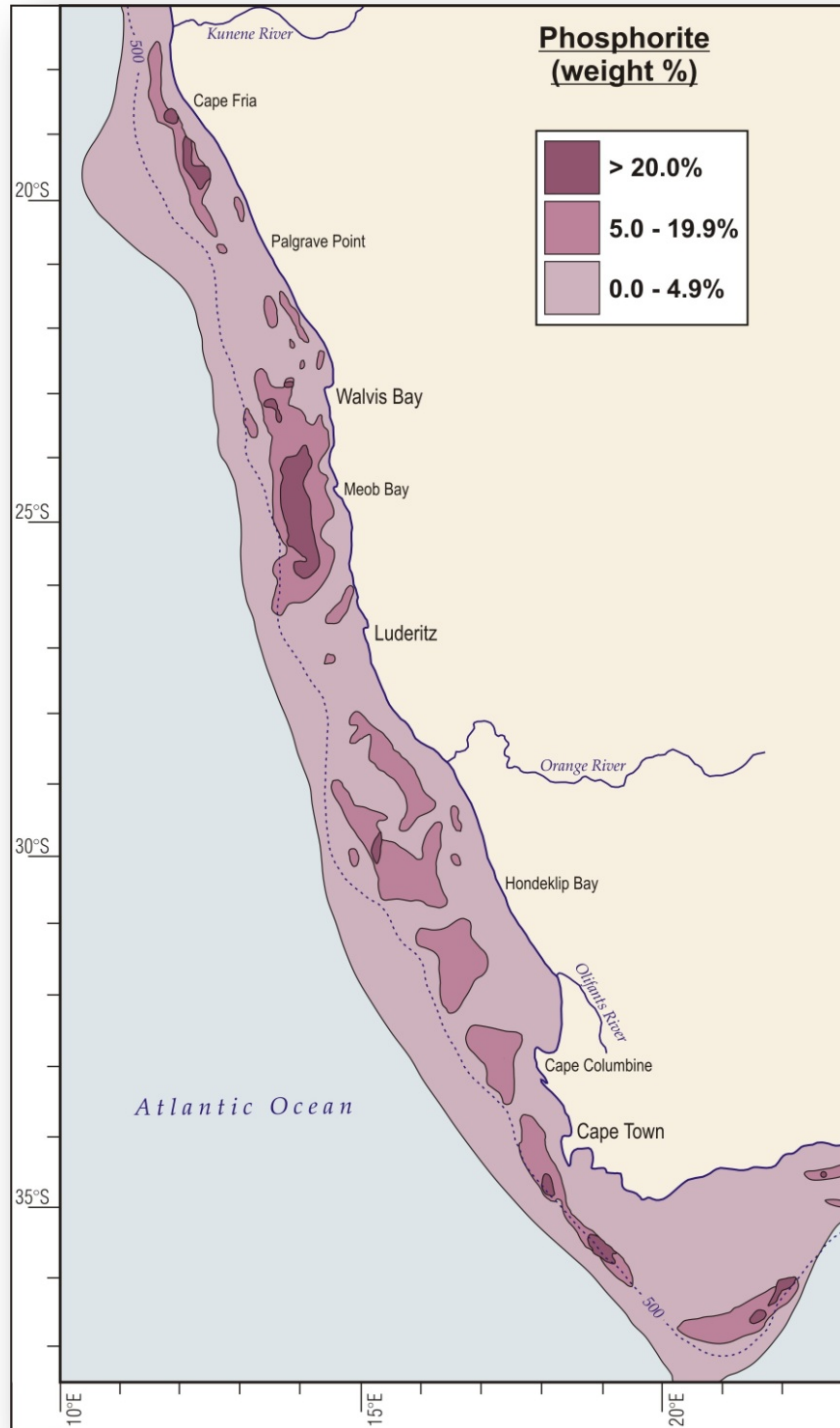


Figure 4.4: The abundance of phosphorite on the middle to outer shelf (from Rogers & Bremner 1991).

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Phosphatic sediments of several different types occur in the Namibian offshore region. Close to Walvis Bay in water depths around 100 m, concretionary phosphatic sediments are presently being formed as soft, yellowish material within a large body of diatomaceous mud. These lithified concretions, of which a great variety exists, are mainly Holocene in age and lie dispersed within the diatomaceous mud. At approximately 200 m, on the middle shelf, pelletal phosphatic sediment, and to a lesser extent, glauconitized pelletal phosphatic sediment exist, these are believed to be Miocene in age. This deposit, mixed with gravel (molluscan shells) and mud (biogenic and terrigenous), varies in thickness from 1.3 m in the south to 0.3 m in the north and extends continuously over hundreds of square kilometers. The enriched part of the pelletal phosphatic deposit (>30% phosphatic sediment) lies between Conception Bay and Spencer Bay with a length of approximately 180 km, and a width of approximately 40 km. (Figure 4.4). This area is situated along, and seawards of the 200 m isobath. This reserve is estimated to contain approximately 1000 Mt > 5 % Phosphate (P₂O₅) in a relatively small area of approximately 10,000 km², Coles *et al.* (2002).

4.1.1.4 Formation of Pelletal Phosphorite

This section is a review from Rogers and Bremer (1991).

Formation

The following environmental and physiographic conditions are envisaged: the continent's west coast has a number of arid, subtropical estuaries each leading into northward-opening lagoonal areas sheltered behind a developing spit. Due to a strong and persistent southerly wind regime, the phosphate and plankton-enriched upwelled oceanic water is continuously drawn in to these lagoons. In this sheltered environment the pH is raised (and the EH lowered) due to the decomposition of organic material on the intertidal mud flats. Simultaneously the water temperature is raised through solar heating which causes bacterial activity. Small rivers carrying a mud rich partially suspended load introduce clay minerals into the lagoon environment, where Mg ions are adsorbed from the seawater and simultaneously Fe ions are released into solution.

On the estuary's intertidal mud flats this results in the inorganic precipitation of apatite as a gel, in thin layers (1 mm), together with relatively high amounts of organic matter and minor amounts of terrigenous silt and clay. During low tides the mudflats are exposed, dessicated and the phosphatic (apatite) surface-layer disintegrated into small sand-sized intraclasts. These intraclasts are progressively modified in size and reach equilibrium with the prevailing estuarine wavelets. The smaller intraclasts physically accrete additional phosphate via the "snowball" effect, whereas the larger intraclasts are eroded down to grain size of local equilibrium.

The present, extensive, lateral distribution of high concentrations of pelletal phosphorite is explained by a late Miocene transgression, advancing over the estuaries, winnowing the dense phosphorite grains and transporting them alongshore northwards. Repeated winnowing and northward spreading continued during the Late Pliocene and during the numerous Quaternary fluctuations of sea level.

*Chapter 4: Description of the Environment***Age**

Namibian pelletal phosphorites have been dated radio chemically using equilibrium values of the activity ratios of U^{234} / U^{238} and Th^{230} / U^{234} . The system is regarded as radio chemically closed, and a pre-mid-Pleistocene age (> 700,000 yr) has been assigned. Bremner (1978) postulated a Miocene age on the grounds that stiff muds seaward of the phosphorite have been dated on nanofossil evidence as Miocene-Pliocene.

Petrography

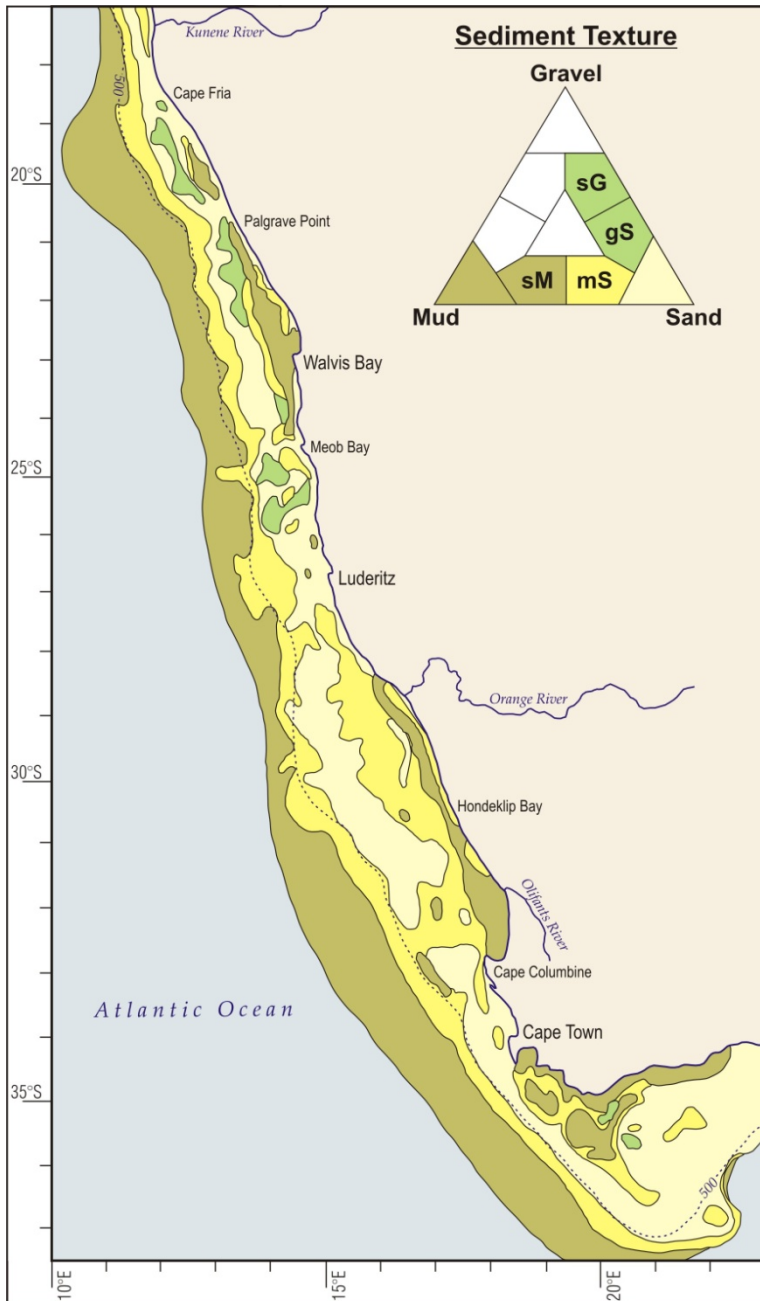
The size distribution of pelletal phosphorite grains is generally in the sand size fraction, with a prominent mode between 177 – 250 microns, and a size range of very coarse to very fine sand. The assemblage is generally well-sorted, leptokurtic and weakly coarse-skewed. Individual grains are generally spheroidal, rounded to well rounded, very dark brown with a resinous luster, indurated and non-magnetic. In thin section grains are opaque with a thin transparent pellicle. Approximately 20% of grains have a concentric internal structure in their outer parts and 5% of grains contain an allogenic particle of quartz, glauconite or fish bone in their inner parts.

4.1.1.5 Other Sediments

The organic content of the sediments mantling the continental shelf of the Benguela region is at least as important as the sediment particle size composition, if not more so, in determining the benthic communities inhabiting these sediments. Particulate organic matter in and on these sediments forms the basis of the benthic food chain at depths below adequate light penetration to support photosynthesis. However, decomposition of the vast quantities of organic matter continually raining down on the shelf as a result of the high productivity in surface waters also causes depletion of oxygen, and generation of oxygen-depleted deep water masses. These cause periodic substantial mortalities of benthic communities when low-oxygen water is driven shorewards by summer upwelling processes. Where such low oxygen water masses persist, ensuing anaerobic decomposition generates the methane gas trapped in the mud layers and the sulphur dioxide which causes, large-scale 'sulphur eruptions' for which the Namibian coast is known. These features are discussed further in Appendices 1b and 1c.

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Sediments: Texture



On the central Namibian shelf from north of Walvis Bay to Meob Bay, the inner shelf is mud and sandy mud (the mud belt) dominates, coarsening seaward to a muddy sand, to sand and back to muddy sand before the shelf break (at 500 m) where muddy sandy and then increasing muds again dominate. Between Meob Bay and Conception Bay, sand dominates inshore, with seaward partially inter-fingered lobes of gravely sand - sandy gravel and muddy sand are distributed. At the shelf break muddy sand dominates, with sandy mud and muds dominant on the shelf slope.

The 'gravels' from the Walvis middle shelf are in fact molluscs and mollusc fragments, which dominate along the 200 m isobath. The common bivalves of the middle shelf are *Lucinoma capensis*, *Dosinia Lupinus*, and *Tellina gilchrist* and the most common gastropods was *Nassarius vnctus*. Size fractions: gravel (> 2mm), sand (2mm to 0.063mm) and mud (< 0.063mm) to produce a map of the texture of the sediments on the seafloor (Figure 4.5).

Figure 4.5: Texture of unconsolidated seabed surficial sediments on the continental shelf and upper slope from the eastern Agulhas Bank to the Kunene River (from Rogers & Bremner 1991).

Sediments: Composition



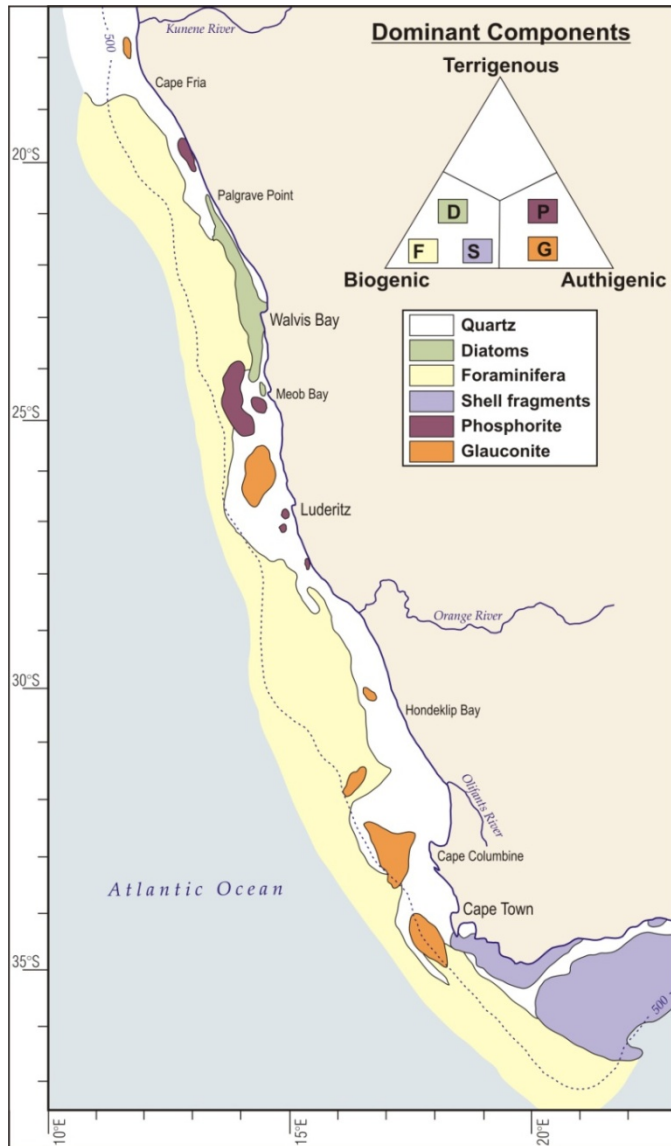
The composition of the sediment was established by determining the abundance of the biogenic component, (calcareous & siliceous), as well as the authigenic component (phosphorite and glauconite). The residue was assigned to the to the terrigenous component. (Figure 4.6).

Land-derived terrigenous components are dominant along the inner shelf, whether inshore sand or offshore mud. The middle shelf is the domain of the authigenic components, which are usually sandy. The sediments on the outer shelf and the continental slope, by contrast are calcareous. The Namibian inner shelf is distinctive in having biogenic sediments on the inner shelf, extending right into Walvis Bay.

Figure 4.6: Sediment composition of seabed surficial sediments on the continental shelf and upper slope from the eastern Agulhas Bank to the Kunene River (from Rogers & Bremner 1991).

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Sediments: Dominant components

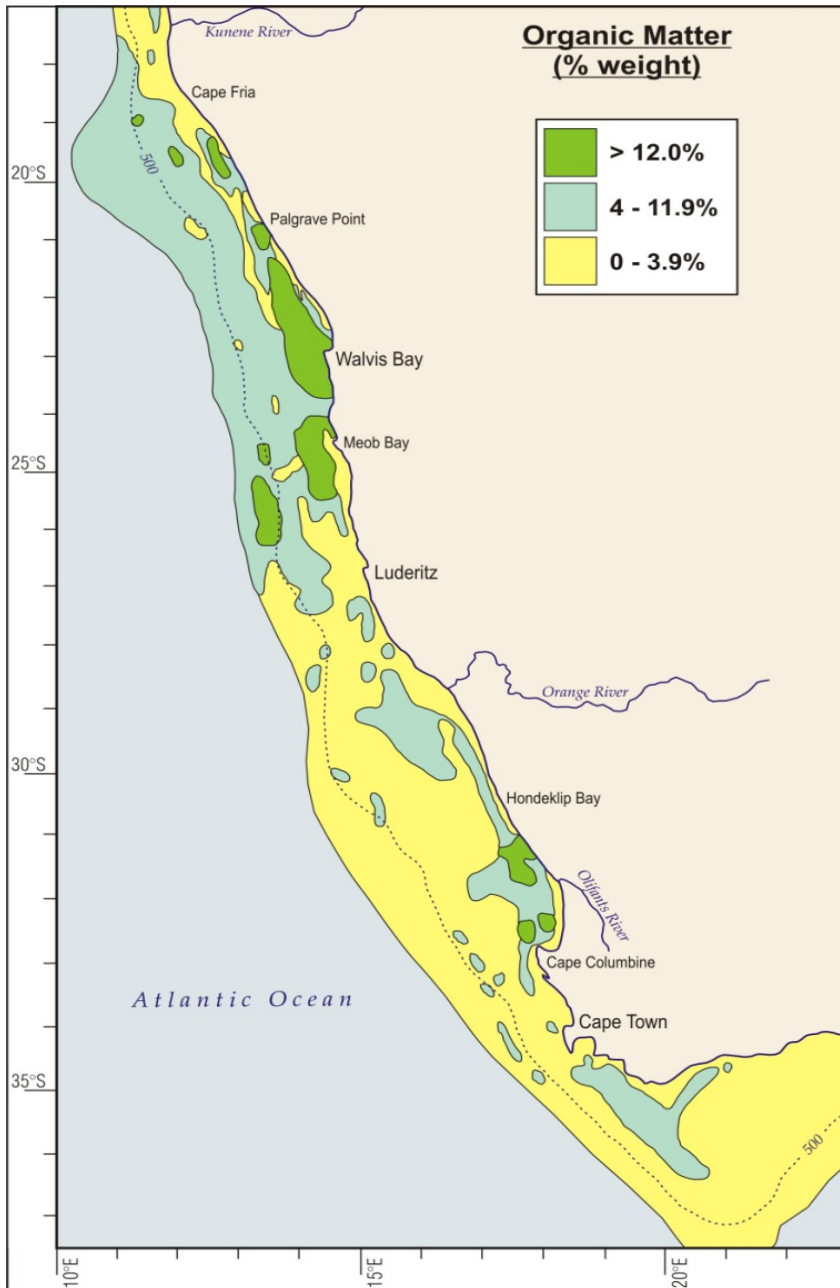


Studying the sand-size components (Figure 4.7) under a binocular microscope, reveals that the inner-shelf sediments off Namibia are dominated by siliceous diatoms, Quartz dominates the sand-fraction of the terrigenous sediments along the inner shelf with the potassium-rich, dark green mineral, glauconite being the dominant authigenic component along the middle shelf off South Africa and southern Namibia. Midway between Lüderitz and Walvis Bay, the dominant authigenic mineral is brown pelletal phosphorite. Both these authigenic minerals are of potential economic importance in the field of agriculture. Foraminifera (forams), mainly planktonic forams dominate the sediments of the outer shelf and the continental slope, siliceous diatoms dominating on the inner shelf off central Namibia. (Rogers and Bremner 1991)

Figure 4.7: Dominant components of seabed surficial sediments on the continental shelf and upper slope from the eastern Agulhas Bank to the Kunene River (from Rogers & Bremner 1991).

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Sediments: Organic Matter



The distribution of organic matter in the sediments between Lüderitz and the Namibia/Angola border off the Kunene River is shown in Figure 4.8. The sediments are highly enriched in organic matter, particularly in the Holocene diatomaceous ooze along the inner to mid shelf, where concentrations of organic matter area as high as 25% (Bremner, 1978, 1980, 1981). Sediments of the mid to outer shelf, as well as the continental slope show lower organic matter content, ranging from 4 to 11.9%.

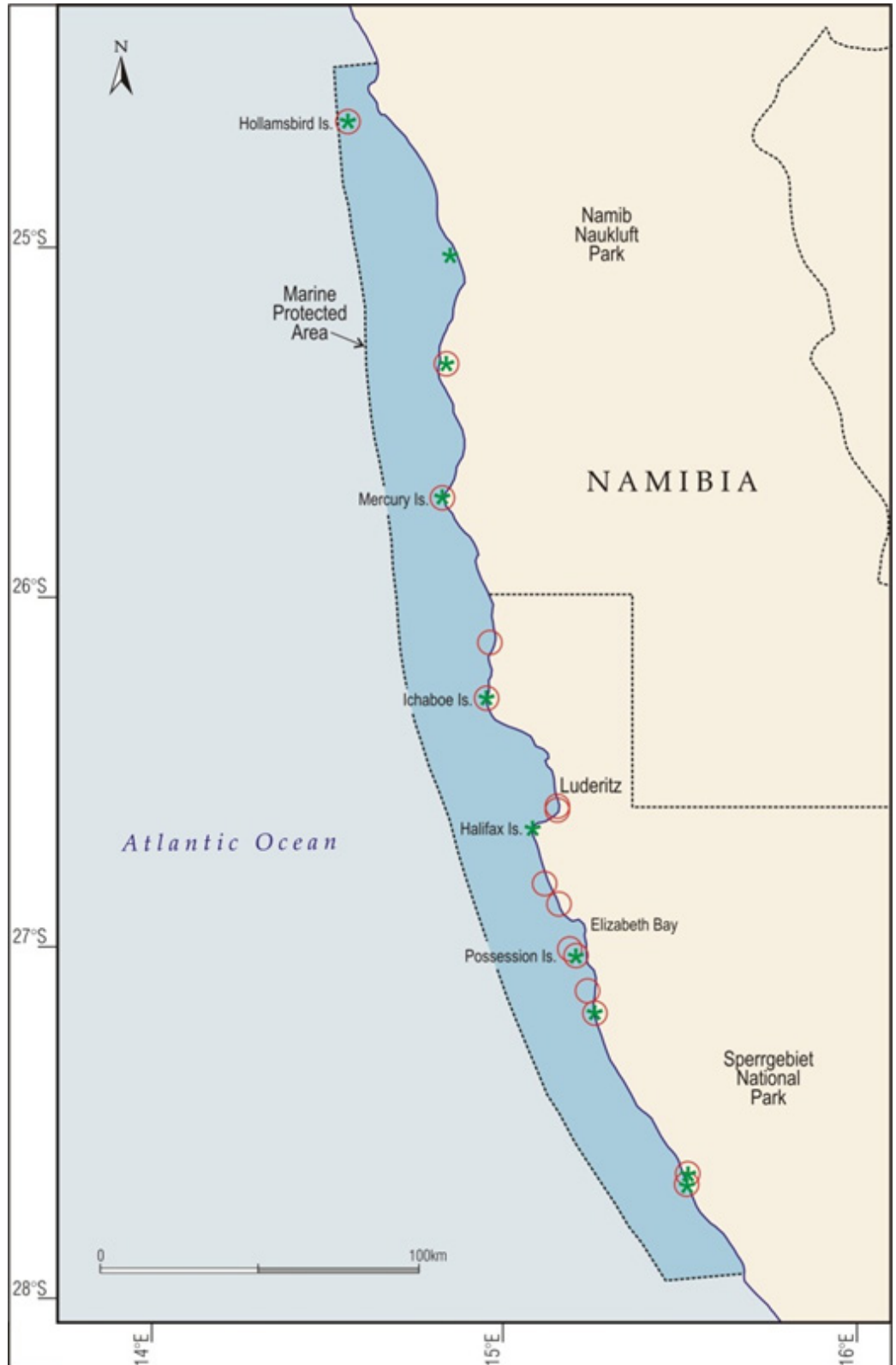
Figure 4.8: The distribution of organic matter from seabed surficial sediments on the continental shelf and upper slope from the eastern Agulhas Bank to the Kunene River (from Rogers & Bremner 1991).

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4.1.1.6 Marine Protected Area

Namibia's first Marine Protected Area (MPA), the Namibian Islands Marine Protected Area (NIMPA) was proclaimed in 2009. The NIMPA runs for 400 km southwards from Hollamsbird Island along the southern coast of Namibia. It covers approximately 10 000 sq km and averages 25 km in width (Figure 4.9).

Figure 4.9:
Namibian Islands
and MPAs.



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4.1.2 Meteorology

4.1.2.1 Offshore wind and atmospheric conditions

The meteorological conditions along the Namibian coast are controlled by the ever-present South Atlantic anticyclone, the northward-flowing Benguela Current (with associated upwelling) and the divergence of the south-east trade winds along the coast. The semi-permanent temperature inversion caused by the warm, dry air mass overlapping the cool air mass above the ocean is ideal for the formation of fog and low stratus cloud.

Wind conditions characteristic of the Licence Area (Figure 4.9) were inferred from data from voluntary observing ships (VOS) collected in the immediate vicinity over a 51 year period. These data are presented in the form of seasonal wind roses and an annual average wind rose. These predominant winds are from the south and south east quadrant and generally are stronger in spring and summer than in autumn and winter.

4.1.2.2 Nearshore wind and atmospheric conditions

The VOS wind data (Figure 4.9) display a strong southerly component. There is some seasonality with southerly winds strongly predominating in summer whereas in winter the south-easterly component is almost as frequent as the southerly. The VOS data do not reflect the strong easterly to north-easterly katabatic winds that can occur in winter. These events can carry aerosol plumes of sand and dust up to 150 km offshore. Shannon and Anderson (1982) present a striking NIMBUS-7 satellite image of such dust plumes extending offshore along almost the entire coast of Namibia (Figure 4.10).

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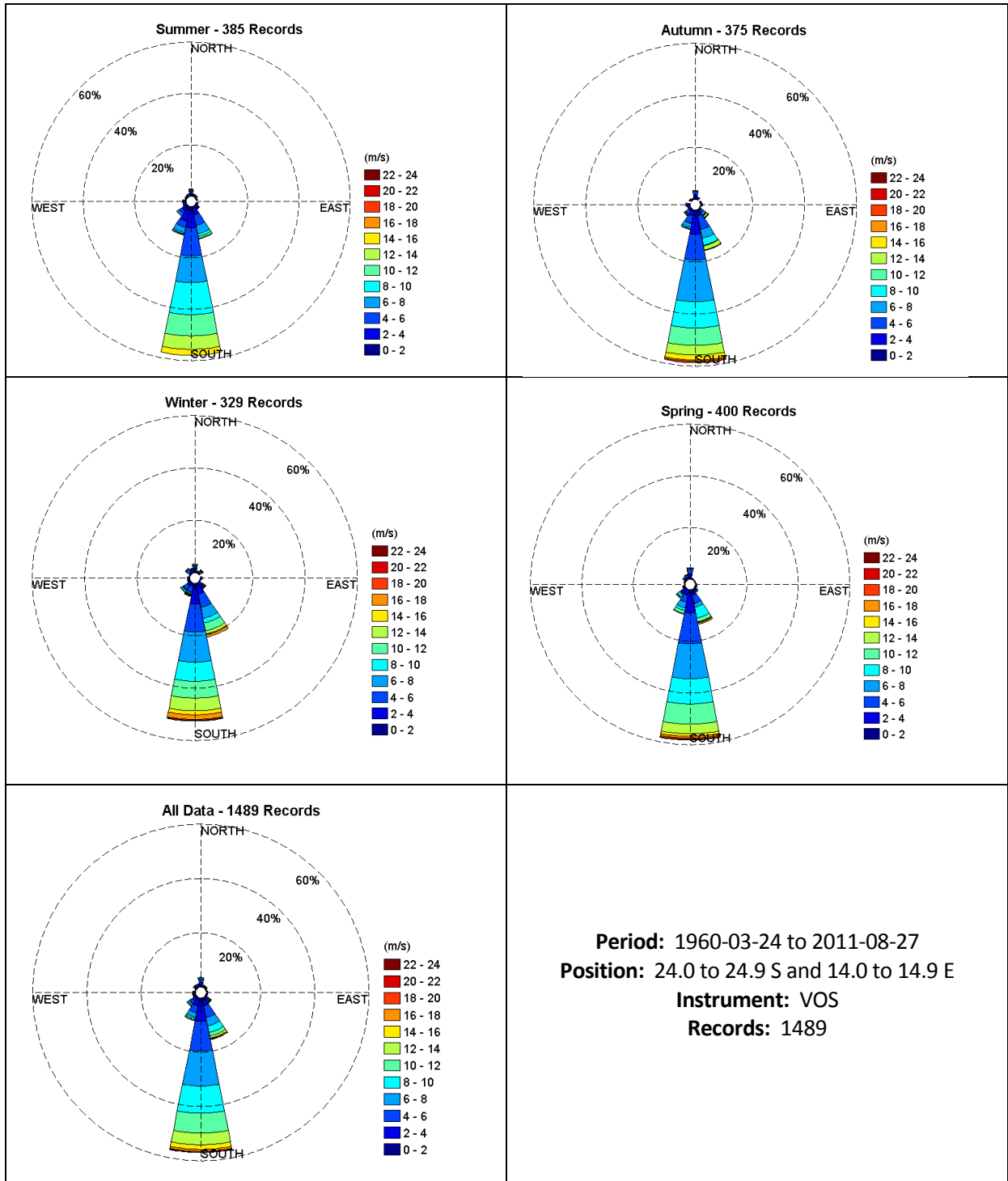


Figure 4.10: Seasonal wind roses for the offshore area 24.0° to 24.9°S; 14.0° to 14.9°E. Voluntary Observing Ship (VOS) data from the Southern Africa Data Centre for Oceanography (SADCO).

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4.1.2.3 Fog

Fog is the most distinctive feature of the coastal climate of the Namib and is usually considered to be a hazard since it reduces visibility. On the other hand, it is a significant source of moisture for desert animals and plants and may contribute to weathering and mineral breakdown. The semi-permanent temperature inversion caused by the warm, dry air mass overlying the cool mass above the ocean is ideal for the formation of fog and low stratus cloud. The fog lies close to the coast extending about 20 nautical miles (~35 km) seawards (Olivier, 1992, 1995), thus it may occasionally adversely affect dredger discharge operations. Within a 15 - 20 nautical mile zone offshore, fog frequency may be as high or even higher than at coastal stations. This fog is usually quite dense, visibility less than 300 m, and appears as a thick bank hugging the shore.

The coast from Walvis Bay southwards to 25°S experiences between 50 and 100 fog days per year, with the highest fog day frequency in the Walvis Bay – Swakopmund area (Figure 4.11). Fog precipitation often exceeds rainfall and is considerably more reliable. At Swakopmund 130 mm of fog precipitation was measured in 1958 - seven times the mean annual rainfall. In the Central Namib, fog precipitation averages 34 mm/year at the coast.

4.1.3 Physical and Biological Oceanography

4.1.3.1 Waves

Wave conditions offshore of the Namibian coast consist not only of locally generated seas induced by local winds but also of swells of noticeable intensity propagating into the area from distant generating sources. These generating sources are formed by the low pressure systems of the South Atlantic Ocean which, once formed, move from west to east, passing the southern tip of Africa with great regularity.

Good quality wave data in the form of 20 minute records at six-hourly intervals, collected from Waverider buoys off the Orange River mouth in a depth of 106 m, for the period November 1981 to May 1988 and off Port Nolloth in a depth of 100 m, from April 1987 to August 1996 are available for detailed information on wave conditions.

These data show that the south-south westerly swell direction is predominant throughout the year except in summer when the direction is more southerly (Figure 4.12).

Significant wave heights range, for most of the time, between 1.5 and 3.5 m with an annual mean of about 2 m to 2.5 m. Local sea conditions can be associated with wave period of 5s and 8s and swell with wave periods of 11s and 16s. Seasonal differences in wave conditions are small.

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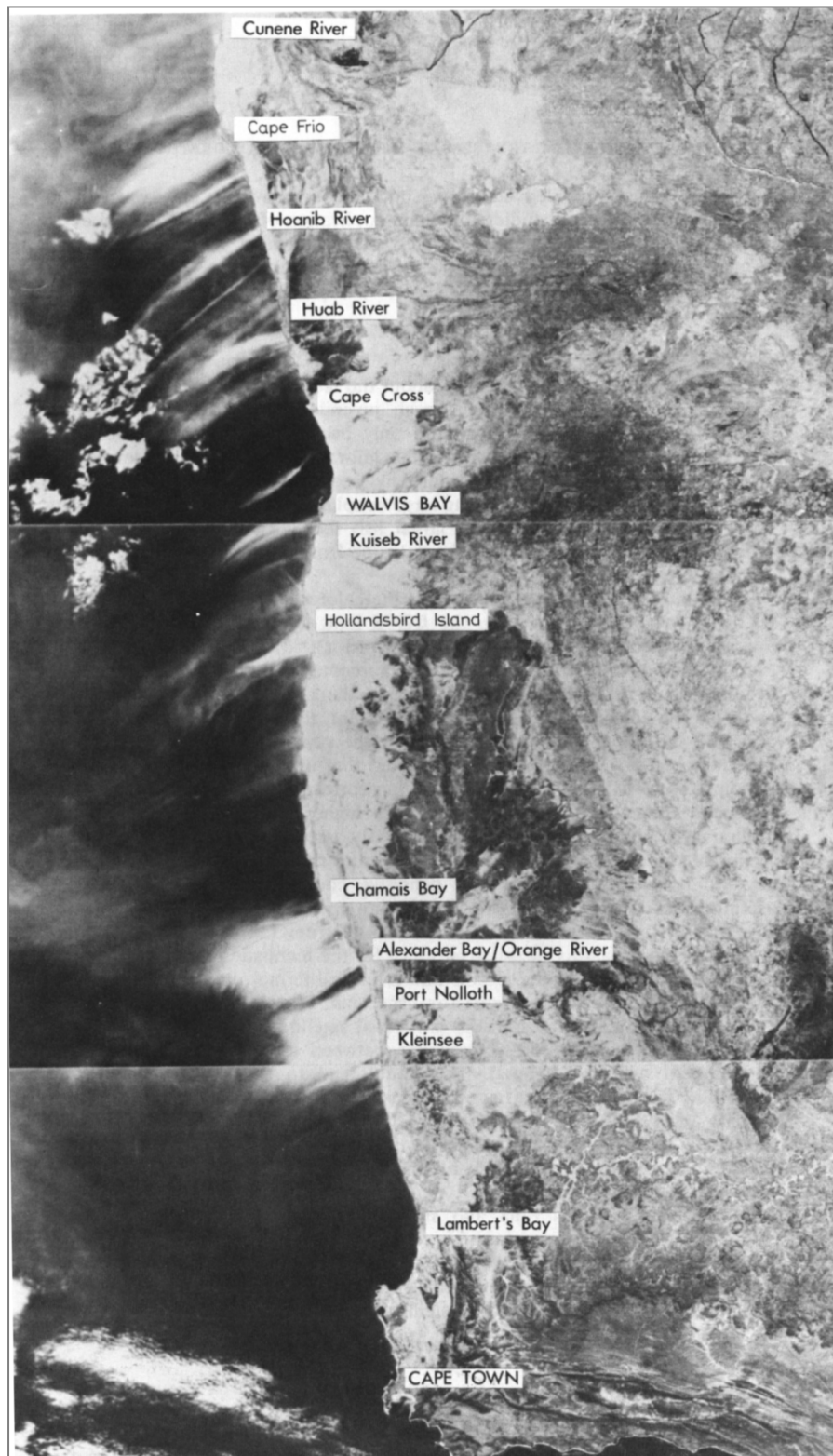


Figure 4.11: Katabatic winds along the west coast of southern Africa carrying aerosol plumes of sand up to 150 km offshore (from Shannon and Anderson, 1982).

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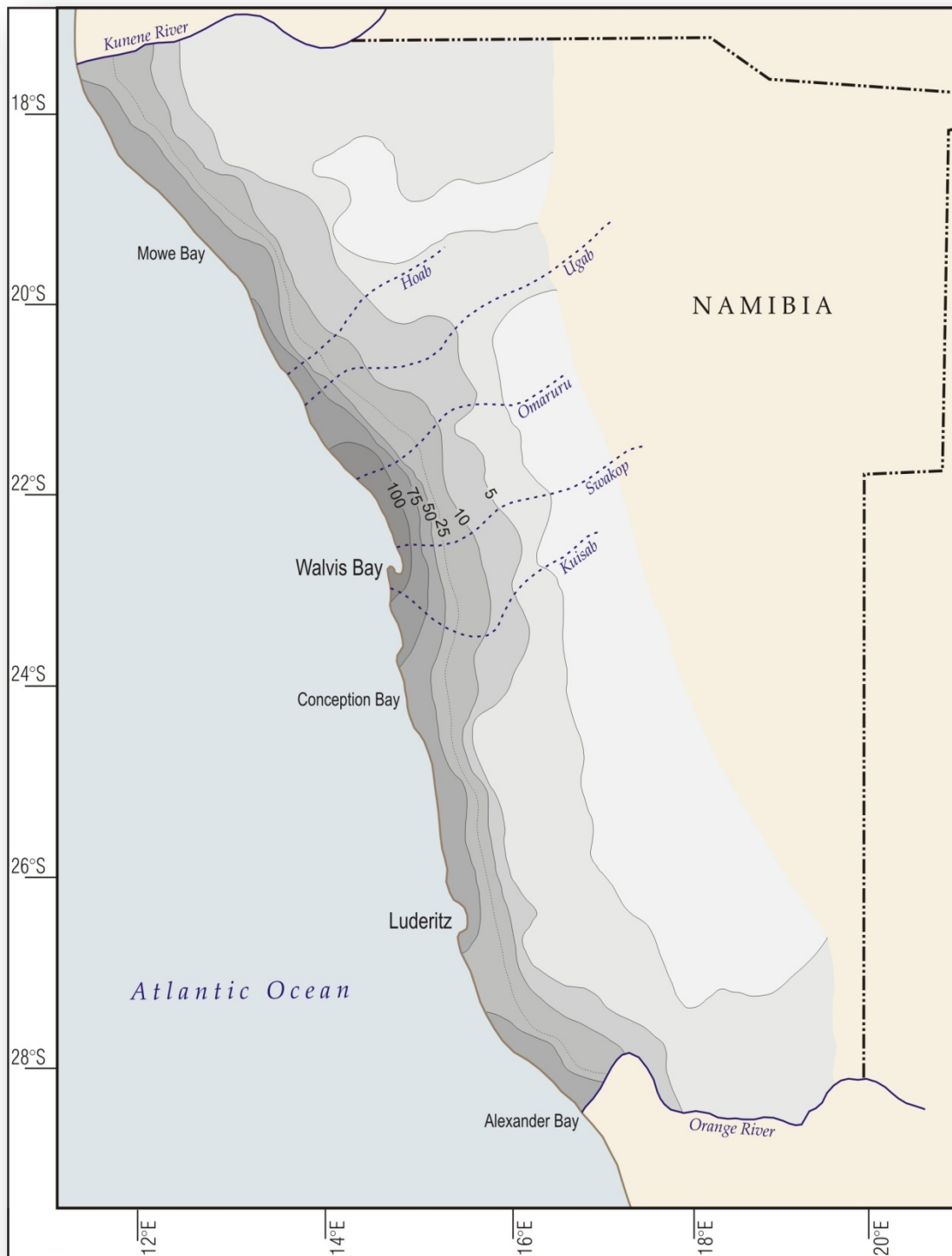


Figure 4.12: 1984 Fog day frequency using Meteosat Images (after Olivier, 1992 and 1995).

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Note: Contours indicate iso-lines (days) of fog occurrence.

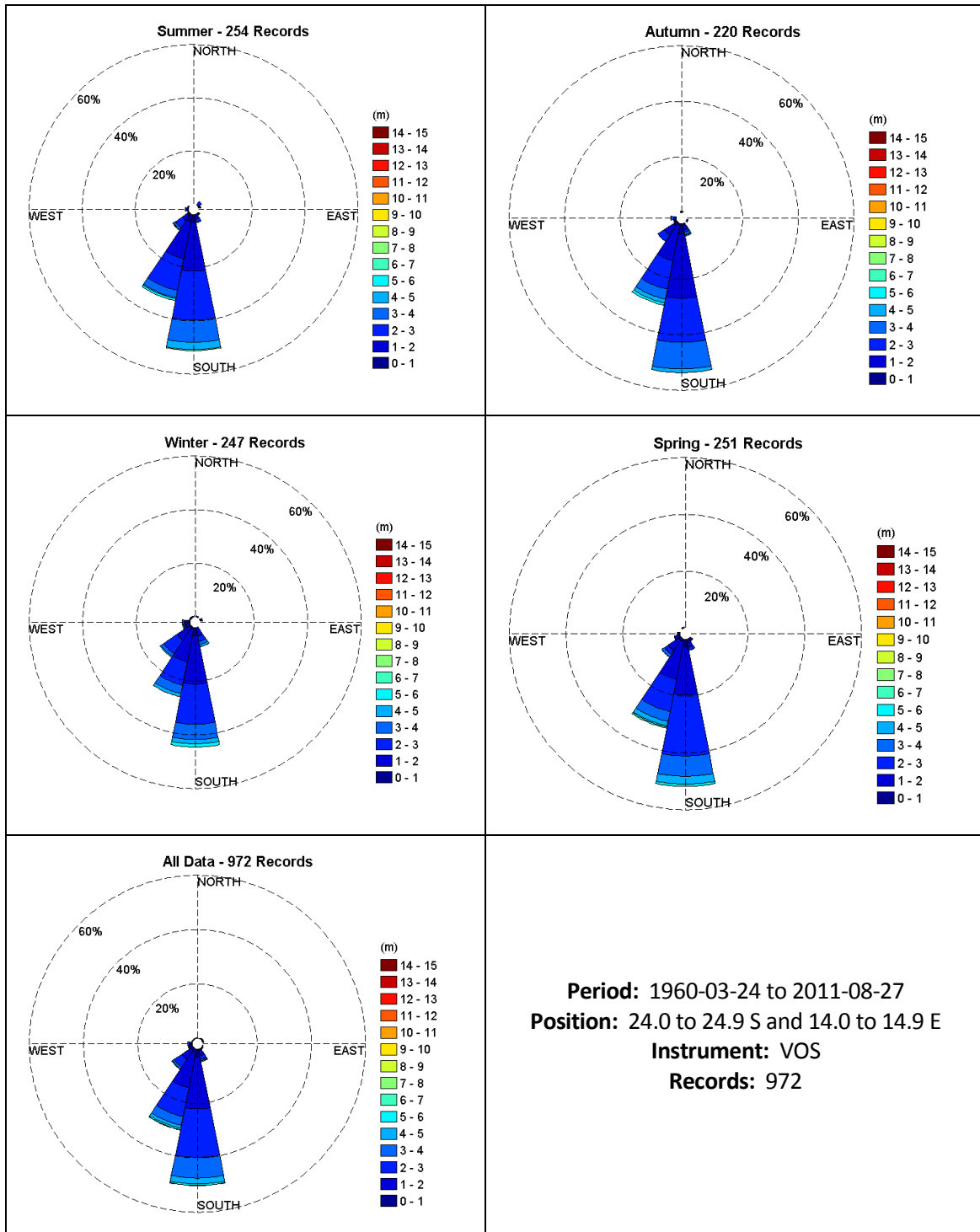


Figure 4.13: Seasonal wave roses for the offshore area 24.0° to 24.9°S; 14.0° to 14.9°E. Voluntary Observing Ship (VOS) data from the Southern African Data Centre for Oceanography (SADCO)

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4.1.3.2 Tides

Tides in the area are semi-diurnal and statistics for Walvis Bay apply.

Lowest Astronomical Tide (LAT)	0,00 m
Highest Astronomical Tide (HAT)	+ 1,97 m
Mean Low Water Springs (MLWS)	+ 0,27 m
Mean High Water Springs (MHWS)	+ 1,69 m
Mean Low Water Neaps (MLWN)	+ 0,67 m
Mean High Water Neaps (MHWN)	+ 1,29 m
Mean level (ML)	+ 0,98 m

All levels quoted are relative to Chart Datum which is -0,865 m.

4.1.3.3 Water masses and temperature/salinity relationships

Shannon (1985) has summarised the characteristics of the water masses that occur in the Benguela current system. The water masses occurring in, and inshore of, the quadrant will be predominantly South Atlantic Central Water (SACW) with temperatures of origin between 6° and 16°C and salinities in the range of 34,5 to 35,5 ‰.

The temperature characteristics at the surface can be modified by sun-warming of previously upwelled, or upwelled and mixed, SACW. Shannon (1985) indicates that the SACW found in the region of the quadrant enters the area from the south and south-west. There may be some Indian Ocean Central Water mixed in this water but its contribution is probably small. There is a seasonal variation in surface temperature, with the average summer and autumn temperatures being ~2°C higher than in winter and spring. In the short term this is modified by upwelling (see below) and in the longer term by El Niño events (Boyd and Agenbag, 1985; Shannon, 1985).

4.1.3.4 Water circulation

A schematic of the surface currents in the Benguela system is shown in Figure 4.13. The currents in the vicinity of the Licence Area trend predominantly NW with a mean speed of 17 cm s⁻¹ (Shannon, 1985). There is some evidence of 'topographic' steering (Nelson and Hutchings, 1983) in that the currents follow the shelf break and velocities vary with the gradient of the shelf slope.

The probable movement of water in the 200-300 m depth range is depicted in Figure 4.14. As pointed out in the section on water masses there is an indication of southward flow penetrating to the latitude of Lüderitz. Andrews and Hutchings (1980) present evidence of this southward flow reaching south of Cape Columbine. These features are discussed further in appendices 1b and 1c.

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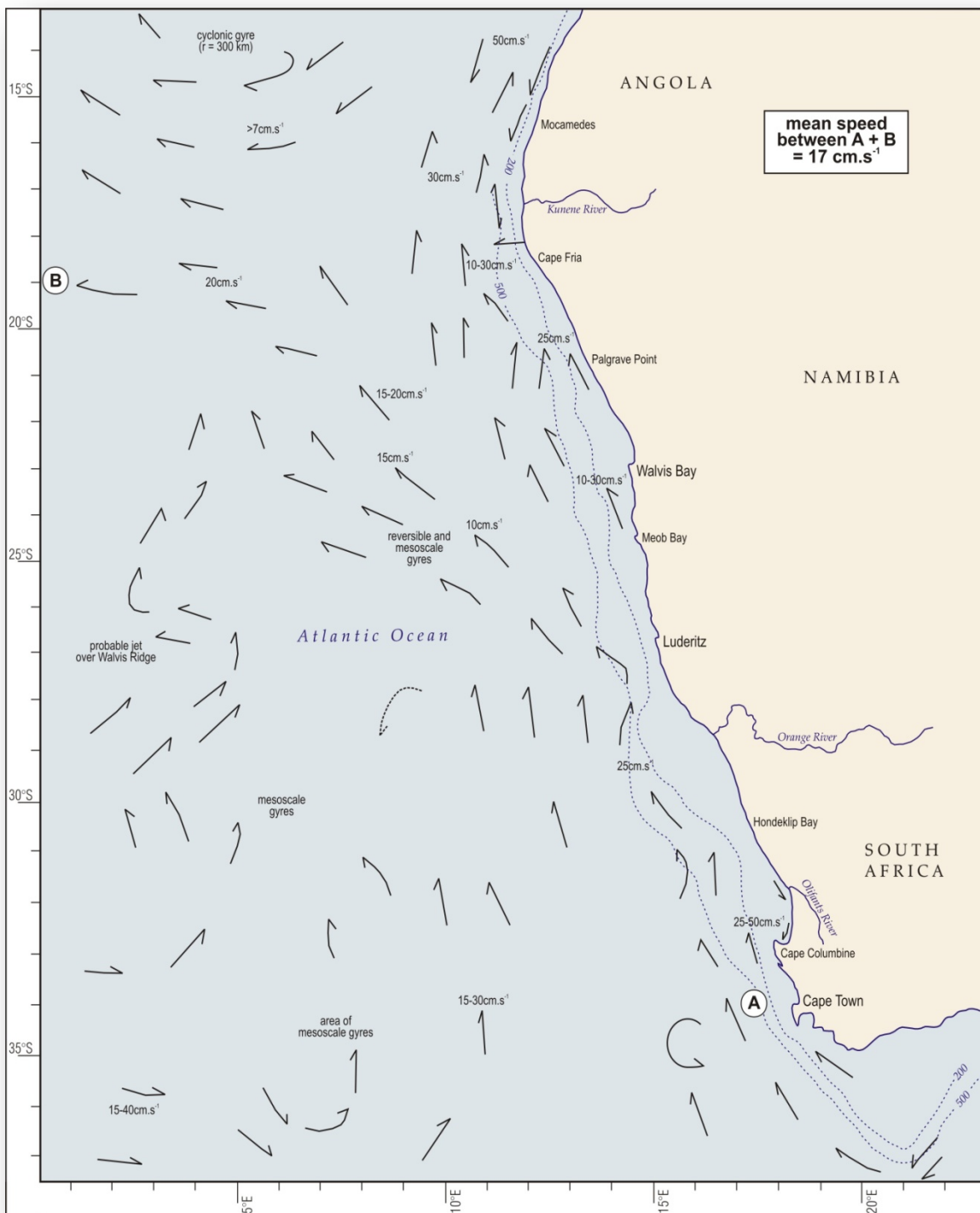


Figure 4.14: Surface currents off the west coast of southern Africa (from Shannon, 1985).

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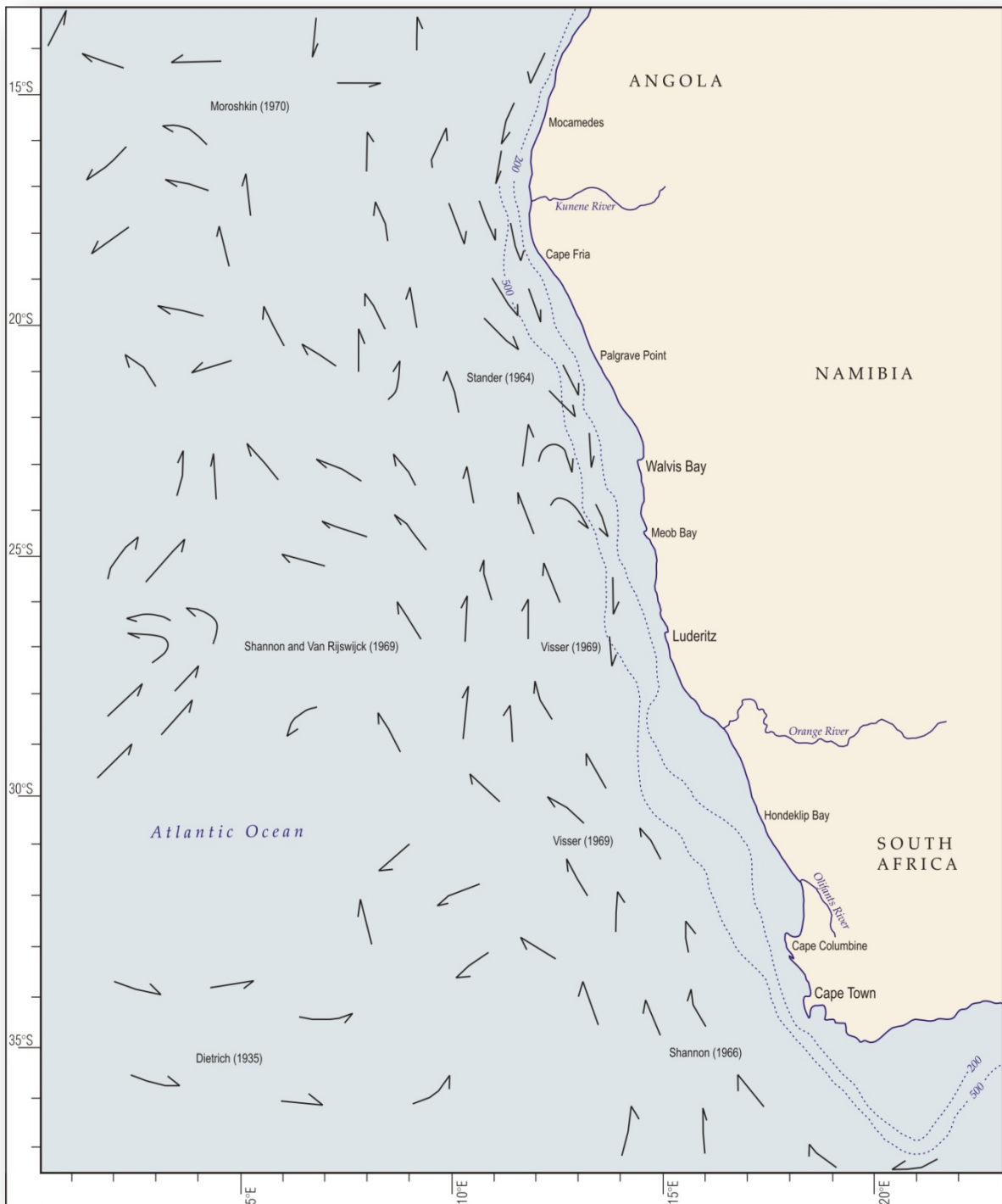


Figure 4.15: Probable movement of central water between 100 m and 300 m off the west coast of southern Africa (from Shannon, 1985).

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4.1.3.5 Upwelling

The Licence Area lies to the north of the Lüderitz upwelling cell which is the principal upwelling centre of the Benguela (Shannon, 1985 and authors cited therein). Upwelling at this site is semi-permanent but there is sometimes a short quiescent period in autumn. The upwelling cell acts as a major physical and biological barrier in the Benguela system.

During the upwelling process, driven by southerly winds, 13°C and <35 ‰ salinity water is uplifted and may breach the surface at the coast. In vigorous upwelling events tongues of cold water extend offshore to the NW with the upwelling effect detectable at the surface up to 30-50 nautical miles offshore (Shannon 1985, Figure 4.15 from Bang 1971). Stander (1964) presented data that showed that the upwelling effect was detectable to 400 m depth in the form of distortions to temperature and salinity distributions.

During the decay phase of upwelling the newly upwelled water mixes with older, sun warmed and previously mixed upwelled water. The mixing events add nutrients to these waters and through stabilisation support the very high biological productivity typical of the Benguela system. These features are discussed further in appendices 1b and 1c.

4.1.3.6 Nutrient and Oxygen Distributions

As described above SACW comprises the bulk of the water in the study area either in its 'pure' form or mixed with previously upwelled water of the same origin. According to Jones (1971), cited in Chapman and Shannon (1985), 'true' SACW nutrient concentrations range from 10-18 µM nitrate-nitrogen, 0,8-1,5 µM phosphate and 6-15 µM silicate.

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations. SACW itself has depressed oxygen concentrations, ~80% saturation value, (Chapman and Shannon, 1985), but lower oxygen concentrations (<40% saturation) occur frequently (e.g. Visser, 1969, Bailey *et al*, 1985). The low oxygen concentrations are attributed to nutrient remineralisation in the bottom waters of the system.

Bailey *et al.* (1985) showed that oxygen concentrations in the vicinity of Lüderitz were lower (1,0-2,0 ml l⁻¹) during quiescent conditions than during active upwelling (> 2,0 ml l⁻¹). These authors further showed that extremely low oxygen concentrations (<0,5 ml l⁻¹) occurred in water overlying organically rich sediments located northward. These features are discussed further in appendices 1b and 1c.

4.1.3.7 Plankton

The Benguela system is a highly productive ecosystem, with primary production rates > 300 g C/m²/yr, making it one of the most productive marine areas in the world (Shannon & O'Toole 1998). The phytoplankton form the base of the pelagic trophic structure, while the heterotrophic zooplankton supply the dietary requirements for most of the small pelagic fish in the ecosystem such as sardines, anchovy and red-eye, and so in turn provide the energy needed to sustain larger fish, bird and mammal predator species. Plankton are discussed further in appendix 1b.

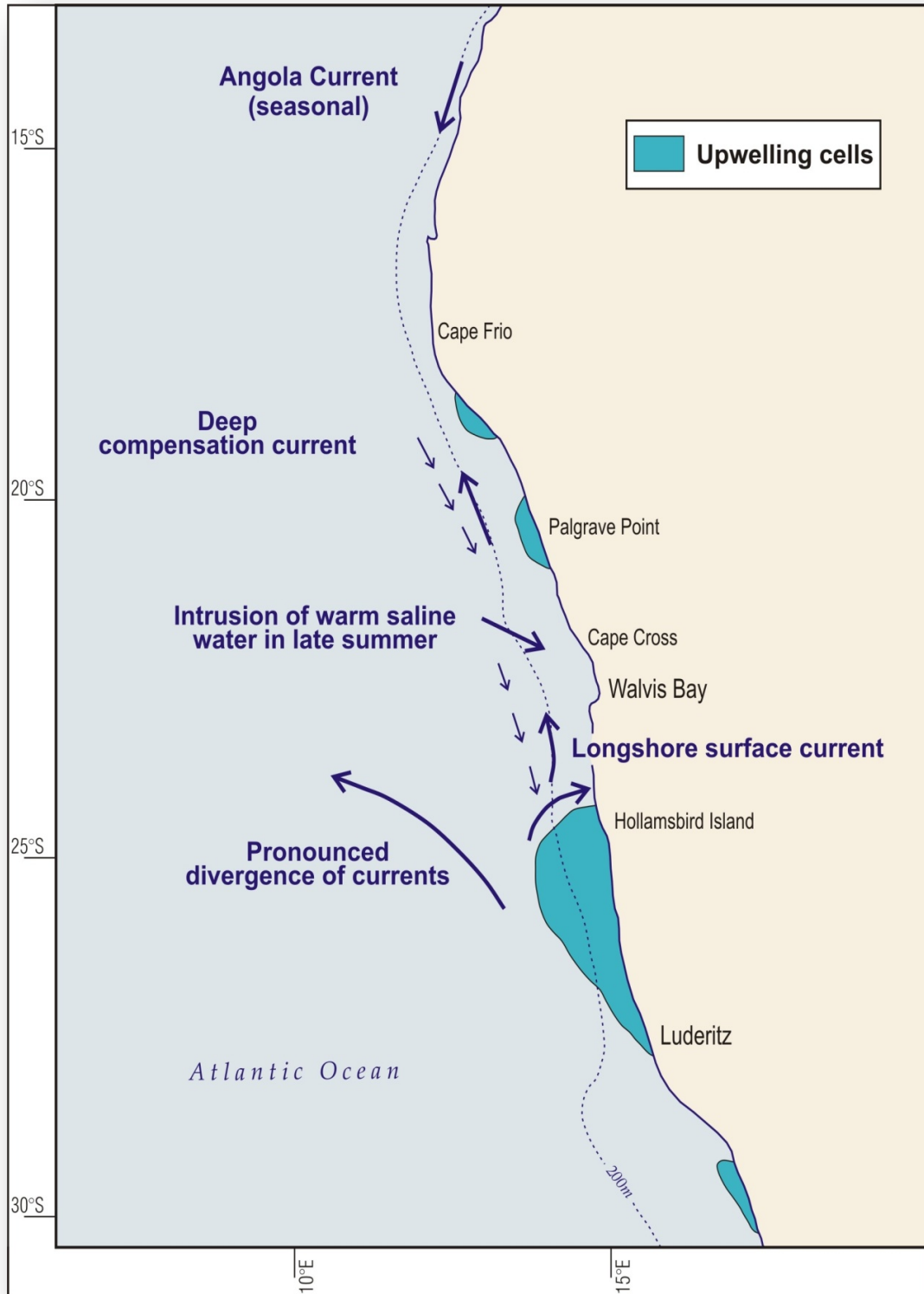


Figure 4.16: Upwelling centres on the west coast of southern Africa with schematic of currents (from Shannon, 1985).

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4.1.3.8 *Benthos*

The initial study of the benthos on the continental shelf of southern Namibia was undertaken by Field *et al.* (1996). The study was carried out as part of the environmental impact assessment of Debmarmine's deep sea diamond mining operations in the Atlantic 1 Mining Licence Area. Subsequently comparisons of the benthic fauna of the unmined and mined areas were made.

The Namibian continental shelf is subject to periods when the water is hypoxic. The Namibian benthos thus may constitute a distinct community able to survive oxygen-deficient conditions. Field *et al.* (1996) determined that the main phyla contributing to the benthic fauna are: Annelida e.g. *Diopatra* spp. and *Terebellides* spp.; Mollusca e.g. the gastropods *Nassarius* spp. and the bivalves *Macoma* spp; and Crustacea e.g. *Hippomedon longimanus* and *Ampelisca* spp. Notable is the paucity of echinoderms.

Two macro benthos surveys (100 samples have been collected from 20 stations) have been conducted over the Mining Licence Area, with analysis by N. Steffani. These studies and related project matters are discussed in appendix 1c.

4.1.3.9 *Fishes*

The fish fauna of the Namibian coast is characterised by a relatively low diversity of species compared with warmer oceans: Approximately 76 fish species are found in the area under consideration compared to an equivalent area on the east coast of Africa inhabited by over 800 species (Bruton, 1996).

The Namibian ichthyofauna is characterised by high numbers of commercially important fish species, particularly the shallow-water hake *Merluccius capensis*, deep-water hake *M. paradoxus*, cape gurnard *Chelidonichthys capensis*, monkfish *Lophius vomerinus*, elephant fish *Callorhinchus capensis*, snoek *Thyrsites atun*, jacobever *Helicolenus dactylopterus*, maasbanker *Trachurus trachurus*, buttersnoek *Lepidopus caudatus* and kingklip *Genypterus capensis*. Three of these ten species (snoek, maasbanker and buttersnoek) are pelagic species as adults that sometimes feed on benthic prey. The other species are demersal and mainly feed on benthic organisms.

The ichthyofauna of highly variable upwelling zones, such as the Benguela Upwelling System of the west coast of southern Africa, tends to have the following suite of characters: low species diversity, low species interdependence, rare species are uncommon, migratory species are common, sedentary species are uncommon, low speciation rates, low extinction rates, low species saturation, wide trophic niches, high fecundity, typically generalist life styles, high adaptability, and subject primarily to density-independent mortality (Bruton, 1989).

Two of the fish species, the west coast sole *Austroglossus microlepis* and the bearded goby *Sufflogobius bibarbatus*, have relatively narrow distributions, being endemic to Namibia and the west coast of South Africa. None of the species on the list are known to be rare or endangered (none appear in the 1994 IUCN Red List of Threatened Animals, Groombridge, 1993), whereas some of those listed are very widespread and abundant. For instance, the jacobever is ubiquitous at depths of 55 – 550 m from Walvis Bay to Delagoa Bay (Smith and Heemstra, 1988).

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The vulnerability of a fish species to anthropogenic disturbance (fishing, mining, pollution or other impacts) is subject to three main factors: fish abundance, fish distribution and the particular life-history characteristics of the fish species affected.

Characteristically upwelling zones are inhabited by altricial fish producing large numbers of small eggs which hatch into small, undeveloped young that are mainly subject to density-independent mortality (Bruton, 1989). These fish play a 'low-risk, high-number' game in that the parental investment in each individual young is low, but the risk of mortality is spread among a large number of offspring. Each individual young therefore has a low fitness compared with the young fish from a more stable environment that play a 'high risk, low number' game (Bruton, 1989). These more altricial species may however, be vulnerable to long-term impacts on the survival rates of their eggs and larvae.

Some of the fish that occur off Namibia are not altricial species, such as the live bearing dogfish *Squalus* species and the mouth brooding white seacatfish *Galeichthys feliceps*, but the general trend of higher levels of altriciality in an upwelling zone does appear to hold. Altricial fish that are better able to adapt to random and even catastrophic mortalities; petroleum exploration and production and patchwork mining activities in a small part of their range are not likely to have a lasting detrimental impact. An exception is during the most vulnerable stages of the life cycle – the eggs, larvae and post-larvae stage may be affected by a pervasive environment perturbation, such as the deoxygenation of the water column in the vicinity of the thermocline, where they typically accumulate. These features are discussed further in appendices 1a.

4.1.3.10 *Seabirds*

A total of 51 species of seabird has been recorded in the waters of southern Namibia (Appendix 1a - 1). Of these, 13 (25%) are southern African breeding species, 14 (27%) are non-breeding migrants from the northern hemisphere, and 24 (47%) are non-breeding migrants from islands in the Southern Ocean (Ryan and Rose 1989; Sinclair *et al.* 2011).

Conservation concern has been expressed for more than one third of the seabird species occurring in southern Namibian waters. Threatened species include both migrants (albatrosses and petrels) and southern African breeding species. No species is considered to be Critically Endangered and five are considered Endangered. Of the 51 species, 18 (35%) have been given a IUCN (World Conservation Union) category of threat. Five seabird species are Endangered, five are Vulnerable, six are Near Threatened and two are of Least Concern (Sinclair *et al.* 2011; <http://www.iucnredlist.org/>). Seabirds are discussed further in appendix 1a.

4.1.3.11 *Cetaceans*

The cetacean fauna of the Namibian coast comprises between 22 and 31 species (Cetus Projects 2008; Currie *et al.* 2009 (cited in Pulfrich, 2007), the diversity reflecting both species recorded from the waters of Namibia and species expected to be found in the region based on their distributions elsewhere along the southern African West coast. The range in species number is due to taxonomic uncertainty at species and sub-species level, rather than uncertainty of occurrence or distribution patterns. Nonetheless, the diversity is comparatively high, reflecting

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the cool inshore waters of the Benguela upwelling system and the occurrence of warmer oceanic water offshore of this. Cetaceans can be divided into two major groups, the mysticetes or baleen whales which are largely migratory, and the toothed whales or odontocetes which may be resident or migratory. The range in the number of species reflects taxonomic uncertainty rather than a lack of information on distribution patterns. Cetaceans are discussed further in appendix 1a.

4.1.3.12 *Seals*

The Cape fur seal (*Arctocephalus pusillus pusillus*) is common along the Namibian coastline, occurring at numerous breeding sites on the mainland and on nearshore islands and reefs. All have important conservation value since they are largely undisturbed at present, as public access to the southern Namibian coast is restricted. South African (Cape) fur seals generally foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy 1979), with bulls ranging further out to sea than females. Tracking of South African fur seal with time depth recorders has shown that two females from Kleinsee dived to 200 m (although dives to 150 m comprised less than 10% of measured dive profiles) (David 1989). The mining area falls within feeding range of South African fur seals. Seals are discussed further in appendix 1a.

4.1.4 *Commercial Fisheries*

The Benguela Current system supports one of the world's most important commercial fisheries. Effort is primarily focussed on the demersal hake (*Merluccius spp*) and the pelagic/epipelagic anchovies (*Engraulis encrasicolus*). Sardine (*Sardinops ocellata*) previously dominated the Namibian waters but have been depressed since 1968 (Crawford *et al*, 1987). Consequently, horse mackerel (*Trachurus trachurus capensis*) increased in importance in the overall tonnage landed since the decline of the sardine. In the past sardine was caught predominantly by purse-seine vessels. The fishery for horse mackerel targets this species using midwater trawl vessels. Tuna, snoek, monkfish, kingklip, and chub mackerel are also significant resources in the Benguela as are rock lobster, although the latter has declined significantly in recent years.

The demersal trawling industry operates offshore of the 200-m isobath. The trawling grounds thus overlap with the Mining Licence Area and will therefore have been subjected to trawling disturbance. Commercial fisheries and related matters are discussed further in appendix 1a.

4.1.5 *Jellyfish*

Lynam *et al*. 2006. indicate that jellyfish now account for significantly more biomass in the northern Benguela waters than do fish. Based on the data they obtained from over 30,000 nautical miles of survey. They estimate the total biomass of jellyfish in the region to be 12.2 million metric tons (mostly contributed by the large *A. forskalea* species), whereas the biomass of fish accounts for only 3.6 million metric tons. Large jellyfish species such as *Chrysaora hysoscella* and *Aequorea forskalea* are more commonly reported. Jellyfish biomass has risen in numerous locations worldwide, possibly as a consequence of increased fishing effort. Climatic changes could also contribute to jellyfish population shifts. Jellyfish have few predators and jellyfish abundance

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has significant potential consequences for oceanic ecosystems, including slowed or attenuated fish-stock recovery. Jellyfish and related matters are discussed further in appendix 1a.

4.1.6 Shipping and Navigation

The main shipping lanes off the west coast of southern Africa lie seawards of the mining licence area (Figure 4.16). However, both coastal shipping and fishing craft may be encountered in the mining area and between it and the coast.

Fog is a particular navigational hazard for both sea and air operations. The coast from Elizabeth Bay northwards to Sandwich harbour experiences an average of 50 fog days a year (Figure 4.4). The fog lies close to the coast and extends perhaps 20 nautical miles (~35 km) offshore (Olivier, 1992, 1995).

Buoyage in Namibian waters follows the IALA convention for region A. Apart from satellite navigation systems, Decca navigation is also provided for. Maritime radio services for emergency (Channel 16) services, weather bulletins and navigation warnings are provided by Walvis Bay Radio (Call sign ZSV).

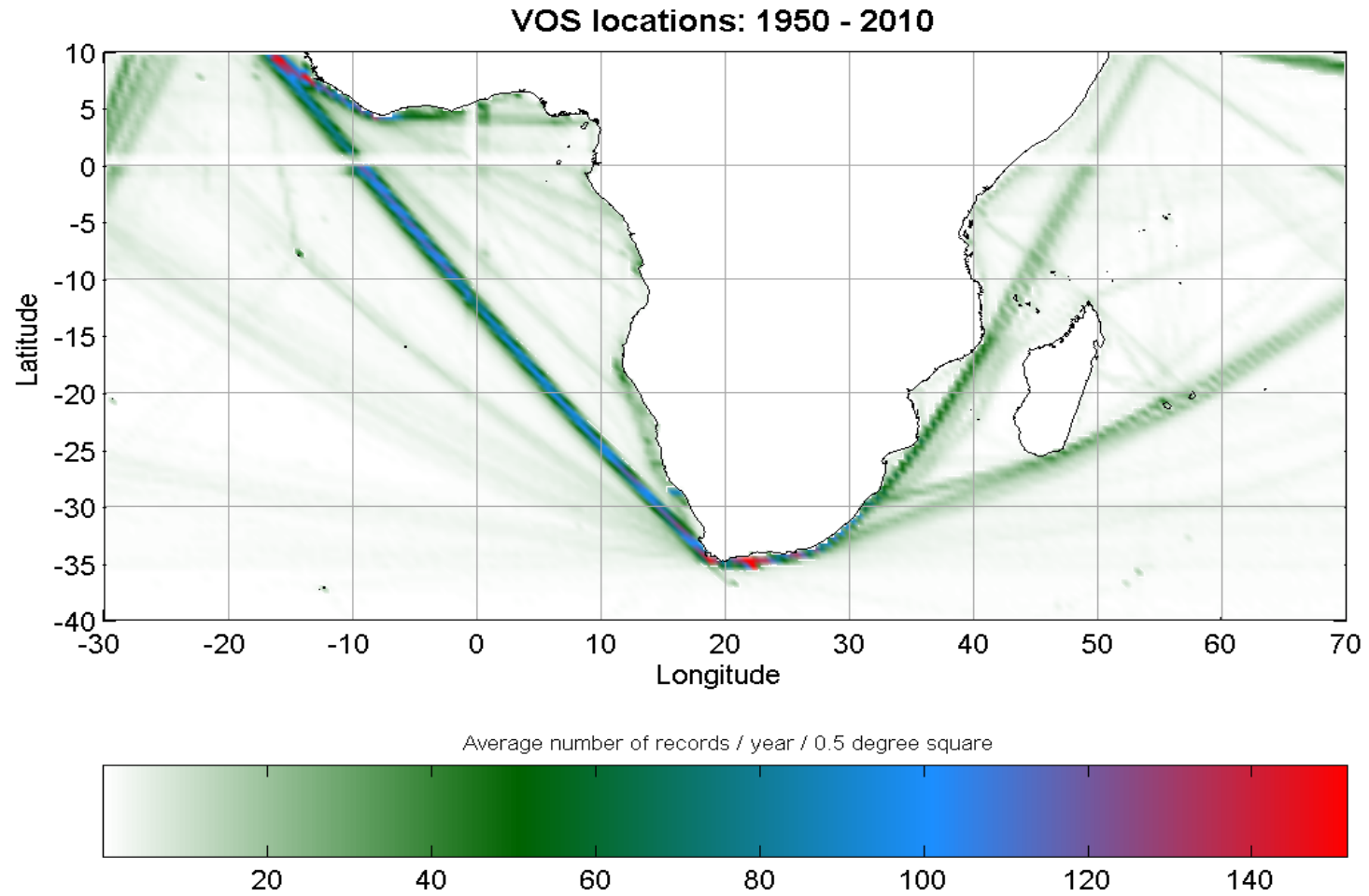


Figure 4.17: Shipping routes off the west coast of southern Africa

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