

Chapter 3



Study area, vessels and surveys

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“Survey objectives ranged from fish biomass estimation, to sampling oceanographic processes and whole ecosystems.”

Abstract

For the purpose of this study, the Western Indian Ocean was divided into six subregions, based on a combination of known marine ecoregions, geopolitical boundaries, and the spatial coverage by past RV *Dr Fridtjof Nansen* surveys. The Somali Coast, East Africa Coastal Current subregion (including Kenya and Tanzania), Mozambique, Madagascar and Comoros, Mascarene and Seamounts subregions extended 200 nautical miles seawards from the coast. The first *Nansen* (active between 1975 and 1993) surveyed in the Western Indian Ocean between 1975 and 1990, whereafter there was a 17 year gap before the second *Nansen* (active between 1994 and 2016) returned to the region in 2007. Survey objectives ranged from fish biomass estimation, to sampling oceanographic processes and whole ecosystems. The Mozambique subregion was surveyed most frequently (14 times) and over the broadest time period (1977–1990 and 2007–2014). Other subregions were surveyed only once, or a few times over four decades, thus providing point estimates, but not time-series information. Chapter 3 is intended as a reference chapter, showing the locations of all sampling stations attended by the *Nansen* between 1975 and 2014, and their grouping into six geographic subregions for comparative purposes in the following chapters.

Previous page: Pelagic and demersal trawl nets on the RV *Dr Fridtjof Nansen*. © Bernadine Everett

Opposite page: Disclaimer – The designation employed and the presentation of material in the maps are for illustration only and do not imply the expression of any opinion whatsoever on the part of the authors concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers and boundaries.

3.1 Study area

Spalding *et al.*, (2007) subdivided the Western Indian Ocean into 12 marine ecoregions, or “areas of relatively homogenous species composition, clearly distinct from adjacent systems”. Biogeographic forcing agents that characterize these ecoregions include upwelling cells (for example the Central Somali Coast), nutrient inputs from fresh-water influx (Sofala Bight / Swamp Coast), the influence of ocean currents (Northern Monsoon Coastal Current), bathymetric or coastal complexity (East African Coral Coast), or differences in temperature regimes or sediments. The boundaries of these ecoregions do not align with geopolitical boundaries of coastal countries in the Western Indian Ocean. Consequently, past *Nansen* surveys, which were often limited to the waters of a specific country (for instance Mozambique, in several years), also did not align with the ecoregions.

A combination of ecoregions, geopolitical boundaries and the spatial coverage by past

Nansen surveys was therefore used to define six subregions, as a geographical framework for this review (Figure 3.1). From north to south, these are:

Somali Coast subregion

– from the Horn of Africa to the northern border of Kenya, including the Socotra Archipelago and some sampling stations in the Gulf of Aden. This subregion includes parts of three marine ecoregions,

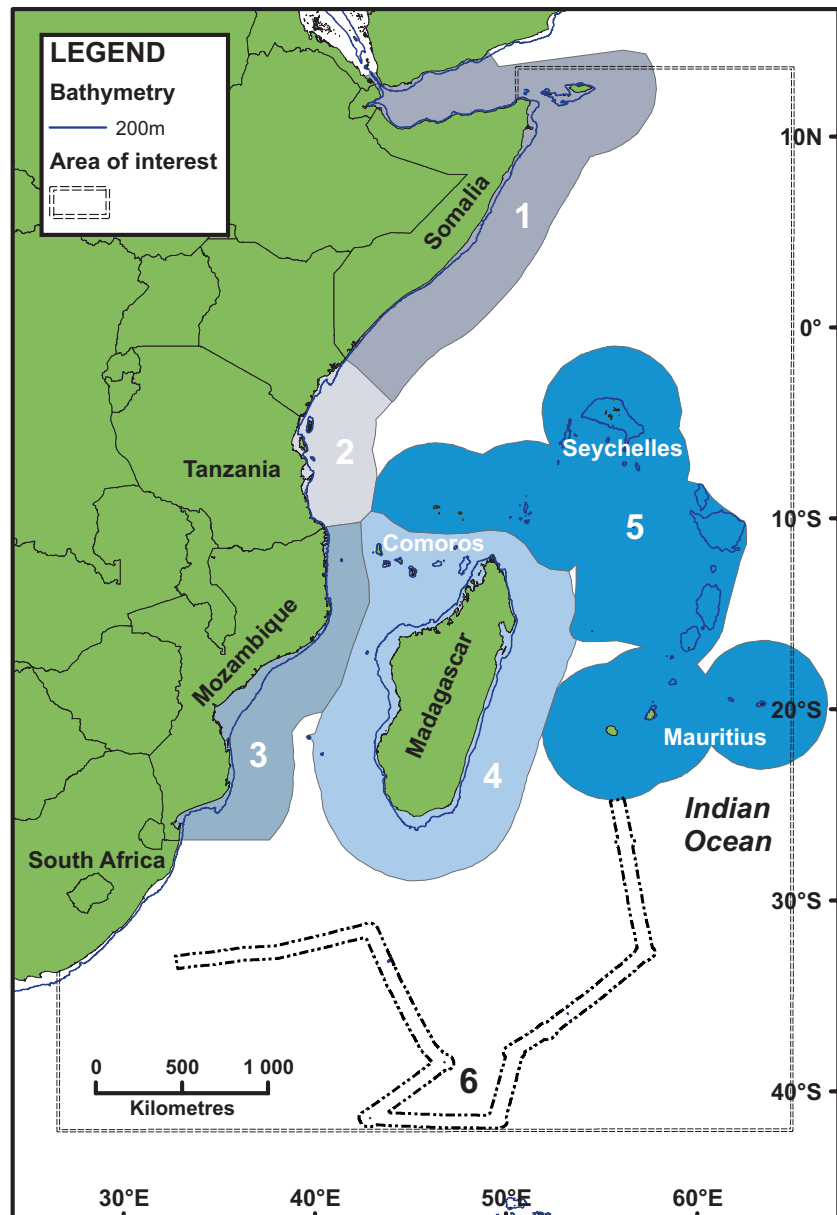


Figure 3.1 The Western Indian Ocean showing the six subregions. Key:

- 1 = Somali Coast
- 2 = East Africa Coastal Current
- 3 = Mozambique
- 4 = Madagascar and Comoros
- 5 = Mascarene
- 6 = Seamounts

The Seamounts subregion was determined from the track that the vessel sailed with 20 nm added onto both sides of the track. See disclaimer on the opposite page.

namely the Gulf of Aden, Central Somali Coast and most of the Northern Monsoon Current Coast (see Spalding *et al.*, 2007). It is typically an upwelling area, influenced by the Socotra Eddy, Great Whirl, Southern Gyre and the East Africa Coastal Current (Schott and McCreary, 2001). Surveys in this subregion were restricted to the early years of the *Nansen's* surveys in the Western Indian Ocean: from 1975 to 1976, and 1984. The Somali Coast subregion was also the very first to be surveyed by the *Nansen* Programme.

East Africa Coastal Current subregion

– from the northern border of Kenya to the southern border of Tanzania, encompassing most of the East African Coral Coast marine ecoregion (Figure 3.1), as well as the southernmost extreme of the Northern Monsoon Current Coast. This subregion is characterized by distinct seasonality, caused by the effects of the Northeast and Southwest monsoons. The seasonality affects annual patterns of physical, chemical and biological processes, reflected in seasonal changes in species composition of fish in catches (McClanahan, 1988). The *Nansen* surveys in this subregion were also restricted to the early years of the study period, between 1980 and 1983.

Mozambique subregion

– from the northern to southern borders of Mozambique, including surveys done in the Mozambique Channel in 2008. The subregion is ecologically diverse, and includes the southern extent of the East African Coral Coast marine ecoregion in northern Mozambique, the Sofala Bight / Swamp Coast in central Mozambique and the Delagoa ecoregion in southern Mozambique. Eastern South Africa was not surveyed by the *Nansen*, and therefore the southern part of the Delagoa ecoregion and the Natal ecoregion were excluded from the study area. The Mozambique subregion was extensively surveyed by the *Nansen* between 1977 and 2014, albeit with a 17 year gap between 1990 and 2007.

Madagascar and Comoros subregion

– surrounds Madagascar and the Comoros islands in the northern part of the Mozambique Channel,

and combines two marine ecoregions: Southeast Madagascar and Western and Northern Madagascar. This subregion is also ecologically diverse, with upwelling along southeast Madagascar, oceanic waters along the Madagascar east coast, and turbid waters along the west coast, where river outflows augment nutrient and sediment loads. Large shallow-water prawn fisheries operate along the west coast of Madagascar. The *Nansen* undertook three surveys off Madagascar in 1983, 2008 (east coast) and 2009 (west coast). The Comoros gyre in the Mozambique Channel was surveyed in 2009.

Mascarene subregion

– includes the waters around the Seychelles and Mauritius, and along the Mascarene Plateau between them. The submarine Mascarene Plateau, located north and east of Madagascar, extends approximately 2 000 km, from the Seychelles in the north to Réunion Island in the south. It covers an area of over 115 000 km² of shallow water, with depths ranging from 8 to 150 m, plunging to the abyssal plain at 4 000 m deep at its edges. This subregion is tropical and oceanic, and combines the Seychelles, Cargados Carajos / Tromelin Island, and Mascarene Islands marine ecoregions. *Nansen* surveys in the Mascarene subregion took place in 1978, 2008 and 2010.

Seamounts subregion

– includes seamounts in the high-seas to the south of Madagascar, which the *Nansen* surveyed in 2009. These seamounts fall outside the marine ecoregions defined for the Western Indian Ocean (Spalding *et al.*, 2007). Seamounts form hotspots of biological activity in the oceans, with higher primary productivity around them than in surrounding oceanic waters. Another source of enhanced production is the advection of phytoplankton, zooplankton, larger organisms, particulate organic material and nutrients from far-afield into the sphere of influence of a seamount (White *et al.*, 2007). In such cases, enclosed or semi-enclosed circulation patterns may act to retain the new arrivals. The seamounts surveyed by the *Nansen* are located in warm-temperate waters.

Table 3.1 Surface areas (/1000 km²) of shallow (≤ 20 m depth), shelf (20–200 m), slope (200–800 m) and deep water (> 800 m) for the six subregions, calculated in ArcMap 10.3 **

DEPTH	1	2	3	4	5	6	TOTAL AREA	SURVEY EFFORT (No. of stations)
	Somali Coast	East Africa Coastal Current	Mozambique	Madagascar and Comoros	Mascarene	Seamounts		
Shallow ≤ 20 m	10.4	10.2	19.3	42	9.3	0.01	91.2	293
Shelf 20–200 m	56	12	58.2	79.3	111.8	0.3	317.6	1 179
Slope 200–800 m	70.8	25.7	55.5	32.8	70.6	2.9	258.3	590
Deep > 800 m	947.7	271.4	502.3	1 369.2	2 466.2		5 556.8	125
Total	1 084.9	319.3	635.3	1 523.3	2 657.9	3.2	6 223.9	2 187*

* 28 stations had no bottom depths recorded in the data.

** Surface areas reflect whole subregions, and may differ from areas calculated for specific sampling purposes (i.e. parts of subregions) of surveys described in the following chapters.

Each subregion was divided into four depth strata:

- shallow (≤ 20 m deep);
- continental shelf (20–200 m);
- slope (200–800 m); and
- deep water (> 800 m).

The surface area of each depth stratum was calculated using the ETOPO1 one arc-minute global relief model (Amante and Eakins, 2009), in ESRI ArcMap 10.3. The Seamounts subregion had the smallest shallow (10 km²), shelf (240 km²) and slope areas (2 900 km²). The area of the > 800 m depth stratum was not calculated for the Seamounts, because this would have included vast stretches of abyssal plains between seamounts, which were not surveyed. The largest shallow area (≤ 20 m depth) surrounded Madagascar (42 000 km²), which also had the longest coastline (Table 3.1). The largest shelf area (20–200 m depth) was the plateau between Seychelles and Mauritius, in the Mascarene subregion (112 000 km²).

Slope areas (200–800 m depth) were of similar size (approximately 70 000 km²) in the Somali Coast and Mascarene subregions. These areas dictated the survey strategy that could be followed in each subregion. For example, few bottom trawls were

done in the Seamounts subregion, or around the Comoros archipelago, because the seabed areas between 20 and 800 m depth were relatively small and often too steep or rough for bottom trawling.

3.2 Vessels and gear

Two research vessels were used over the review period. The first RV *Dr Fridtjof Nansen* was active in the Western Indian Ocean between 1975 and 1990. It was replaced by a larger and more modern *Nansen* in 1994, although this vessel first surveyed the Western Indian Ocean in 2007 (Table 3.2). Detailed descriptions of gear used for measuring oceanographic features (Chapter 4), sampling ocean productivity (Chapter 5), acoustic and trawl sampling of pelagic (Chapter 6) and demersal fish resources (Chapter 7) are provided in the respective chapters.

No specialised software was used to capture or store data collected by the first *Nansen* during the early years of surveys, and much of the data were captured in hard copy only. From the late 1980s, data were captured onto the Nansis database (Chapter 2). The Nansis database collates

Table 3.2 Attributes of the two RV *Dr Fridtjof Nansen* vessels that operated in the Western Indian Ocean from 1975 to 2014.



1st RV DR FRIDTJOF NANSEN

2nd RV DR FRIDTJOF NANSEN

	1st RV DR FRIDTJOF NANSEN	2nd RV DR FRIDTJOF NANSEN
Year commissioned	1974	1994
Overall length (m)	46.35	56.8
Width (m)	10.3	12.5
Draft (m)	6.5	6.9
Gross tonnage (t)	491	1 444
Engine power (hp)	1 500	2 654
Navigation	Satellite	Satellite
Crew space (crew and scientists)	28	33
Deck machinery	Split trawl winch	Split trawl winch
Trawl door type	Waco combi	Thyborøn type 7 combi
Trawl door area (m ²)	6	7.41
Trawl door weight (kg)	1 200	1 720
Year decommissioned	1993	2016

information on stations and catch, stores data on length frequencies, maturity, sex, and body weight for selected species, and can be used to perform analyses such as calculating biomass on a swept area basis. In addition it provides a basic tool for mapping the location of sampling stations, and showing the distribution and abundance of catches made by species.

Environmental data were collected with Nansen bottles and thermometers on the first *Nansen*, and the results were captured on paper with copies made on carbon paper. At the end of each survey, these records were sent to the Oceanography Department at IMR for capture into a database. A CTD sonde was fitted to the second *Nansen*, and from 1994 onwards, data were logged electronically into flat text files. Quality control was undertaken at the end of each survey, when CTD “spikes” (outliers caused by equipment malfunction) were removed from the data.

Salinity measured by the CTD sonde would then be adjusted after analysis of water samples collected in salinity bottles. Density profiles were stabilised and while the initial quality of the oxygen and salinity sensors was fairly poor, the sensors were improved over time to record more accurate information. After completing quality control checks, data were imported into the Quick Cast database. At the end of each survey, data were sent to the Norwegian Maritime Data Centre.

Apart from the earliest years, when the first *Nansen* ventured as shallow as 10 m depth over the shelf to obtain samples, neither vessel worked in waters shallower than 20 m. This measure reduced the risk to the *Nansen*, but also prevented sampling of inshore waters, generally a productive part of marine ecosystems. After 2007, surveys in the Western Indian Ocean were restricted to south of 10 °S, to reduce the threat of piracy to the *Nansen*.

3.3 Surveys

The first RV *Dr Fridtjof Nansen* conducted 27 surveys in the Western Indian Ocean, of which the majority were in the Mozambique and Somali Coast subregions (Table 3.2). The second *Nansen* conducted 13 surveys, mostly in the Mozambique and Mascarene subregions. Besides individual survey objectives, provided below for each subregion, the Nansen Programme had an over-arching objective to develop scientific capacity in the region. Local scientists and post-graduate students were therefore hosted on-board during surveys, to gain practical experience. Detailed descriptions of surveys, including dates, operating areas, objectives and survey types are provided in Appendix 3.1.

The initial surveys in 1975 and 1976 covered the Somali Coast subregion and extended into the Gulfs of Aden and Oman (not shown). The Somali coastline was completely traversed on numerous occasions during this period (Figure 3.2), covering both the northeast and southwest monsoon seasons. After an initial six surveys in the mid-1970s, the vessel returned to the area once more in 1984 to complete three surveys in the north-eastern coastal area. Initially the surveys were undertaken to explore the extent, distribution and life history of pelagic resources (IMR, 1975, 1976a, b, c)

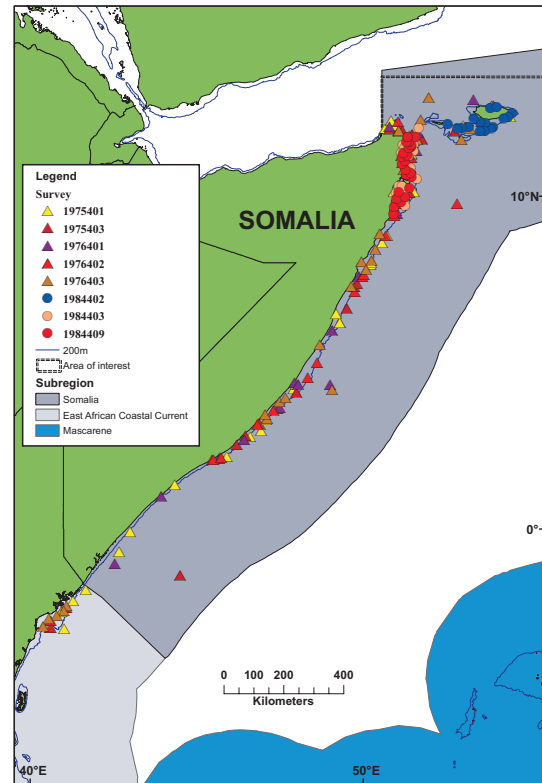


Figure 3.2 Sampling stations in the Somali Coast subregion.

Table 3.3 Temporal and spatial distribution of surveys conducted by the RV *Dr Fridtjof Nansen* in the Western Indian Ocean between 1975 and 2014: 1 survey 2 surveys 3 surveys

Subregion:	Somalia			East Africa Coastal Current		Mozambique	Madagascar and Comoros		Mascarene		Seamounts	TOTAL per year
	Somalia	Kenya	Tanzania	Mozambique	Madagascar	Comoros	Mauritius	Seychelles				
1975												2
1976												3
1977												2
1978												3
1980												2
1982												5
1983												4
1984												3
1990												3
2007												1
2008												5
2009												4
2010												2
2014												1
TOTAL per country	8	4	3	14	3	1	4	2	1			40
TOTAL per subregion	8	7		14	4		6		1			

* Survey conducted in the Mozambique Channel. Demonstration survey undertaken between Jakarta (Indonesia) and Durban (South Africa) in 2015 not included.

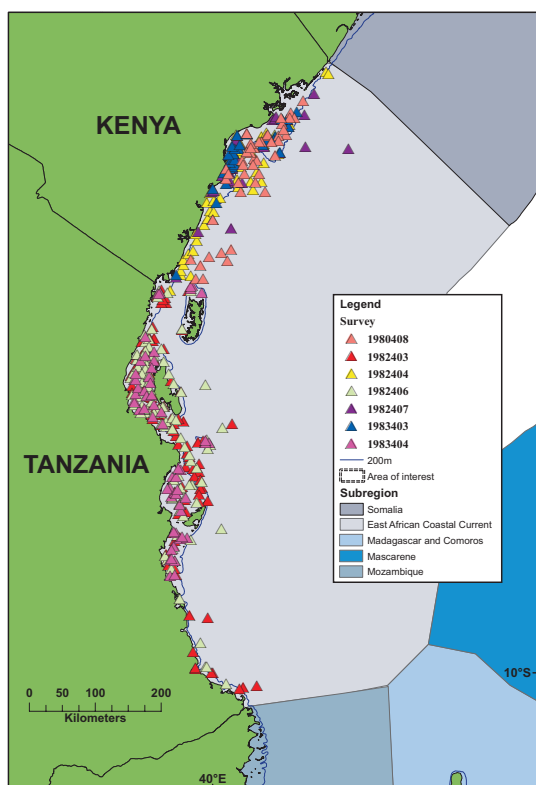
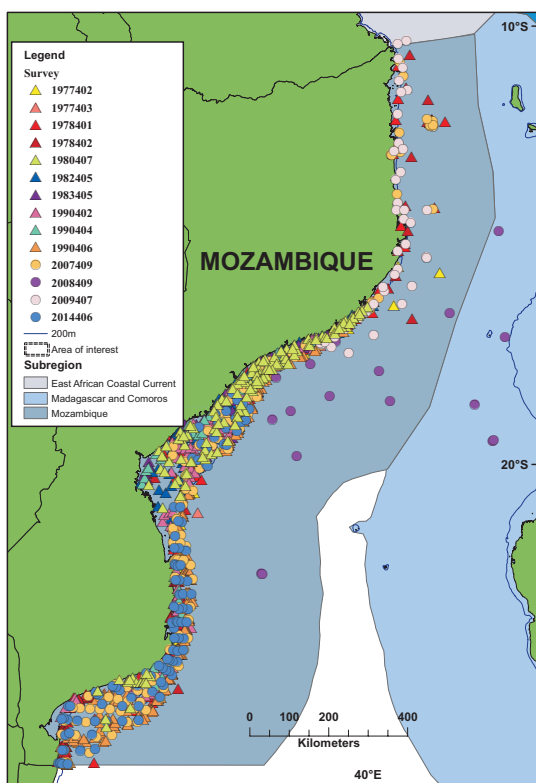


Figure 3.3 Sampling stations in the East Africa Coastal Current (EACC) subregion.



while later surveys searched for all major stocks within the survey area (IMR, 1976b, c, 1977b). The surveys in 1984 were combined acoustic and trawl surveys that explored fish resources in general (Blindheim, 1984) and small pelagic fish resources in particular (Strømme, 1984).

Surveys of the East Africa Coastal Current (EACC) subregion in Kenya and Tanzania were restricted to the period between 1980 and 1983 (Table 3.3). Several surveys were planned for the Southwest Indian Ocean Fisheries Project (SWIOFP, 2008–2013; van der Elst *et al.*, 2009) but could not be undertaken because of security concerns resulting from piracy (van Holst Pellekaan, 2014). The *Nansen* surveys in Kenya and Tanzania (Figure 3.3) were undertaken as exploratory fishing in deep water, to assess small pelagic and mesopelagic fish acoustically and to explore the demersal fish resources from shallow to deep water (Nakken, 1981; Myklevoll, 1982; IMR, 1982a, b, c, 1983a; Iversen, 1983). Hydrographic transects were undertaken and the hydrological regime of Tanzania was charted. Even though the EEZs of Kenya and Tanzania extend to 200 nautical miles offshore, sampling stations were restricted to the narrow continental shelf and upper slope areas.

Some 35 percent of *Nansen* surveys in the Western Indian Ocean covered the Mozambique subregion (Table 3.3). The early surveys in Mozambique, between 1977 and 1983, were focussed on the industrial fishing grounds of Delagoa Bay, Boa Paz and Sofala Bank. A second group of three surveys were carried out in 1990 (Figure 3.4), but these were the only surveys carried out by the *Nansen* in the Western Indian Ocean during the 1990s, and up to 2007. The subregion was surveyed again 17 years later, in 2007 to 2009, and in 2014. Survey objectives varied over time but included exploring the distribution and abundance of commercially important species, focussing on pelagic fish species, shallow- and deep-water shrimps and other deep-water resources (IMR 1977a, 1978a, b, c, 1990a, b, c; Brinca *et al.*, 1981, 1983, 1984). The later surveys had broader objectives, including sampling of biodiversity, benthos, hydrography, nutrients, plankton, mammals, birds and fisheries resources (Johnsen *et al.*, 2007; Kaeher *et al.*, 2008; Olsen *et al.*, 2009).

Figure 3.4 Sampling stations in the Mozambique subregion.

The Madagascar and Comoros subregion was surveyed by the first *Nansen* in 1983, and thereafter by the second vessel, 25 years later, in 2008 and 2009. The latter surveys formed part of the regional ASCLME and SWIOFP projects, and covered the Madagascar east and west coasts in successive years, and the Comoros gyre in 2009 (Figure 3.5). The 1983 survey was a combined acoustic and trawl survey that investigated fish abundance and species composition on the shelf (<200 m depth) on the east and south coasts (IMR, 1983b). Some limited hydrographic studies were also undertaken. The later cruises were multi-disciplinary and covered hydrological processes (currents in particular), productivity and biodiversity studies of the pelagic ecosystem, and species diversity of the demersal fish fauna (Krakstad *et al.*, 2008; Alvheim *et al.*, 2009; Roman *et al.*, 2009).

The first *Nansen* surveyed the Mascarene subregion around Seychelles in 1978 and it was 30 years before this subregion was revisited by the second vessel. The second set of surveys covered a much larger part of the Mascarene Plateau, including around Mauritius (2008 and 2010), the northern part of the subregion stretching southwards from Seychelles in 2008, and the southern part of it stretching northwards from Mauritius in 2010 (Figure 3.6). The surveys covered prominent features in the subregion, such as the Nazareth, St Brandon and Soudan Banks, and Saya de Malha. The 1978 survey investigated the distribution, abundance and biology of commercially important fish stocks on the Mahé Plateau (IMR, 1978d) whereas later surveys had a broader focus and multidisciplinary approach. Surveys after 2007 studied the hydrographic characteristics of the Mascarene Plateau, and the productivity, biodiversity and biomass of the pelagic ecosystem (Mehl *et al.*, 2008). The demersal resources of the St Brandon Banks were investigated (Strømme *et al.*, 2009; Krakstad *et al.*, 2010) as well as the small pelagic species of Mauritius and the southern Mascarene (Strømme *et al.*, 2010).

The seamounts south of Madagascar and along the Southwest Indian Ocean Ridge (Figure 3.7) were investigated during a single survey in 2009. The sampling stations included an Off ridge station [1], Atlantis Bank [2], Sapmer Seamount [3], Middle of What Seamount [4], an Off ridge cold water station [5], Coral

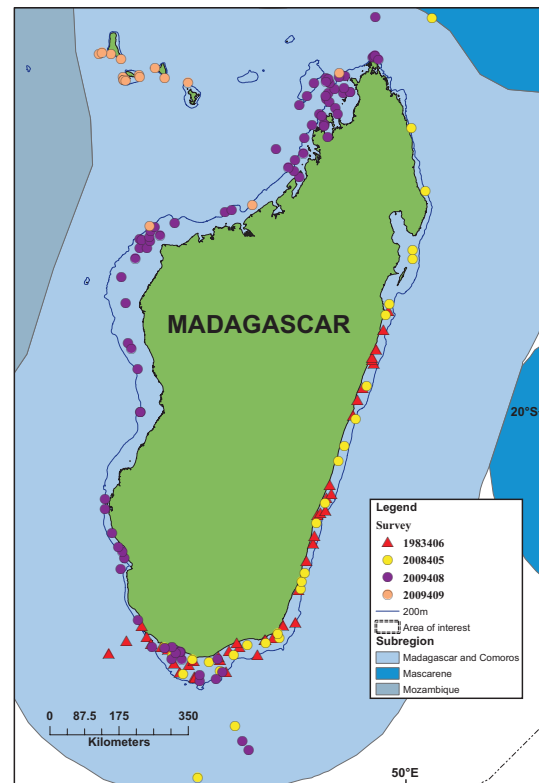


Figure 3.5 Sampling stations in the Madagascar and Comoros subregion.

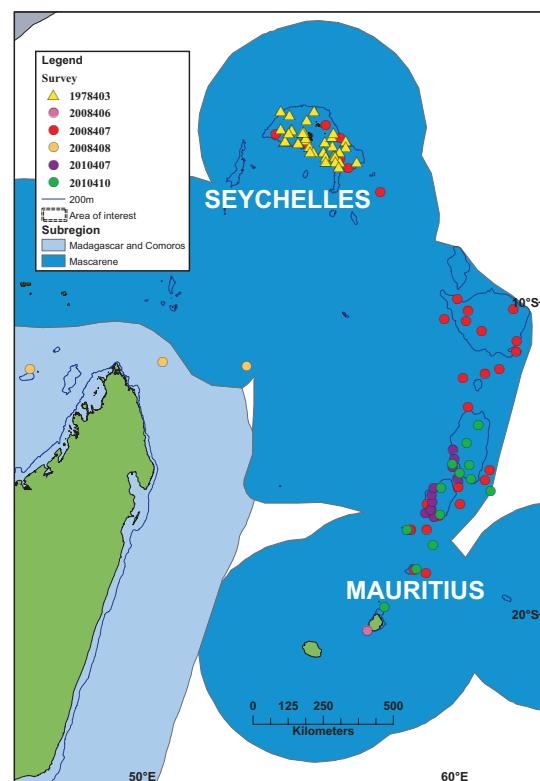


Figure 3.6 Sampling stations in the Mascarene subregion.

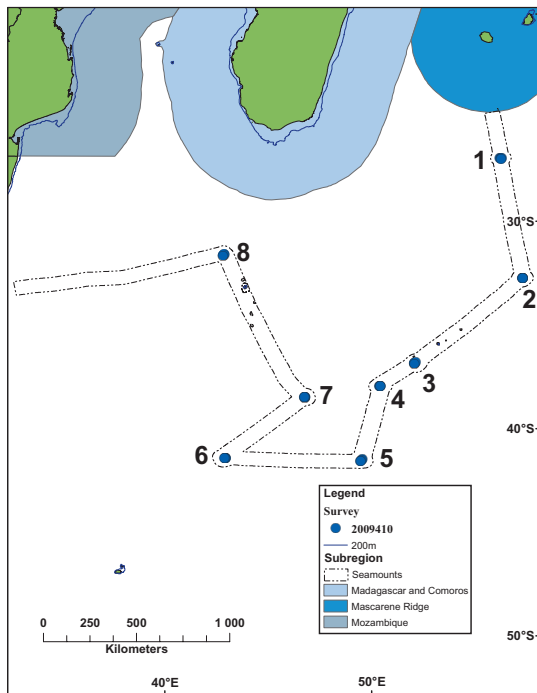


Figure 3.7 Sampling stations in the Seamounts subregion.

Seamount [6], Melville Bank [7] and an unnamed Seamount at Walters Shoals [8]. The aims of this survey were to document both physical and biological features and to obtain samples from the seamounts. Specific attention was given to phytoplankton communities and water column structure, tidal influences on the seamounts and the influence of seamounts on the nearby pelagic ecosystems (Rogers *et al.*, 2009).

3.4 Summary

Chapter 3 serves as a reference chapter, showing the locations of all sampling stations attended by the *Nansen* between 1975 and 2014, and their grouping into six geographic subregions. The subregions are used as a comparative framework in Chapters 4–7, to ensure consistency in the treatment of *Nansen* survey information. More detailed survey information is available in Appendix 3.1. ■

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