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# ATLAS OF AQUACULTURE POTENTIAL IN COASTAL KENYA

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**The Technical Cooperation Programme between the Ministry of Agriculture, Livestock and Fisheries and the Food and Agriculture Organization of the United Nations (FAO) in the Republic of Kenya, 2016–2017**

## Project TCP/KEN/3502 & FMM/GLO/112/MUL

**"Support to the implementation of mariculture in Kenya within an ecosystem approach & Blue Growth Initiative in Support for Food and Nutrition Security, Poverty Alleviation & Healthy Oceans"**

***Cover photo credit:*** Mangrove sensitization taking place in Kilifi County @ Tafiqul Islam (FAO Kenya)

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# PREFACE

The Blue Growth Initiative (BGI) is an FAO flagship initiative that aims to support the development of more productive, responsible and sustainable fisheries and aquaculture sectors that create decent employment, build social capital by improving the governance and management of aquatic ecosystems, conserve biodiversity and habitats, and empower communities. Pilot projects are being implemented in Africa, Asia and Latin America (Cabo Verde, Seychelles, Kenya, Madagascar, the Philippines and Santa Lucia) following the FAO ecosystem approach to aquaculture.

The BGI pilot project in Kenya has been supporting the development of aquaculture within the integrated water resources management and integrated coastal zone management frameworks. One of the goals of the project is to foster investment in mariculture.

The expansion and long-term sustainability of mariculture in Kenya — where there is considerable potential for development — requires good spatial planning and management, starting with the appropriate zoning and selection of sites, followed by the adoption of good area management practices. Spatial planning will help determine where and how to best develop aquaculture enterprises that are socially inclusive, equitable and environmentally responsible, and that provide opportunities for sustainable and profitable aquafarming and decent work, as well as from the additional economic activities that support it.

This aquaculture atlas for Kenya is the outcome of the application of spatial planning tools to support the development of environmentally sustainable and socio-economically responsible mariculture. The atlas provides invaluable information to help guide the Government of Kenya and others in formulating a systematic plan for the expansion of aquaculture by allocating zones for certain culture systems and species, and to facilitate decision-making for investors when selecting locations for their farms. Finally, it can also help in the creation of integrated coastal zone development plans, and help anticipate and address the impact of sea level rise on the intertidal and supratidal locations required for marine aquaculture.

Gabriel Rugalema
FAO Representative in Kenya

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# Summary

The potential for the continued development of mariculture in Kenya is immense. However, its expansion and long-term sustainability require proper planning, which starts from appropriate zoning and with the selection of the right sites, followed by the adoption of good management practices. Appropriate zoning will determine how and where to develop aquaculture enterprises that are socially inclusive, equitable and environmentally responsible, and which provide opportunities for sustainable and profitable aquafarming in addition to the economic activities that grow around it.

The main objective of this Atlas is to identify appropriate mariculture zones and sites that take into account the aforementioned objectives. This Atlas includes comprehensive information on various key themes, as well as providing users with maps and satellite images showing the areas that have been selected in accordance with reliable information on the main site-selection criteria in Kenya. It should be noted that decisions over siting are often complex and require the interpretation of data and specific ground surveys.

In general, this Atlas will assist investors or governments who wish to establish marine cage aquaculture projects along the Kenyan coastline. The provision of geo-referenced information on some of the main criteria will guide them in the selection of the most appropriate areas, while enabling a reduction of conflicts with other coastal users and minimizing environmental impacts.

**Saunders, J., Menezes, A., Aguilar-Manjarrez, J. & Matere, J.** 2017. *Atlas of Aquaculture Potential in Coastal Kenya*. FAO Project "Support to the implementation of mariculture in Kenya within an ecosystem approach & Blue Growth Initiative in Support for Food and Nutrition Security, Poverty Alleviation & Healthy Oceans". FAO and Kenyan Ministry of Agriculture, Livestock and Fisheries. Rome, Italy.

# INTRODUCTION

Aquaculture, is a growing industry that currently supplies approximately 50 percent of the world's global fish market. This growth trend will certainly continue, with an anticipated global increase in production of 30 million tons required by 2050 in order to provide fish products to a growing global population. Despite competing needs, the marine environment offers an available resource and space for expansion.

Kenya has a coastline of some 640 km, which expands to around 850 km when all of the bays and inlets are measured. There are also large expanses of brackish water suitable for mariculture on the Tana River and Athi River deltas, river water and other small water bodies that can be harnessed for coastal aquaculture. Kenya is expected to expand its mariculture activities, and these zonal maps and atlas have been developed on this assumption. The methodology used to determine both the potential areas for mariculture and the existing fisheries-related activities has been used on other coastlines such as the Saudi Red Sea and is generally applicable to most coastlines.

The expansion and long-term sustainability of mariculture in Kenya will depend on the development and adoption of best management practices, which essentially includes the identification and selection of suitable sites on which to locate fish farms. Locating these sites is the objective of this atlas. Any aquaculture project includes, among its early primary tasks, the selection of the most suitable site for the farming business. Any error in the mariculture site's selection or location evaluation can strongly influence the site's profitability, impacting on running costs and production capacity. Effects would also be noticed on fish mortality, health and welfare which, when combined, would make any longer-term fish farming unsustainable.

Prior to a site being selected and operations begun, the selection of suitable zones for deploying the physical infrastructure necessary to grow fish in cages requires a number of environmental, socio-economic and governance considerations. This atlas includes comprehensive information on various key themes, and provides users with maps and satellite images showing where areas have been selected based on reliable information, using the main site-selection criteria within Kenya. It should be noted that decisions over siting are often complex and require interpretation of data and specific ground surveys. For example, a site with good water flow will enable the removal of waste and the replacement of oxygen in the cages; however, the site is likely to remain unsuitable if it is too shallow or in an area that is too exposed to rough conditions. Conversely, a deep water site is useful, but not if the water flow is very weak. The areas selected in this atlas should therefore serve as background information for a more detailed site-selection process. Exact identification of potential cage sites should be undertaken following a dedicated survey and then a proper siting performed according to the investor's production plans, target species and the technology to be adopted – particularly with larger commercial farming.

In general this is an atlas to support good site selection spatially, with the provision of geo-referenced information on some of the main criteria, which may allow for a reduction of conflicts with other coastal users. For the government or investors who wish to establish marine cage aquaculture projects along the Kenyan coastline, this atlas will assist in the selection of the most appropriate areas.

It is currently the responsibility of the Ministry of Agriculture and Fisheries to manage and develop aquaculture activities within Kenya. A previous study (Report May 2015) – prepared by the Ministry of Land, Housing and Urban Development, Physical Planning Department and the Kenya Marine Fisheries Research Institute (KMFRI), State Department of Fisheries – entitled, "*GIS for Aquaculture Suitability Mapping for the Coast of Kenya*" aimed at identifying the nature and suitability of sites for aquaculture, including socio-economic factors. The study recognized the huge potential for mariculture particularly in exiting Salinas (salt-works) and tidal floods to produce fish (milkfish and rabbit fish), mud crabs, seaweeds, Artemia and finfish. Kenya first introduced seaweed culture, albeit in a commercially unsuccessful trial, in 2004 and then again in 2009 with the support of an EU-COI project, with the first container load shipped in 2011.

Although this study focussed on aquaculture and mariculture, the output from the spatial analysis was conducted on a very broad scale and very little zoning for mariculture was produced. FAO identified that further capacity building was needed within Kenya, including: the installation of Quantum Geographic Information System (QGIS) software, a free and open-source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis; continued research to identify potential aquaculture sites; and training. It was also suggested that inventories of existing aquaculture activities should be carried out and spatial data be employed to empower the Ministry of Agriculture with adequate information on the sector's overall developmental potential. This enables the Ministry and stakeholders in the counties to properly quantify and prioritize the support to be channelled to relevant governmental institutions. Having now been established, the GIS software and database provide the means for even further analysis of spatial information in order to help identify suitable sites for development as more data is collected.
Methodologies using GIS were selected to provide a consistent and robust approach to the capture, interpretation, storage and analysis of the data. This included the use of existing data from KMFRI and others, in addition to the capturing of new coastal and terrestrial data —particularly that relating to the Kenyan coastline and to mariculture. All spatial datasets are stored in the GIS and could be used where appropriate as part of the analysis for site selection, inventories, carrying capacity and the identification of potential areas for development.
Some additional important datasets have been captured from the interpretation of high-resolution satellite imagery such as existing earthen ponds for milkfish and shrimp, salt-works, tidal flats and other features.

As part of the study this atlas has been produced, identifying the location of potential sites for cage aquaculture and showing potential areas of environmental and social conflicts. This provides guidance for the Ministry of Agriculture and Fisheries and other stakeholders to: (i) assist current and future investment in mariculture; (ii) advise where to issue licenses if required; (iii) advise where to carry out further, more detailed investigations such as site surveys, carrying capacity analyses or environmental impact assessments (EIA); and (iv) advise on any other studies required before establishing the cage farms or developing tidal flats. This atlas is also expected to be of practical use to the scientific and educational communities, policy and decision-makers, as well as to commercial enterprise.

# THE KENYAN COASTLINE

The coastline of Kenya is situated between 4°50′ south latitude and 1°40′ south latitude and 39°10′ east longitude and 41°40′ east longitude. It is approximately 640 km in length and over 50 000 km$^2$ of the Kenyan marine area. (Figure 1)

**FIGURE 1**
**Kenya, showing its coastline and international boundaries**

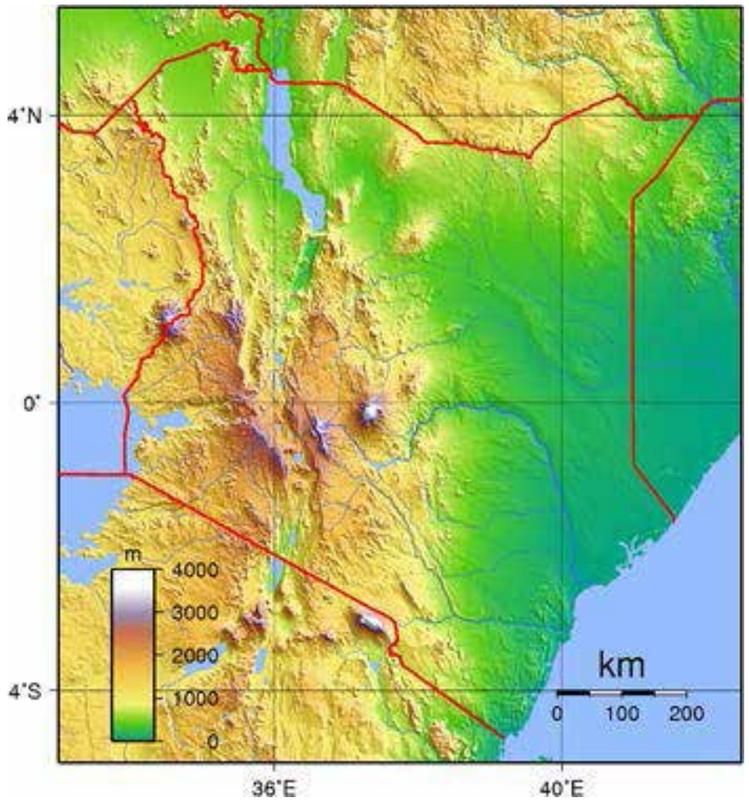



*Photo credit:* © Justin Saunders

## SITE-SELECTION CRITERIA IMPORTANT FOR MARICULTURE

The site identification and selection aspects for coastal and marine aquaculture (mariculture) mapping used satellite imagery, combined with other available mapped information (such as coastal habitats, rivers, navigation routes; infrastructure, including aquaculture zones such as Beach Management Unit (BMU); and coastal features such as bathymetry/water depths and topography) using GIS to perform a spatial analysis of the acquired dataset/layers to determine potential aquaculture areas.

Species should be mainly those with proven culture technologies and with established national or international markets. Some environmental concerns can be overcome by selecting native species depending on the region of interest, the species already cultured, or those undergoing trials. The identification of potential areas for aquaculture should be based on criteria that would be favourable for grow-out of these species. For instance, it is well-known that temperature affects the feeding, growth and metabolism of fish and shellfish; water temperature is thus a common area selection criterion for all species.

Also essential is a broad assessment of areas where it is technologically feasible to place appropriate culture installations. For example, sea cages for fish grow-out and longlines for mussel grow-out are the prevalent culture structures in current mariculture practice. Both sea cages and longlines are tethered to the sea floor, and thus the key assumption is that both sea cages and longlines will, for the time being and until technology develops, be located close to coastlines because of the technical and cost limitations related to the depth of tethering. For land-based systems, especially ponds for the growth of relatively cheaper species, costs become an issue, so ready access to a suitable freshwater source is needed on relatively flat land whose soil structure means ponds do not need to be lined.

The selection of suitable sites is generally influenced by:

- environmental (chemi-physical) parameters affecting the suitability of the site for fish production;
- potential environmental impacts;
- infrastructure for servicing considerations; and
- the need to safeguard the interests of other users of coastal waters.

Other, more specific factors also need to be taken into account when determining the acceptability of mariculture development proposals. These include:

- distance to other fish farms;
- proximity to nature conservation interests, including marine parks, corals and turtle nesting beaches;
- methods of operation (e.g. waste discharge, feeding, disease treatment, etc.);
- planning context (local plans, or coastal zone designations) including existing aquaculture zones or area management plans;
- potential impacts on the landscape and visual seascape;
- availability of any land access and necessary infrastructure;
- impact and proximity to areas of coastal security, plus various other activities or restrictions;
- effects on recreation and tourism; and
- impact on navigation and other fishery interests.

## GENERAL CRITERIA FOR MARINE FISH PRODUCTION

The broader general criteria to be considered when **selecting potential sites** suitable for cage aquaculture include:

### BOUNDARIES

**Territorial waters (or a territorial sea):** These are defined by the 1982 United Nations Convention on the Law of the Sea as a coastal marine belt extending at most 12 nautical miles (22 km; 14 miles) from the coastline (usually the mean low-water mark) of a coastal state. The territorial sea is regarded as the sovereign territory of the state.

As the marine area along the Kenyan coastline is a relatively deep water body, the areas with suitable water depth for cages are all inshore, within territorial waters.

**Exclusive Economic Zone (EEZ):** Under the 1982 United Nations Convention on the law of the sea, an Exclusive Economic Zone (EEZ) is defined as a sea zone over which a state has special rights over the exploration and use of marine resources. It stretches from the seaward edge of the state's territorial sea out to 200 nautical miles (370.4 km).

### CONSERVATION AREAS

**Protected areas:** There are six protected marine areas along the coast, designated by the Kenya Wildlife Services. There are a number of other, additional, environmentally-sensitive areas that have been identified for important bird life. Caution is required when developing aquaculture in these environmentally-sensitive areas. Although all the protected areas have been considered in this atlas – and potential sites within them excluded – it would be possible to reconsider certain sites in the future, if for some reason the designated areas became available. To reduce any kind of threats to protected areas, a minimum distance of 1 km from these sites should be maintained.

**Sensitive habitats and species:** Sites of particular value for nature conservation should be protected; this is especially true for Marine Protected Areas, conservation areas, areas that

FIGURE 2
**Mangroves are environmentally-sensitive areas and require protection**

*Photo credit:* © Tafiqul Islam (FAO Kenya)

have important bird populations, wetlands of importance as waterfowl habitats, and nesting beaches for turtles.

**Mangroves:** Mangroves provide natural protection to the coastlines, as well as providing breeding, nursery and feeding grounds for wild fish, which is important for stocking smaller farms with natural stock. Shrimp or milkfish pond construction should not destroy mangrove areas and so ponds should be located at least 500 m away from natural mangrove areas. Mangroves are easily visible from high resolution satellite imagery (50 cm from QuickBird or WorldView imagery) and represented as polygons. A buffer zone of 500 m was applied to the mangrove classification.

**Coral reefs:** Often called "rainforests of the sea", coral reefs form some of the most diverse ecosystems on Earth. They deliver ecosystem services to tourism, fisheries and shoreline protection. If fish cages are located too close to corals, the suspended solids that are produced can settle and smother the coral. The protection of corals is essential from an environmental viewpoint, and large amounts of tourism revenue in Kenya comes from people wishing to visit the corals and marine parks. It is therefore recommended that the distance between the edge of the farm area and the coral reef crest be greater than 500 m. Coral areas have, together with the buffer, been excluded from being allocated as a potential mariculture locations.

FIGURE 3
**Corals are environmentally-sensitive areas and require protection**

*Photo credit:* © emapsite.com

## ENVIRONMENTAL

**Bathymetry (water depth):** Water depth is one of the most important criteria used for the siting of mariculture, particularly marine cages. Suitable depths:

- allow for dispersion of particulate matter;
- facilitate good water exchange in combination with suitable currents;
- facilitate the use of deeper nets where water quality and temperature are more stable and there is a reduced water movement during storms.

Generally, in waters more than 25 m deep, cages should be placed in areas that offer maximum security from poaching and the least exposure to waves, and have the least environmental impact. Moorings placed in waters deeper than 80 m are difficult to inspect and maintain by divers.

For the Kenyan coastline the suitable water depth for cages has currently been established as between 20 m and 80 m, depending upon the type of cages being considered.

Bathymetry data were sourced from the General Bathymetric Chart of the Oceans (GEBCO), the most authoritative, publicly-available bathymetry data set for the world's oceans at 10 metre intervals. It was also possible to compare these with satellite imagery, which provided a more detailed spatial resolution to identify and avoid shallow areas.

FIGURE 4
**Bathymetry contours showing depth in metres**

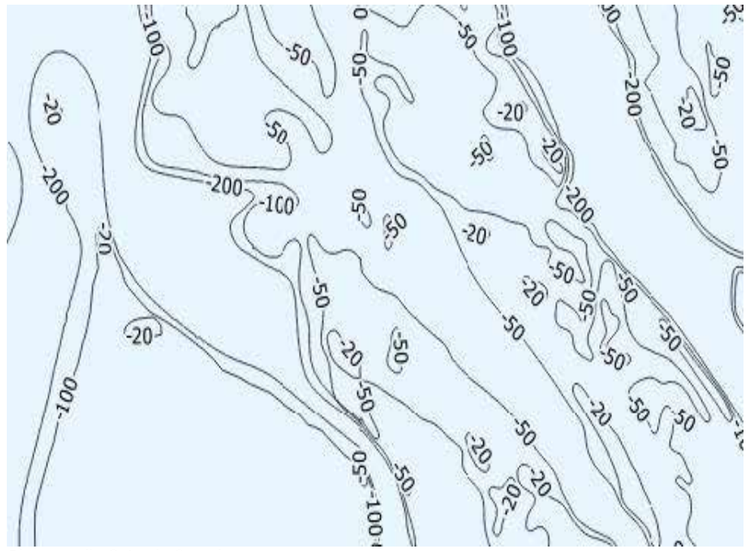


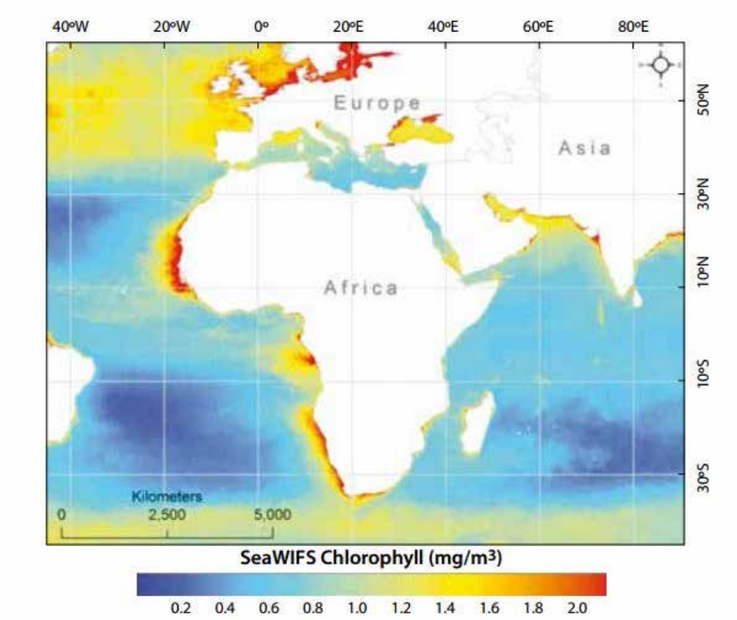

*Photo credit:* © Justin Saunders

**Sea surface temperature:** The temperature range of the water must be suitable for the species being cultured. Therefore, sea-water temperature data must be considered when selecting species. Temperature has a direct influence on fish metabolism and consequently on oxygen consumption, fish activity, ammonia and carbon dioxide production. Water temperature can be measured from satellite imagery. The temperatures of the Indian Ocean along the Kenyan coastline are consistently high throughout the year, ranging from 23 °C in July to 27 °C in March: this is acceptable for many of the potential and proposed species such as milkfish, red drum, and European sea bass (already introduced in Mauritius). Temperatures within this range mean there are no constraints to considering site selection along the whole coastline.

**Chlorophyll-a concentrations:** Chlorophyll-a concentrations can also be measured from satellite imagery and are an important indicator in evaluating nutrition status, water quality and the extent of organic pollution, providing useful information for monitoring harmful algal blooms. Kenya experiences lower chlorophyll levels of 0.5–0.85 mg/m$^3$ in comparison to the western African coastline. (Figure 5)

**FIGURE 5**

**Calculated annual average (example year 2009) of chlorophyll-a concentration (mg/m$^3$) extracted from satellite data (SeaWIFS) for the Indian Ocean and the Eastern Atlantic Ocean. It clearly shows how oligotrophic the waters of the Western Indian Ocean are in comparison to other adjacent waters that border the African continent (Arabian Sea, Mediterranean Sea and the Atlantic Ocean). Data downloaded from NASA (National Aeronautics and Space Administration) – GIOVANNI Ocean Colour Radiometry online visualization and analysis – Global monthly products**




*Source:* http://www.gdata.sci.gsfc.nasa.gov/

**Water salinity:** During the southeast monsoon the shifting of ocean currents brings highly saline Pacific Ocean water into the South Equatorial Current, while during the northeast monsoon the South Equatorial Current draws water of low salinity from the Malay Archipelago. These changes in turn result in changes in salinity in the East African Coastal Current waters. A further influence on salinity is the incidence of rainfall, especially the heavy rains of March to May, when the most significant discharges from all the major river systems – as well as all the minor, seasonal ones – occur. As is to be expected, offshore waters are mainly influenced by the oceanic currents; surface water salinities in Kenyan coastal waters vary from a minimum of 34.5 ppt to a maximum of 35.4 ppt.

Due to the low tolerance of some species to high levels of salinity, water salinity is important for the selection of some temperate species that might be cultured.

**Wave climate:** Of all the possible problems in marine cage culture, wave action is of primary concern. Wave climate is important as it influences the choice of both the design and strength of materials (for cages, nets and moorings) as well as influencing a farm's operational aspects.

Four factors influence the formation of waves:

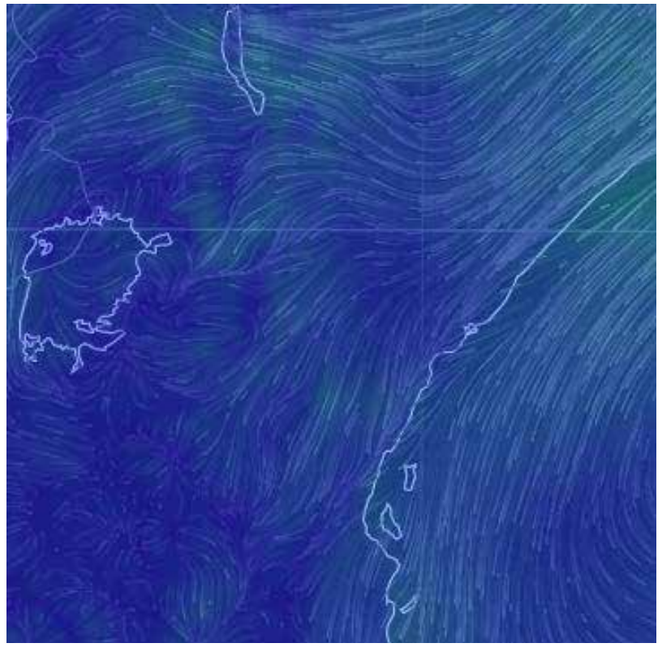
- wind speed
- distance of open water that the wind has blown over (called the fetch)
- width of area affected by fetch
- length of time that the wind has blown over a given area.
- All of these factors work together to determine the size of wind waves. The greater each of the variables, the larger the waves will be.

**Site exposure:** Shelter from the strongest prevailing wind and/or wave direction is important. Much of the Kenyan coast is exposed to both wind and waves, but there are many areas where cages could be located that would be protected by coral reefs.

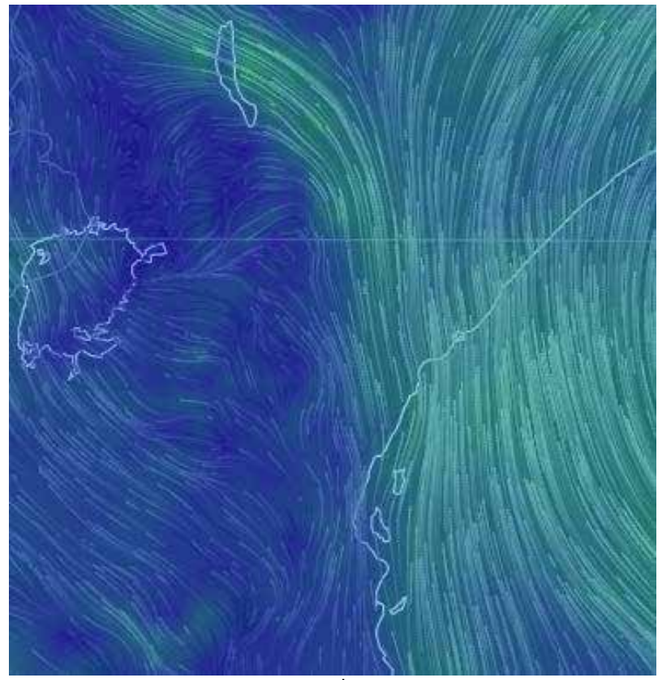
Wind conditions. Weather conditions on the Kenyan coastline alter significantly between the winter and summer months. The winds determine the onset of Kenya's two rainy seasons, with the hot northeast monsoon or *kaskazi* blowing dry air in from the Persian Gulf from November to March/April, and the warm, moist *kusi* monsoon blowing in from the southeast from April/May to October. The sea conditions vary throughout the year, with the most reliable months for good water clarity and turbidity falling between October and March, and especially January and February. Heavy rains bring run-off into the rivers so it is not advisable to locate mariculture activities where large rivers carrying sediment enter the ocean. Prevailing winds tend to come from the north in December and from the southeast in June. (Figure 6)

**FIGURE 6**

**Winter and summer prevailing wind conditions for the Kenya coastline**



December



June

*Source:* https://earth.nullschool.net/

**Tides:** For inland brackish water areas where the tidal range is adequate, experience in Kenya has shown that earth ponds constructed to impound spring tide water are the most suitable structures for mariculture. This can be done with little difficulty in areas where the land is more or less flat or has a slight slope, and the nature of the soil is satisfactory. On the other hand, the construction of earth ponds and the use of manually constructed channels depending on the use of tidal water harnesses gravitational force, in the form of tides for the water supply.

Tidal characteristics in relation to land elevation at the proposed farm site should be determined. Places where tidal fluctuation is moderate, between 2 and 3 metres, are most suitable for farms using tidal flow to fill the ponds. If tidal fluctuations are larger than 4 m the place is unsuitable because very high and expensive dikes will have to be constructed to prevent flooding during high tide. Also it would be difficult to hold water during the low tide, as water loss and seepage, crab holes etc. would be greater as a result of the high pressure of the high water column. Areas with a narrow tidal range of 1 metre or less are also unsuitable, as it would be difficult to fill the pond properly, without recourse to artificial pumping. The use of pumps is advised in areas where the tide is less than 2 m or greater than 3 m.

Before siting farms, actual measurements of tides should be made by consulting Tide tables, especially reviewing the maximum and minimum fluctuations over the year, so as to determine the high and low tide benchmarks. The highest tides during past floods and storms, as well as wave action during normal tides, storms and floods should also be known, perhaps by making enquiries with local residents, if no other information is accessible.

Tides are important for mariculture activities on Kenya's coastline. Tidal fluctuation is semi-diurnal with two highs and two lows during each 24-hour period. The tidal reference station for Kenyan waters is Kilindini Harbour at Mombasa. According to the tide tables for East African ports prepared by the Kenya Ports Authority, the ebb and flood times occur 40 minutes later than the reference station at Lamu and five minutes later at Malindi. All heights are based on the datum of the largest-scale admiralty charts for Port Kilindini.

For example the highest tide for 1986 occurs on 25 April at 4.02 m and the lowest on 3 November at 0.02 m below the datum. This gives the 1985 range as 4.04 m. There should only be very slight variation in the annual range from year to year. Indeed the annual range is always taken to be equal to 4.0 m by the Fisheries Department. For 1986 the various standard mean heights were determined as follows:

| | |
|---|---|
| Mean higher high water | 3.15 m |
| Mean lower low water | 0.65 m |
| Mean lower high water | 2.78 m |
| Mean higher low water | 0.80 m |

The average high tide is 2.96 m and the average low tide 0.71 m. Again, there should only be slight variations in these figures from year to year.

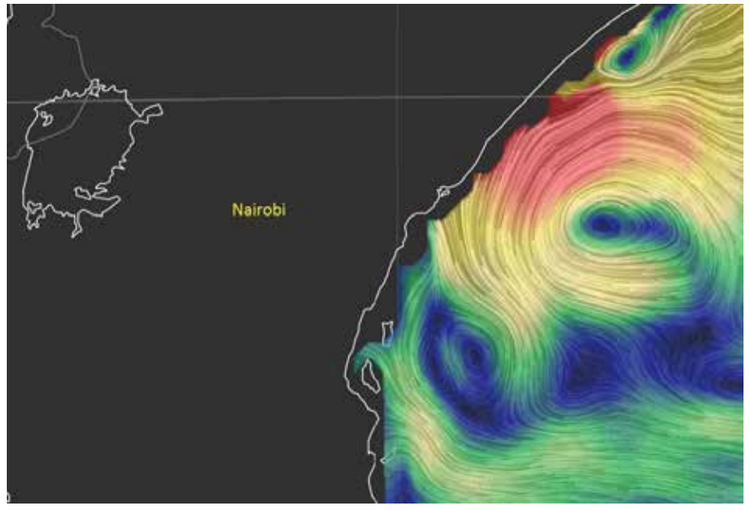
Tidal currents can be extremely strong, particularly along breaks in the reef or narrow passages, and provide a good exchange of water, which is ideal for mariculture practices.

**Current speed:** Good water exchange through the cage nets is essential for the replenishment of oxygen and the removal of waste metabolites; however, strong currents can deform the cage shape, reducing net volume. Current velocities in coastal marine areas typically range from 0 $ms^{-1}$ to 0.25 $ms^{-1}$ at some sites during strong winds or tides (Beveridge, 2004). Offshore, currents vary seasonally and tend to be dependent on the prevailing wind strength.

There are four oceanic currents affecting the Kenyan coast. These are the South Equatorial Current, the East African Coastal Current, the Equatorial Counter Current and the Somali Current. The westward-moving South Equatorial Current divides into two branches once it reaches the African coast at Cape Delgado. It generates the Mozambique Current which flows southwards, and the East African Coastal Current which flows north-eastwards, parallel to the coast. The East African Coastal Current flows northwards all the year round at least as far as Malindi. During the southeast monsoon it continues beyond Malindi northwards, joins with the Somali Current and continues right to the Horn of Africa. During the northeast monsoon (November to March) however, the northward extent of the East African Coastal Current is more restricted. At this time it meets and joins the southward-flowing Somali Current (which changes direction under the influence of the monsoon) with this convergence taking place anywhere between Malindi and north of Lamu, depending on the strength of the monsoon in any particular year. The two streams then turn eastward and flow offshore as the Equatorial Counter current. Figure 7 shows the general trend of currents during winter and summer.

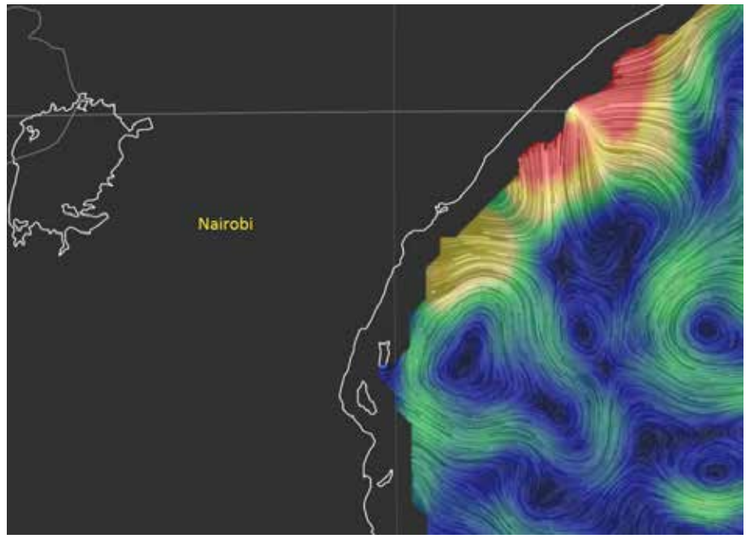
**FIGURE 7**

**Winter and summer prevailing currents conditions for the Kenya coastline**




June 2017 currents

0.0 m/s 1.0 m/s 1.5m/s




December 2016 currents

0.0 m/s 1.0 m/s 1.5m/s

*Source:* https://earth.nullschool.net/

**Rivers:** Although rivers do not flow intensely throughout the year, there are occasions during the rainy season when there can be high levels of freshwater passing through. This can:

- cause changes in water temperature and water turbidity;
- cause changes in salinity with stratification of the water column;
- bring drifting objects down the river into the water body and then into the nets (trees, timbers, large manmade floating objects).

Therefore, to prevent any restrictions caused by river flow, fish cages should be located at least 500 m from river outlets.

**Coastal land characteristics:** In Kenya there are no regulations (except local planning) that would be imposed by the national coast-guard about what can be developed in close proximity to the shoreline. Access is generally available and is being managed by Beach Management Units along the coast.

**Coastal topography:** topography of land suitable for aquaculture: low-lying deltaic, coastal and hilly areas with a suitable slope facilitate water supply, drainage and low cost of construction; importance of ground elevation in relation to tidal ranges for locating coastal pond farms, ground elevations suitable for marine farms at different tidal ranges; topography of sea bed sites suitable for sublittoral enclosures and sea bed cages; stability of shore and banks.

### SOCIO-ECONOMIC

**Infrastructure:** Aquaculture requires basic infrastructure for the construction of facilities, the operation, servicing and marketing of the product:

**Roads:** There must be all-weather roads nearby so that operational supplies, personnel and fish production can be delivered and transported from the site.

**Electricity:** There should be an electrical supply close to the site for water pumps, office air conditioning, ice-making etc. (particularly at nurseries and fish landing sites).

**Jetties:** For cage culture sites there should be a jetty with sufficient water depth for boats with feed and fish to load safely, especially during strong wind conditions. There are many existing fish landing sites along the Kenyan coast that may be suitable to accommodate mariculture needs.

### RISK FACTORS

Climate change: Consideration of anticipated, future climate change is becoming increasingly important for the selection of suitable mariculture sites.

- Sea-level rise: the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) predicted that by 2100, global warming will lead to a sea level rise of 180 mm to 590 mm. However more recent research finds that sea level rise by 2100 is likely to be at least twice as great as that presented by IPCC AR4. Significant sea level rise will make low-level coastal areas more prone to flooding and onshore shrimp farms should be located in areas at least 2 metres above present sea level.
- Increasing temperatures: Climate change models are predicting an increase in mean sea-water temperatures of between 1.0 oC and 1.4 oC by 2050.

**Industrial plants and oil spill:** Industrial plants discharge waste, alter the quality of the water and can prove fatal for plant, animal and human life. Given that this may cause serious problems for fish culture, it is recommended that a buffer zone of at least 1 km should be established from such plants.

A dataset of industrial locations was not provided but previous studies and fieldwork have identified industrial areas where oil spills have been a problem recently and in the past.

## GENERAL POTENTIAL CONFLICTS WITH OTHER USERS

### BOUNDARIES

**Country boundaries:** Aquaculture registrations are generally conferred by counties or municipalities that have jurisdiction over their own water bodies. Farms that are located across county or municipality boundaries may therefore cause conflict, and should be located wholly within one administrative area.

**National border areas:** National border areas are usually sensitive security locations, aquaculture should therefore be located away from these areas. In Kenya, current issues with Somalia restrict the northern part of the coast.

**Distance from shore:** There are a number of technical and operational considerations to be taken into account with respect to the maximum distance that cages can be located farther offshore.

- Operational extent. Offshore cages need to be serviced on a daily basis to bring food to the fish, undertake feeding and husbandry activities, change nets and take harvested fish back to shore. If the cages are located too far offshore, more than 10 km away, and there is no permanent offshore platform located at sea, boat journey times can cause operational and logistical difficulties that should be carefully assessed and evaluated.
- Offshore (out of sight). Cages can cause visual conflicts (affecting seascape) if they are placed in front of an urban area, tourist facilities or weekend and holiday homes. Potential conflict is minimized if they are placed out of sight of the shore.

Maps are provided with dotted lines indicating distances of 5 km and 10 km from the coastline.

As part of the locating of suitable sites/zones for potential offshore cage farms, two categories were produced by dividing the areas into those between 500 m (to avoid potential near-shore conflicts) and 5 km (Category A), and between 5 km to 10 km (Category B). Areas further out would not only be more costly to service but could also be subject to harsher conditions as potentially more exposed sites.

**FIGURE 8**
**Boats servicing fish farms often travel large distances with feed and maintenance materials. Reducing this distance and time has the benefit of reducing operating costs**

*Photo credit:* © Arron Anon

## CONSERVATION AREAS

**Fish nursery or spawning grounds:** Mangroves, coral reef, and underwater seagrass meadows are areas proven to be relevant for fish stock reproduction and/or are used as nursery and spawning grounds by local species. Cages should be not located near these areas as they may interfere with wild fish behaviour or, in the case of significant escapes of predator species, become a threat to juvenile populations. It is recommended that the cage farms be located in such a way as to avoid its establishment on spawning and nursery grounds.

**Turtle beaches:** Marine fish farming sites may cause disturbance to turtle nesting through excessive light, noise and boat usage. Furthermore, the construction, use and maintenance of shore bases built to support finfish farms may disturb turtles and lead to the deterioration of their habitat through physical damage to nesting beaches. A buffer zone of 1 km is suggested. Several beaches along the Kenyan coast are turtle nesting sites that need to be protected, such as Watamu Beach, illustrated below in Figure 9.

**FIGURE 9**
**Sea turtle returns to the Indian Ocean at Watamu Beach after nesting**

*Photo credit:* © Michael Thomas

**Areas of archaeological interest:** Kenya is endowed with a rich pre-historic fossil heritage dating back over 100 million years, to the dinosaur age. The sites within the coast of Kenya which have been instrumental in archaeological studies over the years include Mtwapa, Manda and Gede. These areas must be avoided, as ruins or other findings can be damaged by underwater moorings or by land-based construction.

## AQUACULTURE

**Aquaculture farms:** Waste feed and faeces from fish farms can collect on the seabed under fish cages. This increase in organic matter has an impact on this benthic environment, affecting the nature and chemistry of sediments, and can reduce the diversity of animals living there. Water quality can also be affected locally, which could cause problems for farms sharing the same water supply. In addition there is a risk of disease transfer from one farm to another if farms are not sufficiently separated.

**Other fish cage farms:** At least 3 km from any existing finfish cage site, or in accordance with a local area plan or coastal zone management plan.

**Existing shrimp/fish farm and hatchery water inlets:** There should be a buffer between fish cage areas and water intakes for shrimp farms, or fish or shrimp hatcheries. (Suggested buffer zone: 3 km).

Information on the locations of other aquaculture and mariculture farms is available on the maps to facilitate the user's site-selection process.

The geographic locations of aquaculture sites have been made available by the Ministry of Agriculture, with some verified using satellite images and/or direct field verification.

## FISHING

**Traditional fishing areas:** Conflicts with the fishery sector can arise mainly in competition for access to traditional fishing grounds. Areas traditionally exploited by local fishing communities should be not used for cage aquaculture. However, limiting the access in these areas to fishers will generate conflict between the fishery sector and farmers. Where conflict may arise it is advisable for the two sectors to come to a zonation agreement. As part of the atlas compilation the existing fisheries areas are demarcated on the maps, and even reveal the conflicts within them by indicating encroachment on marine parks and existing coral reefs.

**Port areas or sea infrastructures:** Mooring inside a port or near the outer harbour entrance should be avoided. This is to enable the safe manoeuvring of ships and boats approaching or exiting the port. Port authorities will indicate the buffer zone to be respected according to the type of ship/boat traffic using the harbour.

**Fish landing sites:** Existing fish landing sites provide ideal locations for potential aquaculture as these sites already have established jetties and can often be expanded more economically than developing new facilities.

Geographic coordinates of fish landing sites were made available by the KMFRI.

***Photo credit*: Mangrove sensitization taking place in Kilifi County. © Tafiqul Islam (FAO Kenya)**

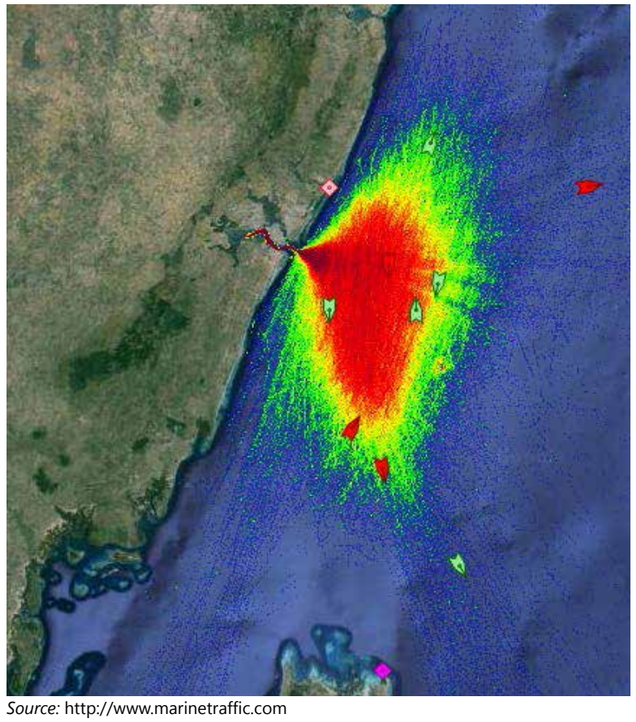
## SHIPPING

**Vessel anchorage areas:** These areas are often located in the vicinity of harbounrs, straits or industrial areas. They are used as standby anchorage for managing the flow of marine traffic and for vessels waiting to anchor. They are usually indicated on marine charts and cannot be occupied by aquaculture cages. A buffer zone of 500 m from anchorage areas is therefore recommended.

**Ports and dockyards:** There could be conflicts between port or dockyards and offshore cages due to the navigation routes for boats entering or exiting the area. A buffer zone of at least 500 m is therefore recommended.

**Navigation routes:** Large vessels (oil tankers, cruise ships, cargo ships etc.) passing through marked navigation routes can disturb fish production by virtue of the waves they create, in addition to underwater engine and propeller noise, etc. Therefore, for safety and production reasons, fish cage licences should be located an appropriate distance from navigation routes (1 km).

**FIGURE 10**
**Navigation routes, such as this image showing Mombasa (March 2016) traffic, can now be found online at websites such as www.marinetraffic.com**



*Source:* http://www.marinetraffic.com

A navigation route dataset was developed using maps of traffic density (in this case March 2016) for the Kenyan coast available online (www.marinetraffic.com). Ship traffic density maps were digitized into the GIS and buffered by 1 km. Most of the activity was located around Mombasa and it gave a good indication as to which areas to avoid, particularly when locating potential cage sites to the south of the port.

**Coast-guard stations**: Coast-guard stations which are located near to jetties servicing the aquaculture industry are ideal for safety reasons. Kenya has no coast-guards but it is recommended that this service be established.

## TOURISM

**Areas of interest for tourism:** Tourism is highly developed along the Kenyan coastline, and tourist areas have been developed along certain sections of the coast, interactions with aquaculture can generate conflicts and objections against both land- and water-based farm facilities. Farm siting must take into consideration tourist needs and they should be located at a distance of at least 3 km from tourist hotels and beaches.

**Recreational boating and diving:** Areas that are important for recreational boating (such as yachting or fishing) or important dive sites (wrecks or corals) should be avoided. These areas might need to be officially designated. In Nairobi, people enjoy boat rides, a popular pastime, on the artificial lake in Uhuru Park.

## MILITARY

**Areas of military importance:** There could be zones of military importance, such as navigation routes or firing ranges in marine areas, where cage aquaculture activity cannot be developed. A buffer zone of 5 km is recommended.

## INDUSTRIAL

**Waste dumping areas and underwater coastal pipe outlets:** These points must be avoided and mariculture sites must be located at a distance of at least 1 km. This layer of information was not available as part of the atlas analysis.

**Areas with underwater cables or conduits:** These areas must be avoided and no moorings or cages should be deployed here (a suggested distance of 200 m is recommended).

**Urban areas:** In coastal urban housing areas there can be conflict between the residents and aquaculture, particularly because of visual aspects (the seascape). Therefore it is recommended that there is a buffer of 3 km between urban areas and fish cages. Planned zonation of urban areas should include mariculture developments as part of the planning process.

**Industrial, agricultural and domestic effluent outlets:** Sources of water pollution can cause problems for fish survival and growth. Because sources of fish farm effluents can be a biosecurity risk for the fish in the cages, the cage license areas should be located at an appropriate distance from effluent outlets (suggested buffer zone of 500 m).

## GENERAL CRITERIA USED IN THE ATLAS FOR ZONING MARICULTURE AND THE SELECTION OF POTENTIAL AREAS SUITABLE FOR CAGE AQUACULTURE

The major criteria used to identify the most promising areas for mariculture development were determined mostly by the importance/relevance and availability of the data within Kenya. The project was fortunate that, by using recent satellite imagery and obtaining other existing GIS data – mostly from KMFRI – GIS-based functions (such as buffering, intersecting and other spatial queries) could readily be used to determine suitable potential sites for aquaculture as well as locating existing sites and features already involved, or which might impact upon future mariculture. It should be noted that having established this mariculture atlas the next steps for site selection would be to carry out a **detailed site survey** of the general areas indicated in the atlas.

The project was endowed with numerous datasets to carry out spatial analyses of habitat, environment, physical and socio-economic features, as well as conflicts to be avoided when zoning or looking for potential sites for mariculture. Previous surveys of existing mariculture activities were also incorporated into the atlas and became part of the analysis.

Below is a list of the general criteria used for zoning and the selection of potential areas suitable for cage aquaculture. Descriptions of each are provided in the previous sections.

**Conservation areas**
Protected areas
Sensitive habitats and species
Mangroves
Corals

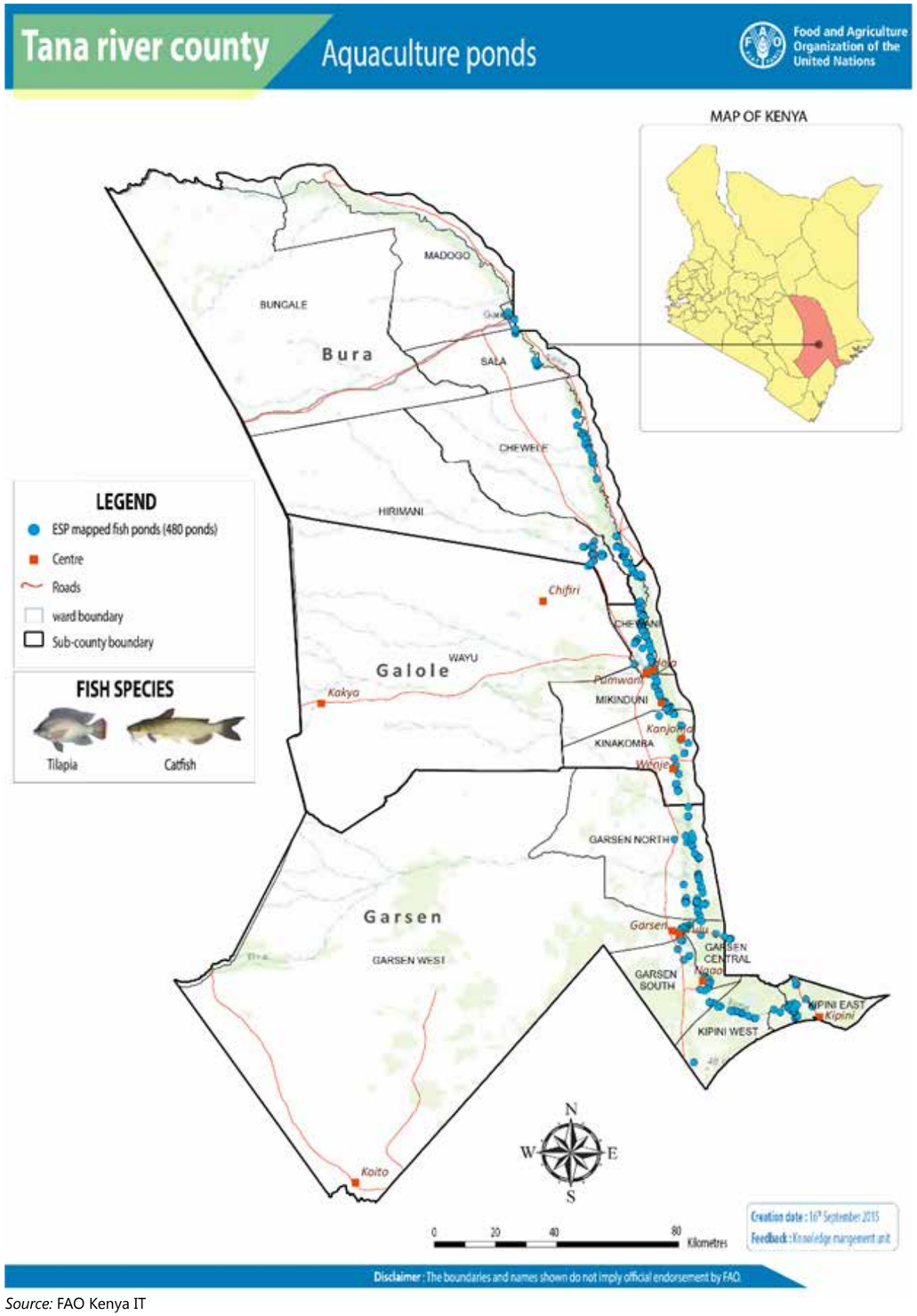
**Environmental**
Bathymetry
Rivers

**Pollution**
Industrial plants and oil spills

As well as looking for potential aquaculture sites, a number of field studies were carried out by the FAO GIS team to locate existing ponds that have been developed in the six counties. These sites were identified and mapped during a field exercise. These ponds are generally run by the User groups and are often small-scale ponds that are on-shore and managed by the communities. Some of this information was collected during field visits to the areas while other sites were digitized from the available satellite imagery. It was observed that these are in close proximity to the shore where ponding is likely and also near to other ponds such as salt-works. Close proximity to existing mangroves was observed at many sites using the satellite imagery; this presents some environmental concerns, as it potentially becomes a environmental conflict zone.

An example of a county is shown in Figure 11, revealing the extent of small ponds that are being run by the user groups within the communities.

**FIGURE 11**
**Tana River county aquaculture ponds, predominantly Tilapia and Catfish species**




*Source:* FAO Kenya IT

Coastline biological ranking was carried out to indicate areas of high sensitivity in terms of biological ranking. Areas containing mangroves and coral reefs were identified as very high-ranking, while areas of urban population or bare rock were categorized as low sensitivity. This ranking gives a good indication of where environmental and biological conflicts could affect fisheries activities.

A number of key features were considered as part of the selection process. Good proximity to fishing piers and fish landing sites benefits any potential new areas for development because the infrastructure is already built. Locating potential sites away from hotels and tourism is necessary. A number of key reasons and selection criteria are described below, particularly related to existing physical, biological and social features that are already in place and therefore must be considered.

As part of the exercise of locating suitable sites/zones for potential offshore cage farms, two categories were identified: areas that were less than 5 km from the coastline (Category A) and areas between 5 km to 10 km (Category B). Areas in Category B would not only be more costly to service because of the transportation of food, but could also be subject to harsher climatic conditions as they are likely to be more exposed.

The atlas has been presented as a series of 46 maps in total generated at a scale of 1:120 000. It features a series of 23 maps on the left-hand side, including satellite imagery of existing aquaculture, biological zoning and showing potential areas suitable for cage farming, along with a series of 23 GIS maps on the right-hand side showing the criteria collected (inventory of related resources) and data used as part of the overall zoning process.

The legend items are shown in Figure 12.

**FIGURE 12**
**Legend for the Atlas showing features used as part of the site-selection process**


*Source:* © Justin Saunders

## RESULTS

### Methodology used for the identification of potential marine aquaculture sites

A methodology was adopted so as to provide a consistent and robust approach for the capture, interpretation, storage and analysis of spatial data. This included the capturing of new coastal and terrestrial data along the Kenyan coastline and at an appropriate scale to carry out the site-selection study. All spatial datasets were stored at the FAO office in Nairobi and can now be used as part of site selection and for the identification of potential areas for development. Many of the datasets presented in this atlas were made available from Kenya Marine Fisheries Research Institute (KMFRI), while others were captured from publicly-available satellite imagery.

The following statistics were calculated for potential cage farm areas according to their distance ranges:

| Type | Hectares | km² |
|---|---|---|
| Category A | 25 322 | 2 532.2 |
| Category B | 107 338 | 10 733.8 |

**A**

| County | Hectares | km² |
|---|---|---|
| Kilifi | 11 412 | 1 141.2 |
| Kwale | 4 872 | 487.2 |
| Mombasa | 579 | 57.9 |
| Lamu | 7 237 | 723.7 |
| Tana River | 1 222 | 122.2 |
| | 25 322 | 2 532.2 |

**B**

| County | Hectares | km² |
|---|---|---|
| Kilifi | 29 134 | 2 913.4 |
| Kwale | 4 757 | 475.7 |
| Mombasa | 0 | 0 |
| Lamu | 38 036 | 3 803.6 |
| Tana River | 35 411 | 3 541.1 |

## INDEX MAP

This atlas consists of 23 map sheets generated at a scale of 1:120 000 if printed at A3 size.

**FIGURE 13**
**Map Index**

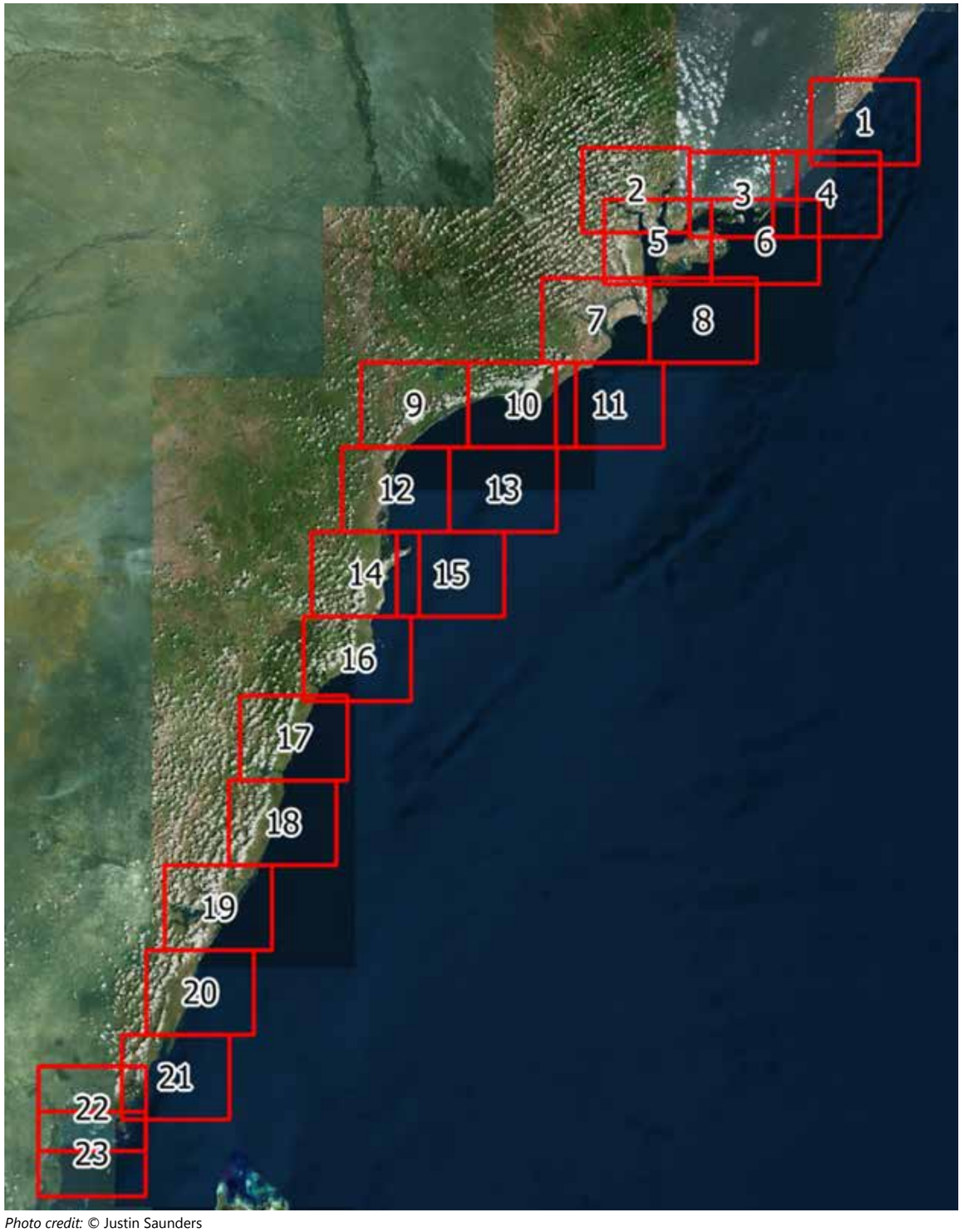
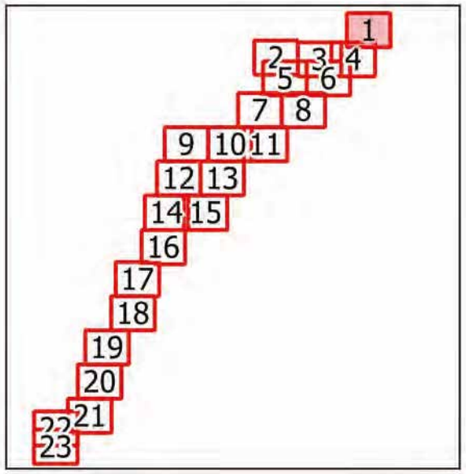



*Photo credit:* © Justin Saunders

# Mariculture Zoning Map - Lamu - KENYA




## Legend Atlas

### Boundaries
- Territorial waters
- 5km from coastline

### Conservation areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Coastline Biological Ranking
- Very high
- High
- Medium
- Low

### Aquaculture
- Kilifi ponds
- Mombasa ponds
- Ponds from satellite imagery
- Category A potential cage sites
- Category B potential cage sites

### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns

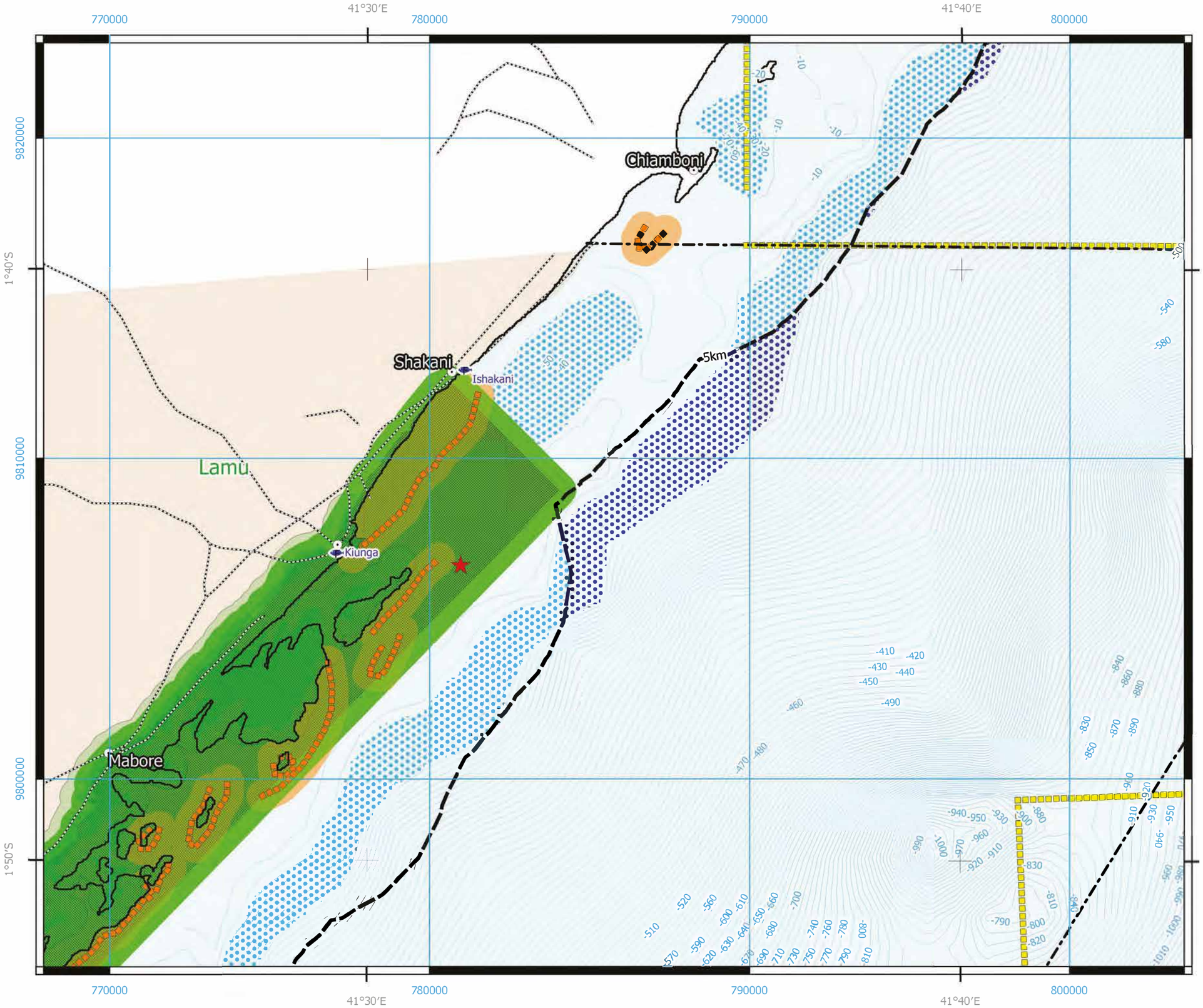



Atlas production by Justin Saunders

Scale 1:120,000

# Mariculture Zoning Map - Lamu - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

## Legend Atlas

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- Territorial waters
- Coastline
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County
- Kilifi
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- KWS marine parks 500m buffer
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### Urban/industrial
- Hotels
- Towns
- Oil exploration blocks

### Transportation
- Navigation routes
- Roads

N W E S

**Projection**

NAME: UTM zone 37S
CODE: 16137
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
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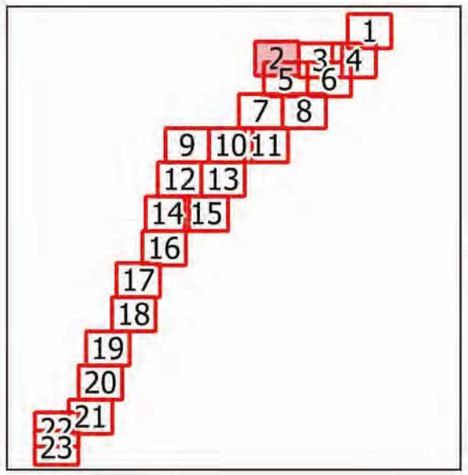


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Atlas production by Justin Saunders

700000 40°50'E 710000 720000 41°0'E

9800000 1°50'S

9790000

9780000 2°0'S

Kiangwe

0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

Scale 1:120,000

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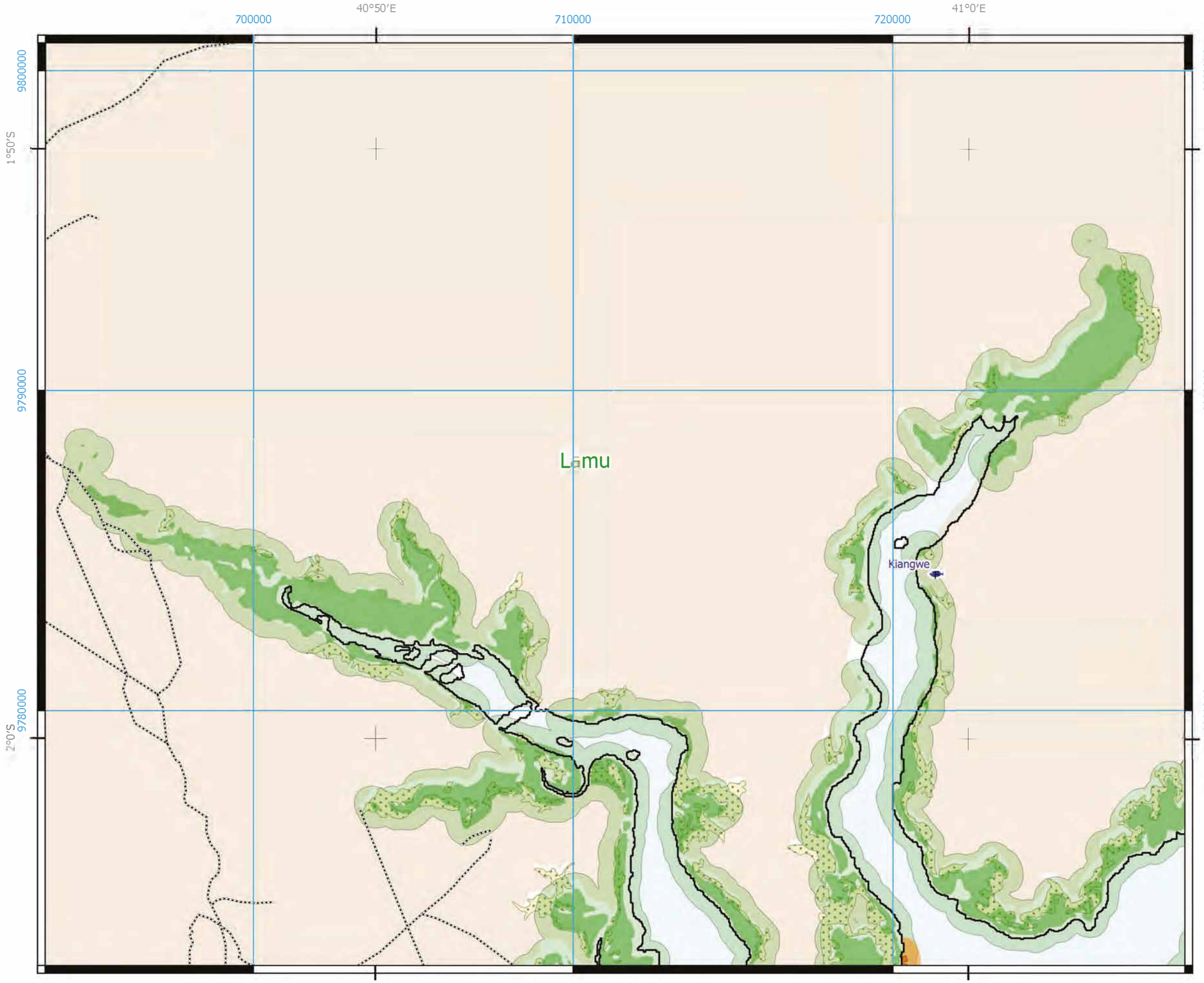


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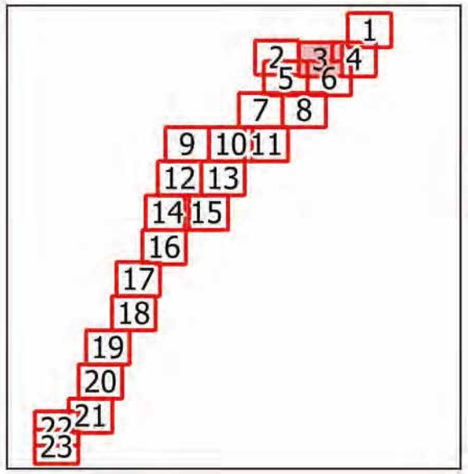


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Atlas production by Justin Saunders

730000 740000 750000 760000
41°10'E 41°20'E
1°50'S 2°0'S
9790000 9780000

S
Ashuwei
Mvundeni
Rubu
Mkokoni
Chandani
Ndau
Ndau
Kiwaiyu
Kiwayu
5km
Faza Rasini
Faza
Nyambogi
Kisingitini
Kizingitini

0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

Scale 1:120,000

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730000 740000 750000 760000

41°10′E 41°20′E

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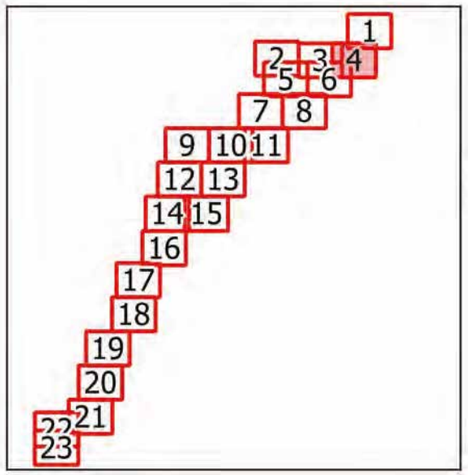


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Atlas production by Justin Saunders

41°20'E 760000 770000 41°30'E 780000 790000

1°50'S 9790000

2°0'S 9780000

Rubu
Simambaya
Ashuwei
vundeni
Rubu
Chandani
5km

0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

Scale 1:120,000

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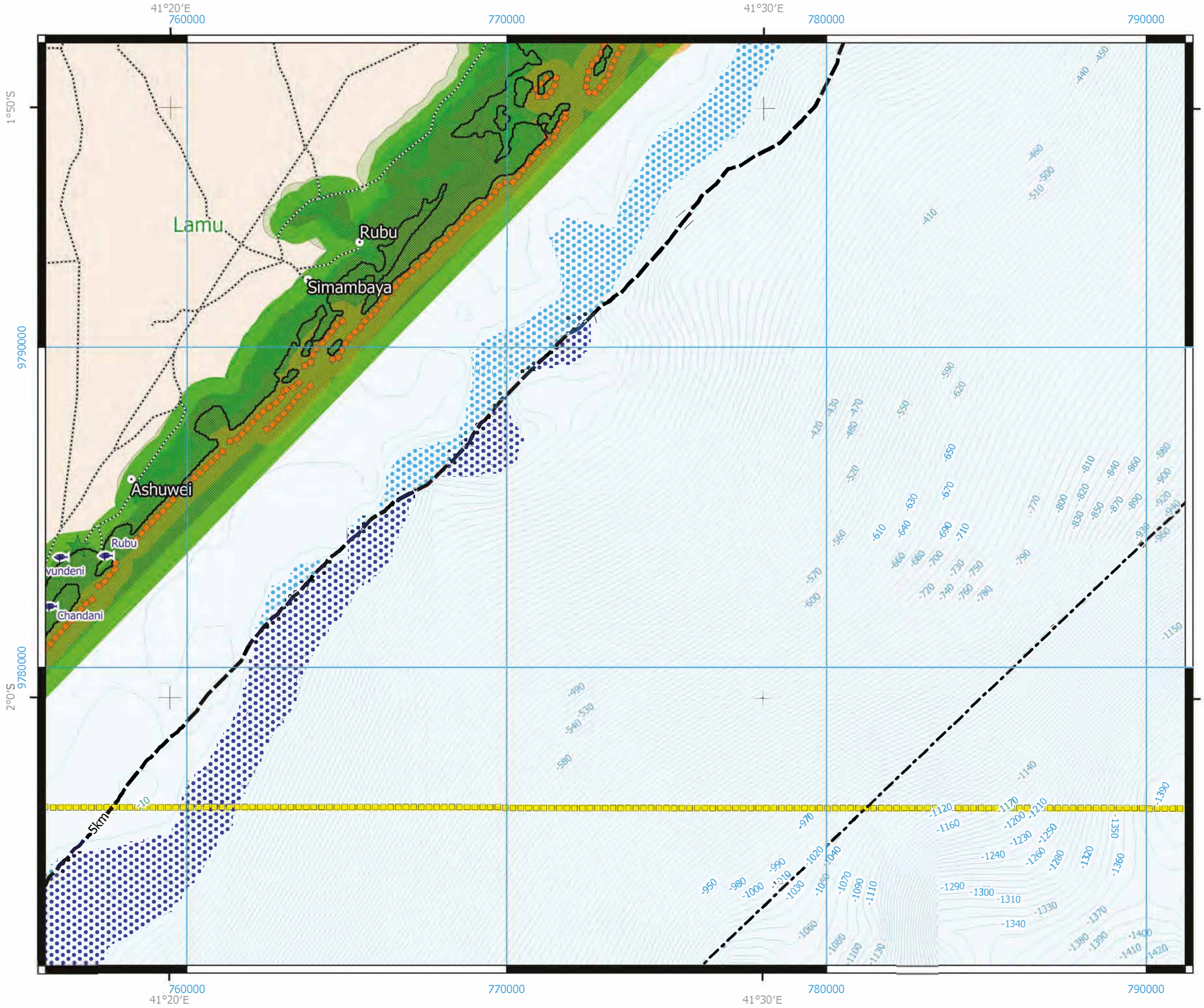


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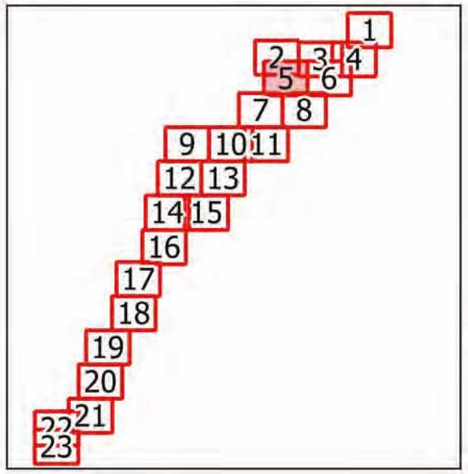


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### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns



40°50'E 710000 720000 41°0'E 730000

2°0'S 9780000

2°10'S 9760000

Mgini
Faza
Siyu
Tchundwa
Mtangawanda
Shanga Rubu
Pate
Shanga
5km

0 2.5 5 7.5 10 km

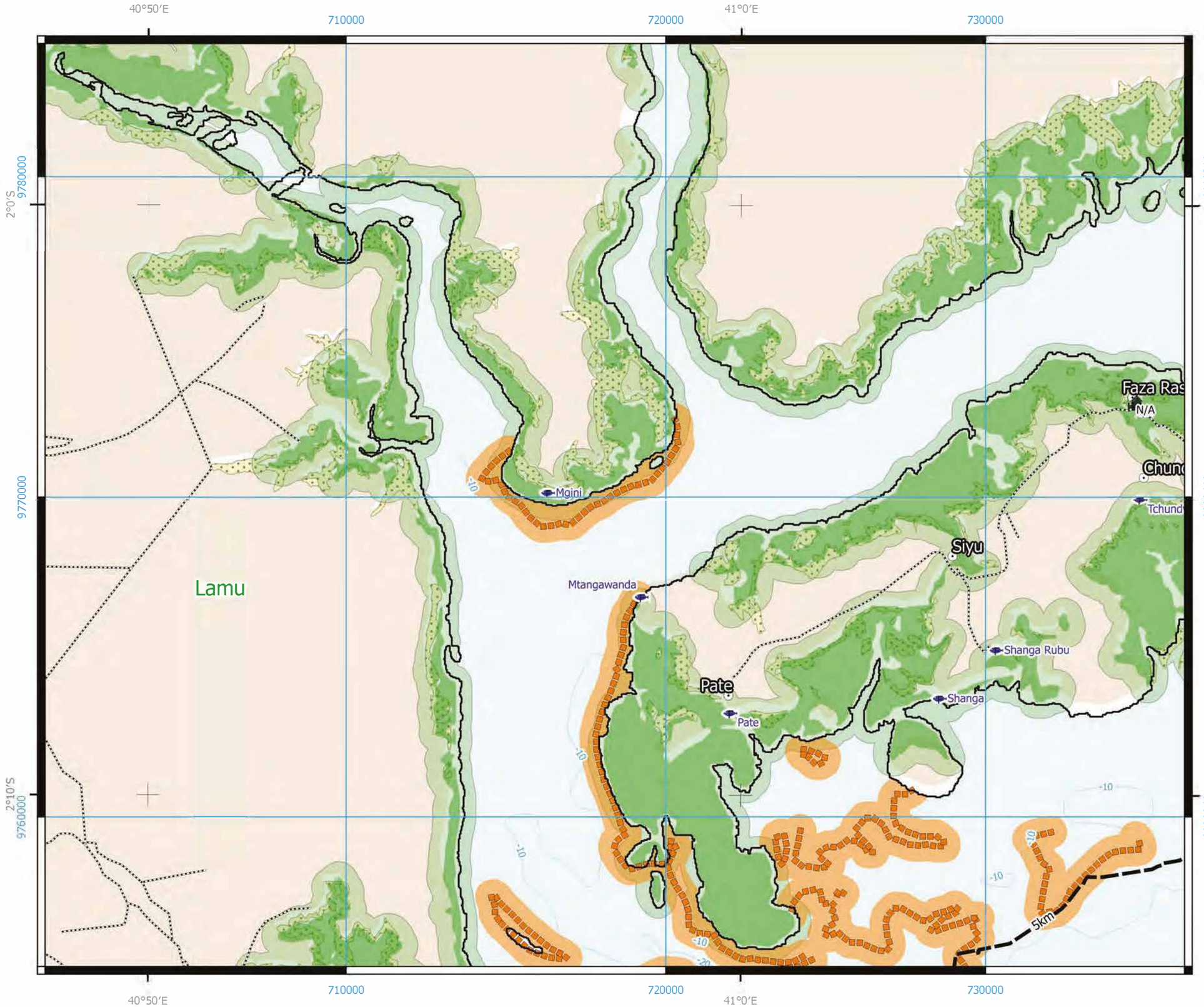
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Lamu - KENYA






## Legend Atlas

### Boundaries
- Territorial waters
- Coastline
- 5km from coastline
- Bathymetry 10m contours

County
- Kilifi
- Kwale
- Lamu
- Mombasa
- Tana river

### Conservation areas
- Turtle nesting sites
- Turtle conservation groups
- Mangroves
- Mangroves 500m buffer zone
- Coral reefs
- Coral 500m buffer zone
- KWS marine parks
- KWS marine parks 500m buffer
- Important bird areas
- Prawn trawling areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Aquaculture
- Category A potential cage sites
- Category B potential cage sites

### Fishing
- Fish landing sites

### Urban/industrial
- Hotels
- Towns
- Oil exploration blocks

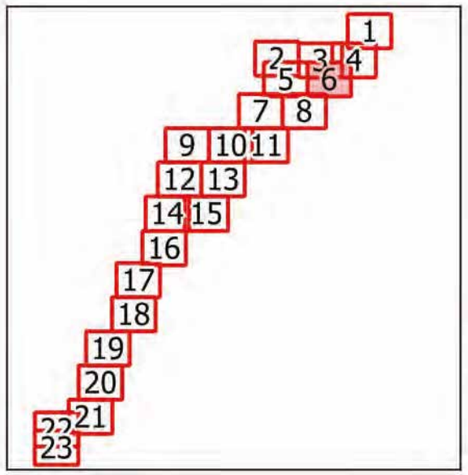
### Transportation
- Navigation routes
- Roads

**Projection**

NAME: UTM zone 37S
CODE: 16137
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Lamu - KENYA




## Legend Atlas

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- Salt works
- Sand mud
- Tidal flats

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- Very high
- High
- Medium
- Low

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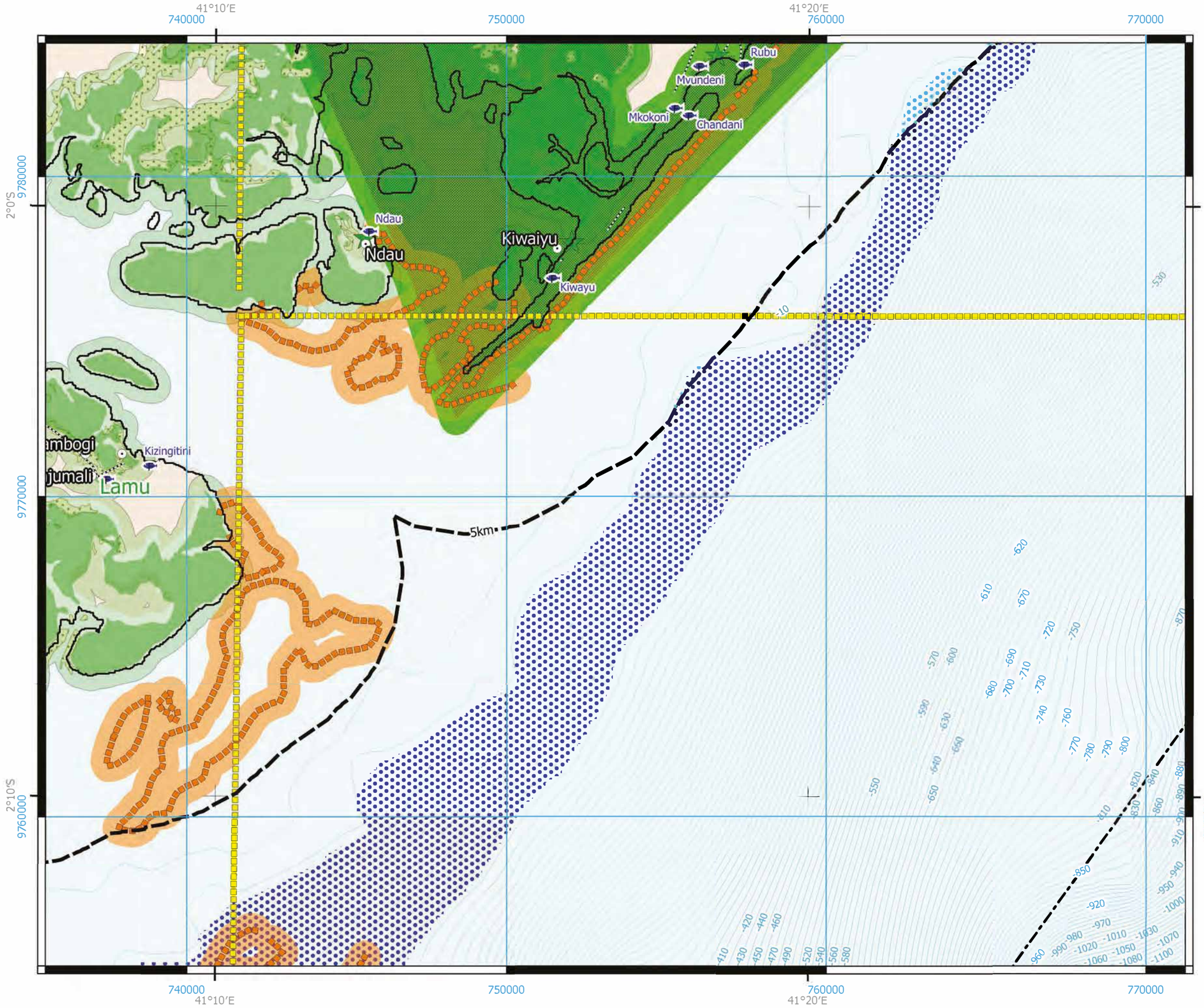
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns

Scale 1:120,000

# Mariculture Zoning Map - Lamu - KENYA



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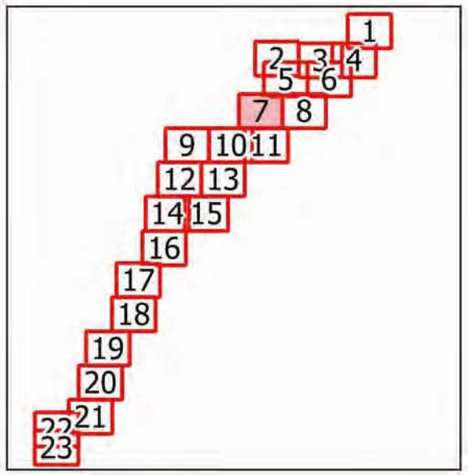


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Atlas production by Justin Saunders

40°40'E 690000 700000 40°50'E 710000

9750000 2°20'S 9740000 9730000

Mokowe
Ndununi
Mwana Mariyam
Matondoni
Matondoni
Lamu
Amu
Shella
Shela
Mataani/Mkunumbi
Mkunumbi
Kipungani
Kipungani
Mea
Ndambwe
Mapenya
Kibaoni
5km
Kiongwe

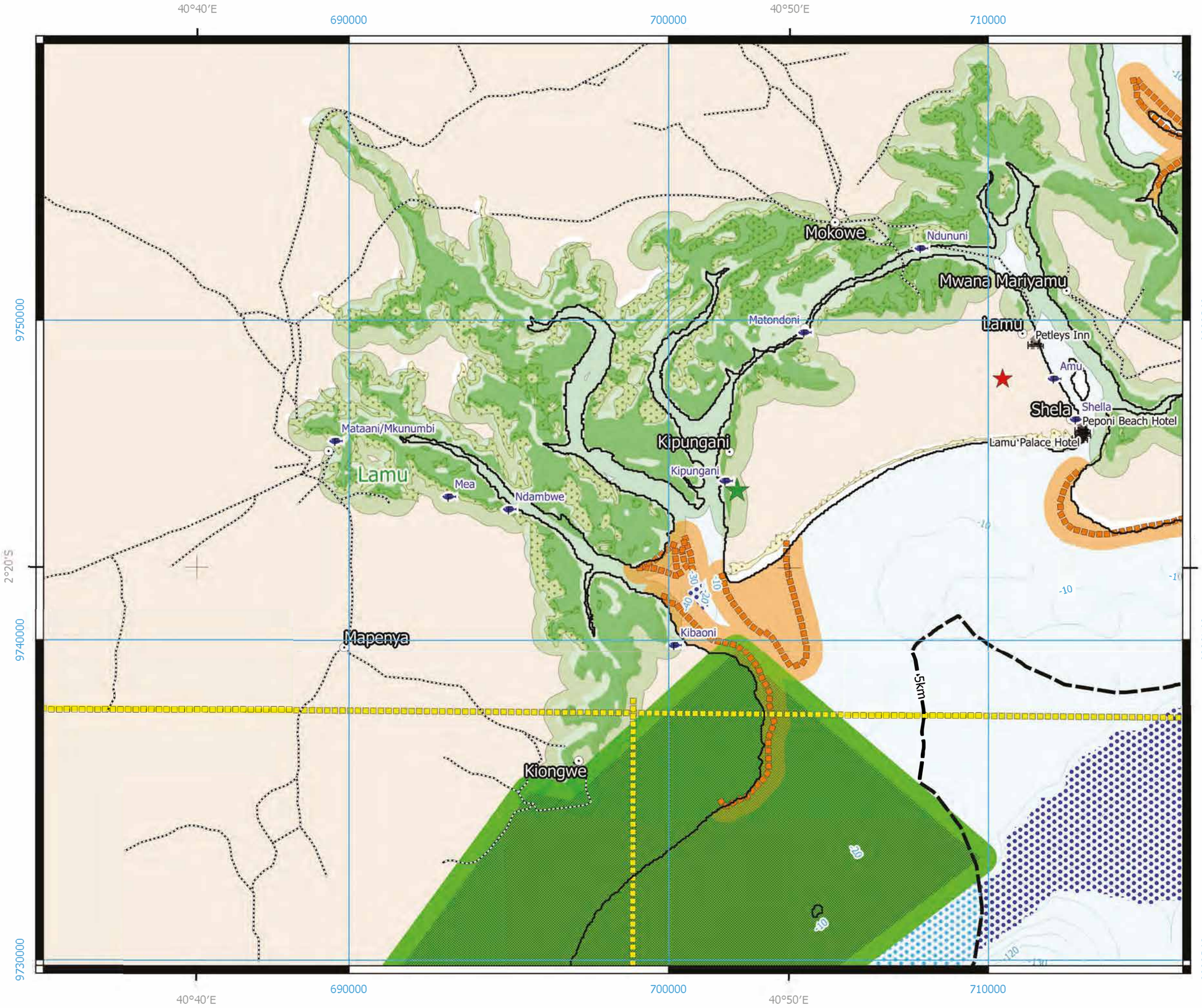
0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

# Mariculture Zoning Map - Lamu - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

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- Towns
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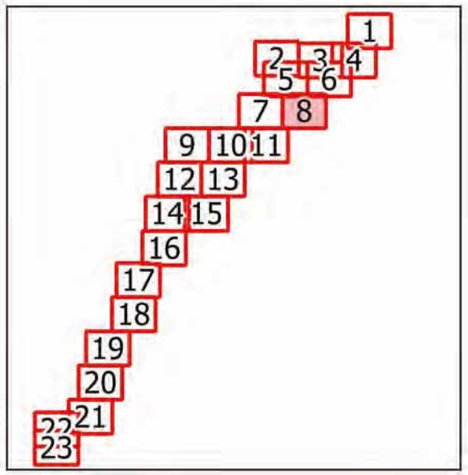
# Mariculture Zoning Map - Lamu - KENYA

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### Fishing
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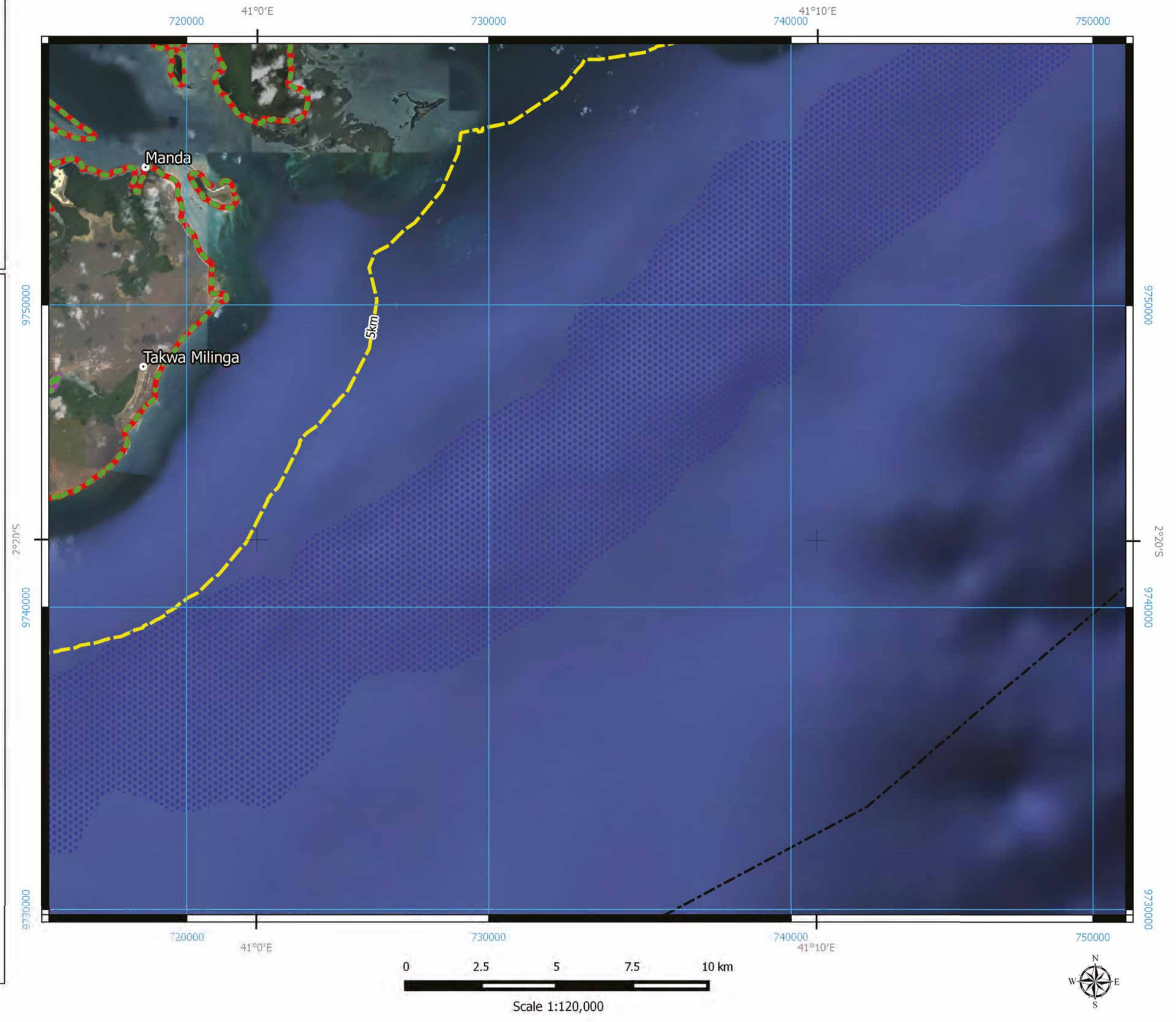
- Towns

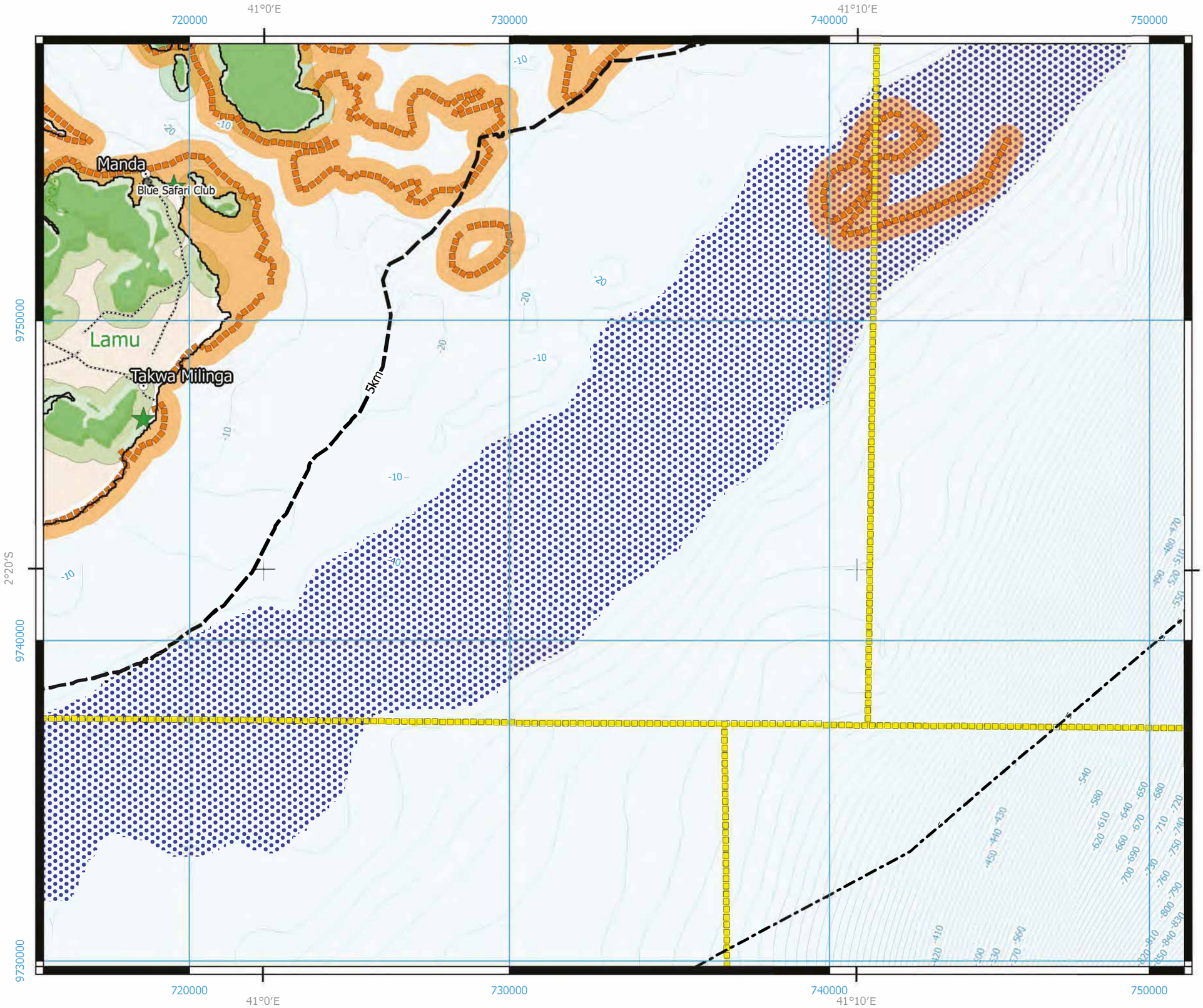

Atlas production by Justin Saunders



Scale 1:120,000

# Mariculture Zoning Map - Lamu - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

## Legend Atlas

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- Oil exploration blocks

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N W E S

**Projection**

NAME: UTM zone 37S
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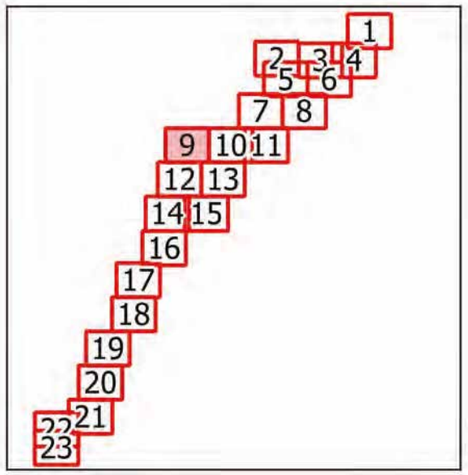
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Tana River - KENYA




## Legend Atlas

### Boundaries
- Territorial waters
- 5km from coastline

### Conservation areas
- Existing fishing grounds
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- Tidal flats

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- Very high
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- Category B potential cage sites

### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

40°10'E 630000 640000 40°20'E 650000

9730000 9720000 9710000

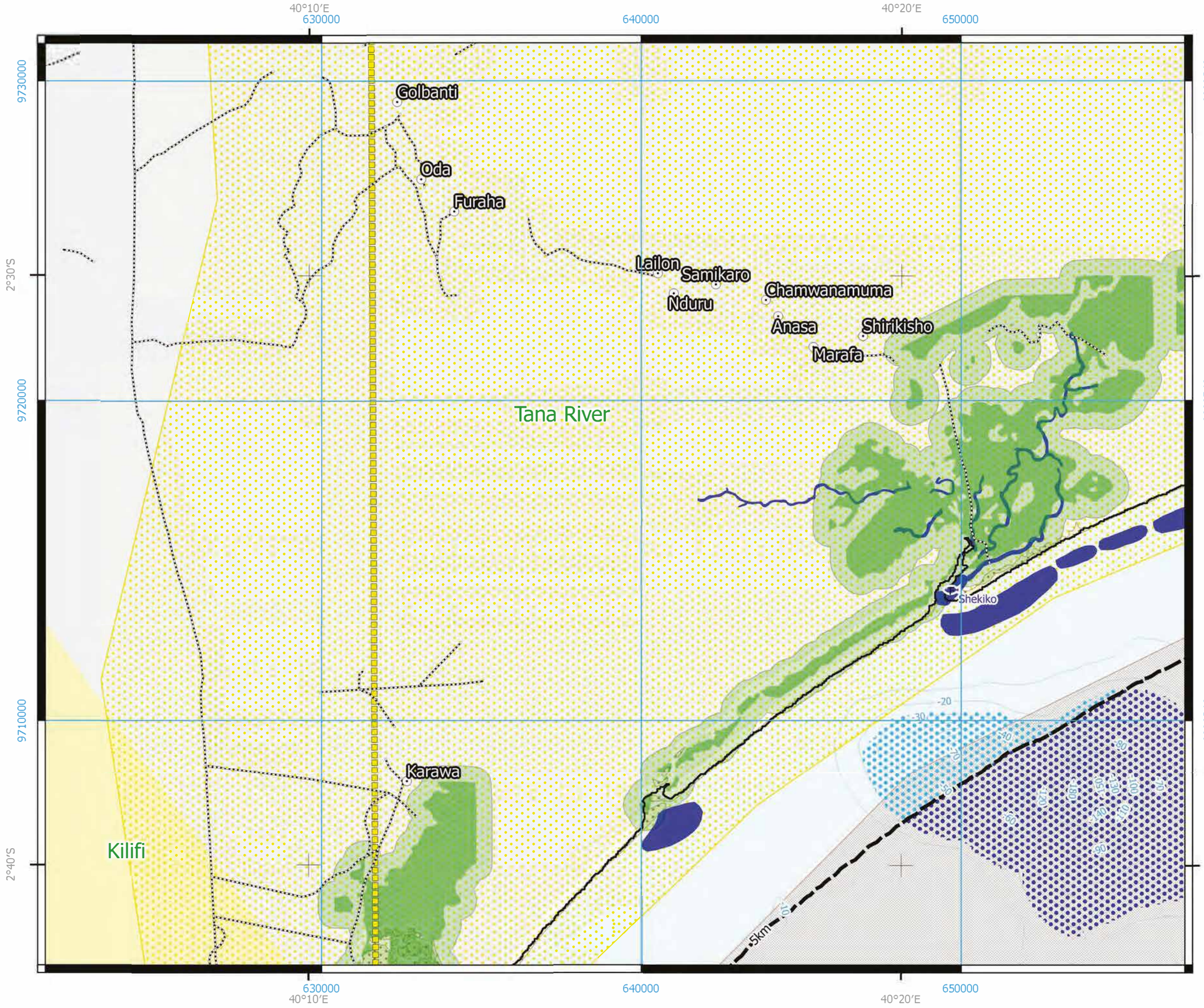
2°30'S 2°40'S

Golbanti
Oda
Furaha
Lailon
Samikaro
Nduru
Chamwanamuma
Anasa
Shirikisho
Marafa
Shekiko
Karawa
5km

0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

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County
- Kilifi
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- Category A potential cage sites
- Category B potential cage sites

### Fishing
- Fish landing sites

### Urban/industrial
- Hotels
- Towns
- Oil exploration blocks

### Transportation
- Navigation routes
- Roads

N W E S

0 2.5 5 7.5 10 km

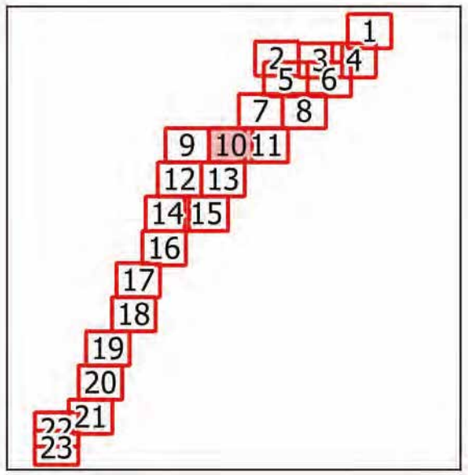
Scale 1:120,000

**Projection**

NAME: UTM zone 37S
CODE: 16137
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Tana River - KENYA

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### Boundaries
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- Salt works
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### Coastline Biological Ranking
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### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

660000 40°30'E 670000 680000 40°40'E 690000

9730000 2°30'S 9720000 9710000 2°40'S

Kau
Kidhanga
Ozi
Kipini
Naghea
Nagea Fishermen Group
Kipini Community Conservation Management Forum
KICE CBO
Kipini BMU
Kipini Fishermen Association
Ozi BMU
Ras ya Mwana
5km
Ziwayuu

0 2.5 5 7.5 10 km

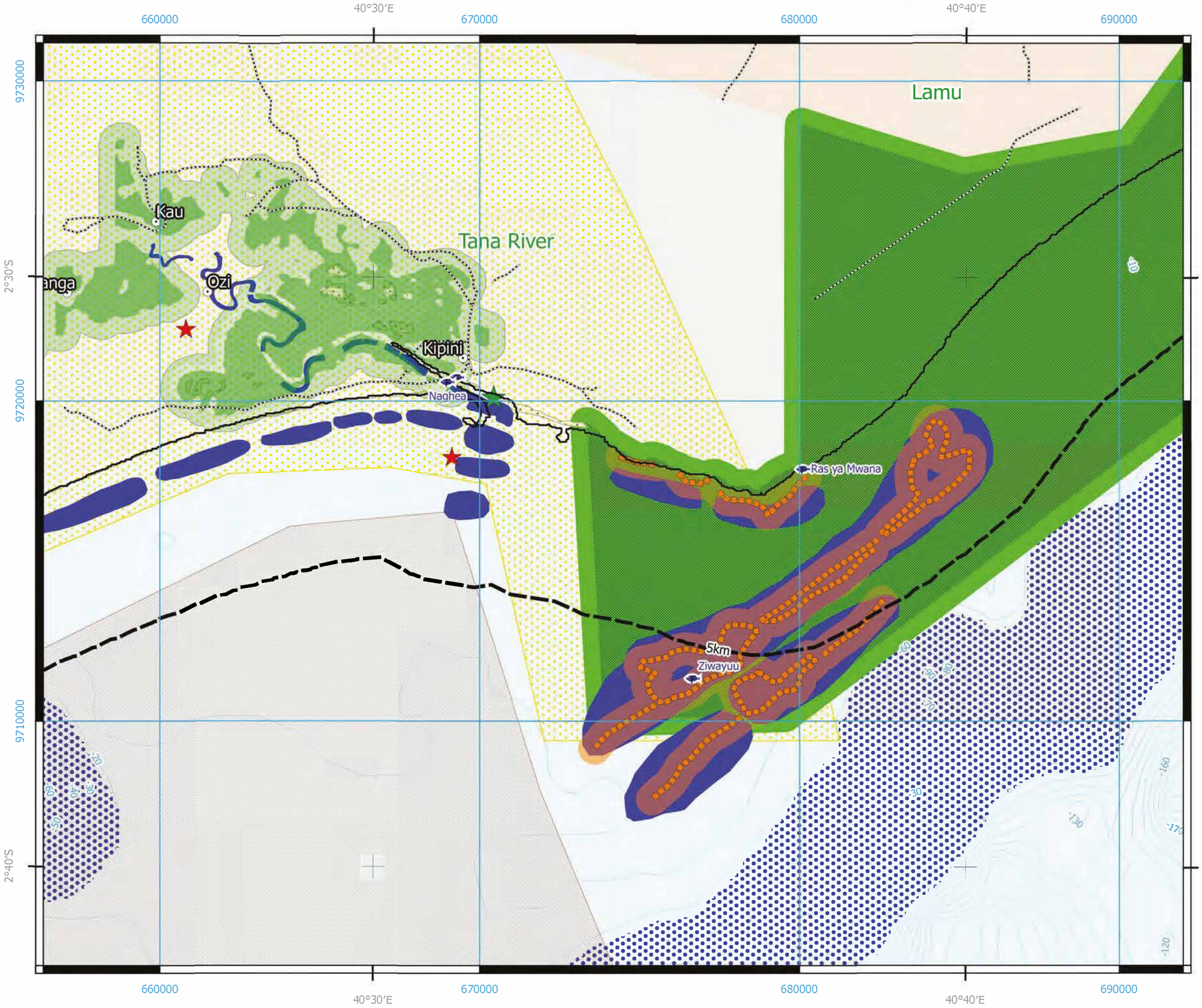
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Tana River - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

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NAME: UTM zone 37S
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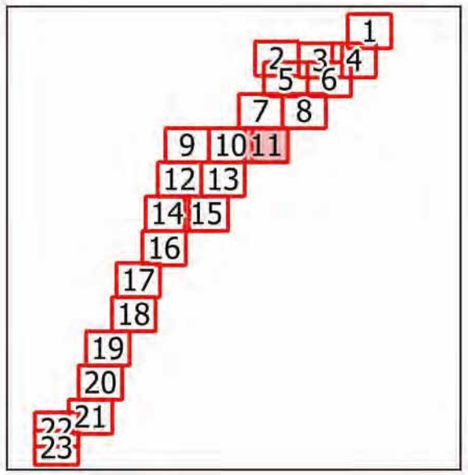
N W E S

# Mariculture Zoning Map - Tana River - KENYA

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Atlas production by Justin Saunders

40°40'E 690000 700000 40°50'E 710000 720000

9730000 9720000 9710000

2°30'S 2°40'S

Tenewi

5km

0 2.5 5 7.5 10 km

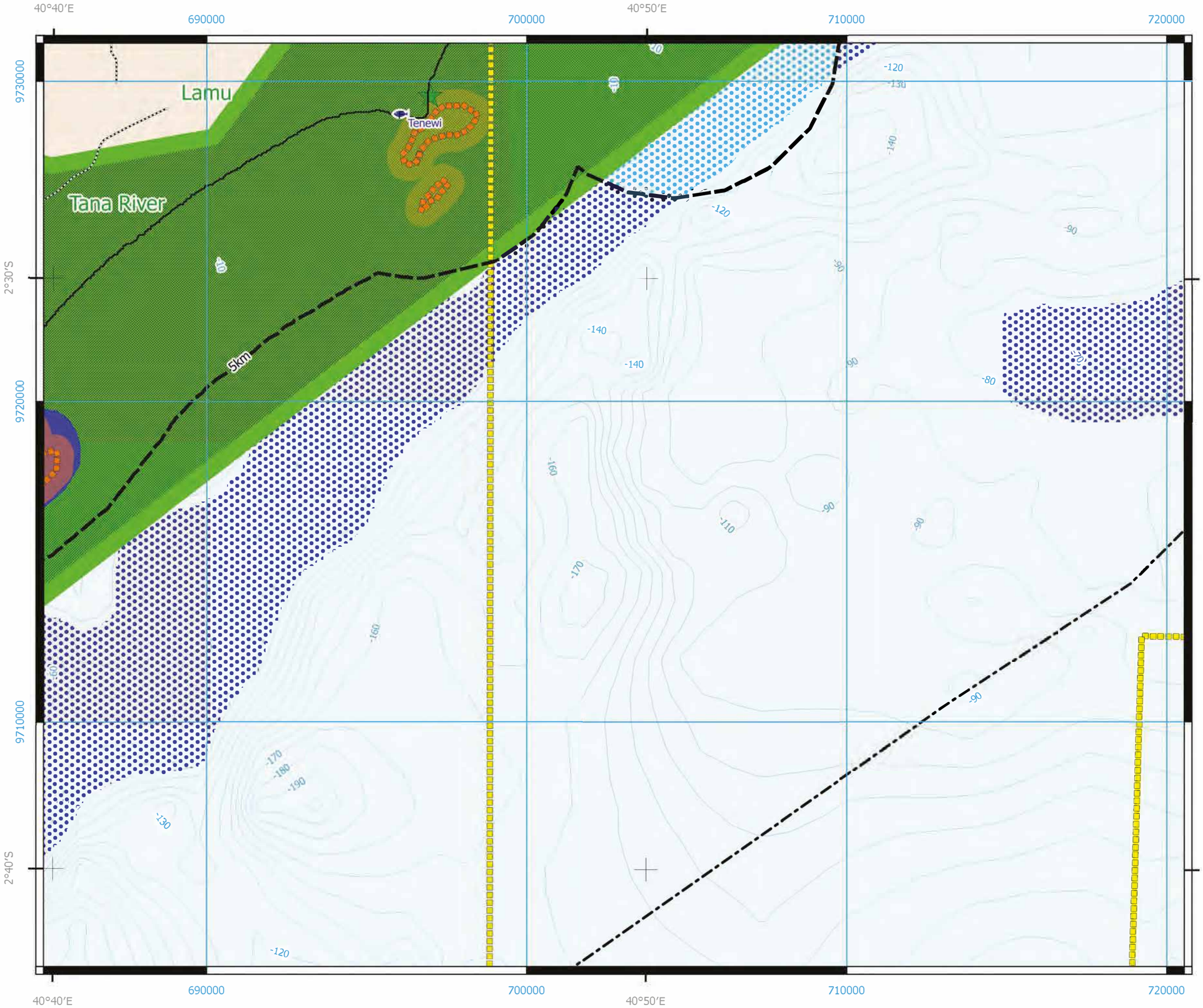
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Tana River - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

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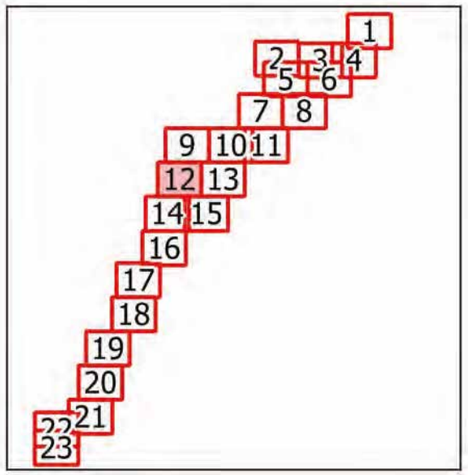
# Mariculture Zoning Map - Kilifi - KENYA

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Atlas production by Justin Saunders

620000 630000 640000 650000
40°10'E 40°20'E
9700000 9690000 9680000
2°50'S

Pompwani
Bwana Saidi
Kaswakini
Muyu Wa Kaye
Marereni
Mto wa Mawe
Kinyaole
Fundisa
Fundisa Kibaoni
Fundi Isa
5km

0 2.5 5 7.5 10 km

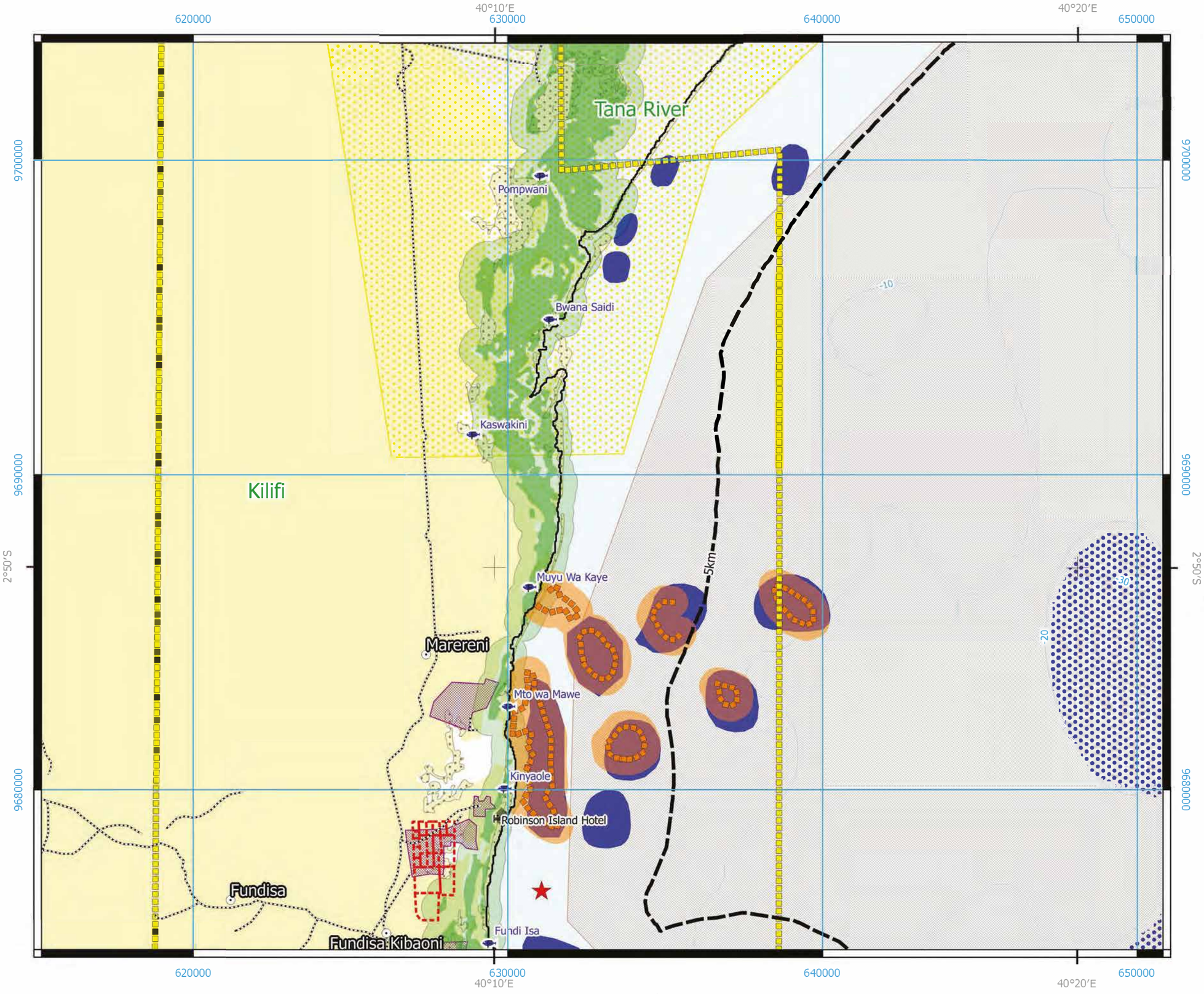
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA



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Scale 1:120,000

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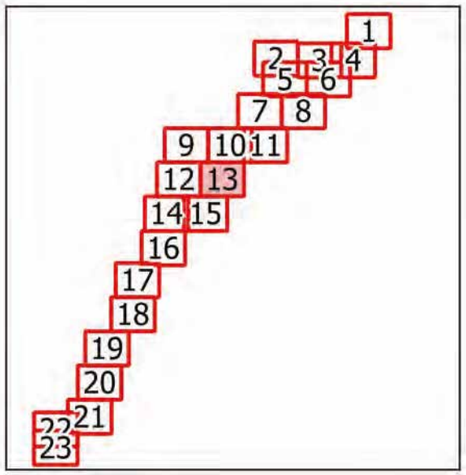


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660000 40°30'E 670000 680000 40°40'E

9700000 9690000 9680000

2°50'S

0 2.5 5 7.5 10 km

Scale 1:120,000

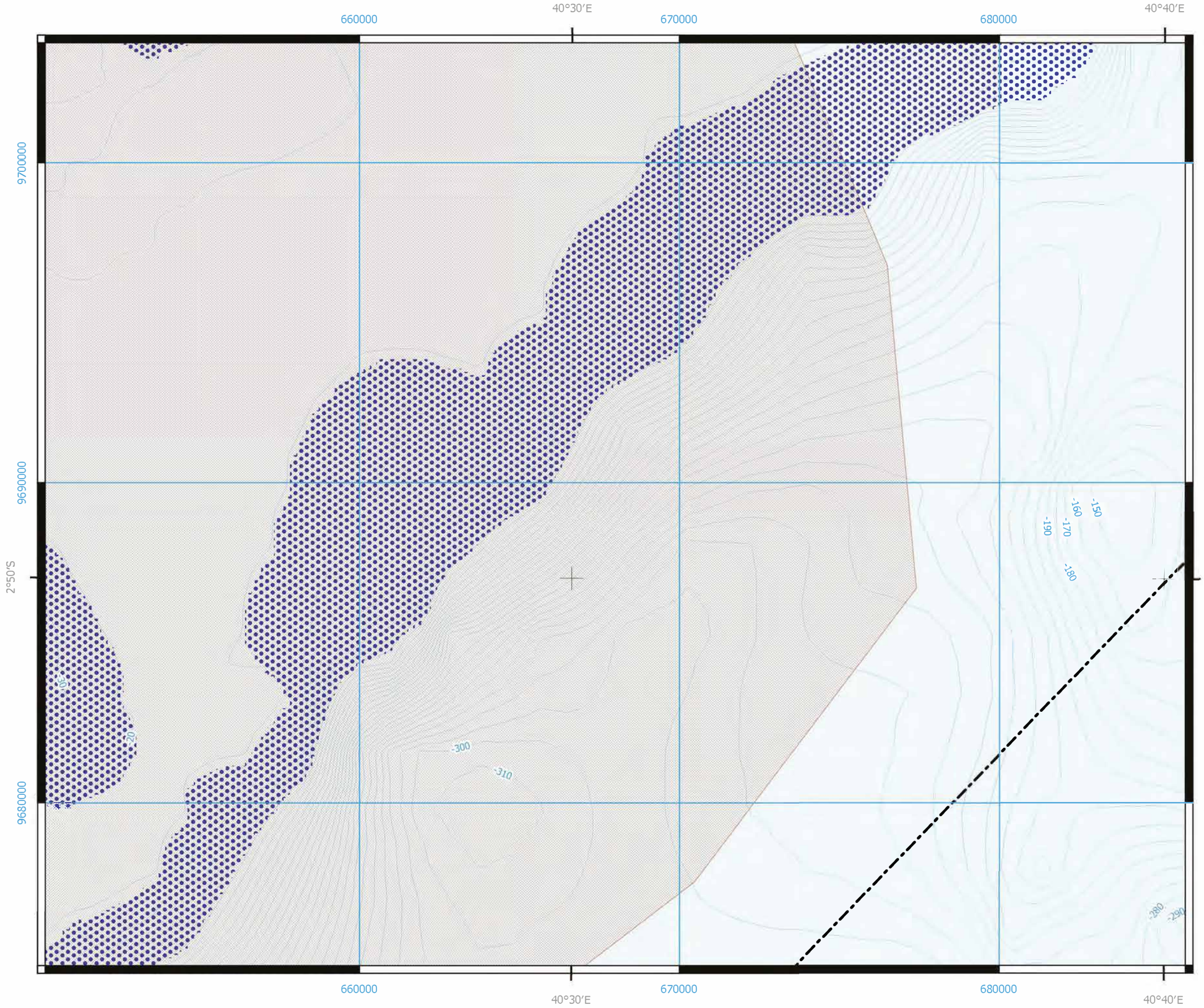
N W E S


Atlas production by Justin Saunders

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






0 2.5 5 7.5 10 km

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- Mangroves 500m buffer zone
- Coral reefs
- Coral 500m buffer zone
- KWS marine parks
- KWS marine parks 500m buffer
- Important bird areas
- Prawn trawling areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Aquaculture
- Category A potential cage sites
- Category B potential cage sites

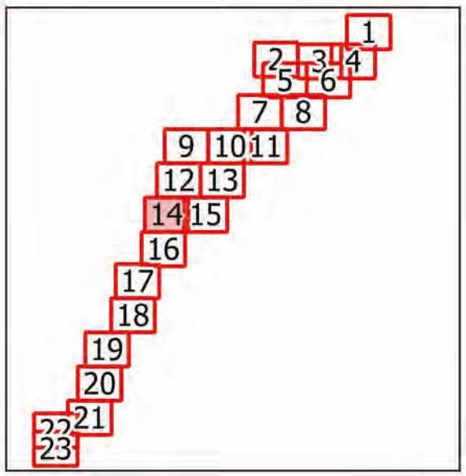
### Fishing
- Fish landing sites

### Urban/industrial
- Hotels
- Towns
- Oil exploration blocks

### Transportation
- Navigation routes
- Roads

N W E S

# Mariculture Zoning Map - Kilifi - KENYA




## Legend Atlas

### Boundaries
- Territorial waters
- 5km from coastline

### Conservation areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Coastline Biological Ranking
- Very high
- High
- Medium
- Low

### Aquaculture
- Kilifi ponds
- Mombasa ponds
- Ponds from satellite imagery
- Category A potential cage sites
- Category B potential cage sites

### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

40°0'E 610000 620000 40°10'E 630000 640000

3°0'S 9670000 9660000 3°10'S 9650000

Fundisa Kibaoni
Fundi Isa
Rasi ya Ngome
Ngomeni
Ngomeni
Kimaru
Ngoemeni Secondary School
Marafa
Gongoni
Kichwa cha kati
Cheshale Crab Farm
Cheshale fish landing site
Mansour Naji Said
Kafumbi Kenga Jeffa
Galana Secondary School
Wilson Zawadi
Marikebuni
Peter Nyiro
Mambrui
Mambrui
Ali Kidiku
5km
Total Health Village Group
Emmanuel Karisa
Furaha Charo Karisa
Burangi Primary School
St. Francis Rehabilitation

331 333 334 336 330 337 338 355 360 315 316 319 317 318 320 298 301

0 2.5 5 7.5 10 km

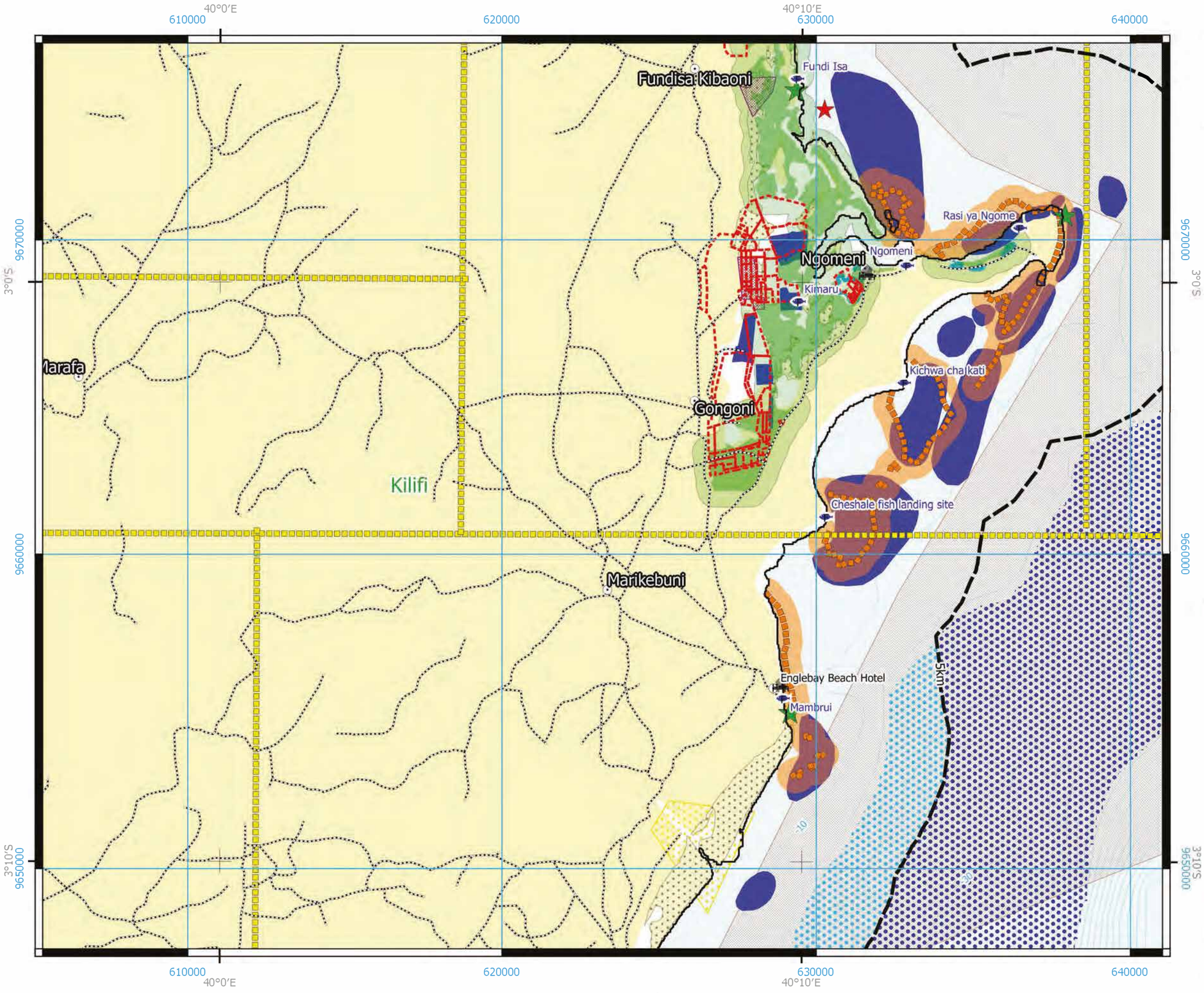
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






## Legend Atlas

### Boundaries
- Territorial waters
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- 5km from coastline
- Bathymetry 10m contours

County
- Kilifi
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- Lamu
- Mombasa
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- Hotels
- Towns
- Oil exploration blocks

### Transportation
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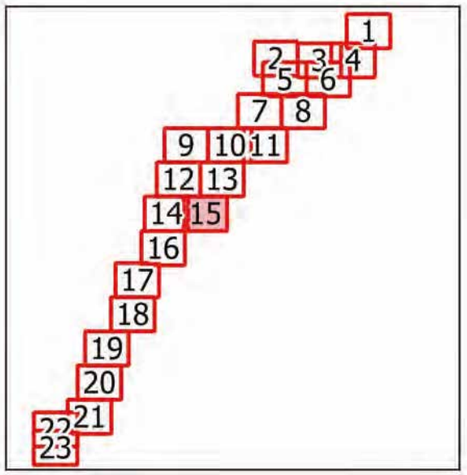
- Roads

**Projection**

NAME: UTM zone 37S
CODE: 16137
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Kilifi - KENYA

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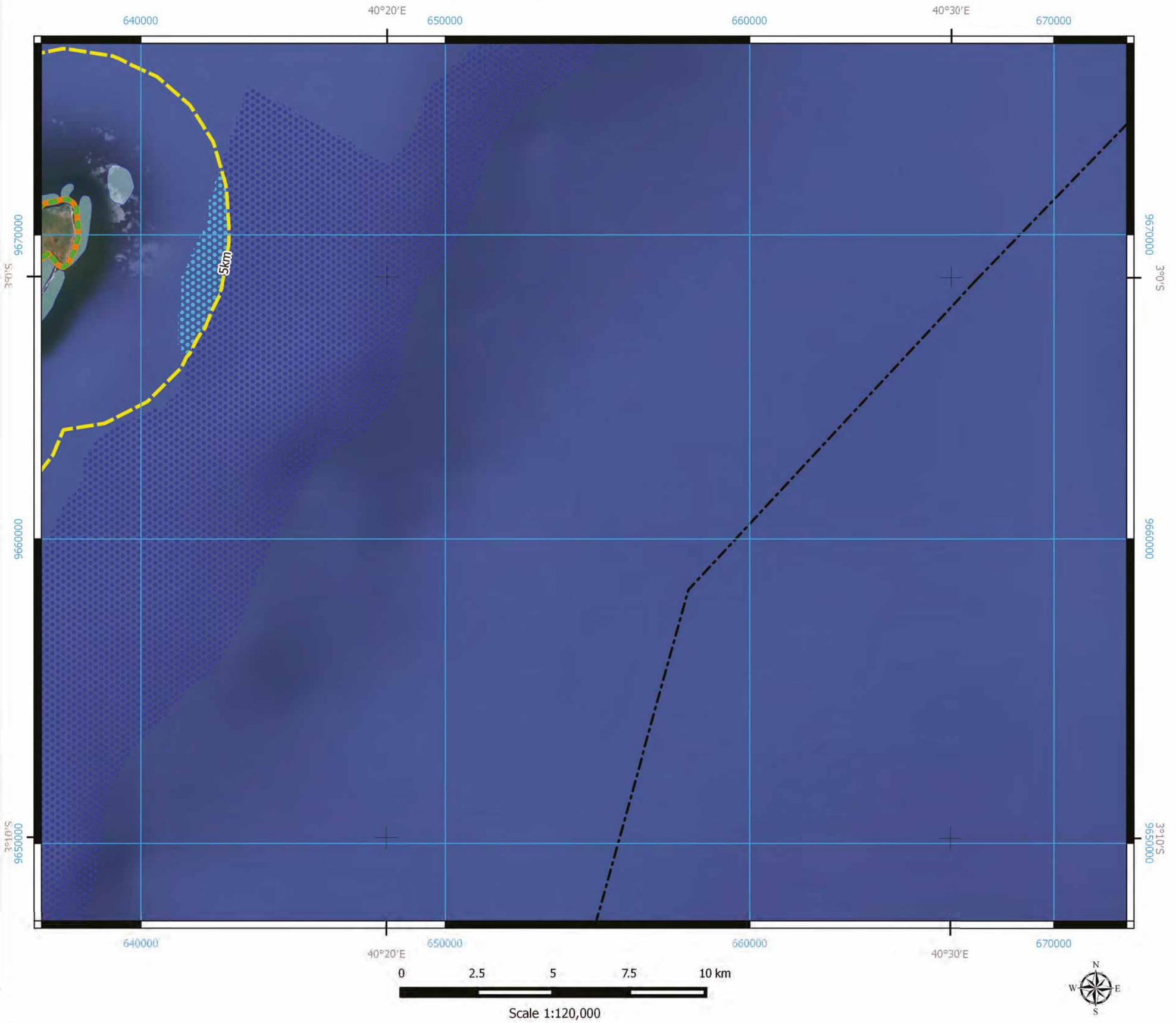
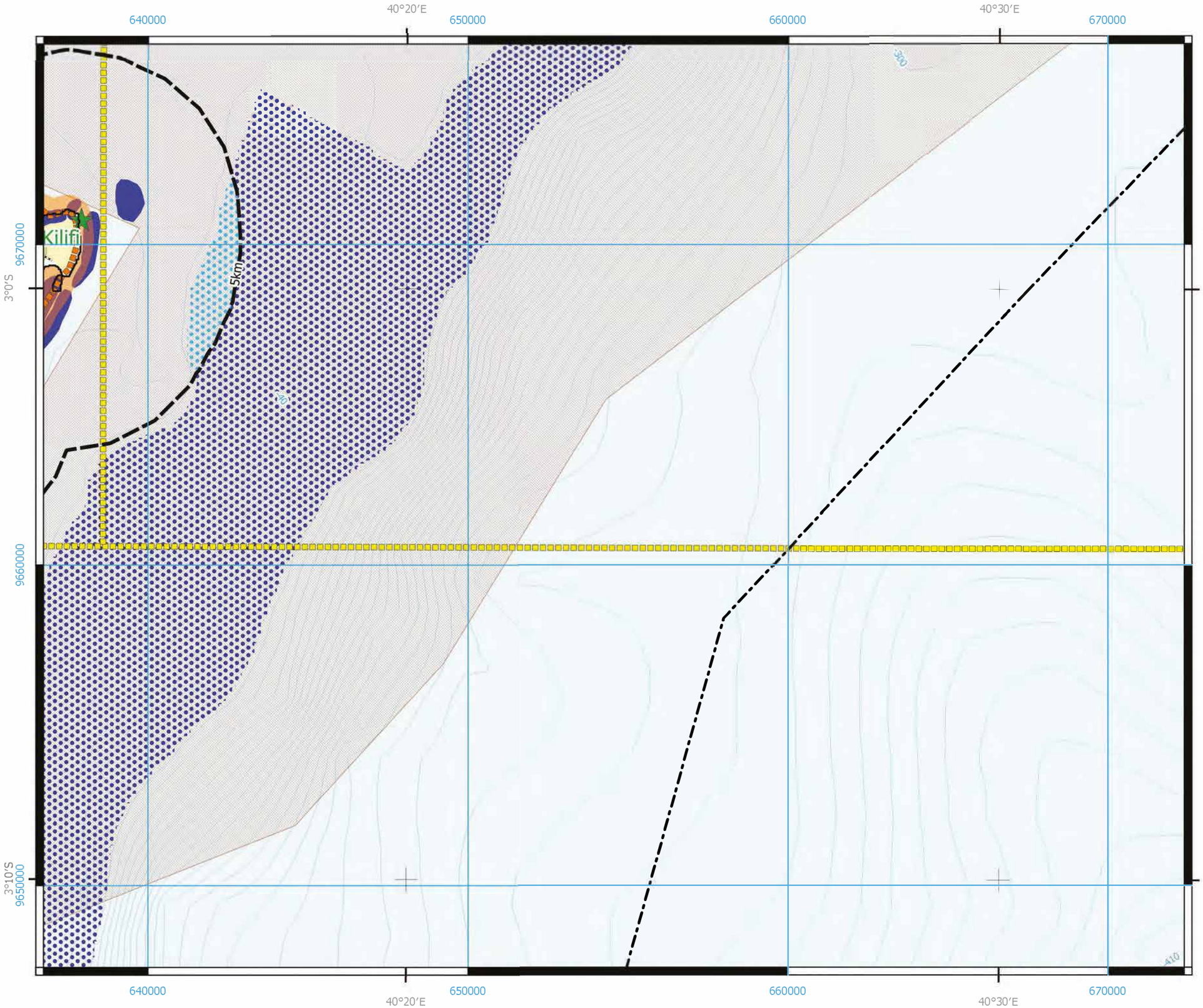



Scale 1:120,000

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

## Legend Atlas

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N W E S

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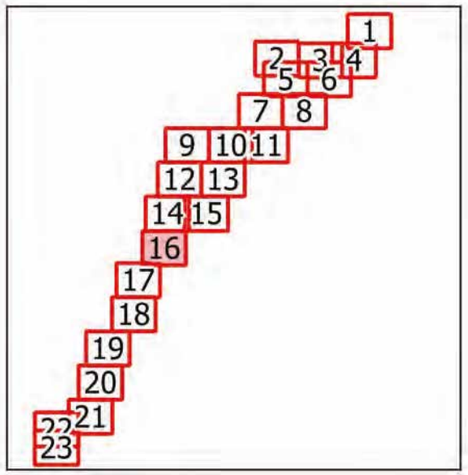
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Kilifi - KENYA




## Legend Atlas

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- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns



40°0'E 610000 · 620000 · 40°10'E 630000

9640000 · 9630000 · 9620000

3°20'S

Sidi's tailoring college · Ganda · Malindi · Malindi Prison · Omar Thoya · Mwembe Resort · ECK Church · Mijikenda · Mbuyuni · Drift wood · Malindi High School · Johnson Mutsembi · Feisal Ahmed · Julia Ramtu · Mama Naumy · Kivulini · Mayungu · Gede · Rabeka · Safari Kifda · Mida · Jakaranda · Makangani · Mida · Mure · Sita · Dabaso Primary · Dabaso · Darakasi · Watamu · Watamu · Mawe ya Kati · Barracuda/Mkoko · Dabaso Prawns Lake · Dongo Kundu · Bandari ya Zamani · Captain Andy · Uyombo · Kavunjeni · Gongoni · Shee hamisi · 5km

0 2.5 5 7.5 10 km

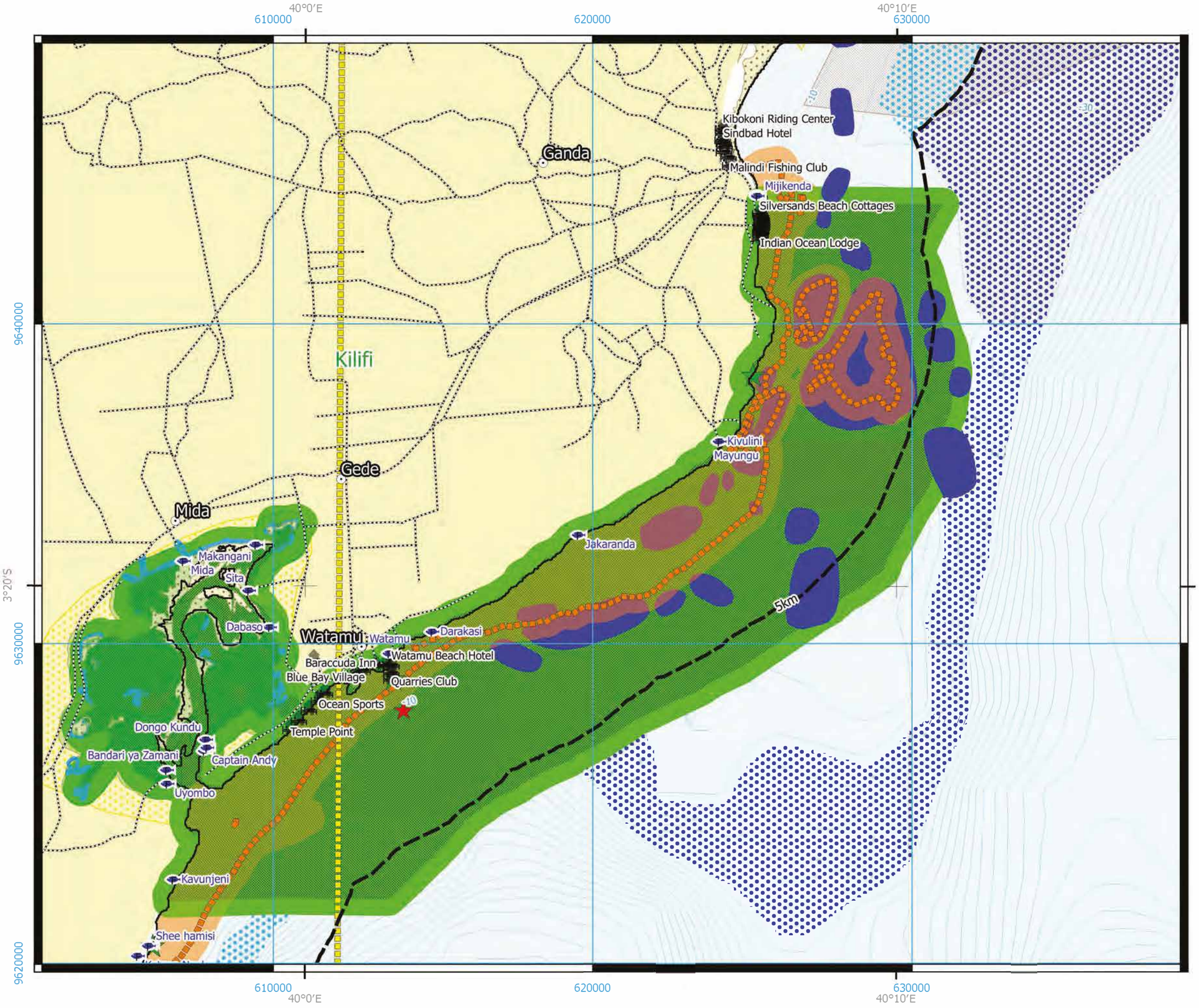
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






## Legend Atlas

### Boundaries
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- Bathymetry 10m contours

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- Towns
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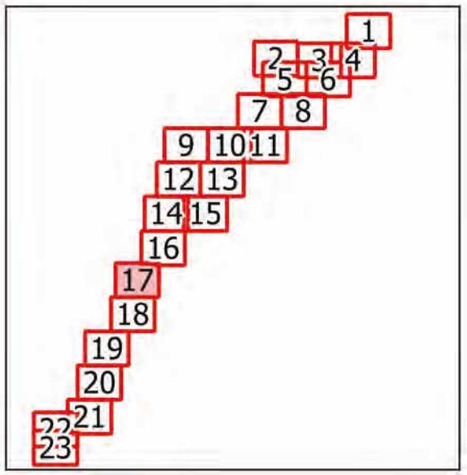
# Mariculture Zoning Map - Kilifi - KENYA

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- Kwale user group
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- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

590000 39°50'E 600000 40°0'E 610000

9620000 3°30'S 9610000 3°40'S 9600000

Kavunjeni
Gongoni
Katana Ngala
Shee hamisi
Kwa Mwafrica
Wesa
Sokoke
Kipangani
Kwa Ngala
Bofa
5km
Laini kuchi
Kibokoni
Umoja Group Kilifi
Maringoni
Maya
Sea Horse
Kilifi
Ilaleni Group
Kilifi Old Ferry
Vinasini
Boat Yard
Veterinary
Mnarani
Kidundu

0 2.5 5 7.5 10 km

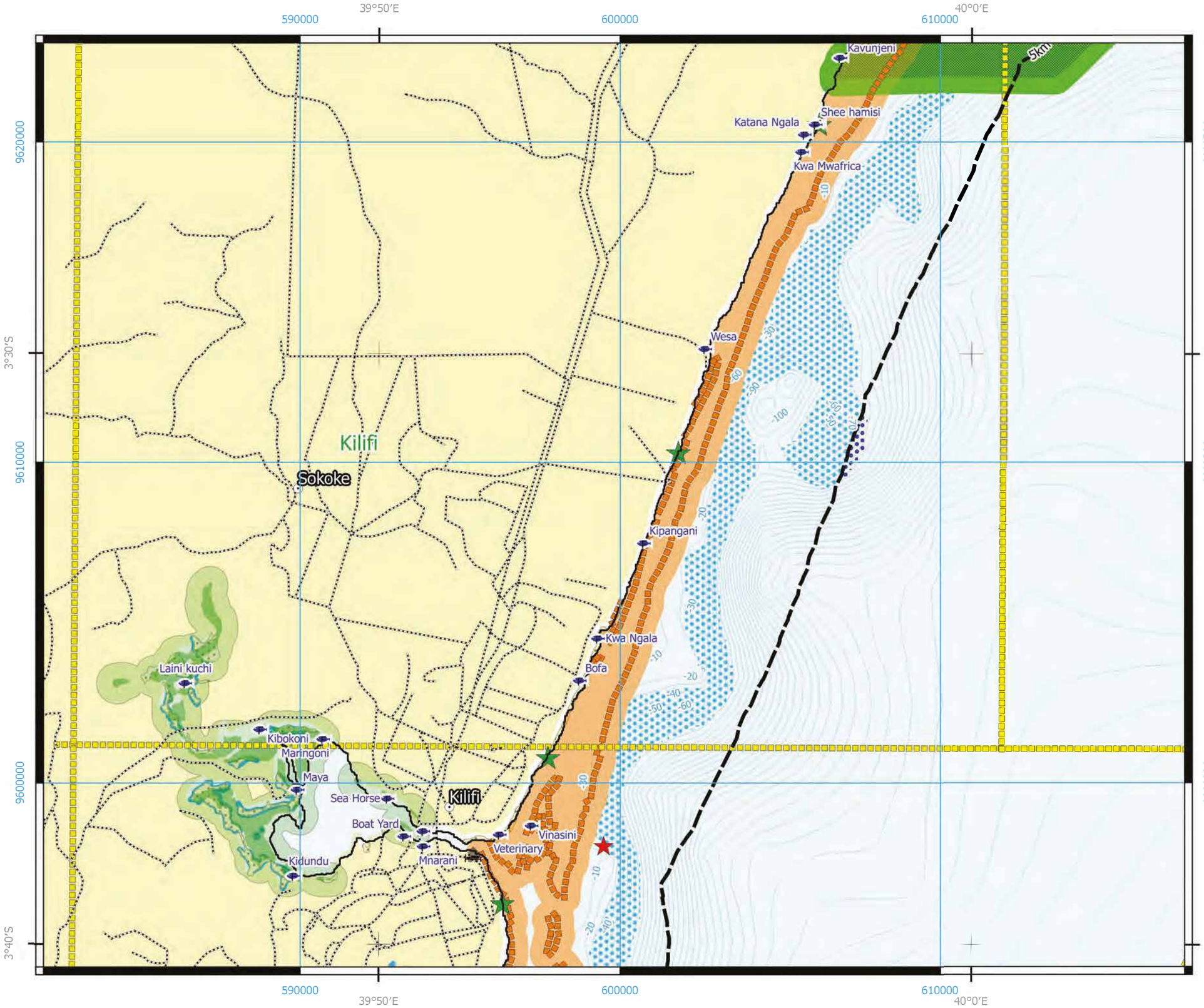
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






## Legend Atlas

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- Bathymetry 10m contours

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N W E S

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CODE: 16137
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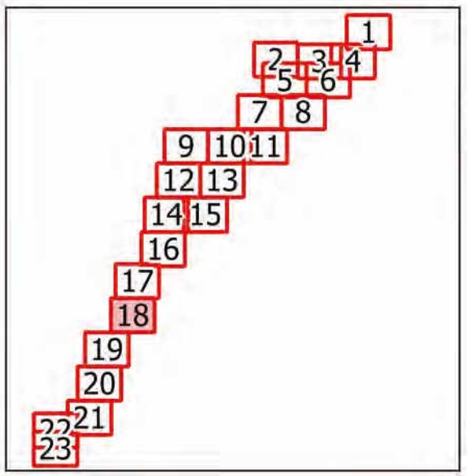
NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

# Mariculture Zoning Map - Kilifi - KENYA

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- Mombasa user group
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### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

580000 590000 39°50'E 600000 610000 40°0'E

3°40'S 3°50'S

9590000 9580000 9570000

Takaungu
Kitangani
Takaungu
Vitangaviwili
Vuma
Mwanamia
Kijangwani
Kuruwitu
Kinuni
Vipingo
Bureni
Mjororoni
Mkunguni
Ngoloko
Sun and Sand
Kanamai Mvuvi
5km

0 2.5 5 7.5 10 km

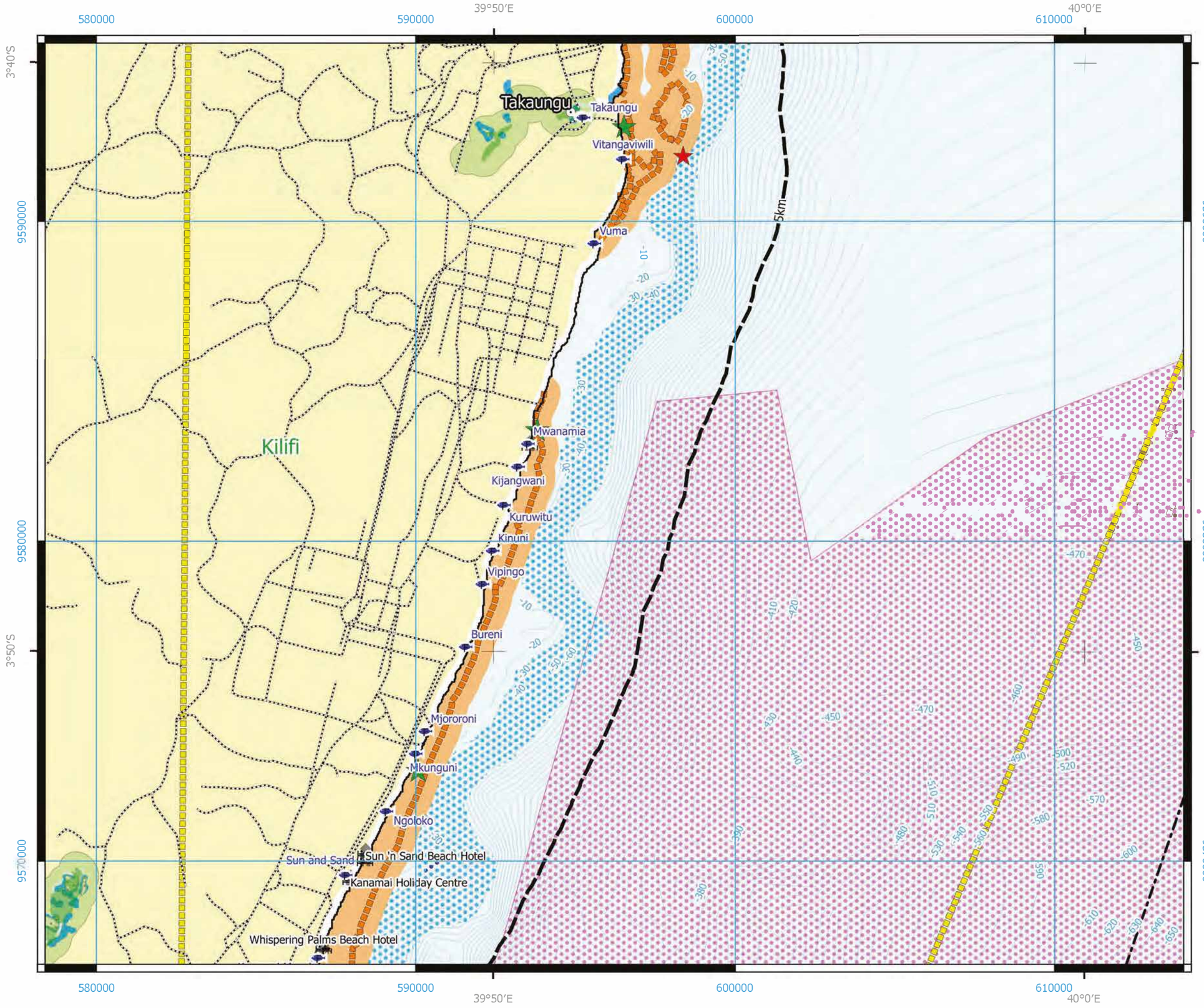
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kilifi - KENYA






0 2.5 5 7.5 10 km

Scale 1:120,000

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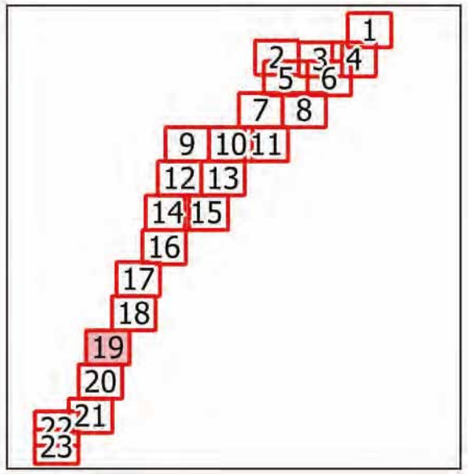
N W E S

# Mariculture Zoning Map - Kwale - KENYA

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- Mombasa user group
- Kilifi user group
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### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

560000 570000 39°40'E 580000 590000 39°50'E

9560000 9550000 9540000 4°0'S 4°10'S

Rabai
Mazeras
Kidongo
Mooring
Shimo la Tewa
Mtwapa
Marina
Kanamai Mvuvi
Mwendo wa Panya
Kazungu wa Shungu
Jumba Ruins
Jomvu
Aldina
Kijiweni
Bamburi
Gomora
Frere Town
Mkupe
Maweni
Weso Farm Mtongwe
Tudor
Kisauni
Mombasa Beach
Shimanzi
Mombasa water sports
Kitanga Juu
Kwa Skembo
Mombasa
Nyali
Nyali Mkunguni
Tsunza
Madobini
Mbuyuni
Mkomani
Old Town
Dimbwi Rose
Mkunguni
Dongo Kundu
Hawaii
Shaza
Mama Kamau 2
Weso Farm Mtongwe
Mwadumbo
Mwangala
Kwa Hassan Fish Ponds
Migingo
Dume
Likoni
Kibuyuni
Timbwani
buta Mazingira Conservators Youth Group MMC
Teja
Mwakuzimu
Hezoni Farm
Kwa Mayai farm
Hacot centre
Mama Wangari Fish Farm
Shelly Beach
Hezoni Farm
Magoda
Mavovoni
Pungu Villa
Ngomeni Farm
Mvumo/Pungu
Ndongole
Chitsanga
Ngomeni Farm
Mwagandizo
Mwamnyerere
Matuga
Waa
5km

0 2.5 5 7.5 10 km

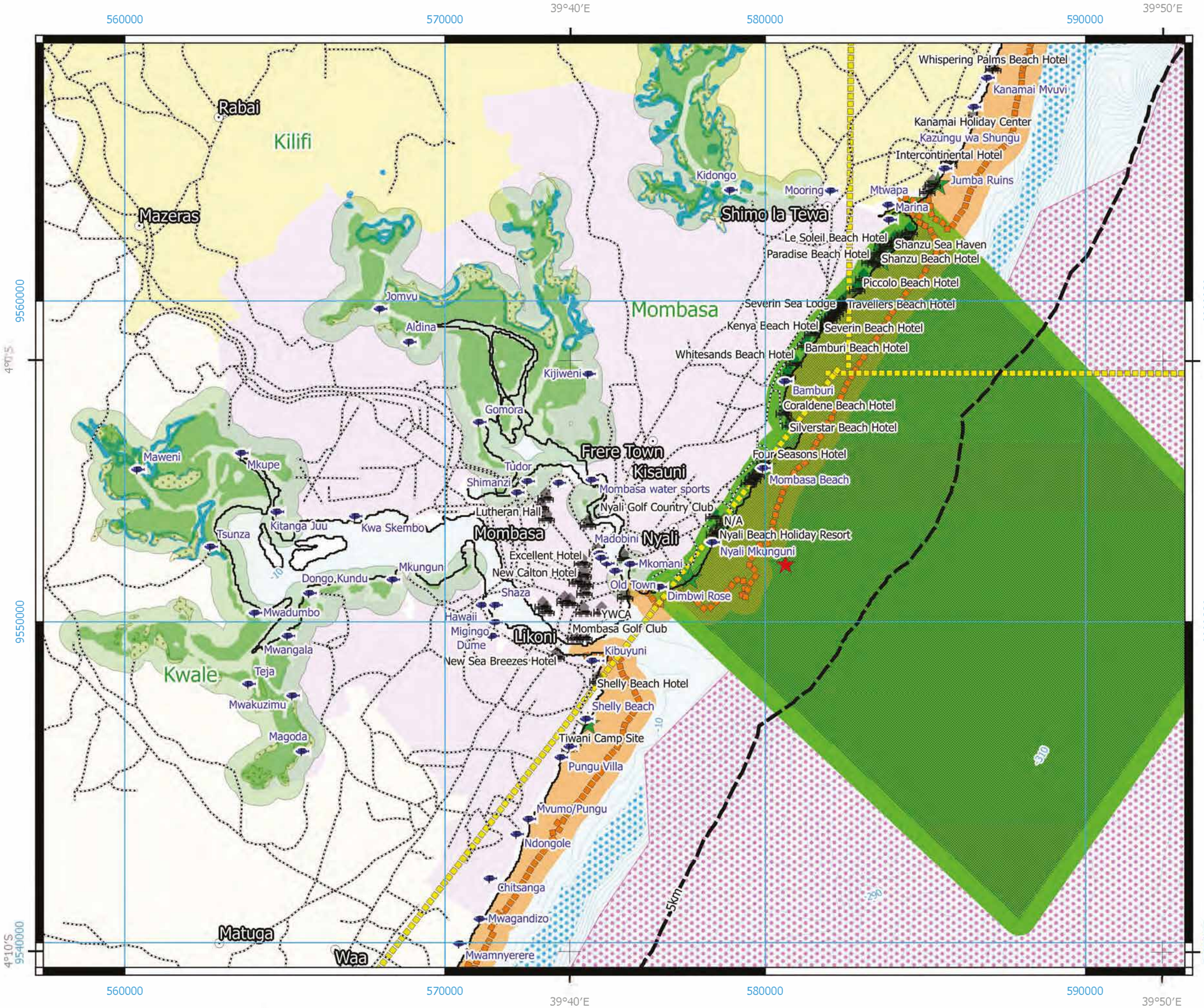
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kwale - KENYA



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**Projection**

NAME: UTM zone 37S
CODE: 16137
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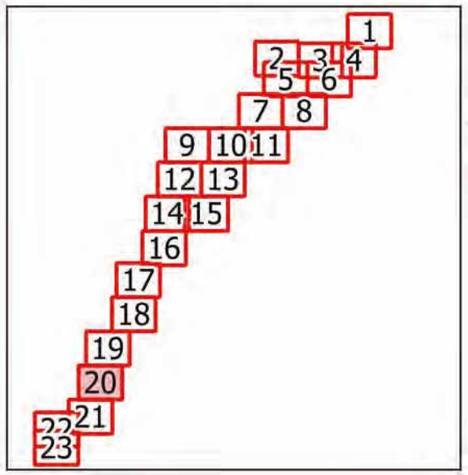
# Mariculture Zoning Map - Kwale - KENYA

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- Fish landing sites
- Towns


Atlas production by Justin Saunders

39°30'E 560000 570000 39°40'E 580000

4°10'S 9540000 4°20'S 9520000 9530000

Matuga
Waa
Mwamnyerere
Kikadini
Kikadini
Nyari
Tiwi
Tiwi
Mwakamba
Mwamambi
Ukunda
Trade Winds
5km
Muhaka
Mwabungu
Mwaepe
Mvuleni
Mwanyaza A
Mwanyanza B
Mgwani
Chale Jeza
Mwakore

0 2.5 5 7.5 10 km

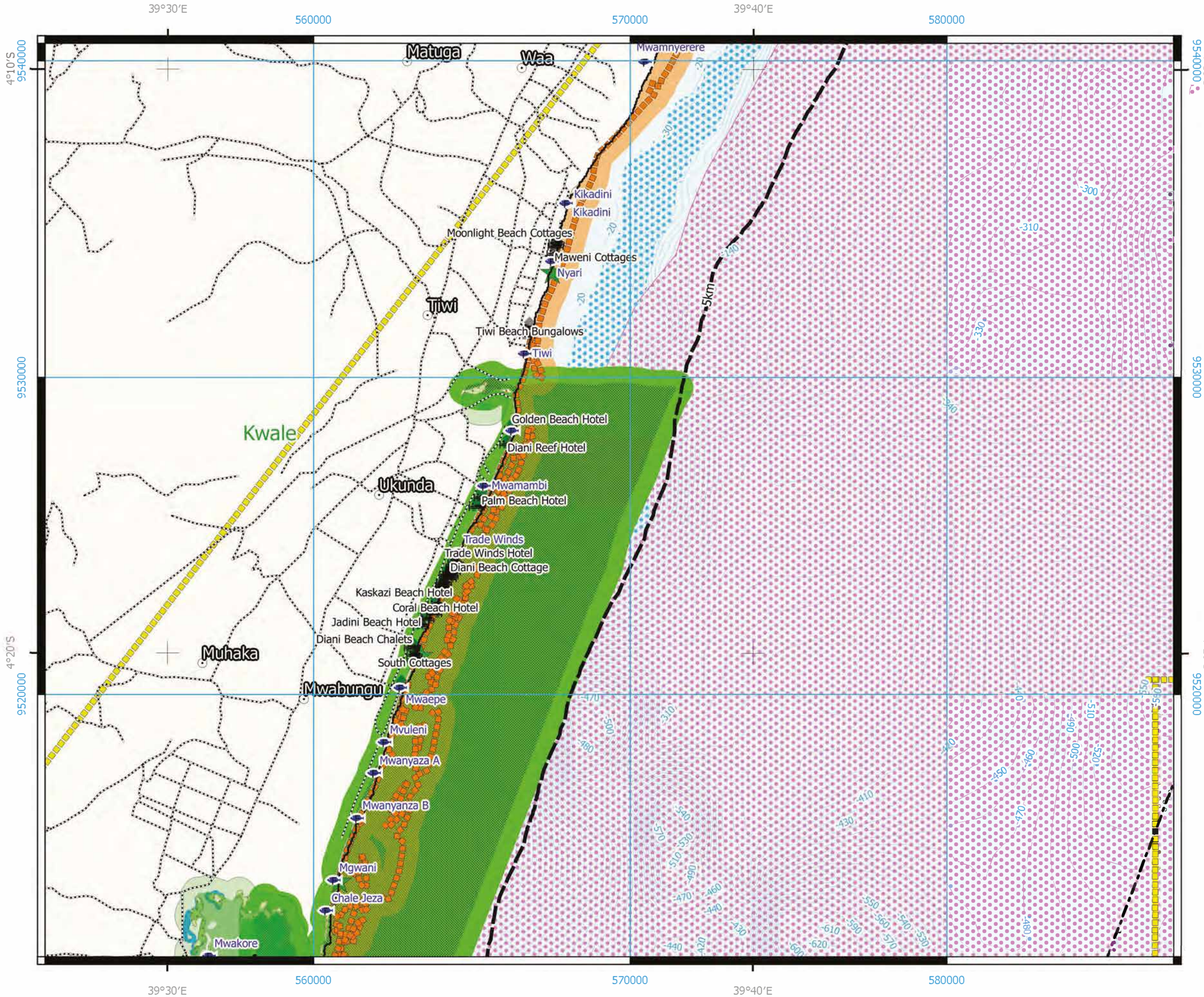
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kwale - KENYA



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N W E S

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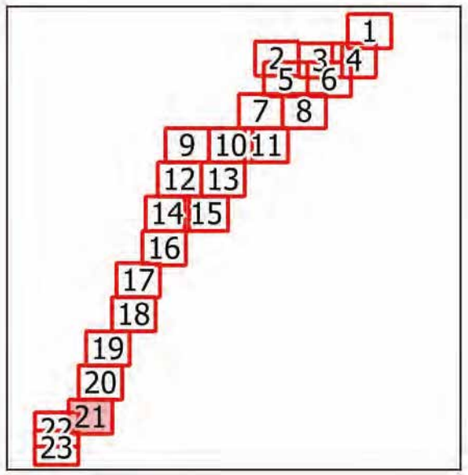
UoM: Metres

# Mariculture Zoning Map - Kwale - KENYA

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Atlas production by Justin Saunders

550000 39°30'E 560000 570000 39°40'E

9510000 4°30'S 9500000 9490000 4°40'S

Gazi
Mwakore
Gazi
Gasi group
Nyumba Sita
Mwandamu
Kisima Chande
Mkunguni
Mawezani
Msambweni
Msambweni
Mwaembe
Kingwede
5km
Ramisi
Munje
Shirazi
Bodo
Funzi
Funzi
Mwembeni
Anzwani
Mji wa Kwale

0 2.5 5 7.5 10 km

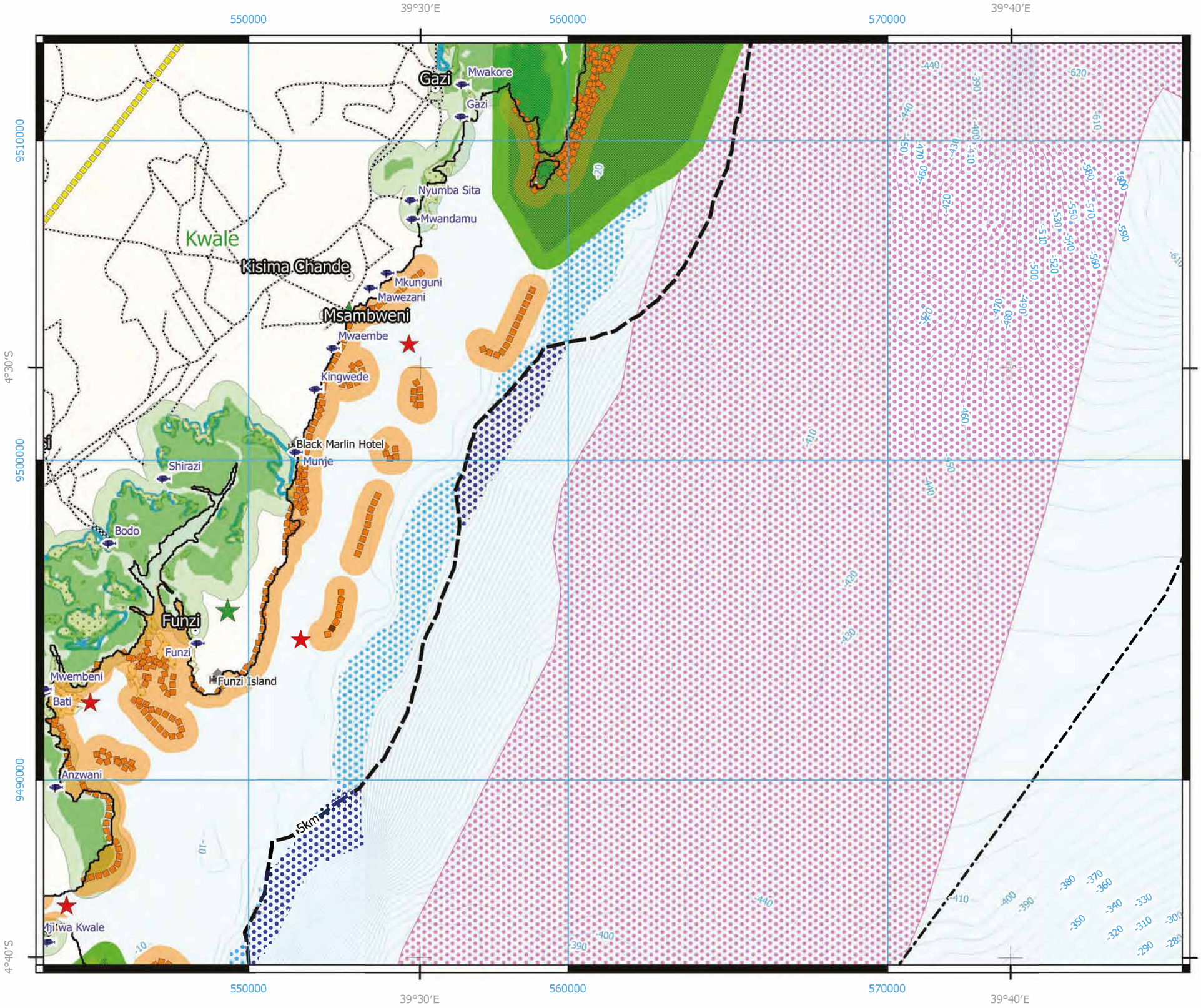
Scale 1:120,000

N W E S

Scale 1:120,000

# Mariculture Zoning Map - Kwale - KENYA






## Legend Atlas

### Boundaries
- Territorial waters
- Coastline
- 5km from coastline
- Bathymetry 10m contours

County
- Kilifi
- Kwale
- Lamu
- Mombasa
- Tana river

### Conservation areas
- Turtle nesting sites
- Turtle conservation groups
- Mangroves
- Mangroves 500m buffer zone
- Coral reefs
- Coral 500m buffer zone
- KWS marine parks
- KWS marine parks 500m buffer
- Important bird areas
- Prawn trawling areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Aquaculture
- Category A potential cage sites
- Category B potential cage sites

### Fishing
- Fish landing sites

### Urban/industrial
- Hotels
- Towns
- Oil exploration blocks

### Transportation
- Navigation routes
- Roads

N W E S

**Projection**

NAME: UTM zone 37S
CODE: 16137
AREA OF USE: World - S hemisphere - 36°E to 42°E Open
CONVERSION METHOD: Transverse Mercator

NAME: Arc 1960
CODE: 4210
CRS TYPE: Geographic 2D
DATUM: Arc 1960 Open
COORDINATE SYSTEM: Ellipsoidal 2D CS. Axes: Latitude, Longitude
UoM: Metres

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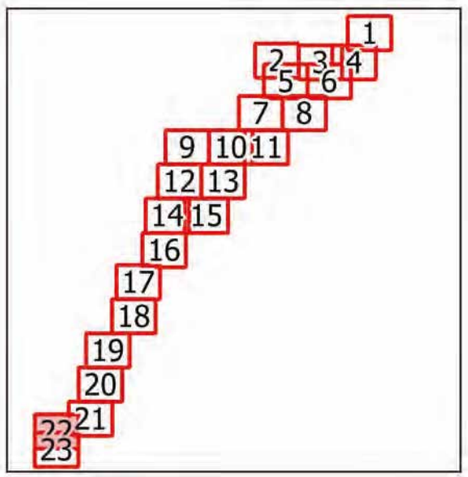


## Legend Atlas

### Boundaries
- Territorial waters
- 5km from coastline

### Conservation areas
- Existing fishing grounds
- Salt works
- Sand mud
- Tidal flats

### Coastline Biological Ranking
- Very high
- High
- Medium
- Low

### Aquaculture
- Kilifi ponds
- Mombasa ponds
- Ponds from satellite imagery
- Category A potential cage sites
- Category B potential cage sites

### User groups
- Kwale user group
- Mombasa user group
- Kilifi user group
- Tana river user group

### Fishing
- Fish landing sites
- Towns


Atlas production by Justin Saunders

39°10'E 520000 530000 39°20'E 540000 550000

9500000 9490000 9480000

4°40'S

Ramisi
Shirazi
Bodo
Funzi
Funzi
Bati
Mwembeni
Kiwambale
Anzwani
Mwenjeni
majoreni
Kivuma
Aleni Mwakimatu
Chete Cha Kale
Mtimbwani
Kiwegu
Kiromo
Kibuyuni
Kibuyuni
Kijiweni
Shimoni
Shimoni
Changai
Wasini
Wasini
Mji wa Kwale
Nyuma ya maji
Bogoa
Jego
Vanga
Vanga
Jimbo
Jimbo
5km

0 2.5 5 7.5 10 km

Scale 1:120,000

N W E S

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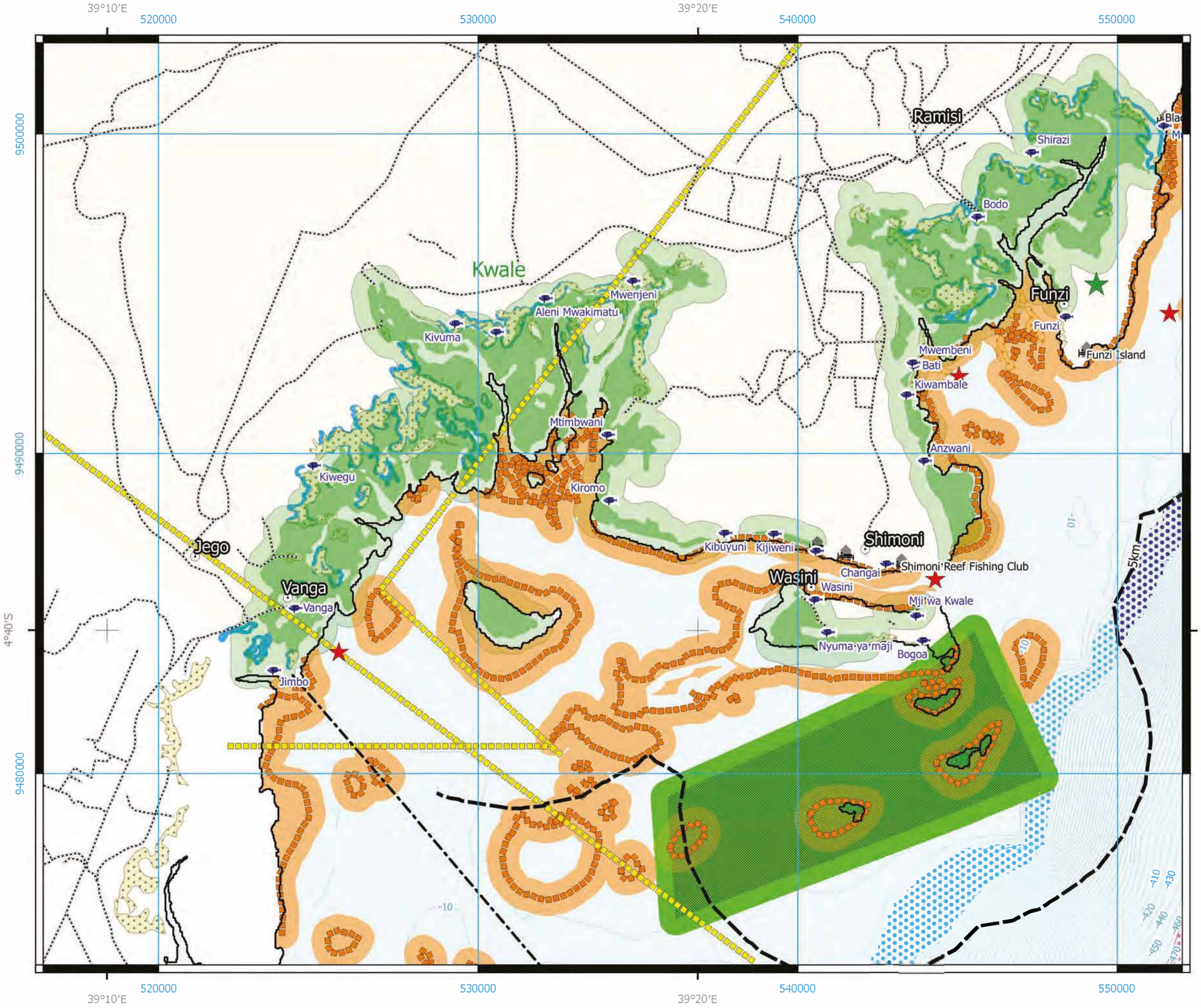


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Scale 1:120,000

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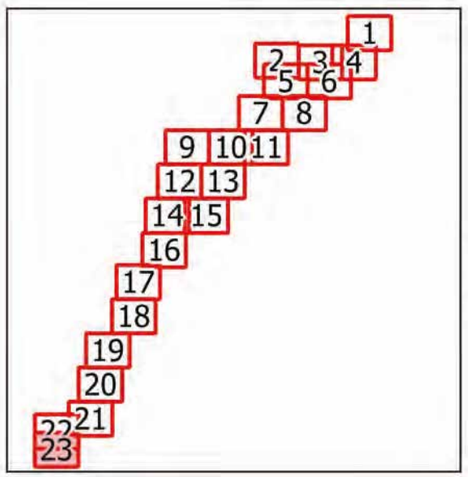


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39°10'E 520000 530000 39°20'E 540000 550000

4°40'S 9480000 9470000 4°50'S 9460000

Jego
Vanga
Vanga
Jimbo
Jimbo
Moa
Kijiweni
Shimoni
Shimoni
Kibuyuni
Changai
Wasini
Wasini
Mji wa Kwale
Nyuma ya maji
Bogoa
5km

0 2.5 5 7.5 10 km

Scale 1:120,000

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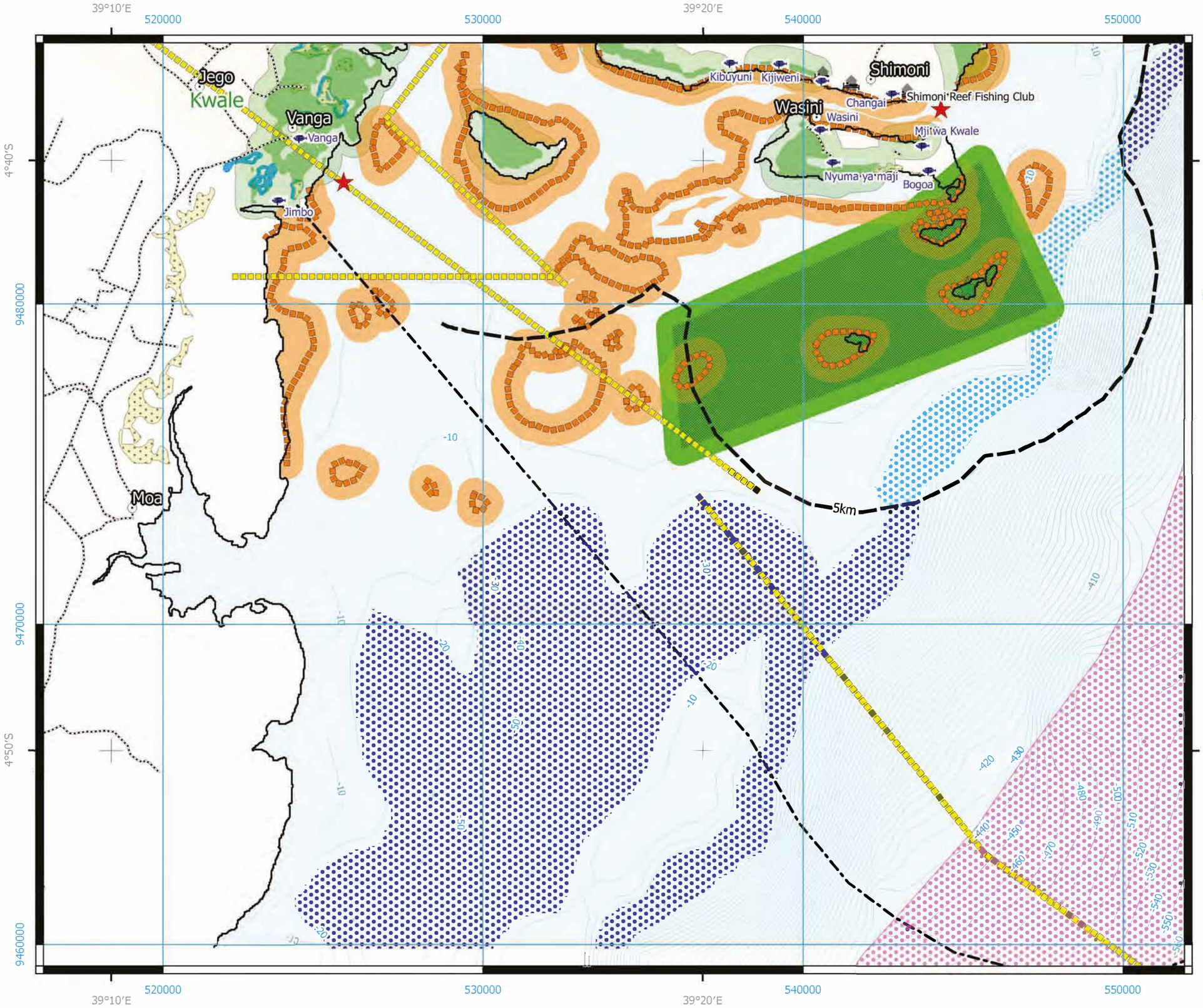


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The potential for the continued development of mariculture in Kenya is immense. However, its expansion and long-term sustainability require proper planning, which starts from appropriate zoning and with the selection of the right sites, followed by the adoption of good management practices. Appropriate zoning will determine how and where to develop aquaculture enterprises that are socially inclusive, equitable and environmentally responsible, and which provide opportunities for sustainable and profitable aquafarming in addition to the economic activities that grow around it.

The main objective of this Atlas is to identify appropriate mariculture zones and sites that take into account the aforementioned objectives. This Atlas includes comprehensive information on various key themes, as well as providing users with maps and satellite images showing the areas that have been selected in accordance with reliable information on the main site-selection criteria in Kenya. It should be noted that decisions over siting are often complex and require the interpretation of data and specific ground surveys.

In general, this Atlas will assist investors or governments who wish to establish marine cage aquaculture projects along the Kenyan coastline. The provision of geo-referenced information on some of the main criteria will guide them in the selection of the most appropriate areas, while enabling a reduction of conflicts with other coastal users and minimizing environmental impacts.

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