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Cover image: Woman collecting ascideans at Ponta Mazondue, Inhaca Island, Mozambique (© José Paula, 2005)

Factors influencing migrant fisher access to fishing grounds

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Abstract

Fisher migration plays a critical role in artisanal fisheries in the Western Indian Ocean. The present study uses a multiple method approach to evaluate fishing behaviour of migrant fishers at four destinations in Kenya, and focuses on fishing grounds used by migrant fishers to illustrate spatial characteristics that attract or determine access and fishing behaviour. Migrant fisher knowledge of natural trends, cycles and oceanographic processes that influence the abundance of target resources largely determines access to fishing grounds. Calm winds and a fairly high Chl-*a* concentration make favourable conditions at fishing grounds on the north coast during the northeast monsoon. Fishing grounds on the south coast include sheltered areas that remain accessible during the southeast monsoon. Increased fisheries productivity is experienced during the rainy season due to sediment loading and increased supplies of particulate matter. The main catch landed on the north coast included octopus, grouper and tripletail that were found within the reefs and on the deep slopes, while on the south coast it included needlefish, tunas and mackerels, barracuda and sardine, among other highly migratory pelagic species. Besides natural conditions, local regulations at the destination, including gear and licence restrictions, were also found to be important determinants of access by migrant fishers.

Keywords: Environmental factors; Fisher knowledge; Migration destination; Space; Strategies

Introduction

Artisanal fisheries support over 10,000 small-scale fishers in Kenya. These fishers use multiple gear and target multiple species (Fondo, 2004; Mangi *et al.*, 2007; Obura and Wanyonyi, 2001). Fisher migration is a common feature in coastal East African fisheries (Fulanda *et al.*, 2009; Glaesel, 2000). Unlike non-migrant fishers who are often limited in range to inshore shallow waters, within sheltered reefs and lagoons adjacent to their landing sites (Mangi and Roberts, 2007; Obura and Wanyonyi, 2001; Samoilys *et al.*, 2017), migrant fishers travel to distant fishing grounds (Crona and Rosendo, 2011; Fulanda *et al.*, 2009; Wanyonyi *et al.*, 2016b). They try to avoid competition and conflict with local fishers by choosing remote locations away from designated landing sites.

Migration expands the fishers' access beyond their place of origin to include fisheries resources at the destination locality. However, access is subject to conditions at the destination that influence availability of target species such as changes in natural cycles or the rules governing access and use of resources (Allison and Ellis, 2001). Fishing, like other natural resource-based livelihoods, reflects the seasonal and cyclical trends of resources (Allison and Ellis, 2001). Users embrace various adaptive strategies to be assured continued access. The expanded space at migration destinations is subject to the influence of governance

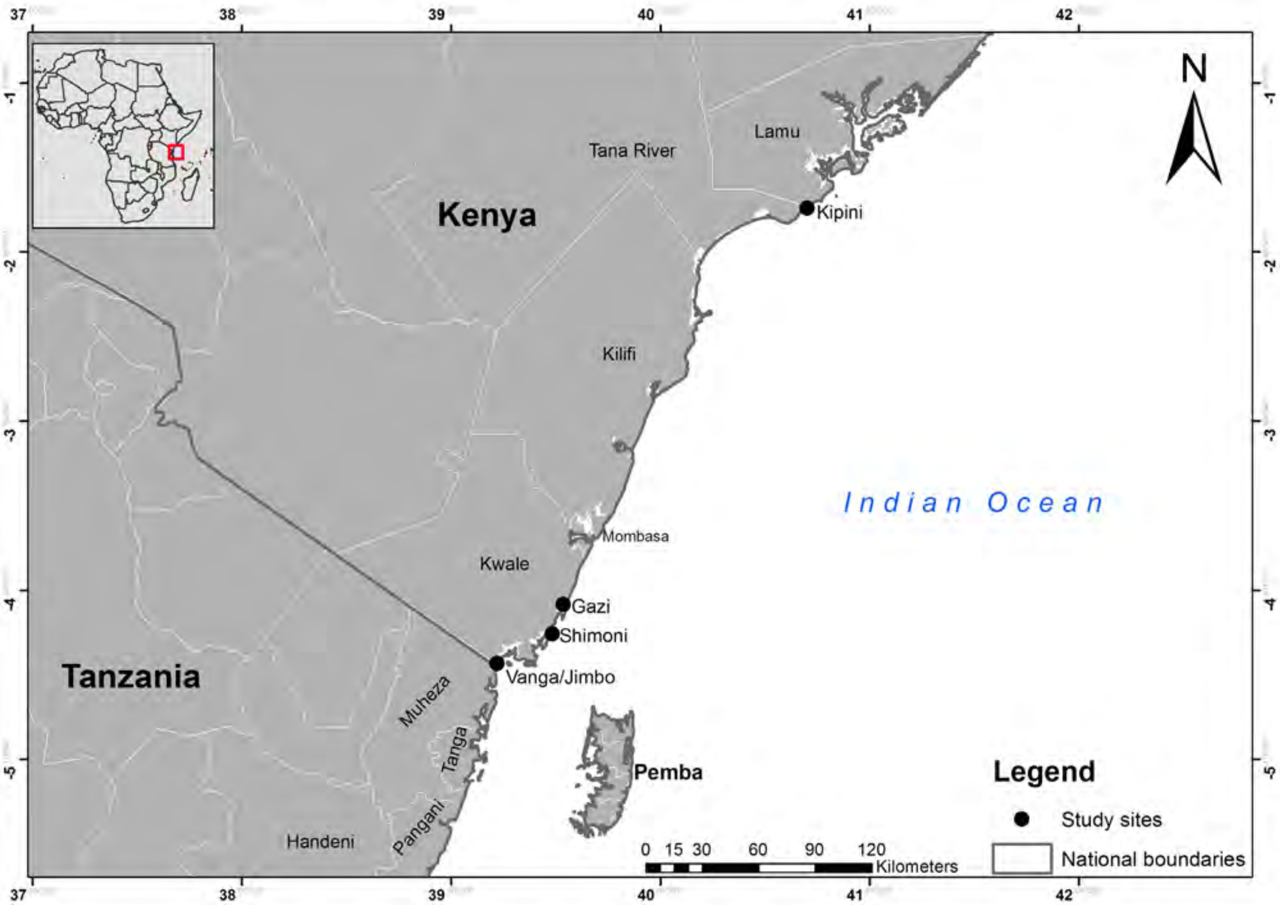

Figure 1. Map of study sites at four migrant fisher destinations in Kenya.

institutions that determine access to the fishing grounds. Among the common approaches used to regulate fisheries include limiting access through licensing, No Take Zones, and gear regulations (Mangi *et al*., 2007). These factors, in addition to natural cycles and trends, influence access for migrant fishers.

The patterns of fisher migrations largely reflect the seasonality in the fish stocks (Fulanda *et al*., 2009; Jiddawi and Ohman, 2002). Fisher migration is mainly seasonal, lasting 2-3 months during the northeast monsoon, but other patterns also exist and migrations can last between 1-7 months (Fulanda *et al*., 2009; Wanyonyi *et al*., 2016a). The behaviour of migrant fishers at destination fishing grounds is relatively unknown. This paper empirically attempts to fill that gap by evaluating ecological, oceanic and governance factors influencing migrant fisher access to, or choice of, fishing grounds.

Methodology

Study Location

The study was conducted at Vanga-Jimbo, Gazi, Shimoni and Kipini, which are well known migrant fisher destinations in Kenya. Kipini was the remotest of the locations while Vanga-Jimbo, lies within the Pemba Channel, and is closest to Pemba Island, which is the place of origin of most migrant fishers (Fig. 1).

The study used a mixed methods approach to collect data between October 2010 and March 2011. Migrant fishers were involved in mapping by tracking and locating their fishing grounds using a geographic positioning system (GPS). They recorded information about their fishing operations using fisher log books. Additional data was sourced from available literature, and long term reef monitoring and remote sensing data.

Geographical, fishery, ecological and oceanographic aspects of relevance to migrant fisher's access to fishing grounds

Migrant fisher 'spaces' were assessed in terms of their geographical, fishery, ecological, and oceanographic attributes. To assess local geography, three fishing vessels representative of the main migrant fishing vessels and gear at each site were randomly selected to participate in tracking their fishing routes using a GPS. GPS track data was converted into a fishing ground

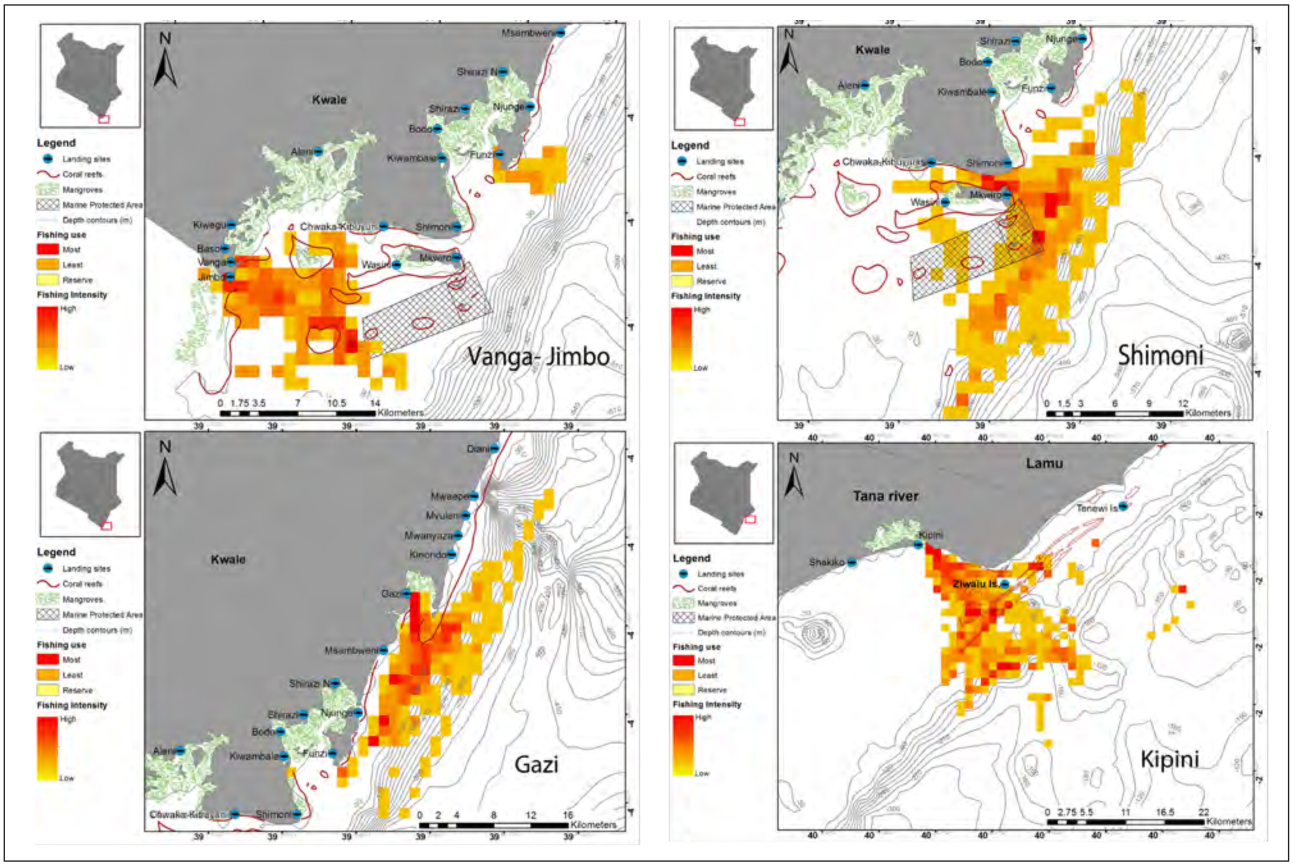

Figure 2. GPS map of principal fishing grounds used by migrant fishers combined by landing site.

intensity of utilisation map in ArcGIS software. Maps of vessels operating from one landing site were combined into a single intensity map per site (Fig. 2).

Fisheries at destination were assessed to determine the scale of resource use by migrant fishers. Each vessel recorded the number of fishers on board, type of gear, type of vessel, size and main composition of catch during each fishing trip on log sheets. Analysis of this data determined fish families targeted per vessel/gear type and landing site. Fishing duration and catch per unit effort (CPUE) by vessel/gear types at each destination was analysed using the Kruskall-Wallis test followed by the Mann-Whitney *post hoc* test after failing parametric assumptions of normality and homogeneity of variance. Generalised linear models (GLM) were used to study fishing intensity associations with crew size, fishing site depth, fishing site distance, and fishing vessel type, which allowed accounting for the non-independence of samples.

Data from Nighttime Moderate Resolution Imaging Spectroradiometer (MODIS) (NASA Goddard Space Flight Center-Ocean Ecology Laboratory-Ocean Biology Processing Group) covering the northern Tanzanian and Kenyan coast at 4 km spatial resolution was used to map sea surface temperature (SST), chlorophyll-*a* concentration (Chl-a), and detect thermal fronts. Thermal fronts are areas of sharp temperature gradient between adjacent water masses (Legeckis, 1978; Mooers *et al.*, 1978). They are indicators of many oceanographic processes apart from being sites of increased biological activity. Monthly level 3 data from 2003 to 2016 was downloaded from the NASA Jet Propulsion Laboratory (JPL) Physical Oceanography Distributed Active Archive Center (PO.DAAC) and processed using Matlab to create seasonal plots. Data is presented for December to February, the peak season for migrant fisher arrival in Kenya (Wanyonyi *et al.*, 2016a). The rest of the data is available as supplementary information. Detection of thermal fronts was achieved using the single image edge detection (SIED) algorithm as derived by Cayula and Cornillon (1992; 1995). Remote sensing data was chosen over direct measurement of the biological and physical parameters due to its reliability in providing a synoptic-scale window into the ecosystem in coastal areas, which are characterised by

Table 1. Migrant fisheries and fishing area characteristics at four landing sites.

Landing site	Kipini	Gazi	Shimoni	Vanga-Jimbo
Gear	Hook and line, hook and stick, long line	Cast net, drift net, ring net, shark net	Gill net, hook and line, shark net	Basket trap, long line, ring net, shark net
Crew size	5-20	2-30	2-5	3-28
Fishing duration (hrs.)	6-14	1-16	1-19.8	3-9.5
Fishing area (km²)	582.6	303.7	333.4	280.3
Maximum depth	180	400	510	260
Maximum distance	40	25	22	21

high variability of their physical and biogeochemical processes (Semba *et al*., 2016).

Ecological characteristics of the main fishing grounds were assessed from previous scientific assessments on marine biodiversity and habitat health studies (Coppejans *et al*., 1992; Gullström *et al*., 2002; Obura, 2001a; Samoilys, 1988).

Local governance and migrant fisher access to fishing grounds.

Content analysis of thematic issues using key informant data was used to determine governance institutions with an influence on access to the fishing grounds. Key informants included fish traders, migrant fisher crew leaders, experienced local fishers, and leaders of local beach management units (BMUs) at each study site. Thematic issues discussed included local fisheries governance and the relationship between migrant fishers and local fisheries stakeholders.

Results

Fishery, geographical, ecological and oceanographic aspects of migrant fisher 'space'

According to GPS tracking, the overall resource area utilised by the migrant fishers at Kipini was largest (582.6 km²), and smallest at Vanga-Jimbo (280.3 km²) (Table 1). The fishing grounds at Kipini extended from the northern tip of Ungwana Bay northwards to Lamu, and seawards to about 25 km from the shore (Fig. 2). The highest intensity of use was concentrated within the seagrass beds and fringing reef near Ziwayuu Islands and isolated offshore areas south of the Tenewi Islands. Offshore fishing occurred from 60-120 m deep along the gradual slopes of the small islands and barrier reef. The main fishing areas at Gazi were the fringing reef in front of the Bay, along the reef to Msambweni, the back-reef and fore-reef to 20 m deep, the gradual fringing reef slope to the ocean floor at 60 and 120 m depths further south off Kinondo, and the shallow patch reef in Funzi Bay at about 20 m deep. Offshore areas greater than 400 m deep were not used intensively. The Shimoni fishing grounds included areas inside and on the peripheries of Mpunguti Marine Reserve (Fig. 2). Most of the fishing was concentrated along the fringing reef and slopes at 10-160 m deep. Intensive fishing areas at Vanga-Jimbo were in sheltered lagoons and patch reefs nearshore, and in isolated pools in the Funzi area.

The deepest fishing area in Shimoni was 510 m compared to 180 m in Kipini. The longest maximum distance to fishing grounds was 40 km at Kipini, which was twice that of Gazi and Shimoni, while the shortest was 21 km, at Vanga-Jimbo (Table 1). Fishing areas between Funzi and Moa had overlapping use by migrant fishers at Gazi, Shimoni and Vanga-Jimbo.

Fishing duration varied for different types of vessels and gear. Canoe (dugout or outrigger) fishers in Gazi and Shimoni spent the least time (minimum 1hr) while outrigger canoe and wooden plank boat fishers in Shimoni and Gazi spent the most time (maximum 19.8 and 16 hours respectively) (Fig. 3).

The 14 year MODIS SST plot (Fig. 4a) for December to February showed warm pools of water offshore, southeast of the domain between 40° to 43° E extending to 4° S. The SST range was 27 °C to 27.5 °C around the Pemba Channel. The region's general pattern of surface thermal fronts is illustrated by a dashed line overlay on the SST map (Fig. 4a). Several stable fronts were evident on the south coast of Kenya and marginal waters, in addition to a few open oceans fronts. There was considerable spatial variability in mean chlorophyll concentration (Fig. 4b); the lowest ranging from 0 – 0.1 mg/m^3 in the southeast, and elevated concentrations on the north coast of Kenya, with the highest being the shelf, and moderately high offshore.

A GLM analysis of factors influencing fishing intensity showed crew size, depth of fishing location and distance from the destination landing site were all significant at 5%, and type of vessel at 10% (Table 3).

In general migrant fishers mostly targeted pelagic fish (Fig. 5), although in Kipini octopus were targeted. The main target catch was Belonidae (needlefish), Scombridae (tunas and mackerels) and Sphyraenidae (barracuda) in Gazi, Lethrinidae (emperors) in Shimoni, and Clupeidae (sardine) in Vanga-Jimbo. Clupeidae and Sphyranidae were the common catch taken by ringnets in Vanga-Jimbo and Gazi respectively. Shark nets targeted Dasyatidae (rays) in Vanga-Jimbo, Xiphidae (swordfish) and Carcharhinidae (sharks), and Sphyraenidae and Istiophoridae (billfishes and sailfishes) in Gazi, and Xiphidae in Shimoni. Longlines mainly targeted Dasyatidae in Kipini, and Ophidiidae (cusk eels) in Vanga Jimbo. Hook and lines in Shimoni and Kipini targeted Lethrinidae, similar to the basket trap in Vanga-Jimbo. Hook and stick in Kipini targeted Octopodidae. Gill nets in Shimoni targeted Belonidae and Pomacentridae, while cast nets and drift nets in Gazi targeted Scombridae (Fig. 5).

CPUE for each landing site and vessel/gear type showed variability in catch rates (Fig. 6). Ring nets in Vanga-Jimbo recorded a higher CPUE of 4.8 ± 0.6 kg/fisher/hr compared to basket traps, longlines and shark nets (Fig. 6). Catch rates in Shimoni and Gazi were similar across all gears for the different vessel types, except shark nets in Gazi, which had a relatively higher CPUE of 1.2 ± 0.2 kg/fisher/hr.

The ring nets at Vanga-Jimbo had the highest CPUE, followed by long lines, and hook and line at Kipini (Fig. 6). CPUE of other gear types was < 2 kg/fisher/hr, and lowest for long lines in Vanga-Jimbo and Shimoni.

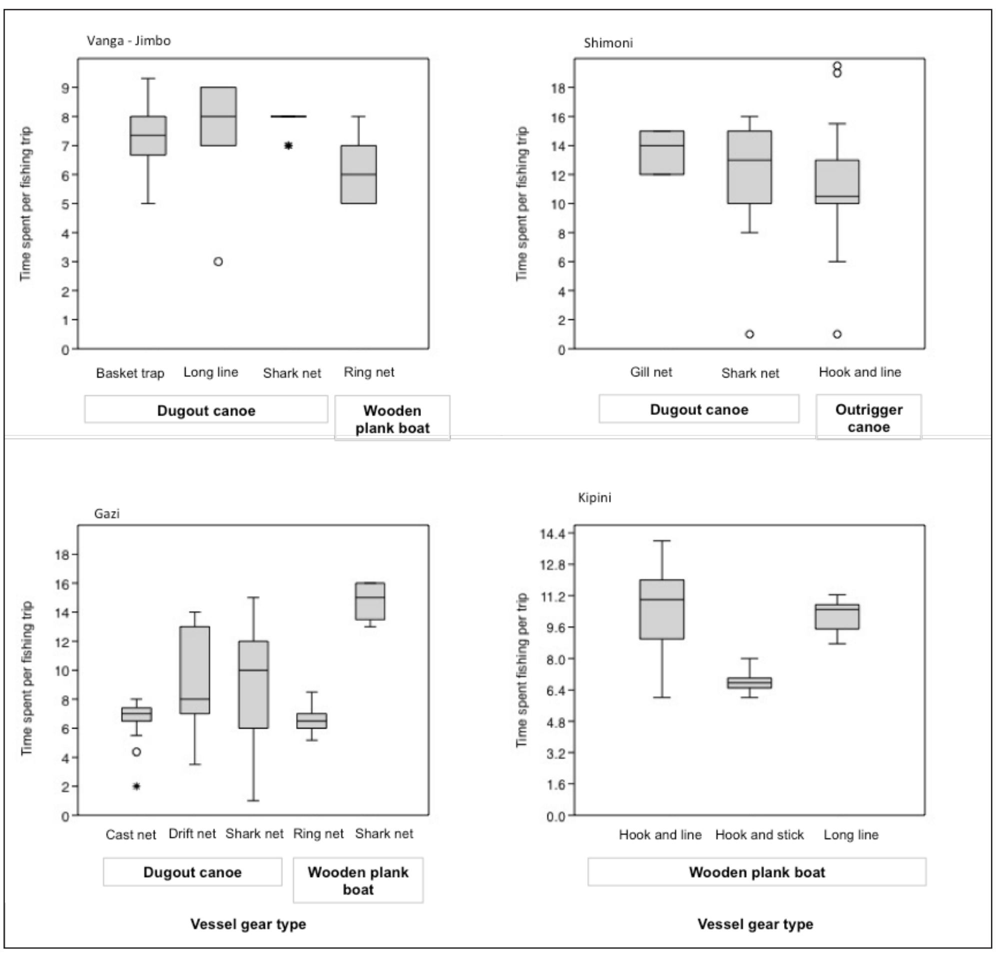

Figure 3. Fishing time (in hours) by different vessel/gear types.

Table 3. GLM of factors influencing fishing intensity

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-2.576	0.18	-14.66	0.00
Crew	0.01	0.01	2.47	0.01
Depth	-0.00	0.00	-3.05	0.00
Distance	-0.01	0.01	-2.15	0.03
Vessel	-0.02	0.02	-1.76	0.08

The largest volume of total catch landed by migrant fishers comprised of squid and sardine landed in Vanga-Jimbo, followed by sharks and rays in Kipini, sardines in Gazi and mackerel in Vanga-Jimbo (Fig. 7). Species landed mainly at one landing site included triple tails and octopus in Kipini, and milkfish in Shimoni.

In terms of volume of catch per landing site, the highest was for reef fish followed by oceanic pelagic fish for Kipini, and coastal pelagic fish followed by reef fish for Vanga-Jimbo, whereas pelagic fish and oceanic pelagics were highest in Gazi and Shimoni, respectively, followed by demersals (Fig. 8).

The main gears used to catch the greatest volume of landings were ringnets in Vanga-Jimbo, and long lines, hook and line, and hook and sticks in Kipini (Fig. 9). In Gazi, various types of net were used (ie. ringnets, castnets, and sharknets), whereas in Shimoni, sharknets and gillnets landed the greatest volume of catch.

Social and institutional aspects determining migrant fisher access to fishing grounds

Traders mainly decided the destination of migrant fishers from Pemba. Traders also facilitated fishing licenses and immigration clearance, and provided fishing equipment, freezers and transport to market. Migrant fishers landed fish at the local landing sites rather than transporting it back to their place of origin. The local BMUs received and approved the migrant fishers using acceptable fishing gear, as long as they had introductory letters from their home authorities and valid travel documents from the host country. The migrant fishers paid levies for all fish landed and boat anchorage fees to the BMU.

Discussion

Spatial aspects of migrant fisher 'spaces' at destination

The East African coast has a wide range of oceanographic environments, as influenced by the monsoon winds that blow from the southeast in boreal summer (South East monsoon (SEM) from June to August)

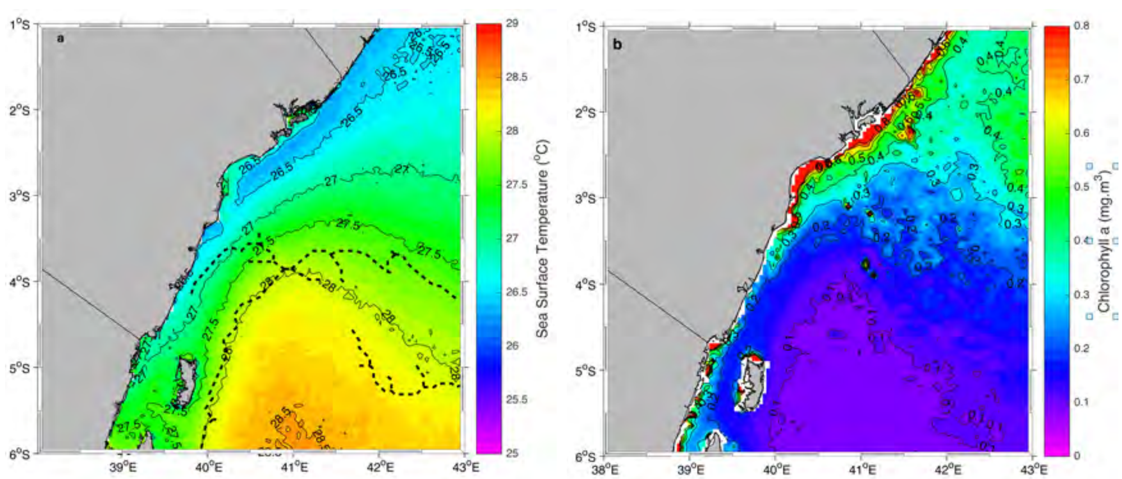

Figure 4. a) Detected thermal fronts overlaid (dashed line) on sea surface temperature plot with contours spaced at 0.5 °C; b) Favourable range of chlorophyll-a concentration with contours spaced at 0.1 mg/m3 from December to February.

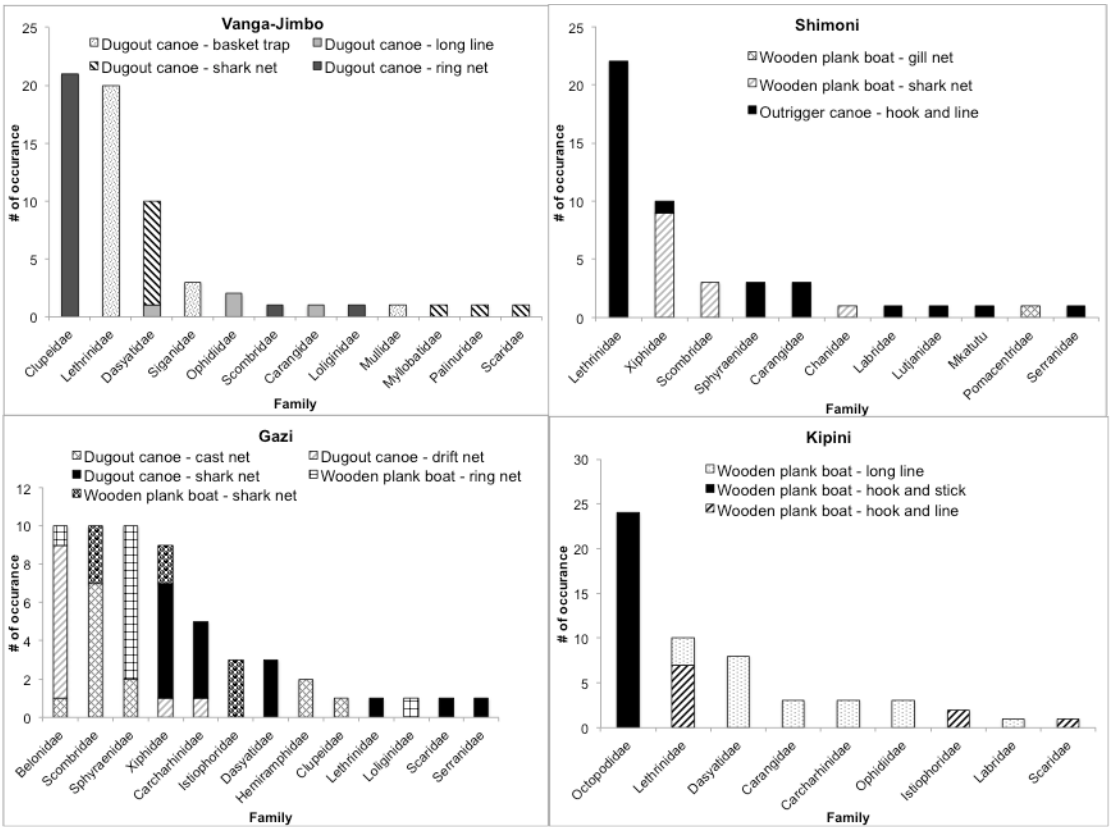

Figure 5. Occurrence of fish families in migrant fisher landings at four landing sites.

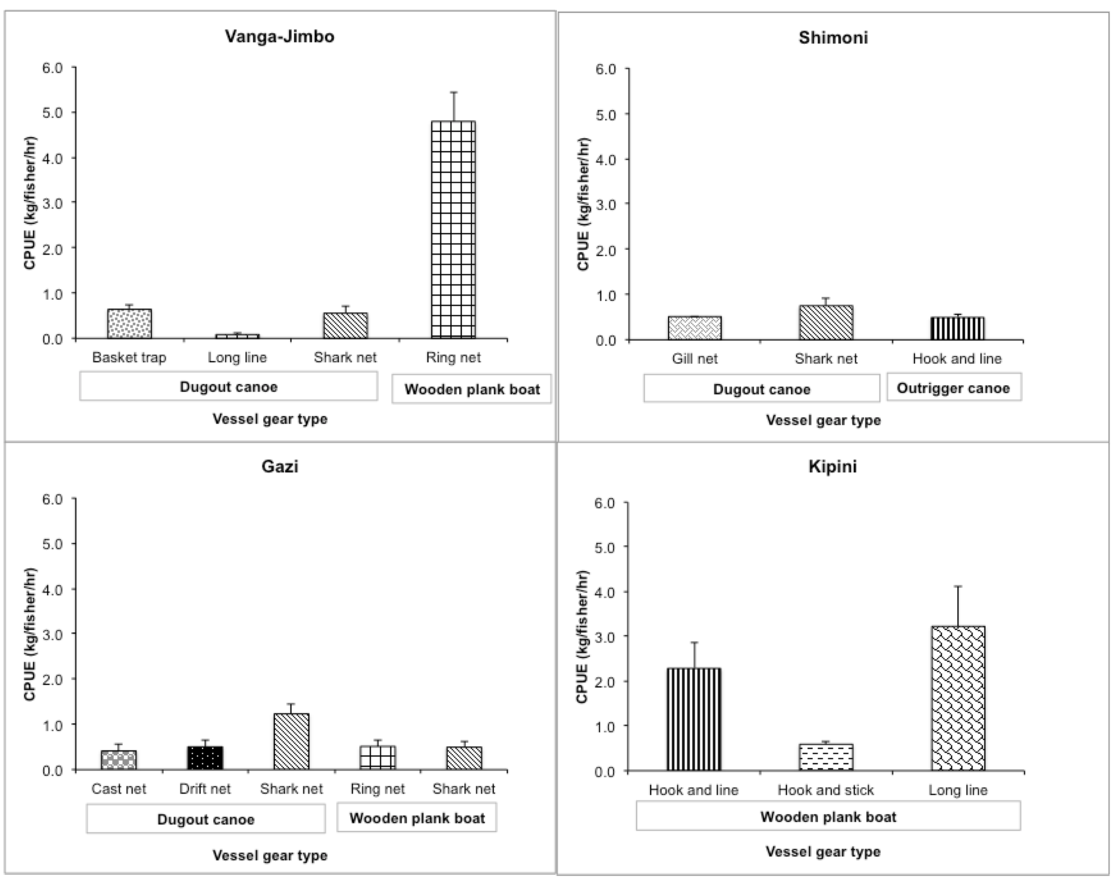

Figure 6. Catch per unit effort of migrant fishers using different vessel/gear types at four sites.

and the northeast in boreal winter (North East monsoon (NEM) from December to February) (Bruce, 1979). These wind patterns play a pivotal role in influencing access to fishing grounds and fish availability. Strong winds during the SEM also enhance wind induced evaporative cooling and vertical mixing of the water. This paper uses satellite data, which provides a synoptic view of ocean factors influencing migration to potential fishing grounds.

The stable fronts on the south of the Kenyan coast influence the distribution of pelagic fish due to nutrient rich water advected by the East African Coastal Current (EACC). Compared to other seasons the December to

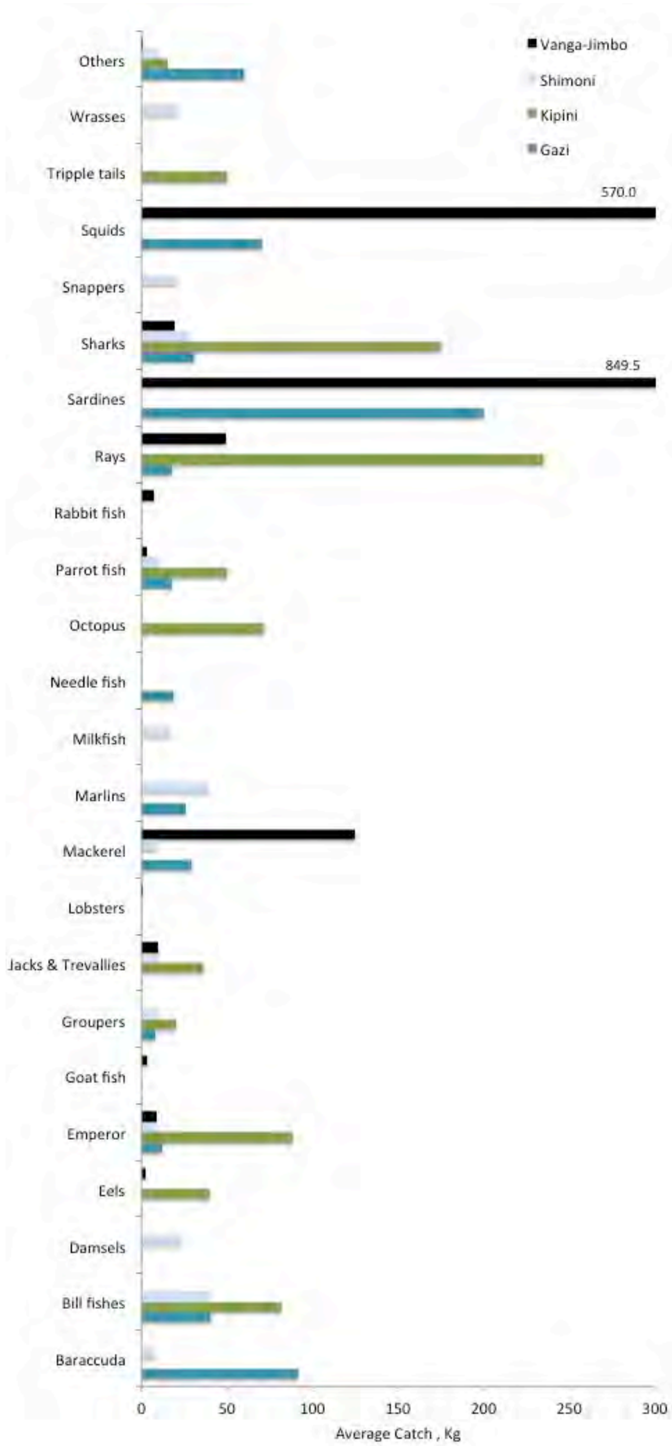

Figure 7. Average catch of target fish in migrant fisher landings.

February season has more thermal fronts, mainly due to the weak NEM, which results in the formation of fronts at the boundary between water masses of different temperature and density. It should be noted that many genuine fronts will not be clearly seen as a single colour palette across the wide range of SST values is insufficient for revealing thermal structures where differences are less than 0.5 °C.

The current study postulates that choice of fishing location on the north coast was associated with high productivity of marine ecosystems. Migrant fishers take advantage of the seasonal variability in the region occasioned by the monsoon patterns. This argument is confirmed by seasonal arrivals of migrant fishers in high numbers and their preference of fishing grounds in the north during the NEM (Wanyonyi *et al*., 2016a). Calm winds and a fairly high Chl-*a* concentration in the north provide favourable conditions at fishing grounds during the NEM. The EACC, which flows northwards throughout the year, is the dominant current and is stronger during the SEM (June-August) on the north coast. Thus, offshore fishing grounds on the north coast are less accessible during the SEM, but migrant fishers continue fishing within sheltered fishing grounds adjacent to Vanga-Jimbo in the south.

The region experiences a bimodal rainfall pattern with the long rains in March/May, and the short rains in October/December (Yang *et al*., 2015), which coincides with the transition periods from the NEM to SEM, and from SEM to the NEM, respectively (Okoola, 1999). Rains are associated with sediment and nutrient loading from rivers such as the Umba, Ramisi and Mwena, and increased turbidity levels in fishing grounds around Vanga-Jimbo and Shimoni (Opello *et al*., 2006). Similar effects are seen in Kipini from the Tana River. Turbid conditions are conducive for basket trap and prawn fishing. The rivers and mangrove bays around the fishing areas of Gazi, Msambweni, Funzi and Vanga ensure a supply of particulate matter that replenishes the marine ecosystems, increasing fisheries productivity through the food chain (Munyao, 1998).

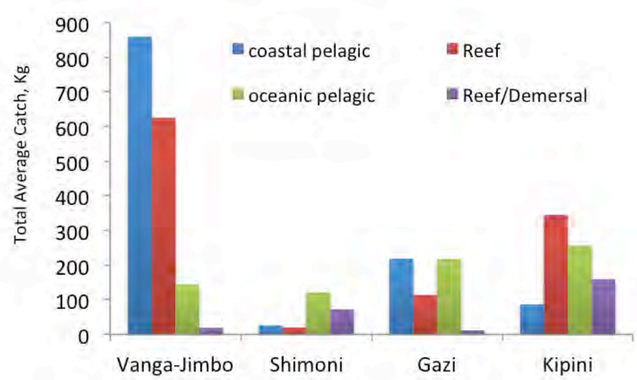

Figure 8. Average catch and type of fish landed by migrant fishers at four landing sites.

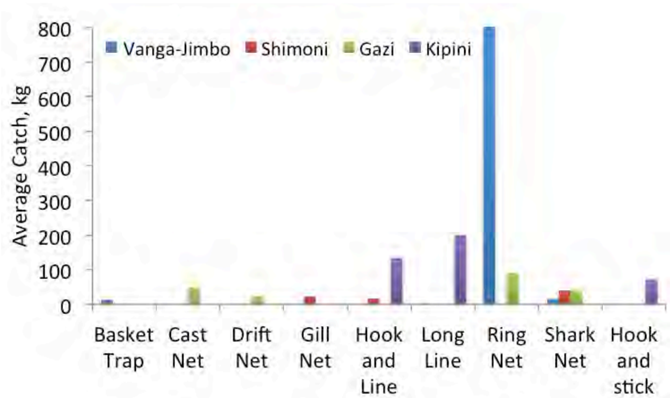

Figure 9. Average catch by different fishing gear used by migrant fishers at four landing sites.

Fishing patterns observed confirm important fishing areas for migrant fishers. In Kipini these are less than 200 m deep, but may be more than 20 km offshore due to the gradual depth change in this area. Gazi Bay appears to be a main access point to fishing grounds in Gazi, Kinondo, Funzi and Msambweni, due to the shorter distance to the main fishing grounds, which includes deep fishing areas. The fishing patterns on the south coast indicating that particular fishing spots are not targeted are consistent with fishers targeting schooling and highly migratory species, which are often caught in deep areas. Conversely, fishers targeting coral reef and seagrass associated species tend to concentrate at particular fishing grounds. These patterns of use have been confirmed by the catch composition on the north coast and south coast, respectively.

The concentration of migrant fishers at particular fishing grounds, as shown from GIS tracking maps, confirm suitability of these fishing areas to migrant fishers. The type of fishing vessels used relate to accessibility of fishing grounds in respective areas. This is reflected in the dominant use of wooden plank boats in the north, and outrigger and dugout canoes in the south. Fishing areas are accessed using specific vessels in combination with particular gear to target particular catch. Various net types were used to catch Belonidae, Scombridae and Sphyraenidae in Gazi, Xiphidae in Shimoni, and Clupeidae in Vanga-Jimbo, while hooks and stick were used for Octopidae in Kipini. These findings are in agreement with previous studies that catch composition largely depends on the gear used and fishing location (Bastardie *et al*., 2010). Artisanal fisher catch is dominated by *Siganus sutor* (African whitespotted rabbitfish) and *Leptoscarus vaigiensis* (seagrass parrotfish) for most gear in Kenya (Samoilys *et al*., 2017). This type of catch indicates a concentration of fishing activity in reef and lagoon areas, unlike what has been shown to be the case with migrant fishers in this study.

Fisher knowledge of their marine environment and geographic location of suitable fishing grounds is an important influence on their use patterns (St. Martin and Hall-Arber, 2008). The diverse ecosystems and habitat types in Kenya, include sheltered seagrass beds and coral reefs, and harbour diverse and economically important species (Samoilys, 1988; Samoilys *et al*., 2011; UNEP, 1998). Migrant fishers target these diverse species, which explains their diverse utilisation patterns at fishing grounds spread out from Kipini in the north to Vanga-Jimbo in the south. Species dominating the migrant catch in Kipini such as crustaceans, octopus, grouper and tripletails are found within the reefs, rocky substrates, deep slopes, coastal waters and estuaries. Pelagic species on the other hand are important to migrant fishers in the south coast areas and include needlefish, tunas, mackerels, barracuda, and sardine, that are found in the open sea, around reefs and in coastal waters (Anam and Mostarda, 2012). The area between Gazi and Vanga-Jimbo has high biodiversity with complex ecosystems making it attractive to fishers (Gullström *et al.*, 2002).

The notable absence of migrant fishers from the fringing reef off Kinondo and Galu and their higher concentrations offshore reflect the attractiveness of the areas to migrant fishers. Local fishers are known to limit their fishing within lagoons and reef areas nearshore, leaving little room for entry of migrant fishers. At the same time, this particular area is over-exploited, with extensively degraded coral reef ecosystems (McClanahan *et al*., 1997; Obura, 2001b), making it unattractive to migrant fishers. The unsustainable resource utilization of coral reefs and continental shelf fisheries is a global challenge, and many are over-utilised (Allison and Ellis, 2001; ICLARM, 1995). Nonetheless, most offshore resources remain underutilized, explaining why they are highly attractive fishing grounds to migrant fishers. In Kipini, however, the state of the offshore fish populations in areas used by migrant fishers is poorly understood and fishing pressure may be relatively high (Samoilys, 1988; Samoilys *et al*., 2017).

On the south coast, spawning grounds for commercially important fish species, including rabbit fish (*Siganus sutor*) and groupers, have been confirmed near Msambweni (Samoilys *et al*., 2013). The high concentrations of migrant fishers, and the sale of most fish landed in Gazi locally, suggest a demand for fish that outstrips supply. This is unlike in the more remote areas of Kipini and Vanga-Jimbo, which depend on distant markets and sale of dried fish due to low demand.

The type of vessel and gear influence access to fishing grounds and fishing time. Wooden plank boats using ring nets in Gazi showed the greatest significant difference compared to other vessel/gear combinations. Fishing duration is also influenced by distance from shore, and fishers at Vanga-Jimbo took the least time to access fishing grounds. This explains the area's attractiveness to migrant fishers during the SEM.

Studies have shown that large vessels are more efficient, accessing distant or deep fishing grounds, usually avoided by small dugout canoes (Wanyonyi *et al.*, 2016a). Wooden plank boats using ringnets in Vanga-Jimbo had the highest CPUE. This is attributed to the catch composition, largely made up of clupeids, the vessel type, the catchability coefficient of gears, and location of fishing grounds. In general, migrant fishers CPUE exceeds the artisanal fisheries average in Kenya, which steadily declined before stabilising at 3.2 ± 0.1 kg/fisher/trip in the 1990s (Samoilys *et al.*, 2017). This suggests that migrant fisher's operations are more efficient and successful than local fishers.

Social and institutional aspects influencing migrant fisher access to fishing grounds

Migrant fishers selected fishing grounds and destinations where they were likely to catch more high value fish. They used their skills and knowledge about rich fishing grounds, and relationship with traders, who also provided them with gear and vessels, to access these fishing grounds.

BMUs are responsible for local fisheries at the landing site (McClanahan *et al.*, 1997; Obura, 2001a). They grant migrant fishers permission to fish and land their catch in the area (Evans *et al.*, 2011). Access to landing sites grants the migrant fishers access to local fishing grounds. BMUs and fisheries agencies can also reject migrant fishers as happened in Malindi, Mwaepe, Mvuleni and Msambweni (Fulanda *et al.*, 2009; Glaesel, 2000; Wanyonyi *et al.*, 2016a) where migrant fishers were associated with using unsustainable practices such as beach seines, spear guns, ring nets, cast nets, monofilament nets and scuba, or using scuba diving equipment during fishing for octopus, lobsters, sea urchins, and ring net fishing.

Conclusion

Migrant fisher resource exploitation patterns are influenced by the drivers for migration, which are best described in spatial terms. Access to fishing grounds reflects opportunities such as availability and abundance of target taxa at the destination fishing grounds, and existing fishing regulations that determine this access. It also depends on migrant fisher knowledge of the environment. Migrant fishers chose productive fishing grounds, and fishing gear and vessels to take advantage of the natural trends in resource availability, and the changes in cycles that redistribute or influence availability of target species. These changes include seasonality of wind and current patterns.

Acknowledgements

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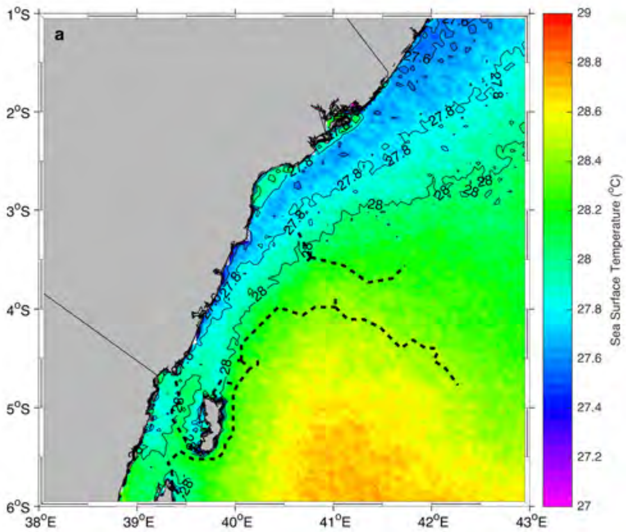
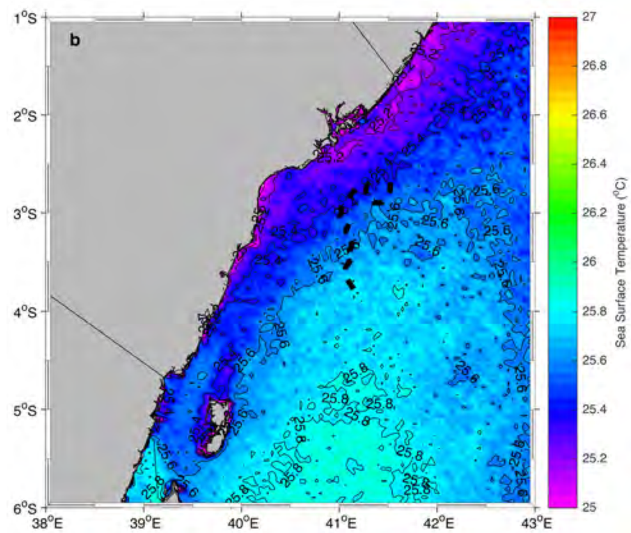
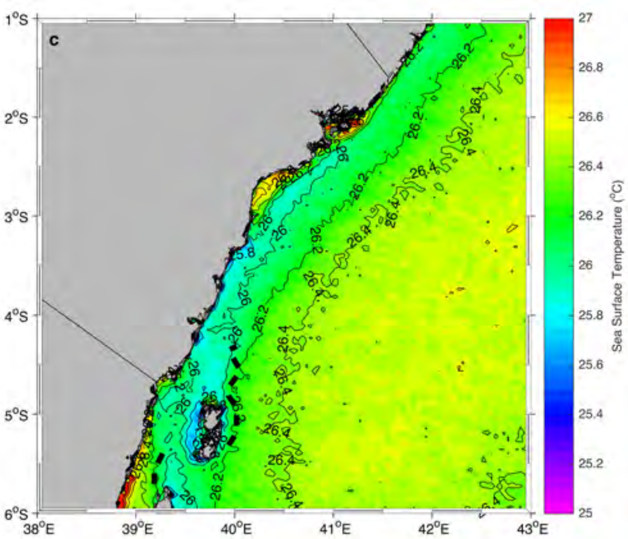
Supplementary information



Supplementary Material -Figure 1. Sea surface temperature plot with contours spaced at 0.5 °C during March to May.



Supplementary Material-Figure 2. Sea surface temperature plot with contours spaced at 0.5 °C during June to August.



Supplementary Material-Figure 3. Sea surface temperature plot with contours spaced at 0.5 °C during Septemeber to November.