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Seaweeds of potential economic importance in Kenya: field survey and future prospects

C. Yarish[1] & G. Wamukoya[2]
[1]*Department of Ecology & Evolutionary Biology, University of Connecticut, 641 Scofieldtown Road, Stamford, CT 06903 U.S.A.;* [2]*Kenya Marine Fisheries Research Institute, P.O. Box 81651, Mombasa, Kenya*

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Abstract

Kenya is a net importer of agar and alginate based on recent government statistics, although it may have the potential to be self-sufficient or even an exporter of these phycocolloids. There is little information on carrageenan importation into Kenya since government statistics incorporate it as agar. Seaweeds are relatively unimportant in the Kenyan diet since they are consumed rarely by coastal people. A survey of 15 sites along of the Kenyan coast evaluated the potential for harvesting seaweeds and for establishing seaweed farms. *Gracilaria* appears to comprise the bulk of the low grade agar import, even though local species of this genus are widely distributed along the Kenyan coast. Major populations of *Gelidium* may be a potential source of high quality bacteriological grade agar. *Eucheuma* may be farmed locally to support the increasing local and regional demands for carrageenan. Recommendations for a national program of management and production for Kenya will be discussed.

Introduction

Most studies of Kenya's seaweeds have been taxonomic in nature (Isaac, 1967, 1968, 1971; Isaac & Isaac, 1968; Kay, 1969; Lawson, 1969, 1980; Moorjani, 1977; Coppejans & Gallin, 1989). The flora of the Kenya coast is rich, comprising over 300 species (Moorjani, 1977), but knowledge concerning potentially commercially important species is relative rare (Ruwa, 1981; Mshigeni, 1983, 1987; Yarish, 1988).

Currently no harvesting of commercially important seaweeds occurs in Kenya. In neighboring Tanzania, *Eucheuma* species have been harvested for carrageenan from wild stocks since 1950 (Mshigeni, 1987). Estimates of exports, as dry tonnage, for Tanzania have been extremely variable ranging from 110 tons (Caddy & Fisher, 1984) to 700 tons (Chapman & Chapman, 1980). With the assistance of the U.S. Agency of International Development's Rural Technology Program during 1981, Tanzania was given assistance for a pilot farming project (U.S. A.I.D. Project 698-0707 to Mshigeni & Semesi). The design criteria for these farms were taken from work described by Ricohermoso & Deveau (1978) and adapted for the Tanzanian coastal zone by Mshigeni & Semesi (Mshigeni, 1987). Currently there is no commercial exploitation of any alginate or agar-containing species in Kenya or Tanzania. Mshigeni (1983) has stressed the need for more research on phycocolloid-containing algae in East-Africa, with special emphasis placed on Kenya.

The present paper summarizes preliminary results of field surveys for potentially economic important seaweeds in Kenya. Statistics on phycocolloid imports from the Kenyan government are presented, as well as an assessment of potential seaweed cultivation in the country.

Material and methods

The Kenya coastline is approximately 880 km in length (Coppola, 1982). It extends from latitude 1° 40′ S to 4° 41′ S and longitude 39° 12′ E to 41° 20′ E (Fig. 1) in a NE-WSW direction (Moorjani, 1977). The coastline is relatively indented and is characterized by fringing reef platforms that are almost continuous along a narrow belt close to shore (generally 3–10 km wide). When breaks occur in the reef, sand and mud shores occur.

The fringing reefs of Kenya are affected by the East African coastal current, which controls the conditions in the upper layer of the sea. This, in turn, is affected by two alternating monsoons: Northeast Monsoon (NEM) and the Southeast Monsoon (SEM). During the NEM period, i.e. from November to March, the winds are light, water and air temperatures are high, duration of sunshine is long, relative humidity is low and the East African Coastal Current (EACC) is deflected

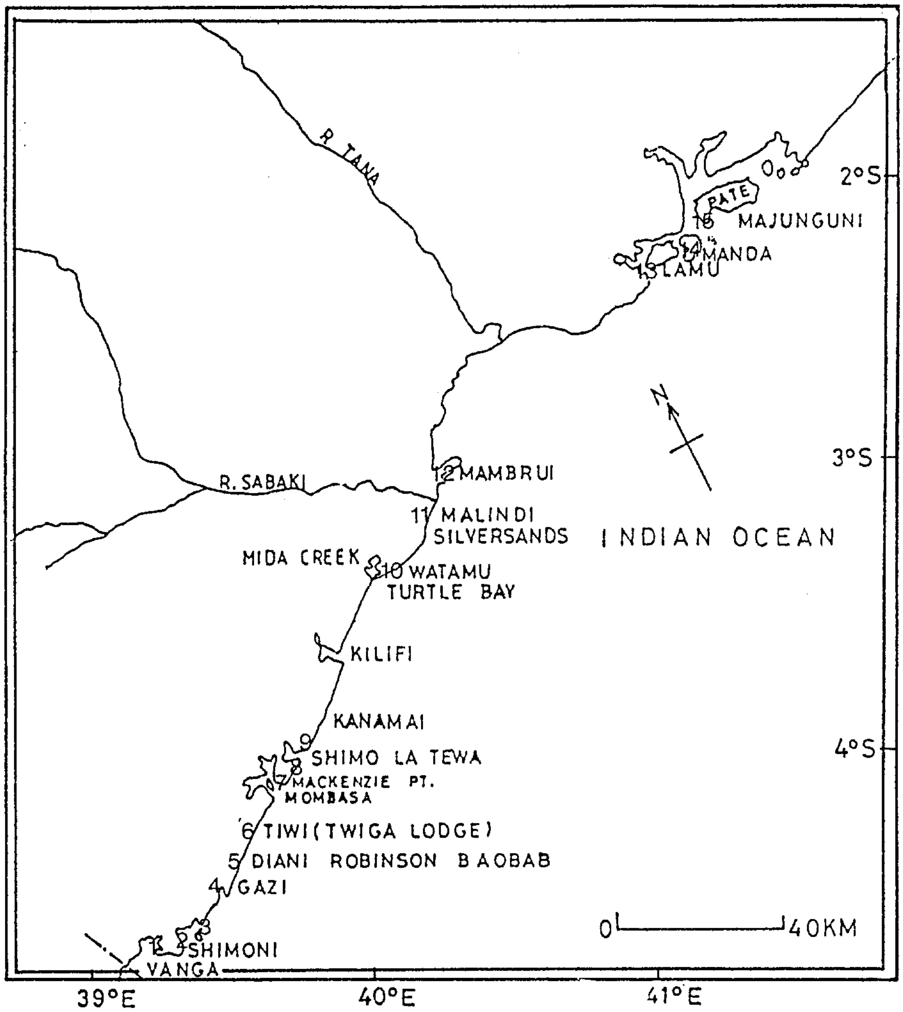

Fig. 1. Kenyan coastline indicating localities referred to and where collections have been made.

towards the ocean by the Somali current between Lamu and Malindi. The period April to October (during the SEM) is characterized by strong winds, low water and air temperatures, extensive cloud cover and high relative humidity. During this period, the EACC flows northwards up to Cape Guardafui (Horn of Africa, Newell, 1957). From November to March, the lowest low tides occur during the day. The corresponding tides occur at night between April and October, which influences the occurrence, distribution and seasonal abundance of the seaweeds (Isaac & Isaac, 1968; Moorjani, 1977).

Seaweed surveys of the Kenya coastline were made during 1987–1989 to observe local usage of seaweeds of potential commercial importance, to collect samples for phycocolloid analyses, and to identify sites for future seaweed farming ventures. Topographical maps of 1 : 250,000 and 1 : 50,000 scale were used and aerial observations of parts of the coastline were made. The location of seaweeds with commercial potential was established through direct visits to the shores at low tides, by sorting specimens found in the drift, and by diving observations. Specific areas with good standing crops of seaweeds were visited after discussion with local fisherman, who utilize some seaweed as bait in their malema traps. More than 15 stations were visited during the survey (Table 1). Transects perpendicular to the shore and extending to 20 or 25 m depth were established at some of these stations. Quadrats 0.25 m^2 were randomly placed along the transect and the area enclosed by each quadrat was cleared of all vegetation. Voucher specimens have been deposited at the Kenya Marine Fisheries Research Institute (KMFRI) herbarium in Mombasa. Taxonomic keys utilized during this study include the general accounts of seaweeds by Jaasund (1976), as well as the more descriptive keys of east African *Eucheuma* species by Mshigeni (1984, 1987).

Kenya government statistics on the importation of seaweed products were compiled from 1980 to 1987. Data on the importation of agar and

Table 1. List of sites visited and ecological notes of habitats (from north to south) along the Kenyan coast.

No. & Site	Salinity (‰)	Temperature (°C)	Substrate type
1. Sii Is. (southeast) (northeast)	33.4–35.0	26.5–30.0	Rocky, coral reef, seagrass meadows mudflats and silt.
2. Shimoni	34.5–35.0	26.5–29.6	Rocky, coral reef, sandflats with seagrass meadows close to shore.
3. Wasini Is.	34.5–35.0	26.5–29.5	Rocky, coral reef with sandflats.
4. Msambweni	30.5–35.5	26.0–30.0	Semi-exposed, rocky.
5. Diani	27.5–35.0	25.5–32.0	Sandy, silty, rocky.
6. Tiwi	30.4–38.0	26.2–30.0	Exposed, rocky.
7. Mombasa (Mackenzie Point)	30.0–35.0	24.6–30.0	Exposed, rocky.
8. Kanamai	30.0–35.0	25.5–30.0	Rocky, sandy, silt.
9. Mtwapa	30.0–37.5	27.5–30.0	Sandy, mud, rocky (including boulders).
10. Watamu	29.8–35.0	26.6–30.0	Exposed, narrow coral reef with sandy beach.
11. Malindi	28.0–35.0	26.5–32.0	Rocky platform with great deal of suspended sediment.
12. Mambrui	29.5–35.0	25.5–29.5	Narrow coral reef rocky.
13. Ras Kitau (Manda Island)	30.0–35.5	26.5–30.5	Exposed, rocky.
14. Manda Toto Is.	32.0–35.0	29.5–30.0	Exposed, rocky, course sand, coral reef, seagrass.
15. Pate Island	34.5–35.0	36.5–30.0	Exposed, rocky.

Table 2. Seaweeds of potential economic importance found along the Kenyan coast during field surveys. See Table 1 for site descriptions.

Species	Site*														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Alginophytes															
Colpomenia sinuosa (Roth.) Derb. & Sol.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
Crystoseira myrica (Gmel.) J. Ag.	–	–	–	–	–	+	+	+	+	+	+	–	–	–	–
C. trinodis (Forssk.) C. Ag.	–	–	–	–	–	+	–	–	+	–	–	–	–	–	–
Hormophysa triquetra (L.) Kütz.	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–
Hydroclathratus clathratus (Bory) Howe	+	–	–	–	+	+	+	+	+	–	–	–	–	–	+
Sargassum spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Turbinaria spp.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
Agarophytes															
Amansia spp.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
Digenia simplex (Wulf.) C. Ag.	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Gelidium spp.	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–
Gelidiella spp.	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–
Gelidiopsis spp.	–	–	–	–	+	+	+	–	–	–	–	–	–	–	–
Gracilaria corticata J. Ag.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
G. crassa (Harvey) J. Ag.	–	–	–		–	+	–	–	–	–	–	–	–	–	–
G. edulis (Gmelin) Silva	–	–	–	–	+	–	–	–	+	–	–	–	–	–	–
G. salicornia (C. Ag.) Dawson	+	–	+	–	+	+	+	+	+	+	+	+	+	+	+
G. verrucosa (Hudson) Papenf.	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–
Pterocladia spp.	–	–	–	–	+	+	+	–	–	–	–	–	–	–	–
Carrageenophytes															
Eucheuma denticulatum (N.L. Burm.) Coll. et Herv.	+	–	+	–	+	–	+	+	+	+	+	–	+	–	+
E. horridum (Harv.) J. Ag.	+	–	–	+	+	–	–	–	+	+	+	+	–	–	–
E. odontophorum Børg.	+	–	+	–	–	–	+	+	+	+	–	–	–	–	–
E. platycladum Schm.	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Kappaphycus cottoni (Weber v. Bosse) Doty	+	+	+	+	+	–	+	+	+	–	–	+	–	–	–
K. striatum (Schmitz) Doty	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Halymenia venusta Børg.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
Hypnea cornuta (Lamour.) J. Ag.	+	–	–	+	+	+	+	+	+	+	+	+	+	+	+
H. hamulosa (Turner) Mont.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
H. pannosa J. Ag.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
H. valentiae (Turner) Mont.	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
Soliera robusta (Grev.) Kylin	+	–	+	–	–	–	–	–	–	–	+	–	–	–	–
Food for humans															
Caulerpa spp.	+	–	–	+	+	+	+	–	+	+	–	–	–	–	–
Chaetomorpha crassa (C. Ag.) Kütz.	+	–	–	–	+	+	+	+	+	+	+	+	–	–	+
Enteromorpha spp.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+
Ulva spp.	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+

* + denotes presence at site; – denotes absence at site.

alginate were obtained from the External Trade Statistics retrieved from the Customs and Excise Department, Ministry of Finance, Kenya.

Results

Table 2 is a preliminary list of potentially important seaweeds found at the 15 sites. No seaweeds currently are being harvested for export or local use, other than *Laurencia papillosa* (C. Ag.) Grev., *Halymenia venusta*, *Dictyosphaeria cavernosa* (Forsskål) Boergesen, and *Chaetomorpha crassa*, which are used as fish bait by local fishermen. During the SEM period (April to October), there were significant standing crops of commercially important seaweeds, but during the NEM, most of these seaweeds were absent, except at the Shimoni site. Many sites visited showed intensive grazing from sea cucumbers, sea urchins and siganid fishes.

It appears that most *Gracilaria* species common along the Kenya coast have a low agar content (*G. corticata* 13–17%; *G. crassa* 17%; and *G. salicornia* only trace levels, H.A. Oyieke, unpubl. results). Significant standing crops of *Gelidium* spp. are limited to the SEM period. The quality of the phycocolloid from those agarophytes has not been determined. Significant stands of the carrageenophytes *Kappaphycus cottoni*, *K. striatum* and *Halymenia venusta* were found in the Shimoni and Sii Island areas, as well as the alginophytes *Sargassum*, *Turbinaria* and *Cystoseira*. Another location with a rich flora of phycocolloid-bearing seaweed was the Mtwapa site. *Kappaphycus cottoni*, *K. striatum*, *Eucheuma denticulatum*, *E. horridum*, *E. odontophorum* and *Halymenia venusta* also were found at that site, as well as the alginophytes *Sargassum*, *Turbinaria*, *Cystoseira myrica* and *Hormophysa triquetra*.

The quantity of agar imported into Kenya from 1980–1987 fluctuated, before increasing sharply since 1984 (Table 3). The value of imported agar in 1987 was equal to U.S. $18.75 million dollars. The major sources of agar were the United Kingdom, the United States, and West Germany. Table 3 also shows an increase in importation of alginate, with the United Kingdom and Norway being the largest suppliers. The imported value of alginate in 1987 was U.S. $44,750.

Table 3. Quantity and value of agar and alginate imports into Kenya from 1980 to 1987.

Year	Agar		Alginate	
	Tons	KShs. million	Tons	KShs. million
1980	100	50.0	40	2.00
1981	130	70.3	65	3.00
1982	120	60.0	50	2.60
1983	80	45.0	35	1.75
1984	100	60.0	40	2.25
1985	200	150.0	50	3.10
1986	300	225.0	100	6.20
1987	360	300.0	130	7.00

Discussion and conclusions

Michanek (1978), McHugh & Lanier (1983), and Bird (1989) reported that the largest part of the world value of commercial seaweeds appears to be for human food. The present study has shown that Kenya has many potentially important seaweeds in its coastal zone. That is, many seaweeds similar to that eaten in the Far East occur, yet the coastal people have failed to incorporate them into their diets. Kenya also has several phycocolloid-bearing seaweed species, including the carrageenophytes *Eucheuma*, *Kappaphycus* and *Hypnea*; the agarophytes *Gracilaria* and *Gelidium*; and the alginophytes *Sargassum*, *Turbinaria* and *Cystoseira*.

Marine agronomy is growing rapidly as a new source for producing phycocolloids (Chapman & Chapman, 1980; Dawes, 1987; Doty, 1978, 1987; Edwards *et al.*, 1982; Edwards & Tam, 1984; Jensen, 1978, Michanek, 1975, 1978, Mshigeni, 1987, Sijian & Ping, 1984). This is undoubtedly where the greatest future lies for Kenya seaweeds (cf. Table 3), since rapidly increasing quantities of agar and algin are imported annually. Although no data could be found concerning the importation of carrageenan, it seems likely this phycocolloid comes into Kenya grouped with 'agar' (Naylor, 1976).

Agar is the most important phycocolloid annually imported into Kenya (greater than U.S. $18.75 million). Most agar appears to be of a cheaper grade extractable from *Gracilaria*. Significant seed populations of *Gelidium*, *Gelidiella*, *Gelidiopsis* and *Pterocladia* occur in Kenya (Table 2) that can produce high quality bacteriological grade agar. Species of *Gracilaria* are most common and widely distributed throughout the Kenya coastal zone. From preliminary observations, we believe there may be sufficient wild stocks of *Gracilaria corticata* for harvest, although agronomic trials in pond culture should be instituted to sustain the supply. *Gracilaria* is cultivated labor-intensively for agar production in tidal ponds in Taiwan (Edwards, 1977, 1979). Both monoculture and polyculture operations with grass shrimp and crabs have been described by Shang (1976) and Chueh & Chen (1982). A typical hectare area for a *Gracilaria* ponds can yield up to 40 wet tons year^{-1} (Chiang, 1981). Hanisak (1987) and Hanisak & Ryther (183) estimated yields of *Gracilaria* culture may be 127.0 wet tons hectare^{-1} year^{-1}. At least two to four men per hectare would be necessary to manage this type of farm in the Shimoni region of Kenya.

The present survey has revealed that the major sources of carrageenan in Kenya would be *Eucheuma*, *Kappaphycus*, *Halymenia* and *Hypnea*, all of which have high gel yields (Semesi, 1979; Mshigeni & Semesi, 1977a, b). *Eucheuma*, *Kappaphycus* and *Hypnea* are distributed plentifully along the Kenya coast, but efforts would have to be made to increase their crop through aquaculture (Haines, 1976; Lapointe *et al.*, 1976; Mshigeni, 1980, 1982, 1984, 1987; Parker, 1974; Trono *et al.*, 1980; Yarish, 1988). Such programs should be centered at the Shimoni and Wasini Island sites. The Phillipine mariculture experience for *Eucheuma*, as described by Ricohermoso & Deveau (1978), Lim & Porse (1980), and others (see Edwards 1977, 1979; Mshigeni, 1987), as well as the Djibouti pilot project (Braud & Perez, 1978) are potential models for seaweed farming in Kenya. Yield information available for *Eucheuma* in Tanzania suggests yields of 500 wet tons may be possible for one hectare farms (Mshigeni, 1987). We expect six men would be needed to manage properly a one-hectare farm in Kenya.

The field survey also suggests that some localized populations of *Sargassum*, *Cystoseira*, *Hormophysa* and *Turbinaria* may be reasonable sources of alginate for the small domestic market (U.S. $43,750). These alginate-producing seaweeds appear to be most abundant during the SEM (Moorjani, 1977; Rao, 1972).

In summary, seaweed farming could be developed in the Shimoni area. The substratum, abundance of the commercially important seaweeds and the physical conditions (salinity, light and temperature) all appear to be suitable for establishment of a pilot *Eucheuma* farm in the sea and/or a land-based pond cultivation of *Gracilaria* (either monoculture or polyculture). A reliable source of labor is readily available that would benefit from a farming effort.

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