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An Exposition on Potential Seaweed Resources for Exploitation, Culture and Utilization in West Africa: A Case Study of Nigeria

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ABSTRACT

The importance of seaweeds cuts across various environmental, ecologic, socio-economic benefits and services as food for man, in the phycocolloids and expanding phycosupplement industries; as sink for excess carbon dioxide and excess nutrients; for sustainable energy generation and as fossil fuel substitutes. In view of this, seaweeds could become an important economic niche for Nigeria and other coastal African countries provided adequate research is undertaken in studying their diversity, biochemical compositions and potentials for culture in order to harness the numerous opportunities which can be derived.

Key words: Seaweeds, utilization, culture, exploitation, benefits

INTRODUCTION

Seaweeds constitute a source of non-phytoplankton production; provide energy for associated grazers and contribute remarkably to the benthic detrital food chains. From an ecological perspective, seaweeds are providers of the structural integrity of many biotopes especially low energy shores where they are predominant in terms of size and occupiers of space. Seaweed beds also form important habitat for fishes and invertebrates. In addition, they are useful as indicators of climate change; can be used to study diversity patterns and are particularly useful for planning the conservation and sustainable use of inshore marine resources (John and Lawson, 1991; Jennings *et al.*, 2001; Bolton *et al.*, 2003).

An earliest record of seaweeds utilization dates to 13,000 years ago at a late Pleistocene settlement in Chile. Other archaeological evidences also indicate that seaweeds have been included in folk medicine for many thousands of years in Japan (13,000-300 BC), China (2700 BC), Egypt (1550 BC) and India (300 BC) (NAAS, 2003; Teas, 2005). Being excellent sources of vitamins, amino acids, carbohydrates, proteins, lipids, growth hormones, micro- and macro-elements including iodine, many seaweed species are used as food throughout Asia and the Pacific region. Furthermore, occurrence of goitre is very rare among the seaweed-eating populations in Japan and other South-East Asian countries (King, 2007).

Industrial utilization of seaweeds began with the production of soda and potash from the brown seaweeds for manufacture of soap, glass and iodine (Dhargalkar and Verlecar, 2009), while industrialization of seaweed polysaccharides or phycocolloids as thickening, binding, stabilizing,

gelling, emulsifying, clarifying and protecting agents expanded in the second half of the 20th century (McHugh, 2001). Development of the phycosupplement industry with various utilizations in pharmaceuticals, botanicals, nutraceuticals, cosmeceuticals, fish and animal feed additives, agrichemicals, soil additives and as sources of natural pigments, bioactive substances, antiviral agents etc., is in full expansion (Chopin, 2007). Seaweeds were the source of about 35% of newly discovered chemicals followed by sponges (27%) and cnidarians (22%) between 1977 and 1987 (Smit, 2004,). Currently, Carraguard, a non- spermicidal microbicide containing carrageenan, a red seaweed derivative has been clinically tested to be a promising product capable of blocking the transmission of HIV/AIDS and lowering the risks of women in contracting the disease (Robertson-Andersson, 2007). Regular consumption of dietary seaweeds in Japan and Korea is attributed to low prevalence rates of HIV/AIDS and low risks of various cancers (Teas, 2005). However, as demand for phycocolloid is expected to increase by 8-10% every year (Dhargalkar and Verlecar, 2009), a much higher demand for seaweed natural products should be expected from the rapid development of novel applications in the phycosupplement industry and utilization as food.

In Japan, overexploitation of natural beds of the edible Nori (*Porphyra yezoensis*) spurred intensive seaweed cultivation in the 17th century. Global production of seaweeds soared from 11.66 million metric tones in 2002 to 16.83 million metric tones in 2008 (FAO, 2010). Approximately 90% of estimated total world seaweed production is derived from cultivation (McHugh, 2001; FAO, 2003). Seaweed cultivation represents close to half of the biomass of the world mariculture production (Chopin, 2007). Tseng and Borowitzka (2003) posit that future supplies are expected from culture, even in countries without a tradition of seaweed culture; improvements of culture techniques and genetically improved culture stock as well as from development of culture techniques for new culture species. However, Dhargalkar and Verlecar (2009) are of the opinion that new areas would have to be explored to provide rich and high quality seaweeds. They also reported that alginate yielding seaweeds with the exception of *Laminaria japonica* cannot be grown vegetatively. Therefore, the dependence on wild stock of alginophytes could be expected to persist for several years.

Emphasis on seaweed exploitation and cultivation to meet growing global demand for the expanding phycosuplemment industry and phycocolloids implies that the technology for their artificial production is practically not yet feasible. Dhargalkar and Pereira (2005) mentioned the presence of formidable chemical barriers in the structures of these commercially important products as a serious constraint to their chemical synthesis. Hence, the dependence on seaweeds particularly as sole source of phycocolloids is bound to continue in the absence of alternative biological sources. Nigeria has a coastline of about 860 km exclusive of indentations in the Niger Delta. The coastal zone has the largest area of mangroves on the continent. However, there is limited information on her seaweed resources. Hence, information on biomass, productivity and utilization of seaweeds resources has not been documented. This study highlights some basic objectives pertinent to research and utilization of her seaweed resources in the near future.

DISTRIBUTION AND BIODIVERSITY OF SEAWEEDS

Generally, seaweeds are known to flourish in temperate waters. Various macroalgal genera are postulated to have originated from the Indo-Pacific region (Chapman and Chapman, 1970). Variability in the distribution and diversity of seaweeds is almost identical with phytoplankton

productivity in areas close to nutrient-rich upwellings (King, 2007). Bolton *et al.* (2003) broadly identified 4 major seaweeds floras in Sub-Saharan Africa. In an order of decreasing species richness, these are:

- A distinctive but depauperate Tropical West Africa flora
- A species-rich Tropical East Africa flora which is continuous with the much larger Indo-West Pacific flora
- A cool temperate, relatively poorer Benguela Marine Province along the West coast of South Africa and the entire Namibian coastline
- A species-rich warm temperate Agulhas Marine Province along the Eastern and Southern coastlines of South Africa

John and Lawson (1991) also opined that with the exception of Ghana, which experiences upwelling along its coast, the tropical province generally has a low diversity of seaweeds. The warm temperate provinces of the Canaries (West African Flora to the North) and Namibia are also considered hotspots of seaweeds diversity. Also, relatively less diverse seaweeds beds are found in the subtropical provinces or transitional zones, North (Senegal-Mauritania) and South (Congo-Angola) of the equator.

So far, about 79 species of seaweeds comprising 38 red, 24 green and 17 brown species as shown in Table 1 have been identified in Nigeria (www.algaebase.org). Ecological factors prevalent in Nigeria's coastal waters and indeed in tropical West Africa such as low tidal amplitude, existence of a shallow, permanent thermocline and negligible upwelling phenomenon imply low nutrient enrichment and consequently low phytoplankton productivity estimated at 100-150 mg/C/m^2/day are plausible reasons for poor seaweed diversity in Nigeria (Amadi, 1991; Bolton *et al.*, 2003). From this analogy, there seems to be a positive correlation between low phytoplankton productivity and low seaweed diversity and vice-versa. Besides these, other factors such as low habitat diversity and heterogeneity associated with predominance of long sandy beaches; a concurrent lack of suitable laterite rocks for attachment; presence of mangrove swamps lining edges of lagoon systems; dilution of coastal water with freshwater from heavy rainfall and large rivers or seasonal lowered inshore salinity and turbidity in coastal waters have also been postulated. Furthermore from a historical perspective, destruction of the tropical West African region during the Pleistocene glaciations and subsequent recolonization by species from the tropical Eastern Atlantic that remained unaffected probably explains its impoverishment, low endemism and floristic similarity.

STATUS OF EXPLOITATION AND CONSERVATION OF SEAWEEDS

Most species of red and brown seaweeds are found in the eulittoral zone of brackish water and coastal environments (John *et al.,* 2001). Common seaweed habitats in West Africa include a range of brackish water environments; the intertidal and subtidal of the coastal and marine environments (Lawson *et al.*, 1995). Naturally, rich beds of seaweeds are found in the intertidal zone despite factors such as fluctuations in salinity, light intensity, temperature and exposure to dryness at low tides which characterize this zone as the most stressful habitat (Jennings *et al.*, 2001). Ghana has moderately high seaweed diversity in its intertidal areas of the shore including natural rocky areas, oil rig and harbour systems (Lawson *et al.*, 1995). Limited research on macroalgae in the marine, intertidal and brackish water environments rather than ecological factors may be the actual cause

Table 1: The seaweed resources of Nigeria

Family	Species
Chlorophyta	*Bryopsis pennata, B. plumose* var. *pennata, B. stenoptera*
	Chaetomorpha antenna, C. capillaris, C. ligustica
	Cladophora montagneana, C. vagabunda
	Cladophoropsis membranacea
	Enteromorpha clathrata, E. flexuosa, E. lingulata
	Gayralia oxysperma
	Microcoleus lynbyaceus
	Phycopeltis expansa
	Rhizoclonium africanum, R. implexum, R. riparium,
	R. riparium var. *implexum*
	Schizotrix calcicola, S. mexicana
	Ulva clathrata, U. flexuosa, U. oxysperma
Phaeophyta	*Asteronema breviarticulatum*
	Bachelotia antillarum, B. fulvescens
	Chnoospora minima
	Dictyopteris delicatula
	Dictyota bartayresiana, D. ciliata, D. ciliolata
	Ectocarpus breviarticulatus
	Feldmania indica
	Giffordia mitchelliae
	Halopteris scoparia
	Hincksia mitchelliae
	Sargassum vulgare, S. vulgare var. *foliosissimum*
	Sphacelaria rigidula
	Stypocaulon scoparium
Rhodophyta	*Acrochaetium microscopicum, A. seriatum*
	Aglaothamnion roseum
	Ahnfeltiopsis intermedia
	Asparagopsis taxiformis
	Audouinella microscopic, A. seriata
	Bangia atropurpurea
	Bostrychia binderi, B. calliptera, B. moritziana
	B. radicans, f. moniliformis, B. simpliciuscula
	B. tenella, B. tenuis, f. simpliciuscula
	Bryocladia thyrsigera
	Callithamnion roseum
	Caloglossa leprieurii, C. ogasawaraensis
	Catenella caespitosa
	Centroceras clavulatum
	Erythrocladia irregularis, E. subintegra
	Falkenbergia hillebrandii
	Gelidium corneum
	Goniotrichum alsidii
	Gracilaria rangifera
	Grateloupia filicina
	Gymnogongrus intermedius, G. tenuis
	Hydropuntia dentata
	Hypnea musciformis
	Jania rubens, J. verrucosa
	Polycavernosa dentate
	Polysiphonia ferulacea
	Pterosiphonia pennata
	Stylonema alsidii

Source: Modified from www.algaebase.org

for the perceived poor status of seaweed diversity. Therefore, intensive sampling in the harbour systems off the coast of Lagos; the numerous oil rigs in the Niger Delta and the intertidal zones along the entire Nigerian coast and subtidal collection by SCUBA-diving or Oceanographic Research Vessel may similarly reveal a corresponding abundance of seaweeds. However, in case of limited distribution of economically potential seaweeds, *in situ* and *ex situ* measures may become necessary to protect the resources from future over harvesting and degradation of the habitats from socio-economic activities. *In situ* measures for the resource in the habitat may be assimilated into an integrated zone management plan for the environment while *ex situ* or biotechnological methods may also similarly be adopted.

CULTURE AND TRANSPLANTATION OF SEAWEEDS

Approximately 741.509 and 48.695 ha of the brackish water and marine environments are amenable to aquaculture activities (Anethekai *et al.*, 2004), which invariably includes seaweed farming. However, they also opined that certain environmental factors, both natural and man-induced limit development of aquaculture in these vast and underutilized areas of the coastal zone.

Consequently, culture of potential useful indigenous species and/or transplantation of exotic species could complement fishing and allied occupations in the brackish water and coastal communities providing the much needed economic niche. These areas which are often isolated or entirely remote from the inland are substantially rural with a high prevalence of poverty and poor socio-economic development owing to declining fish catch, inadequate infrastructural development and lack of basic social amenities, as well as environmental degradation.

The adoption of an appropriate and suitable raft-based method in the absence of rocks and stones which are natural suitable settlings, on-growing substrates and sites for seaweeds could significantly enhance production potentials or capability in their habitat. This method should permit changing of culture depth in response to reception of appropriate amount of light due to effects of high wave action and varying sea levels. This method should also permit easy movement during harvest operations than the placement of large stones or rocks. Artificial substrates are then provided with cuttings or their zoospores for subsequent on-growing. The successful application of the floating raft method particularly in China, has enabled the country achieve higher production levels than Japan in the culture of the Japanese Kelp (*Laminaria japonica*) (Tseng and Borowitzka, 2003). Transplantation of exotic species may be another option. Thus, it may be feasible to introduce commercial species such as *Eklonia* sp. and *Eucheuma* sp. from Togo, Ghana and Cameroon. These countries share similar ecological and biological conditions in their coastal and marine environments with Nigeria in the Gulf of Guinea.

POTENTIAL PRODUCTS AND USES OF SEAWEEDS IN NIGERIA

Chapman and Chapman (1970); Tseng and Borowitzka (2003) elucidated some uses and products of commercial seaweeds. Dhargalkar and Perreira (2005); Dhargalkar and Verlecar (2009) reported more comprehensive uses of seaweeds and their extracts. Based on these, some related seaweeds in Nigerian waters hitherto identified are shown in Table 2. However, utilization of these seaweeds upon harvesting would be based on the design of appropriate technology for colloid production and processing. This and further socio-economic analyses would clearly depend on the production ecology of the wild, cultured or transplanted seaweeds.

Table 2: Utilization and products of potential seaweed resources in Nigeria

Potential utilization/products	Species
Human consumption	*Enteromorpha* sp., *Gelidium* sp., *Gracillaria* sp.
	Grateloupia sp., *Dictyopteris* sp., *Sargassum* sp.
	Ulva sp., *Asparagopsis* sp., *Chaetomorpha* sp.
	Centroceras sp., *Cladophora* sp.
Medicinal/Pharmaceutical-related	*Dictyota* sp., *Sargassum* sp., *Ulva* sp.
	Bryopsis sp., *Jania* sp.
Industrial	*Gracillaria* sp., *Gelidium* sp., *Sargassum* spp.,
	Centroceras sp.
Agricultural	*Sargassum* sp., *Gelideum* sp., *Chaetomorpha* sp.,
	Cladophora sp.
Environmental	*Gelidium* sp., *Gracillaria* sp., *Ulva* sp.

Source: Chapman and Chapman (1970), Tseng and Borowitzka (2003), Dhargalkar and Perreira (2005); Dhargalkar and Verlecar (2009)

BENEFITS OF DEVELOPING SEAWEED SECTOR IN NIGERIA

There is a general perception that seaweed farming is an environmentally non-destructive alternative livelihood that is considered relatively benign on the environment when compared to other mariculture activities (Crawford, 2002; NAAS, 2003). Seaweed cultivation holds great potentials for increasing primary productivity in coastal waters and to ameliorate global warming by sequestering carbon dioxide (Bunting and Pretty, 2007). Macroalgal farms have positive impact on the environment by improving fishing in and around the farm. Additional profits can also be realized by locating fish traps near seaweeds (Deboer, 1981). In their study, Eklof *et al.* (2006) concluded that in areas naturally lacking vegetations such as sand banks, presence of seaweed farms impacted positively on fisheries production by increasing fish catches of certain species. They also surmised that smaller or less intense seaweed farms and the use of farming methods such as long lines or rafts in suitable areas may have less effect on benthic community and sea grass ecosystem as a whole. All these seem to contradict a growing body of evidence of negative impacts of seaweed farming on seagrass beds, which are important fishing grounds for artisans principally in the West Indian Ocean. Phycomitigation, through the development of Integrated Multi-Trophic Aquaculture (IMTA) systems rediscovered in Western countries over the last 30 years has existed for centuries in Asian countries (Chopin, 2007). In areas adjacent to open-water culture facilities such as cages, pens etc., seaweeds have proven capable of eliminating heavy metals; act as efficient biofilters or nutrient scrubbers removing dissolved inorganic nitrogen and dissolved inorganic phosphorous from aquaculture effluents; improving water conservation and economic yields when incorporated in ecologically integrated mariculture systems (Costa-Pierce, 2002; McVey *et al.,* 2002). Utilization of macroalgae as bioremediation in aquacultural systems does not only provide a second crop or product but also provides another source of food for other culture organisms (Tseng and Borowitzka, 2003).

Dietary seaweeds are sources of iodine and protein to combat goitre and protein deficiency; to protect or prevent from HIV/AIDS and as an alternative therapy to antiretroviral drugs that are not only cheaper, readily available but also non-toxic or with no side-effects to slow progression of HIV-infection to AIDS. Furthermore, extensive testing and costs associated with patenting would not be required for whole seaweeds because they are naturally occurring, widely available food (Teas, 2005).

Above all, seaweed biomass can be a veritable source of renewable energy through the conversion of eco-friendly technologies to biogas for electricity generation and biodiesel as low-cost alternative to petroleum-based fuels. Among biomass, algae have a higher photosynthetic efficiency (Dhargalkar and Perreira, 2005; Hossain *et al.*, 2008). From a comparison of alternative processes for oil extraction, macroalgae have less growing costs than microalgae and may yield up to 20% extracted oil per kg of dry matter (Aresta *et al.*, 2004). This could be part of the solution to boost power supply from dismally low levels in the country and may also be the only way to produce enough automotive fuel to replace current petrol/ gasoline consumption in order to combat the emissions of carbon, greenhouse gases and other air contaminants which contribute to global warming.

African coasts have a biodiversity of seaweeds where production from a relatively pollution-free environment may be a key marketing advantage. In addition, these coasts also offer good accessibility and hence are conducive to mariculture. With the exception of countries such as South Africa, Senegal, Namibia, Tanzania, Ghana, Egypt, Togo and Cameroon, there is limited exploitation, cultivation and utilization of seaweeds on the African continent. Hence, this seriously undermines opportunities of direct job and wealth creation and indirectly through backward and forward linkages given the high unemployment situation in most coastal and brackish water communities and the concomitant high labor intensity involved in seaweed culture. As seaweed culture is not compulsorily dependent on imported inputs such as fertilizers, feeds and chemicals, it requires relatively lower investment capital thus providing a rapid and high return on investment. In addition, seaweed culture can be a potential export earner substantially increasing a country's Gross Domestic Product and a catalyst to improvement of trade balance (Hishamunda, 2007).

Development of a seaweed sector in the country will not only improve the standard of living and alleviate poverty but also help to control rural-urban drift in many brackish water and coastal communities where fish, a major aquatic resource is considerably over- exploited and hence fishing major occupation as well as auxiliary services vis-a-vis fish processing, fish marketing, fishing gear production/ repairs etc., are adversely affected. Alternative employment or additional income outside fisheries has often been mentioned as a panacea to help highly fishing-dependent communities tide over periods of loss of income resulting from declining fish catch. Considerable empirical evidence suggests that seaweed farming is a profitable venture for coastal households. Seaweed cultivation can be easily integrated with the traditional activities of fishing. Smith and Renard (2002) reported on the requirements for developing artisanal seaweed cultivation as a source of income for coastal communities in the Caribbean. Seaweed cultivation has been proposed to reduce the use of unsustainable and destructive methods of fishing and as an income alternative to mangrove destruction. However, the attainment of primary goals of reducing fishing pressure from alternative or supplemental livelihood and prevention of economic over fishing is often temporary or not met at all. Job satisfaction among fishers, occupational multiplicity among rural coastal households and most importantly, market prices of seaweeds are determinants of the impact of seaweed farming on fishing effort (Crawford, 2002). Hence, diversification into seaweed farming among other activities is suggested to be a more pragmatic option to overcome large-scale ecological and global market changes.

The development of a seaweed sector is bound to have profound multipliers effect. For instance, in the farming of the Giant Tiger Prawn (*Penaeus monodon*) in Madagascar, every on-farm job generated additional employment in the downstream and upstream farm activities (Hishamunda,

2007). Similarly, the production of colloids from seaweeds will lead to the evolution of seaweed processors, marketing and distribution chain. A seaweed industry also holds the key to economic empowerment of the female gender in coastal//brackish water communities. In India, women outnumber men in the ratio of 70:30 in the collection of seaweeds and have equal employment opportunities in the seaweeds processing sector (Kaladharan and Kaliaperunal, 1999). Commercial interests assisted the establishment and development of an industry based on the culture of Carrageenan containing seaweed in poor rural villages in Zanzibar, Tanzania. Similarly, women also dominate seaweed farming and have utilized their cash incomes on modern housing materials and primary school tuition (Hishamunda, 2007). Thus, it may also be part of the solution to the lingering problem of youth restiveness, militancy and high rate of under-and unemployment in the Niger Delta.

CHALLENGES TO THE EXPLOITATION, CULTURE AND UTILIZATION OF POTENTIAL SEAWEED RESOURCES IN NIGERIA

While the poor status of naturally occurring seaweeds may present a daunting task to their exploitation and utilization, the paucity of information on these resources poses a more daring challenge. Therefore, taxonomic and population biology besides quantitative assessments would be required to estimate the field stock value of seaweeds before commercial harvest, logistics, labor, marketing, processing, shipping costs and utilization of the wild stock could be considered. Further socio-economic and technological analyses would be based on the production ecology of the seaweeds. The objectives would be achieved by conducting a thorough study on the distribution, diversity, production ecology and physiology of natural seaweeds resources in a range of habitats occurring in the brackish water, coastal and marine environments in Nigeria and identify the potential useful species based on their biochemistry. However, harnessing the full potentials of seaweed resources also implies basic research on economically viable species aimed at creating genetically improved and novel strains with increased yield and the capacity for producing new substances. Furthermore, if commercial quantities of potential seaweed species have been established in our environment, then these portends important consequences for conservation and coastal management. Alternatively, the option of transplantation and cultivation of commercially viable exotic species should be given serious considerations on the basis of a higher probability of success arising from similarities in ecological conditions in Nigeria and the exporting country. Such landmark achievement was demonstrated by Malaysia, which has become the world's largest producer of Palm Oil following successful transplantation of the Oil Palm seed from Nigeria in the 1970s.

Furthermore, the Federal Government has a pivotal role to play as facilitator and regulator to make feasible the evolution of a seaweed sector-as a fisheries subsector. This should be seen as a first step towards marine agronomy. Presently, Federal Government's support and opportunities in the development of Small and Medium Scale Enterprises (SMEs) are also favorable to the development of seaweed cottage industries in the country. Clearly, this shall involve funding for research and public enlightenment campaigns to sensitise the coastal communities and the country at large on the socio-economic benefits to be derived. As a matter of urgency, tertiary institutions, the Nigerian Institute for Oceanography and Marine Research (NIOMR) and other affiliated research institutes in the proximity of brackish water and coastal environments should undertake seaweed research. Approach to conduct of research should be multidisciplinary to optimize funds and other resources required which may be limiting factors. Despite the fact that Nigeria is not

mentioned as a country with prospects for seaweed production, it is not impossible that the country can still play an active role as a raw material supplier given the anticipated high demand for colloids and as phycosupplements, which guarantee relatively high market value. Previously, forecast in demand despite increased production kept market value relatively very high after a period of stagnation between 1984 and 1989 (Katavic, 1999). Even as prospects for processing is considered rather slim as a result of complexities involved in technology and engineering for production of seaweed extracts as well as the high capital cost of the equipments in developing countries (McHugh, 2001). Developing and strengthening human capacity building in acquisition of processing technology is fundamental to overcome this problem.

CONCLUSIONS

West African coastal states must be well-positioned not only to satisfy local demands but also to become net exporters in view of the anticipated increase from the phycocolloids and phycosupplememt industries. Though, the poor state of research on seaweeds in Nigeria implies limitations in terms of abundance and species richness for commercial exploitation. However, the growing significance of seaweed cultivation in the world is a promising start towards realizing the goals of becoming a producer and harnessing the socio-economic benefits to be gained from establishing a seaweed sector.

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