PHYCOLOGY AND FISHERIES DEVELOPMENT – A REVIEW

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ABSTRACT

Algae are the chief primary producers in the aquatic environment. Thus, they supply proteins, carbohydrates and mineral salts to the primary consumers and consequently sustain many fishes of commercial interest. Despite algae being a good source of food for some fishes, some cyanobacteria are of low nutritional value and with dinoflagellates may secrete toxins that kill fish. Algae population varies according to seasons and this affects algae - dependent organisms. Optimal algal population is favoured by eutrophication but when there is rapid eutrophication, algal blooms may result. This may lead to the death of zooplankton, game fish and even man. The realization of fish as a major source of protein in Nigeria spurred various workers to investigate the natural food for such fishes as clupeids, Synodontis spp., Chrysichthys spp., Schilbe spp., Tilapia, Alestes, Lates sp. Hydrocynus sp., Siluranodon sp., Eutropus, Bagrus docmac, B. bayad, Heterobranchus sp. Cymnarchus sp., Clarias spp, Hemicynodontus sp. and Brachysynodontis sp. Important fish species cultured in Nigeria include Tilapia nilotica, Tilapia melanopleura, Tilapia galilea, Cyprinus carpio (Common carp), Heterotis niloticus, Lates niloticus (Niger perch), Chrysichtys nigrodigitatus (Catfish) C. gariepinus (Catfish) and others. Aquaculture has not advanced as much in Nigeria as in developed countries where algae could be cultured as feed for fish, shrimps, prawns and other crustaceans in commercial quantities. The economic importance of algae in fisheries cannot be overstressed. Their absence could cause disruption of equilibrium, while excess of them could result to mortality of aquatic fauna.

Keywords: Algae, Primary producers, Algal blooms, Algal toxins, Fish food, Fisheries

INTRODUCTION

The term Phycology is the study of Algae. Algae are photosynthetic thallophytes that show little tissue differentiation. Plant life is the base of all food webs in nature, whether aquatic or terrestrial ecosystem, hence the ultimate source of animal food (Lee, 1992). Algae form an important component of the natural economy of inland waters and oceans in that they function as photosynthetic systems (Talling, 1975; Cooper, 1975; Harris, 1986). In the food chain/web in the aquatic environment, algae sustain the primary consumers.

Algae are usually abundant in eutrophic water bodies and are found as phytoplankton floating in the water; as attached algae (aufwuchs/periphyton) and also as submerged vegetation on some substratum of mud or stone. They thus form an important component of the food of benthic feeding animals (Talling, 1975). Other than seaweeds and certain aquatic plants, they are the principal source of organic materials as primary producers (Boney, 1975). They thus deserve the often-applied term “pasturage of sea” (Round, 1977).

Apart from serving as food for primary consumers, they help aerate the aquatic habitat. On the other hand they may constitute a nuisance when in bloom, resulting in far reaching ecological consequences (Codd *et al*., 2005; EPA, 2006).

MATERIALS AND METHODS

A comprehensive literature search was made from the Internet and serial materials of Nnamdi Azikiwe E-library, University of Nigeria, Nsukka. Various journal articles, proceedings of learned societies of Botany and Phycology, and Food and Agricultural Organization documents and textbooks were consulted vis-à-vis the ecological implications and role of phycology to fisheries development. The data collected were presented in table and figure.

RESULTS AND DISCUSSION

Food Relationships Involving Algae: In a simple food chain, algae as primary producers form the base of the chain and are fed on by primary consumers – zooplankton, crustaceans, Protozoa, rotifers) and benthic vertebrates (oligochaetes, molluscs etc) (Table 1). Lévèque (1979) reported that in lake Chad that 25 % of sunlight is used for photosynthetic yield. Of this, zooplanlankton take up 6 % of the gross

Table 1: Some algal groups and primary consumers

Algal groups	Primary consumers
Flagellated green algae	Protozoa, rotifers, fly larva, ostracods.
Non-motile green algae	Mini crustaceans, frogs, fly larva.
Diatoms	Mini crustaceans, frogs, protozoa, fly larva, oligochaetes and molluscs.
Chara and *Nitella* (Charophyceae)	Water boatman

production. The algae consumed include diatoms such as *Navicula*, *Amphora*, *Fragillaria*. *Cymbella*, *Cocconeis*, which are taken by chironomids (Mackey, 1978); Conchostraca (Royan, 1976); oligochaetes and molluscs (Moore, 1979). Other algae include Chlorococcales like *Ankistrodesmus falcatus* var *mirabilis* and *Scenedesmus obliquus* (Obrdlik *et al*., 1979); *Anabaena flos aquae* and a host of others consumed by cladocerans (Gras *et al*., 1971; Doma, 1979). Other zooplankton that feed on algae include rotifers nymphs of *Povilla adjusta* which in Kainji lake feed on *Microcystis*, *Anabaena* and *Tetraedron* species, and Ephemeroptera (Obrdlik *et al*., 1979; Bidwel, 1979).

The role of phytoplankton in the food web is thus of supplying proteins, carbohydrates and mineral salts to the zooplankton which are termed primary consumers (Boney, 1975; Odum, 1979; Lagler *et al*., 1977). The zooplankton are in turn consumed by fish of commercial interest like *Clarias*, *Alestes*, *Schilbe, Chrysichthys* species in lakes Kainji, Tiga, and Anambra river basin (Beadle (1974; Otobo and Imevbore, 1979; Sturm, 1980; Ezenwaji, 2004). Other zooplankton feeding fishes found include *Brachysynodontis batensoda*, *Hemisynodontis membranaceous* (Gras *et al*., 1979), *Bagrus*, *Aplochelichthys*, and *Stolothrissa* (Beadle, 1974) *Barbus barbus* (Obrdrlik *et al*., 1979; Balirwa, 1979).

There could be extensions of the food chain to form longer chains and complex webs with more trophic levels, with the primary producers being eaten by primary consumers, which in turn are eaten by secondary consumers, which are in turn consumed by fishes (Figure 1). The secondary consumers include nymphs of *Dolania Americana* which feed on chironomid larvae (Tsui and Hubbard, 1979); *Daphnia* species which feed on protozoan and rotifer species (Obrdlik *et al*., 1979); *Asplanchna*, *Synchaeta*, *Choaborus punctipennis* (Edmondson, 1974); *Alestes baremoze*, small fish like *Tilapia*, and other young fry.(Boney, 1976; Moore, 1979; Leveque, 1979). A food web involving algae is presented in Figure 1 (Otobo and Imevbore, 1979)

Increased phytoplankton makes for a larger microfaunal foraging population. Lakes with numerous flora maintain correspondingly dense population of animals (Prescott, 1962). In other words, the rate of primary production together with allotrophic supplies will set an upper limit on the rate of primary production, but a given primary production can be associated with rather different rates of secondary production depending on the effects of such factors as morphometry and seasonal changes in radiation and temperature (Edmondson, 1974; Beadle, 1974). For instance in the temperate region during summer, with longer days and shorter nights, net primary productivity in a lake can be high with consequent rapid increase in biomass of all organisms. Conversely, in winter, characterized by dull days, and long nights, the net primary production is often insufficient to maintain the rest of the population of organisms whose biomass decrease accordingly (Beadle, 1974; Moore, 1979).

In the tropics since there is sufficient light throughout the seasons, more even rate of primary production is to be expected, but this is not so due to fluctuations in nutrients available to the plants that are correlated with movements of water (Beadle, 1974). There is usually dilution of nutrients available in the rainy season and vice versa during the dry season (Holden and Green, 1960; Nweze, 2006).

The effect of these factors is through variation in abundance of the different organisms. For animals, the daily ration and assimilation are proportional to the population density of the food organism. Without continued production of food, there will be decrease. There is thus a relationship between production of food and consumers production (Edmondson, 1974). An investigation by Hrebácêk (1969) on fish stock which were in their third year of life in a pond of about 500 specimens of Carp per hectare disclosed that there was an increase from the original size of the fish of 0.5 kg at the beginning of the year to about an average of 1.5 kg at the end of the dry season. The increase he attributed to their feeding on zooplankton, which were very numerous during the season.

Primary and secondary consumers are fed on by carnivorous fishes like *Cymnarchus niloticus*, *Lates niloticus*, *Heterobranchus bidorsalis*, *Hydrocyanus lineatus*, *H. forskali*, *Clarias gariepinus*, *C. macromystax, Bagrus docmac*, *Bagrus bayad* and *Schilbe mystus*, which reach about 10 kg in weight (Imevbore, 1969; Obrdlik *et al*., 1979; Olatunde, 1979; Ezenwaji, 2004).

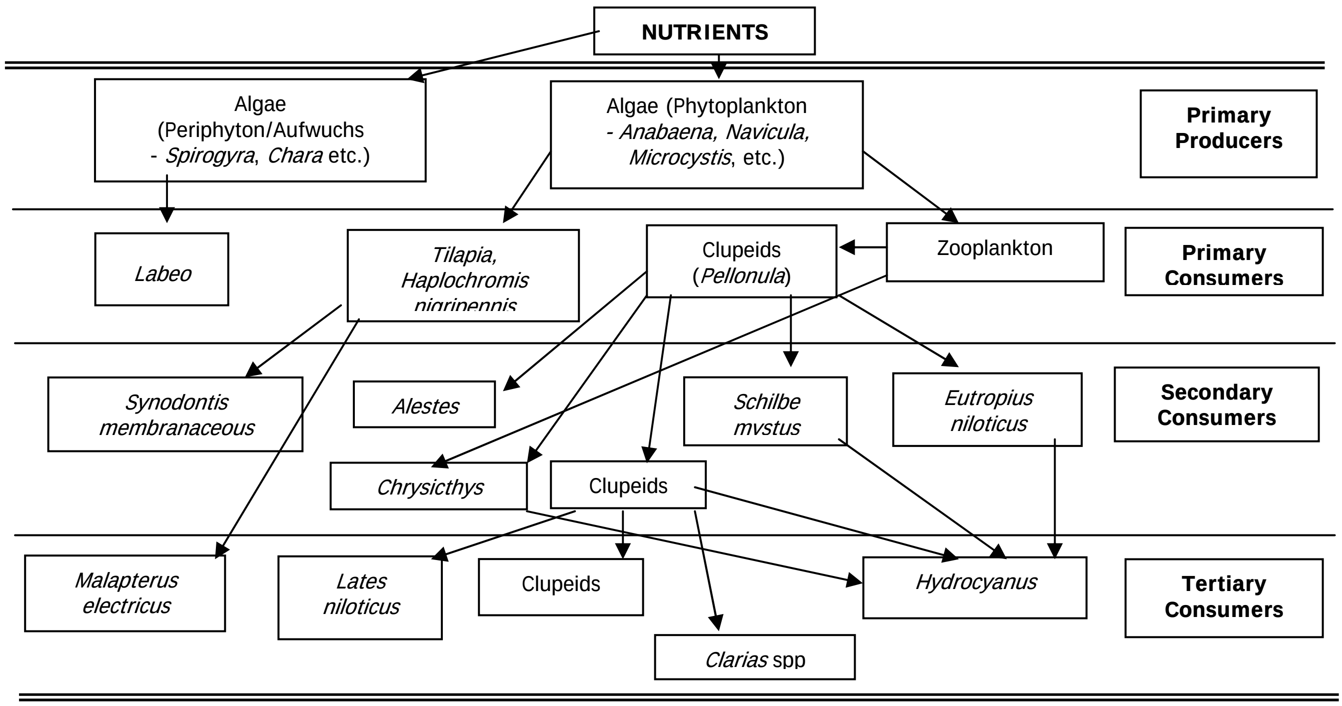

Figure 1: Food web showing the relationships between primary producers, primary consumers, secondary consumers and tertiary consumers

Algae as Direct Food for Fry and some Adult Fishes: Herbivorous fishes such as *Tilapia* and *Labeo* (Beadle, 1974; Round 1977; Otobo and Imevbore, 1979), *Haplochromis gariepinus* (Beadle, 1974), *Siluranodon auratus* (Olatunde, 1979), *Barbus* species, *Synodontis resuionatus* and *S. batensoda* (Willoughby, 1979a) that feed directly on plants have a more efficient production in the sense that there are no intermediaries to dissipate the energy on the way (Figure 1). Fishes that feed on phytoplankton like *Tilapia*, *Menhaden* and *Drosoma* have the phytoplankton separated from water by gill rakers, which are a filtering device on the gill arches (Adiase, 1969; Lagler *et al.*, 1977). Many young fishes (fry) with tiny mouths and often still with yolk in their yolk sac feed on zooplankton (Lagler *et al.*, 1977). It has been observed that fishes that are carnivorous (i.e. zooplankton feeders), under famine conditions feed on algae. Reynolds (1969) working on the biology of Clupeids in Volta Lake confirmed this. He found that *Pellomula* fed on phytoplankton when the potassium available was very low. Also, during high water tide some species of *Synodontis* that are known to be zooplankton feeders browse intensively on phytoplankton most of which are blue green algae (Willoughby, 1979a). Ezenwaji (2004) observed *Spirogyra* sp, *Zygnema* sp. and *Scenedesmus* sp. (green algae) *Microcystis* sp (blue green alga) and *Navicula* sp. (diatom) amongst other food items in the gut of *Clarias macromystax* in Anambra river basin.

Despite the fact that algae are good sources of food for fishes, some of them are of low nutritional value. Some especially the blue green algae have a polysaccharide layer of cellulose surrounding them that makes them indigestible by gastric enzymes of most fishes (Beadle, 1974). Filamentous algae especially *Spirogyra* species have been found to be the mid summer diet of *Pachychiton pictum*, *Leuciscus* and *Rutilis rubilio* despite its generally poor nutritive quality (Kitcheli *et al.*, 1978). Balirwa (1979) observed that in Lake Victoria, East Africa, filamentous algae pass through the gut of some *Barbus* species without being digested.

On the other hand studies using cultures of algae labelled with radioactive carbon ^{14}C have shown that *Tilapia nilotica* and *Haplochromis nigripinnis* from Lake George do in fact digest and assimilate up to 70% of the carbon contained in blue-green algae - *Microcystis* and *Anabaena*, the figure depending on the time of day during which the fish fed (Beadle, 1974). Also, a lot of *Microcystis* has been found to be consumed by *Synodontis membranaceus* in Lake Kainji (Willoughby, 1979b). Experiments have shown that acid conditions in the gut of about 1.4 was responsible for making the polysaccharide coat permeable to gastric enzymes (Beadle, 1974).

Algae as Natural Fish Feed: Algae are the most available primary producers in the aquatic environment all through the seasons. For fishes that take them, an increase in the algal flora will mean an increase in the food available to the fish.

With high concentration of essential ions like phosphorus, nitrogen and right pH, between 7.2 and 9.5, free carbon dioxide, dissolved carbon dioxide and optimum temperature between 25 and 30^{O}C there would be an optimum algal population. Such a body of water with these optimum conditions is said to be eutrophic. Such waters are usually shallow and have a high degree of transparency.

Increasing the algal flora of a fish pond is by addition of super phosphate fertilizers in the right concentration, which increases nutrients available to the algae. This is used mostly in experimental fish ponds (Banerjea and Ghosh, 1971) and in artificial lakes and ponds in homes across the country where *Tilapia* spp. and *Clarias gariepinus* are cultivated. This will increase the plankton flora of the fish pond and both herbivorous and carnivorous fishes can thrive. Moreover, the algae aerate the pond. As noted by Anon (1977), in Nigerian pisciculture, pond fertilizers used include organic fertilizers and inorganic fertilizers. Organic fertilizers such as cow dung, poultry manure, pig dung, horse dung, green manure or compost etc. are applied at the rate of 2,000 kg/hectare/year. Inorganic manures used are NPK, ammonium sulphate, potassium chloride, super phosphate etc, at the rate of 200 to 400 kg per hectare per year. Impoundment of rivers may increase algal crops growing on submerged vegetation, which result in increase in fish crop of the lake thus formed. Typical examples are lake Kainji and Asa Dam both in Kwara State (Anon, 1977).

Also, algae are cultured and used in aquaculture - in fish ponds and in production of crustaceans such as prawns, crayfish, shrimp, oysters and crab for commercial purposes. Algae are cultured for food for larvae of these crustaceans. Algae such as diatoms, *Chlorella*, *Chaetoceros*, *Tetrasimilia* etc, have been successfully cultured in Philippines, for larval rearing of *Panaeus monodon* that is of great economic importance (Platon, 1978). Platon used wooden tanks of about 60 cm depth and 1-ton capacity for algal culture. He noted that shallow tanks had the advantage of allowing light penetration to the bottom of tanks. Ojeda-Ramirez *et al*. (2008) observed greater growth and survival in late nursery cultivation of Cortez oyster (*Crassosterea corteziensis*) using the alga *Pavlova* spp. (Prymnesiophyceae). *Lyngbya aestuarii* (Mert), *Anabaena* species (symbiotic with *Azolla*, a fern) have been used extensively in fish farming (Phang, 1992; Van Howe and Lejeune, 2002). In ornamental fish culture, Pan and Chien (2009), in the culture of red devil, *Cichlasoma citrinellum* (Gunther) used the alga *Haematococcus pluvialis* as a dietary carotenoid to increase colour intensity, growth and viability.

Harmful Effect of Algae on Fisheries: Despite their importance as natural feed, when in excess during algal bloom, algae are deleterious. Algal bloom is caused by rapid primary production resulting from pollution from sewage and other organic wastes and excessive use of chemical fertilizers on neighbouring land combined with efficient drainage system, which transports them into lakes, rivers and streams (Svobodova *et al*., 1993; EPA, 2006).

The bloom on the surface of the water reduces the secchi disk depth (which is the depth to which light can penetrate). There is consequently a reduction in primary production below the bloom, no matter how favorable other conditions are (Cooper, 1975; Nweze, 2003). An investigation by Lam (1979) working with *Oscillatoria* noted that no matter the level of nutrient added, there is an optimum concentration above which there would be no increase in productivity.

During blooms, the algae on the surface usually die due to intense sunlight. There is auto shading and increased bacterial decay of algae leading to depletion of oxygen below the point required for fish (2 – 3 parts per million) and other animals. The bottom organisms die, e.g. chironimid larvae (Round, 1977; Lee, 1992). The algae themselves die also and sediment at the bottom. More oxygen is used up for their decay and the density of the water is thereby increased. This prevents mixing or recycling of nutrients for a long period or even permanently (Beadle, 1974). There is thus enormous loss of game fish (Prescott, 1962; Round, 1977). Biswas (1981) noted that there was a decrease in fish catch in Zambia as a result of urbanization in Samfya. Urbanization resulted in pollution of the water, which consequently resulted in excessive growth of cyanophycean algae.

The harmful effect of blue green algae in lakes that could be termed productive due to rich algal flora has been proved (Hrebacek, 1969). It was found that there was a low figure of about 2 – 5½ % for the effective transfer of primary production to net fish production when the primary production was due to *Aphanizomenon flos-aquae*, a blue green alga.

Incidences of harmful algal blooms (HABs) have been reported in both marine and freshwater habitats, sometimes called red tides and CyanoHABs respectively (Codd *et al*., 2005). Cyanobacteria – blue green algae (*Microcystis aeruginosa*, *Aphanizomenon flos aquae*, *Cylindrospermopsis raciborskii and Anabaena* spp.), are notorious for bloom forming in the freshwater habitat. Blue green algae have been found to produce poisonous substances like hydroxylamine from the decay of proteins. They release toxins such as microcystin, cyanoginosin, nodularin, cylindrospermopsin (Hepatotoxins); saxitoxins (cause paralytic shellfish poisoning, PSP), anatoxin and aphanatoxin (neurotoxins) and lipopolysaccharides (endotoxin) into water (Fritz, *et al*., 1992; Burch and Humpage, 2005). The toxins produced are allelopathic to other phytoplankton (Suikkanem *et al*., 2004; 2006); genotoxic (Shen, *et al*., 2002); suppressive to zooplankton grazing leading to reduced growth, reproductive rate and changes in dominance (Ghadouani *et al*., 2003); hepatoxic on fish (Anderson *et al*., 1993; Burch and Humpage, 2005); accumulate in invertebrates (Lehtiniemi *et al*., 2002) and fish (Megalhaes *et al*., 2001; Jos *et al*., 2005); induce oxidative stress in fish (Jos *et al*., 2005), and reduce fecundity in snails (Gerrad and Poullain, 2005).

Marine algae such as dinoflagellates are known to cause red tides (Lee, 1992). Some dinoflagellates (*Gonyaulax, Prorocentrum, Dinophysis, Gymnodinium, Pyrodinium)* are toxic. Their toxins are concentrated in shellfish that consume them and when man consumes the shellfish there is severe food poisoning known by various names such as paralytic shellfish poisoning (PSP) or saxitoxin poisoning, ciguatera fish poisoning (CFP) diarrhetic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP) and mussel poisoning (Lee, 1992). Domoic acid, a neuroexcitatory amino acid that causes amnesic shellfish poisoning (ASP) is secreted by *Pseudonitzchia australis*, a diatom and concentrated in bivalves (Fritz *et al*., 1992; Engstrom-Ost, *et al*., 2002). These result in the death of zooplankton, fish and aquatic birds and man.

Conclusion: As there has been dearth of work on the direct use of algae in fisheries in Nigeria, the importance of algae in fisheries should not be overlooked. Several investigations have been carried out the type of food taken by different families of fishes found in the country. Such workers like Otobo and Imevbore (1979), Olatunde (1979), Willoughby (1979ab), Gras *et al*. (1971), Leveque (1979) and Ezenwaji (2004) have found out the natural food for such fishes of commercial interest like *Alestes sp, Synodontis sp., Labeo, Sarotherodon sp., Citharinus sp*., *Lates niloticus*, *Clarias spp* and others. Such fishes of commercial importance are cultivated intensively in large fish ponds and homestead ponds; and semi intensively in floodplain ponds (Ezenwaji, 2004) to produce more protein for the masses.

Aquaculture has not been developed in Nigeria as in some countries where algae could be cultured as feed for fish, shrimps, prawns and other crustaceans in commercial quantities (Platon, 1978). Nevertheless, improvements could be made by impoundment of rivers, which could increase algal crops on submerged vegetation resulting in corresponding increase in fish crops of the lake thus formed. Moreover, utilizing other ideas got from research already carried out in other countries could be applied. For example, algae could be cultivated by the method used by Platon (1978) and used for the breeding of fish such as *Labeo* and *Tilapia* which are common in Nigeria's inland waters in commercial quantity. There is therefore the need for interdisciplinary research to produce natural feed from algae for fisheries in Nigeria.

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