LAGOON TILAPIA: BIOPROFILE AND PROSPECTS FOR COASTAL FISHERIES DEVELOPMENT

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ABSTRACT

Lagoon tilapia *Sarotherodon melanotheron* also known as the black-chinned tilapia or the black-cheeked tilapia is a common fish in lagoons in Ghana, constituting over 90% of the ichthyomass in these habitats. Unfortunately its potential in the coastal fishery production has largely been overlooked although it supports important local subsistence and commercial fisheries. This lecture presents a review of the biology of populations of the species in Ghana highlighting my contributions in this regard. It will show how characteristics as tolerance range of brackish conditions, food habits, growth, reproductive habits, and ability to survive under harsh environmental conditions influence the production of natural populations. Recommendations are made for managing the natural lagoon and reservoir stocks, and aquaculture of the species.

1.0 INTRODUCTION

I am greatly honored for the opportunity to share with you aspects of my academic career in my field of specialization that is Zoology, particularly in the area of fisheries biology. Although this academic requirement has delayed three years, it is unique for me as I happen to be the first Professor in Ghana to have a female Vice Chancellor presiding over his Inaugural Lecture. Furthermore it is the first inaugural lecture coming out of the Department of Fisheries and Aquatic Sciences, and the School of Biological Sciences, and the fourth in Zoology. As my lecture deals with an issue in the aquatic sciences, it is imperative that I acknowledge the presentations by my predecessors because what they spoke about largely influenced my choice of today's topic.

The very first lecture was delivered by Professor K. N. Eyeson in 1992 in a paper titled "*The Fishes: Our Aquatic Ancestors*". This was followed in 1995 by Professor Christopher Ameyaw-Akumfi's "*Courtship behavior of Crabs, Crayfish and Lobsters*" and in 2004 by Prof. Kobina Yankson's "*Fish from the Shell: Its potential in the Quest for Adequate Protein in Ghana*". It is noteworthy that my predecessors dealt with aquatic organisms that are important to humankind in nutritional and economic terms. In observance of this tradition, I will present information on the lifestyle of a coastal organism presently of low priority but with the potential of contributing significantly to protein supplies in the country.

Before I proceed further I would like to sound a word of encouragement to junior colleagues in the School of Biological Sciences as they strive to attain the pinnacle of their chosen career in academics. The journey may be tortuous, and as Eyeson (1992) observed in his lecture "the transformation from an assistant lecturer to a full professor normally entails a long gestation period, and for good reason" (unquote). I refer you to read his published lecture for this particular reason, but in summary this goal is achievable in spite of many pitfalls along the path.

2.0 WHAT IS FISH?

Eyeson (1992) described what fishes are but since this happened some 17 years ago, I should like to refresh your memories about this group of animals. Fish refers to aquatic animals that are exploited for food, excluding endangered species as sharks, turtles and dolphins which are also exploited, albeit unlawfully, for food. Going by this definition, fish comes from four major taxonomic groups (Fig. 1):

- Echinoderms, comprising sea urchins and sea cucumbers from the marine habitat
- Molluscs (shellfish), found in the marine, freshwater and brackish water habitats
- Crustaceans (shellfish), found in the marine, freshwater and brackish water habitats
- Finfish, occurring in the marine, freshwater and brackish water habitats

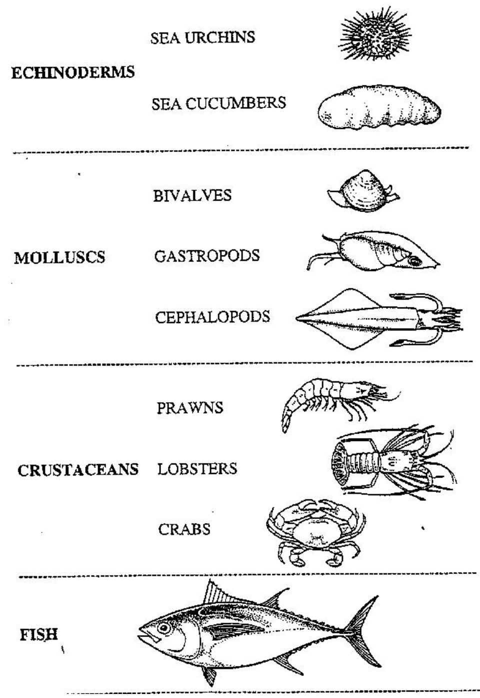


Fig. 1. Organisms that are classified as fish

Fish currently provides the greatest percentage of the world's protein consumption and, in Ghana, it accounts for about 60% of the animal protein intake. However, the current global situation is likely to change soon as most fisheries are being fished at levels above their maximum sustainable yields, with many stocks having been overexploited (FAO, 2006). As a result, the health, economy, and livelihoods of several communities are under serious threat. The reason is that although fisheries resources are renewable, when over-exploited, they cannot be easily restored to their previous levels.

In 2004 the fish requirement of the country was quoted at 700,000 metric tons while production was 300,000 metric tons leaving a deficit of 400,000 metric tons (Duffuor, 2005). In 2008 the Marine Fisheries Management Division of the Ministry of Agriculture reported the annual fish requirement as 880,000 metric tons but production averaged around 420,000 metric tons per annum, indicating a deficit of 460,000 metric tons per annum. With this trend it can be predicted with some degree of certainty that within the next 8-10 years, our fish requirement would climb close to one million metric tons unless something drastic is done to stem this downward trend. Fish supply deficits will continue to be with us if we continue to rely solely on the capture of wild fish since the population of the country and hence the demand for fish is on the ascendancy.

Of the total amount of fish produced in the country about 84% comes from the marine fisheries with the remaining 16% coming from the Volta Lake, other inland waters, fish farms and imports. Brackish water ecosystems (i.e. lagoons, estuaries and coastal marshlands) play a less significant role in fisheries production in the country at the moment although the FAO (1976) has estimated a production capacity of about 15 000 metric tons per annum from these waters. Indirectly these brackish water bodies contribute to the fisheries by providing important nursery grounds for some marine fishes.

In this lecture, aspects of the biology of a lesser known but potentially important brackish water fish in the country will be highlighted primarily based on studies my colleagues and I have conducted on nearby populations of the fish. The pragmatic utility of the biological information for enhancing production of this fish both in the wild and in captivity shall also be underscored. Before that, I should like to say a word about major food fish in the country.

3.0 MAJOR FOOD FISH IN GHANA

3.1 Fish from the Sea

The commonest fish in the Ghanaian fishery are the sardines (*Sardinella* species) which provide a cheap source of protein for many Ghanaians and enhance the livelihood of fishermen, fish processors and traders in coastal areas. In fact, poor fish landings in a particular fishing season in Ghana are attributed to low sardine catches. Other fishes of economic importance include tunas, mackerels, croakers (= cassava fish), and breams (red fish). It is noteworthy that herrings and salmons have not been mentioned in the list although these names are commonly used in our fish markets, and even in official circles. Exclusion of these fishes from the list is not an oversight; it is simply that herrings and salmons do not exist in our waters.

Not long ago (precisely on September 2, 2008), one of our television networks reported bumper harvests of “herrings and salmons” at Tema, but the accompanying video footage showed that the fishes in reference were in fact, sardines (*Sardinella aurita* and *Sardinella maderensis*) and chub mackerels, *Scomber japonicus*. The following day this same information was published in one of the dailies, repeating the fish landed as herrings and salmons. An article we submitted to the editor of that particular daily newspaper to correct this wrong information was expediently ignored. To correct this misnomer herrings are small pelagic fish belonging to the family Clupeidae occurring in the shallow, temperate waters of the North Atlantic, the Baltic, the North Pacific, and the Mediterranean seas. Notable examples are the Atlantic herring of the genus *Clupea*, and the European sprat of the genus *Sprattus*. Their relatives in the tropical Western and Eastern Atlantic oceans are sardines belonging to the Genus *Sardinella*. In Ghana, the round sardine, *Sardinella aurita*, is the dominant fish in the marine fishery as indicated earlier.

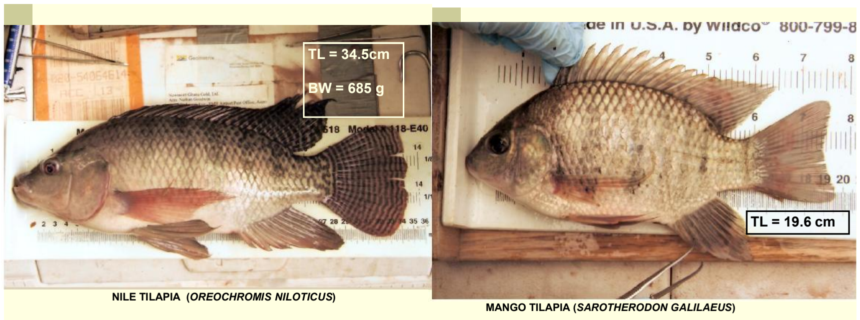
Top: *Sardinella*. Bottom: Chub mackerel (Photo credit: J. Blay)

Salmons are temperate and sub-arctic fishes of the family Salmonidae. The two most common genera are *Salmo* and *Oncorhynchus*. Mackerels on the other hand are tropical and subtropical fishes belonging to the family Scombridae. Apart from the fact that salmons and mackerels live in different geographical areas, they also differ in appearance. While the salmon has many small scales on the body and a small adipose fin (fin without rays) on the dorsal part of caudal peduncle, the mackerel lacks scales and adipose fin. Instead it has five small fins on the dorsal side of the tail, and a similar number on the lower side of the tail.

3.2 Fish from Freshwater Bodies

Of the freshwater fish exploited as food, the commonest and most important are the tilapias. Tilapias belong to the family Cichlidae of which three genera are well known in Ghana: *Tilapia*, *Sarotherodon* and *Oreochromis*. Tilapias have remained an important food source for man at least since recorded history began. According to Bardach, *et al*. (1972) "the fish St. Peter caught in the Sea of Galilee and those which Christ fed the multitudes were tilapia". Hieroglyphics in Egyptian tombs dated about 2500 B.C. reportedly show the harvest of fish which are presumably cultured tilapia. Since then the importance of various tilapia species in the fishery of many countries has been well documented.

The most important species of tilapia in Ghana are the Nile tilapia *Oreochromis niloticus* and the mango tilapia *Sarotherodon galilaeus*. These species are reported to grow to lengths of nearly half a meter in some inland waters (Paugy, *et al*., 2003). They are very popular in the country but relatively expensive in restaurants and the so-called "tilapia joints" where they are roasted on fire and served with "banku" and spices, a cuisine a very good friend of mine refers to as "grillé". When salted and sun-dried, tilapia transforms into the popular "koobi". Another freshwater species, the red-throated tilapia (*Tilapia zillii*) is important in certain localities.



Left: Nile tilapia *Oreochromis niloticus*. Right: mango tilapia *Sarotherodon melanotheron* (Photo credit: Mike McDowell, Geomatrix Consultants)

4.0 LAGOON TILAPIA IN PERSPECTIVE

Madam Chair, there is another tilapia species commonly called the lagoon tilapia because of its primary occurrence in lagoons, although it also occurs in other coastal brackish waters as estuaries and wetland pools. It is also known as black-chin tilapia, and black-cheek tilapia.

My first encounter with this fish dates back to 1973 when I was tasked by my lecturer to investigate aspects of the biology of the populations in the "closed" Fosu Lagoon here in Cape Coast and the "open" Benya Lagoon at Elmina as my undergraduate project. It was the first time I learned to measure the total length and standard length of a fish, determine a fish's gender and reproductive status, and analyze a fish's stomach contents to assess its diet. This work culminated in encounters with other fishes such as the West African shad *Ethmalosa fimbriata* which was the subject of my Masters' Thesis, mango tilapia *Sarotherodon galilaeus*, , grey mullets *Liza* and *Mugil* species, red fish *Pagellus bellottii*, big-eye grunt *Brachydeuterus auritus*, cassava fish *Pseudotolithus senegalensis*, and the goby *Porogobius schlegelii*. It also contributed to my understanding of the biology and ecology of the freshwater shellfish *Aspatharia sinuata* which was the subject of my doctoral research, the mangrove oyster *Crassostrea tulipa*, and the sea turtle *Lepidochelys olivacea*. These encounters further deepened my understanding of the ecology of aquatic habitats which knowledge has come in handy in my studies on the diversity and other ecological aspects of invertebrate communities.

So why have I chosen to eulogize the lagoon tilapia at this forum? First and foremost the lagoon tilapia started the ball rolling in my development as a fishery scientist. Secondly, as a resource, it dominates the fauna of many brackish water systems where it constitutes more than 90 per cent of the total fish biomass (Pauly, 1975, 1976; Blay and Asabere-Ameyaw, 1993; Blay, 1998; Koranteng *et al*., 1998, 2000). Furthermore it is a fish of "many descriptions" as it is called lagoon tilapia, the black-chin tilapia, or the black-cheek tilapia.

When I first encountered this fish its scientific name was *Tilapia melanotheron* but it was renamed *Sarotherodon melanotheron* on the basis of certain behavioral and anatomical features (Trewavas, 1983). The species is distributed throughout West Africa from Senegal to the Democratic Republic of Congo. Five sub-species were described by Trewavas (1983) but this was disputed by Falk, Teugels and Abban (2000) who found three subspecies from genetic studies of several populations. These subspecies are distributed as follows: *Sarotherodon melanotheron heudelotii* from Senegal to Liberia; *Sarotherodon melanotheron melanotheron* from Côte d'Ivoire to Cameroon; and *Sarotherodon melanotheron nigripinnis* from Equatorial Guinea to the mouth of River Congo. Two of Trewavas' subspecies were considered by Falk and his colleagues as synonymous to *Sarotherodon melanotheron heudelotii*. Our specimens therefore belong to the subspecies *Sarotherodon melanotheron melanotheron*.

The lagoon (black-chin) tilapia

Although lagoon tilapia dominates the fish fauna of brackish water systems in the country it is of low economic importance in the fisheries of these waters. The reason for this will be disclosed in due course but this fish is nevertheless a delicacy among the local people living near lagoons. In Cape Coast and Elmina, a kind of sauce prepared with lagoon tilapia as the protein base called *fantse-fantse* which goes along with *kenkey*, *etsew* or moist *gari* is a very popular dish of the local people. In Winneba and its environs this preparation is called *wombeedzi*, and in the Volta Region it is *akpamumudetsi*. The lagoon tilapia is so important to the local inhabitants that the Environmental Protection Agency's recent ban on fishing and consumption of fish from Fosu Lagoon in Cape Coast because of the prevailing high level of pollution was "taken with a pinch of salt". In a Daily Graphic publication on Friday 8th May 2009 immediately following the supposed ban some fishermen were quoted in interviews with the media as saying "we like it if we die eating this fish", and a buyer also said "If I don't die of HIV/AIDS but rather die from eating this fish, I will give thanks to God". This shows the extent to which the fish is relished by some.

5.0 ASPECTS OF LAGOON TILAPIA BIOLOGY

5.1 Salinity Tolerance

Tilapias belong to a group of fishes of the Order Perciformes which originally were resident in the sea, but in the course of evolution they migrated into coastal lagoons and estuaries while others moved further inland to colonize freshwater bodies. Tilapias are therefore tolerant of a wide range of saltwater concentrations and can live comfortably in freshwater and seawater.

Some populations of lagoon tilapia occur in freshwater lakes in Ghana and elsewhere in West Africa. In Ghana they can be found in the Weija, Mankessim and Brimsu reservoirs. In Côte d'Ivoire they occur in Lake Ayame (Ouattara *et al*., 2005), and in Nigeria a population has successfully established in a reservoir in Ibadan, about 150 km from the coast apparently by specimens which had escaped from experimental ponds (Ugwumba and Adebisi, 1992). The species has also been introduced accidentally into a brackish water system in Florida, USA where a population has been established (Faunce, 2000). Given their proximity to the coastal area, the Ghana and Côte d'Ivoire reservoir populations were likely formed by individuals trapped behind the dams when they took advantage of their wide salinity tolerance range to wonder further inland from the brackish zones. Pauly (1976) while investigating the biology, fishery and aquaculture potential of the lagoon tilapia in Sakumo Lagoon near Tema found the fish to survive in salinities up to 72 parts per thousand, about twice the concentration of sea water. Eyeson (1979) studied egg development of the species in various concentrations of saltwater and found that 10 grams of salt per liter of water or 10 parts per thousand of saltwater was ideal for optimum survival and hatching of eggs.

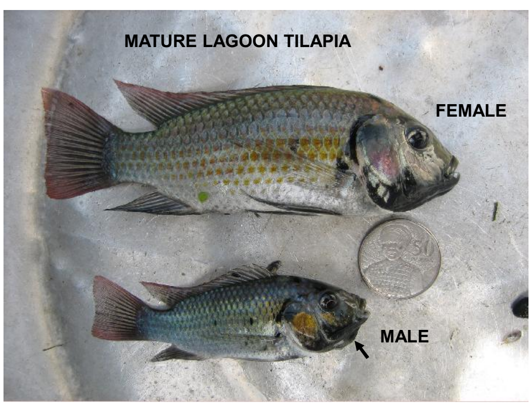
5.2 Food Habits

The natural diet of lagoon tilapia in brackish water and freshwater environments has been investigated by various workers. Fagade (1971) found the food of the population in Lagos Lagoon to consist mainly of algal filaments, diatoms and organic matter, while a wide range of benthic fauna including fish eggs was also consumed on a smaller scale. I recorded similar food items including corn seeds and corn chaff in the stomachs of specimens in Fosu and Benya Lagoons (Blay, Project Report, 1974). Welcomme (1972) reported that populations of the species in "acadja" systems in the Republic of Benin ate both periphyton and benthic fauna, and Pauly (1976) found the stomach contents of the species in Sakumo Lagoon to include diatoms and organic detritus. The freshwater population in Ibadan fed on phytoplankton, zooplankton, insect larvae and organic detritus (Ugwumba and Adebisi, 1992).

In general lagoon tilapia feed on smaller organisms although they also utilize larger food items, thus indicating considerable plasticity in the food habits of this fish.

5.3 Reproduction

Fish of the family Cichlidae have an intriguing reproductive habit in that they exhibit a high degree of parental care. In tilapias, two main behavioral types are recognized: (i) guarding of the eggs and larvae in nests, and (ii) brooding of the eggs and larvae in the mouth. The former is practiced by fish of the Genus *Tilapia* in which both parents guard the eggs and larvae, and the latter by *Sarotherodon* and *Oreochromis* species. In *Oreochromis niloticus*, the female is responsible for brooding and in *Sarotherodon galilaeus*, both parents share the fertilized eggs between them for brooding. In the lagoon tilapia *Sarotherodon melanotheron* it is the father that is the principal brooder as occasionally the mother partakes in this activity as reported by Aronson (1949) and Eyeson (1979) in laboratory-reared specimens, and Eyeson (1992) in wild fish from Fosu and Benya Lagoons. A striking feature of the lagoon tilapia is the occurrence of sexual color differences. The mature female can be identified by a purple color on the gill cover and the male by a metallic gold color of the gill cover.



Top: Female lagoon tilapia (purple gill cover); Bottom: Male lagoon tilapia (golden gill cove) with protruding 'chin' suggesting egg brooding (Photo credit: J. Blay)

Eyeson (1992) found 12% of females in the wild to practice oral incubation and attributed this occasional bi-parental brooding habit in the species to the occurrence of hormonal imbalance during the period of courtship, or the absence of male partners to incubate the eggs. He also found that in the laboratory eggs were incubated from 3 to 19 days with brooding usually lasting 14 days. In tilapias mouth brooders lay fewer eggs than guarders because they have the capacity to ensure maximum survival of the young in addition to the brood size being limited by the size of the brood pouch of the male parent. In fact, all the mature eggs produced prior to spawning are not laid at once but are shed in batches, a behavior described as fractional spawning.

A comparative study of the fecundity of three populations of the species in the Cape Coast area (Blay, unpublished data) showed that the number of eggs produced by an individual lagoon tilapia female increases with size of the fish (Fig. 2). It also showed that size for size, for fish from 6 cm to 12 cm in total length, the Fosu Lagoon tilapia have the highest fecundity, followed by the Benya Lagoon fish, with the Kakum Estuary fish having the lowest fecundity (Table 1).

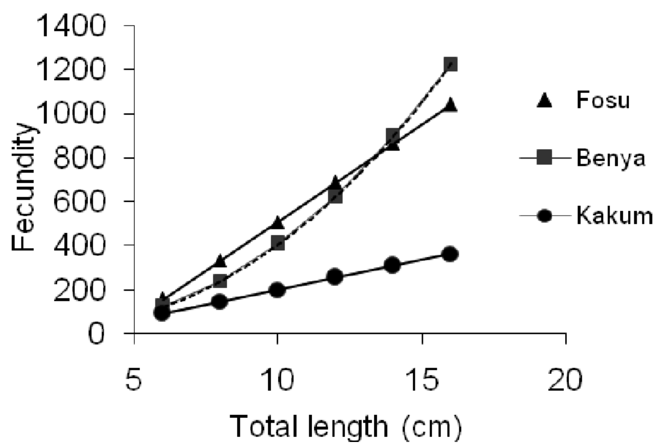


Fig. 2. Relationship between fecundity and length of three populations of lagoon tilapia

Table 1. Fecundity (±s.d.) of various size groups from three populations of the lagoon tilapia. (Blay, unpubl. data) TL refers to total length of fish

TL range (cm)	Kakum	Benya	Fosu
8.0 - 8.9	92±33	176±79	183±76
9.0 - 9.9	110±40	188±52	203±98
10.0 - 10.9	123±35	204±94	273±90
11.0 - 11.9	123±34	289±102	307±173

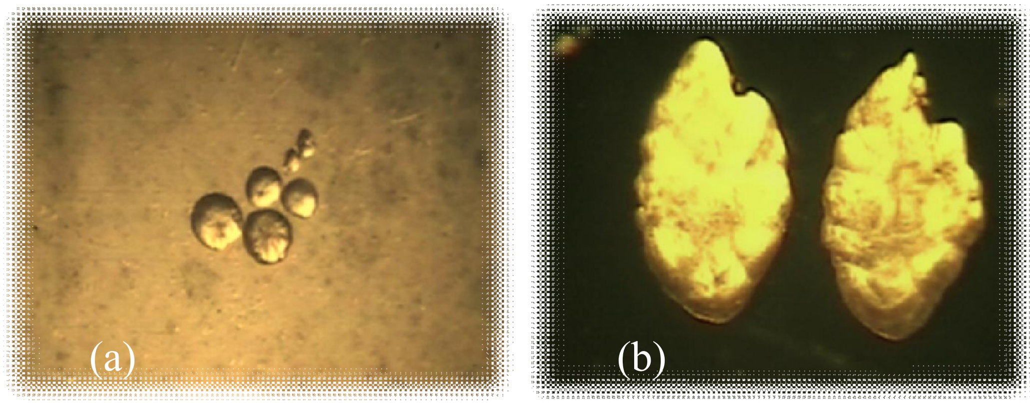
The species is a prolific breeder, spawning throughout the year (Eyeson, 1979), with the major breeding season coinciding with the rainy season when food becomes abundant (Eyeson, 1979; Faunce, 2000). Another interesting habit of the fish is the tendency for the brooding parent to swallow the young when frightened. This is a way to conserve energy spent in producing the young rather than lose them to a natural predator or an artificial predator such as fishing net.

Specimens of the different populations in the country mature and breed at small sizes ranging from 5.7 cm to 7.2 cm in total length, corresponding to 4 months to 6 months in age (Pauly, 1976; Eyeson, 1979; Blay and Asabere-Ameyaw, 1993; Blay, 1998; Koranteng *et al*., 2000). This indicates precocious breeding in the populations, equivalent to "teenage motherhood" in human parlance!

5.4 Age and Growth Characteristics

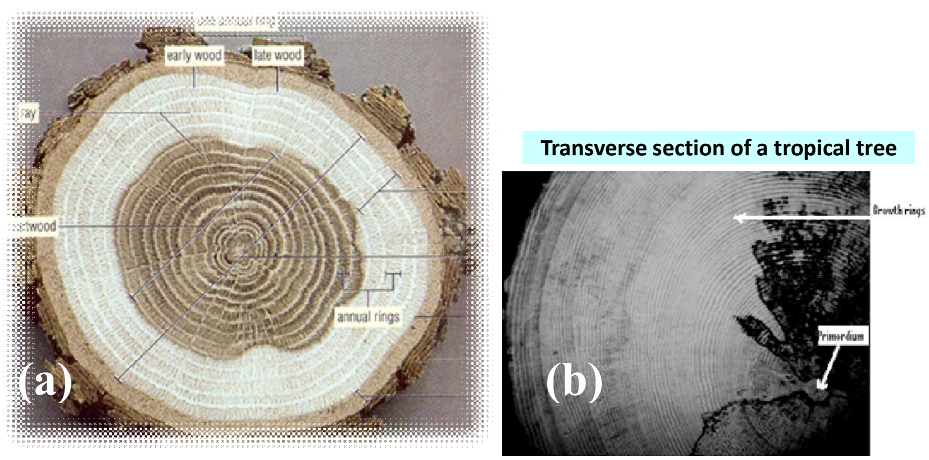
Information on the age of fish helps to determine the growth and mortality rate of populations. Knowledge of these parameters is in turn essential for assessment and management of fish stocks. Ideally, to determine the age and growth of fish, one must the fish's birth date, that is, when it hatches from the egg, and the size at the time it hatched. Since it is impossible to stay with the fish under water to obtain such information, fishery scientists commonly use statistical analysis of length frequency data or counts of periodic markings found in scales, otoliths or ear stones, opercular bones, fin rays and vertebral bones. I will use otoliths to illustrate this point.

If you are a connoisseur of fish heads in your meals you may have crushed some "stones" at one time or the other in your meal. They are the otoliths located in the fish's ear (and similarly in our ears). There are three pairs in fishes but the saggital otoliths are often used in fisheries studies because they are large in size and easy to extract and process.



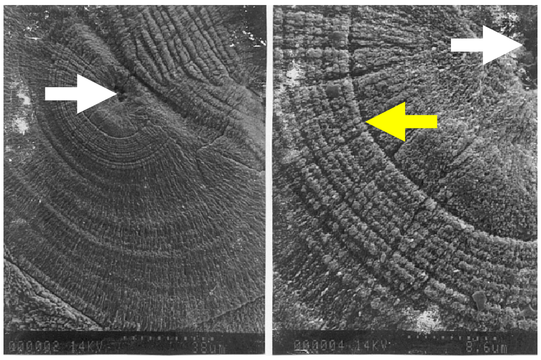
Left: Three otolith pairs from larval lagoon tilapia. Right: A pair of saggital otoliths from older lagoon tilapia (Photo Credit: J. Blay)

Otoliths consist predominantly of calcium carbonate, and they function as hearing and balancing organs. Microscopic examination of the structure of otoliths shows patterns similar to the cut surface of tree trunks. The otolith is equivalent to the "black box" of an airplane, and as it grows, information is stored about the history of the fish which can be decoded by microscopic examination of their structure.

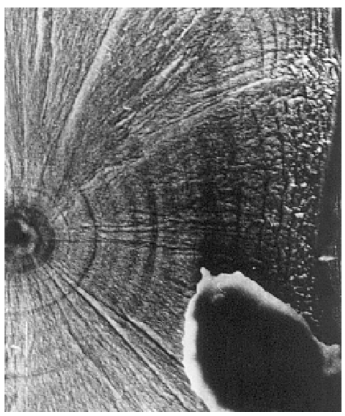


Transverse section of (a) a temperate tree showing annual rings, and (b) a tropical tree showing monthly rings (Photo of tropical tree transverse section by J. Blay)

Information recorded in the otolith includes a hatching ring, a ring that indicates commencement of feeding, when growth increases or slows down, periods of physiological stress such as spawning or starvation, as well as periods of extreme environmental perturbations. Otolith microstructure gives more accurate information on fish age especially in species where daily rings are formed (Pannela, 1971, 1974).



Microstructure of the otolith of the Dover sole as seen under electron microscope. White arrow points to where the otolith begins to develop (primordium), and yellow arrow points to the hatching check. The narrow bands are daily increments (Photo credit: J. Blay).



Scanning electron microscope image of the microstructure of lagoon tilapia otolith from a 21 days old fish (Photo credit: J. Blay)

The first ever study of age and growth of the lagoon tilapia using the microstructure of otoliths was carried out in our Department in collaboration with a colleague from the Centre for Marine Tropical Ecology in Bremen (Germany). Results of the study which are published by W. Ekau and J. Blay in the *Journal of Fish Biology* (2000) Volume **57** pages 1539-1549 showed that one ring (or growth increment) is deposited in the otolith each day which information is of practical utility for studies on the dynamics of populations in the country. This information was used to describe the growth pattern (Fig. 3) of larvae of the lagoon tilapia hatched in aquarium tanks and reared in outdoor concrete ponds in our Department.

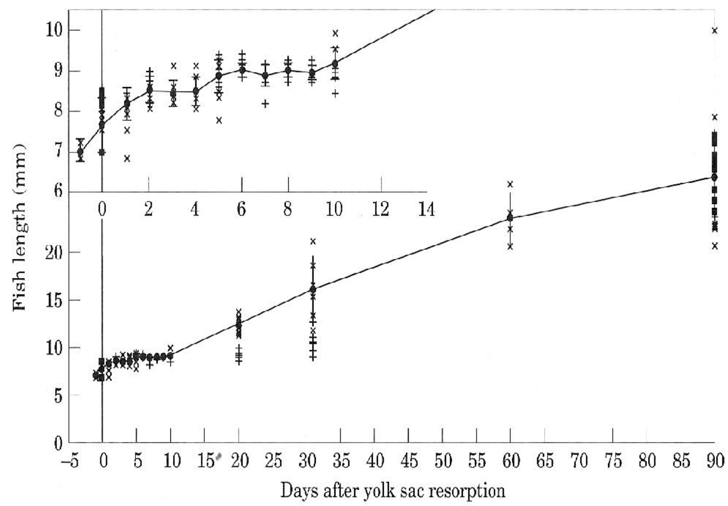


Fig. 3. Average growth of larval lagoon tilapia over a 90 day period, presented as a relationship between total length (mm) and age in days after yolk sac resorption (From Ekau and Blay, 2000).

It was further observed that the rate at which growth rings are laid down in the otolith is independent of the rate at which the fish increase in size. Therefore fish of the same age but different sizes had the same number of rings.

Growth parameters of some lagoon tilapia populations in the country have been estimated from analyses of length frequency data (e.g. Blay and Asabere-Ameyaw, 1993 on the Fosu lagoon population; Blay, 1998 on the populations in the Benya lagoon and the Kakum river estuary; Koranteng *et al*. 2000 on the Muni lagoon population). Results of these studies indicate that *Sarotherodon melanotheron* populations in Ghana grow very fast but reach small maximum theoretical sizes (Table 2). The actual final size attained by fish is always below the maximum theoretical size.

Table 2. Growth parameters of some lagoon tilapia populations (L_{max}= maximum observed length; L_∞= maximum theoretical length; K= growth curvature constant; t_0= age at length zero)

Population	Growth parameter				Source
	L_{max}	L_∞ (TL, cm)	K (yr^{-1})	t_0 (yr)	
Fosu Lagoon	15.9	16.1	0.82	-0.23	1
Benya Lagoon	18.5	19.0	0.61	-0.31	2
Kakum Estuary	11.3	12.1	1.25	-0.18	2
Muni Lagoon	11.0	16.3	0.70	-0.01	3
Lagos Lagoon	-	33.0	0.16	-	4

[1]Blay, J. and Asabere-Ameyaw, A. (1993)

[2]Blay, J. (1998)

[3]Koranteng *et al*. (2000)

[4]Pauly *et al*. (1988)

Significantly larger fish have been sampled from coastal manmade lakes in the country (Weija, Brimsu and Mankessim reservoirs), and individuals measuring 36 cm in total length and weighing more than 1 kg have been caught from the Brimsu reservoir. Thus the freshwater populations appear to have a normal growth. So why are specimens from brackish water populations so small and unattractive for the market? The answer to this question will be discussed in the preceding section.

A 36 cm long lagoon tilapia from Brimsu Reservoir in Cape Coast

5.5 Stunting and Survival of Populations

Studies have found lagoon tilapia populations in the country to show the following growth and reproductive characteristics:

(i) Small maturity sizes ranging from 5.7 cm to 7.2 cm in total length

(ii) Early maturity ages of 4 months to 6 months

(iii) Small maximum theoretical lengths ranging from 12 cm to 20 cm in total length (or 36 g to 182 g body weight)

(iv) Low ratios of maturity length to maximum theoretical length (<0.5) compared to the ratios for normal growing tilapias (0.7 or greater)

(v) Relatively short life spans ranging from 2.4 years to 4.8 years

These attributes indicate that the populations have accelerated growth and life history similar to the mode of life of organisms living under unstable or stressful conditions (Pianka, 1970; Gunderson, 1980; Noakes and Balon, 1982). In fact conditions in many Ghanaian lagoons and estuaries are unstable due to their relative shallowness (maximum depth about 1.5 meters), wide fluctuations in temperature, salinity, and hydrogen ion concentration, and generally low dissolved oxygen concentration (Pauly, 1976; Blay and Dongdem, 1996; Blay and Asabere-Ameyaw, 1993). The lagoons are also polluted to varying degrees by solid waste, sewage and industrial effluents (Biney, 1982) which results in occasional fish kills. Another condition of stress in the brackish waters is the intense fishing pressure resulting in high mortalities in various stocks (Blay and Asabere-Ameyaw, 1993; Blay, 1998; Koranteng *et al*. 1998, 2000). These conditions should normally result in depletion of the stocks but rather lagoon tilapia populations are able to survive and maintain large population sizes under the stressful conditions in their brackish water habitats. The reason unfortunately for tilapia lovers but fortunately for the lagoon tilapia populations lies in their stunted growth characteristic.

Stunting is a condition in which fish breed at an early age and a considerably small body size than normal. It occurs as a result of 'stress factors' that change the physiological state of the fish from growth to reproduction. Once the fish attains maturity status it cannot increase significantly in size because the energy that should go into increasing body weight is diverted into reproduction. Stunted fish therefore literally "rush through" their life cycle so that they can reproduce at least once before they die. That way the species can be perpetuated, otherwise the prevailing harsh environmental conditions in their habitats would see to their demise. It is a common feature of tilapia populations in unmanaged fish ponds and shallow natural water bodies.

Stunting therefore appears to be a strategy adopted by lagoon tilapia for survival in poor brackish water environments. This might explain its total dominance of lagoon fauna, making it an opportunist because it appears to take advantage of harsh conditions in the habitat to the virtual exclusion of other species. It would therefore not be out of place to label this fish as the "cheeky" black-cheek tilapia.

6.0 CONTRIBUTION OF LAGOON TILAPIA TO COASTAL FISHERIES DEVELOPMENT

6.1 Capture Fisheries

Our coastal water bodies, i.e. lagoons, estuaries and wetlands support vibrant artisan fisheries, and exploitation of their resources is for commercial or subsistence purposes, or both. As already indicated the fisheries in these waters are based on the predominant lagoon tilapia. As a result of the high reproductive rate of the species, populations are usually dense and a single throw of the cast net, the principal fishing gear employed in the fisheries often takes many specimens. However because the fishes are stunted, their biomass production is low as an average size fish weighs 7g to 11 g.

Currently the total contribution of brackish waters to the fisheries of the country is not known. Assessment of the production from some lagoons with active fisheries shows that production ranges from 125 to 664 kg/ha/yr (Pauly, 1976; Blay and Asabere-Ameyaw, 1993; Blay, 1998; Koranteng *et al*., 2000). Using an average yield of 250 kg/ha/yr from these lagoons, and assuming a conservative total area of 400 km^2 for all lagoons in the country an estimated total production of 10 000 metric tons per annum would be expected. This is about 0.02% of the total fish produced in the country. Although nationally this is insignificant, it provides livelihood and cheap protein for many coastal dwellers. As an example, in the late 1990s Koranteng *et al*. (1998) reported daily incomes of fishermen from some brackish water fisheries to be about four times higher than the country's minimum wage. If the lagoon fish could grow bigger than their present sizes, higher yields and incomes would be expected. However, the present anthropogenic threats to the existence of brackish water systems and their resources make it unlikely that the fish would grow bigger in these habitats soon. In fact there is evidence that the maximum fish size of some populations has declined over the years. In 1974 I found a 20 cm total length fish among the catches from Fosu Lagoon, but in 1990 the largest fish sampled was 16 cm. Pauly (1976) reported a maximum size of 19.0 cm in Sakumo Lagoon in 1971 compared to 12.1 cm recorded in the late 1980s by Ntiamoa-Baidu (1991).

It would appear that the key to significantly increasing production of lagoon tilapia from capture fisheries lies in enhancement of production in coastal reservoirs because the populations there appear to do better than their lagoon counterparts. This can be achieved by stocking the reservoirs with appropriate numbers of hatchery-produced fingerlings after assessing the state of ecological balance among the fish populations in the lakes (e.g. Blay, 1985). Efforts to improve production in lagoons would require sustained clean-up and dredging of these waters to control pollution and silting.

6.2 Culture Fisheries

Tilapias have been described as "aquatic chicken" because of the ease of their husbandry. Worldwide, the Nile tilapia *Oreochromis niloticus* dominates freshwater tilapia culture because of its fast growing characteristic. A faster growing strain of this fish, called the GIFT tilapia, has been developed at the World Fish Center in Malaysia under the Genetically Improved Farmed Tilapia Project and is currently being cultivated in many countries. A similar strain has been developed by our doctoral student through crossings of some Ghanaian strains and fingerlings of these crosses are being used on commercial fish farms in the country.

The Nile tilapia is the main species cultured in Ghana but because of its low tolerance for salt water, the lagoon tilapia becomes the preferred candidate for coastal aquaculture development. The culture potential of lagoon tilapia in Ghana has earlier been reported (Pauly, 1976) but this is yet to be tried. Laboratory and field studies have shown that various methods and systems of fish cultivation are applicable to lagoon tilapia cultivation. These methods include "acadja fishing" in lagoons, brackish water and freshwater pond culture, and cage culture in lagoons and reservoirs.

6.2.1 "Acadja" Fishing

The closest to culturing *Sarotherodon melanotheron* commercially in the country is the practice of "acadja" fishing in some lagoons e.g. Densu, Sakumo, Keta and Songor Lagoons in the eastern coast of the country. It involves placing tree branches on the bottom of the water to attract fish to the food and shelter provided in the setup. This "brush park" is later ringed with a net to harvest the fish. Yields form this fishery have not been determined in Ghana but Lemasson (1961) predicted that acadjas can contribute about 1,800 kg/ha of fish annually. This method of fishing is very popular in the Republic of Benin where one of the lagoons is reported to have at one time produced 16, 000 metric tons of fish per annum (Welcomme, 1972). A disadvantage of this technique is the tendency to degrade the surrounding vegetation and also silting of the water body because the vegetation used does not decompose quickly enough.

6.2.2 Pond Culture

Being a coastal fish with a wide salinity tolerance range lagoon tilapia can be cultured in both salt water and freshwater. Tidal ponds constructed in the mudflats near open lagoons and estuaries would be ideal for brackish water culture. Fingerlings from lagoons and estuaries or hatcheries can be used to stock the ponds. Tidal ponds are filled naturally with seawater at high tide and partially drained at low tide. This system has the capacity for high yields because the ponds are frequently cleaned of nitrogenous wastes produced by the fish. Culturing lagoon tilapia in the coastal areas is desirable because of they are endemic to the area.

6.2.3 Cage Culture in Lagoons and Reservoirs

The species can be cultured in cages in closed lagoons and reservoirs in the coastal Districts. Cage culture trials in 1 m^3 floating mosquito net cages in Fosu Lagoon in 1989/90 showed that this practice would be feasible. In the trial experiments fry grew from an average weight of 0.1 g to 34 g within 7 months. Fish in the natural population is estimated to reach 8 cm and weigh 10 grams in 7 months while it takes about 4 years for the fish to reach 16 cm or 64 g, its maximum observed size in the lagoon. Hence the fish had a better growth rate in the cages. The study also showed that growth was best in cages stocked at the rate of 60 fry per m^3. Greater yields would therefore be expected from cage culture in the three coastal reservoirs because of the better environmental conditions there.

7.0 LAGOON TILAPIA RESEARCH AT THE UNIVERSITY OF CAPE COAST

Lagoon tilapia research in the Department of Zoology and offshoot, the Department of Fisheries and Aquatic Sciences at the University of Cape Coast, has aimed at its contribution to fisheries development in fulfillment of the agenda of production oriented research proposed by Professor Eyeson in his inaugural lecture. This is evident in works that have assessed the fishery status, growth parameters and reproduction of the stocks in Cape Coast and its environs (e.g. Eyeson, 1979, 1983; Blay and Asabere-Ameyaw, 1993; Blay, 1998; Ekau and Blay, 2000). In assessing the Fosu Lagoon stock it was determined that the mesh size (2.5 cm stretched mesh) being used is adequate to sustain the current production level of the fishery. Furthermore, in anticipation of the species playing a key role in fish farming in coastal areas of the country, studies using our modest experimental facilities have sought to investigate the optimum conditions for its cultivation and its performance under culture.

Eyeson's (1979) observation that a salinity of 10 parts per thousand ensures maximum development of fertilized eggs is significant for the hatchery production of fingerlings, several of which would be required for stocking ponds, cages and reservoirs. From our studies on fecundity and fertility of the species we can determine fingerling production rates to plan stocking activities.

Blay (unpublished report) recorded 100% sex reversal in lagoon tilapia when fry were fed 120 mg of the hormone 17α-methyl testosterone per one kilogram of feed compared to a concentration of 60 mg per kilogram feed required to produce all-male Nile tilapia (Popma and Green, 1990). Culture of all-male tilapia, i.e. monosex culture, is more desirable than mixed culture (males and females together) because it eliminates reproduction, thus preventing overpopulation of ponds and allowing the fish to devote energy to growth. Besides, males grow faster and reach table size within a shorter period than females. Other advantages of this technique include non-wastage of females as would happen if male fingerlings were handpicked from the fingerling population for culture; in addition higher yields would be realized because the fish can be stocked at higher densities.

8.0 CONCLUSIONS

From the foregoing it is concluded that

(i) lagoon tilapia is indeed "king" of brackish water fish fauna. Although dwarfed in their brackish water habitats natural populations continue to provide nutrition and employment for poor coastal dwellers. This is possible because of its precocious development and high reproductive capacity.

(ii) given suitable conditions as prevails in large freshwater environments, the species can grow to sizes comparable to the well-known Nile tilapia, and greater yields can be obtained. Individuals in brackish water populations are unlikely to grow any bigger than current sizes because of the unstable conditions and degraded state of their habitats.

(iii) lagoon tilapia is doubtless the most suitable candidate for aquaculture development along the coast because it is endemic to the area, and its utilization in such venture will ensure maintenance of the sanctity of fish biodiversity in the area.

10.0 RECOMMENDATIONS

Concerns have been expressed lately about the dwindling fish catches in the country. This has often been blamed on the use of destructive fishing methods such as pair trawling, dynamiting, use of poisons, and light fishing by the artisan, industrial and semi-industrial fishers. Another possible culprit is climate change. Since our marine fish production is driven by the process of upwelling it is possible that the increasing atmospheric temperature and changes in wind pattern due to global warming are interfering with this phenomenon to the extent that seasonal bumper harvests are no longer predictable. Though these are real issues confronting our fisheries, we seem to have also overlooked the effects of the increasing human population size on the fish stocks and supplies. An estimated 5 million people lived in Ghana at independence in 1957. Fifty years on, our population stands at around 24 million. Fishery production has apparently not kept pace with this exponential population increase because the fishery has reached the maximum sustainable yield, and the stocks have been over-fished. It is therefore imperative that we intensify our fisheries management efforts and/or develop alternate sources of fish supply.

Having recognized lagoon tilapia as an important resource, I should like to make the following recommendations which I foresee as critical to enhancing its production in the country.

i) Lagoon fisheries which are undoubtedly based on lagoon tilapia should be managed more effectively. Although the Fisheries Act (Act 625, 2002) encompasses all fisheries resources in the country little attention has been paid to most lagoons and estuaries where management is largely vested in traditional authority. Although traditional beliefs and associated taboos such as closed seasons, closed fishing days and times among others have proved worthwhile, traditional management does not appear to pay much attention to the issue of pollution which is a major cause of degradation of these habitats and the consequent poor fish production. In this regard, I wish to suggest that the Directorate of Fisheries of the Ministry of Agriculture and the Environmental Protection Agency team up with the District/Municipal/Metropolitan Assemblies and traditional authorities, to co-manage the fisheries resources in lagoons and estuaries. This should include cleaning and dredging the lagoons most of which are silted, as well as educating the communities living near lagoons on the negative impacts of pollution. The apparent failure of a recent ban imposed on fishing and consumption of fish from Fosu Lagoon by the Central Regional EPA could be attributed to lack of education and consultations with the traditional leaders.

ii) A comprehensive feasibility study funded by Government should be undertaken along the entire coast of the country to identify suitable areas for pond and cage culture of the species. Particularly, open lagoons, estuaries and low lying areas in the coastal savanna should be prime targets.

iii) Following (ii) above, it is proposed that community fish farm projects be established and supported by coastal District Assemblies and Municipal/Metropolitan Assemblies for commercial production of lagoon tilapia with the universities and research institutes providing extension services.

iv) Hatcheries should be established in each of the four coastal Regions to supply fingerlings to farmers on sustained basis to promote the culture of the fish.

It is my conviction that if these measures are considered and implemented the lagoon tilapia would soon become a major fish for culture in Ghana's coastal Districts.

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