A Preliminary Survey of Tilapia Nurseries on Lake Kariba during 1967/68.*

by

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INTRODUCTION

WELCOMME (1964 : 6), in a detailed study of *Tilapia* habitats on Lake Victoria regards slope as a major factor controlling the shoreline environment and introduces the concept of "gradient" and "non gradient beaches". Briefly, the former refers to the maintenance of a thermal gradient running perpendicular from the shoreline to deeper water for at least part of the day. These are found predominantly in shallow, static waters and constitute "the universal habitat of young *Tilapia*". In contrast, "non gradient" shorelines lie at the extremes of long fetches or are steep sloping with temperature and bottom substrate influences being largely controlled by the condition of the main water body which abuts directly against the slope. While gradients can occur in the latter case they are extremely narrow in effect.

Although young *Tilapia* in Lake Kariba occur in varying numbers along all shoreline types throughout the year there is this same marked preference for "gradient" beaches. However, unlike Lake Victoria where water levels are reasonably static, Lake Kariba experiences more drastic fluctuations which have a profound influence on the marginal vegetation and fish.

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*Presented at the "Symposium on Standing Waters", Grahamstown, South Africa, in July 1968.

The Nursery Environment

Tilapia nurseries along the eastern half and Rhodesian shoreline of the lake have been located at the Lakeside, Charara, Gache Gache, Sanyati East, Sanyati West, Sibilobilo and Sengwa cleared areas (Fig. 1). One basic character linking these areas is that all are situ-

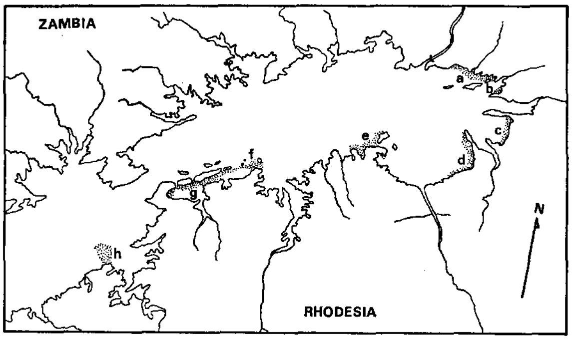

Fig. 1. Map of the eastern half of Lake Kariba showing *Tilapia* nursery areas (stippled) so far located on the southern shoreline. (a) Lakeside; (b) Charara; (c) Gache Gache; (d) Sanyati East; (e) Sanyati West; (f) Bumi; (g) Sibilobilo; (h) Sengwa.

ated over near-horizontally bedded Lower Karroo and Marly Sandstones as opposed to the steep talus slopes of the Basement Gneisses (Bond, 1965 : 42).

A further important aspect of potential nursery topography on Lake Kariba is whether or not the land was bush cleared for fishing pitches. This factor has a direct bearing on *Salvinia auriculata* which tends to accumulate and find anchorage against wind and wave action among the emergent drowned trees and branches in the uncleared areas. This usually results in broad *Salvinia* mats of up to half a mile wide in some instances, extending from the shoreline to the edge of the emergent treeline. Although young *Tilapia* do occur sporadically in small gaps along the shallows, the overall influence of lower oxygen tensions (G. W. Begg, pers. comm.) and the inhibition of submerged aquatic growth by shading renders these zones inhospitable as nurseries.

In contrast, the cleared areas provide a greater diversity of plant life and show marked ecological zonations. On exposed shores *Salvinia* is usually confined to comparatively narrow strips along the littoral where it is either afforded some anchorage by emergent sedges or blown out and heaped on the shore (Fig. 2A). On sheltered or semisheltered shorelines (Fig. 2B and C) the aquatic grass

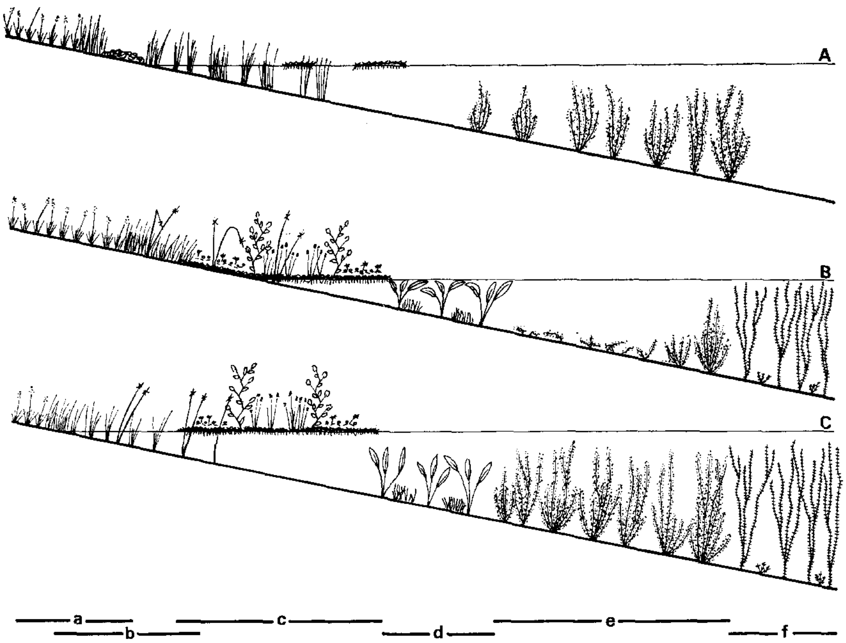

Fig. 2. Diagramatic representation of vegetational zonations in cleared areas from shoreline to approximately 7 metres depth. A, Facies of an unsheltered, wave washed shoreline. B and C, semisheltered shoreline, B at low level (summer months), C at high level (winter months). Zones: (a) terrestrial grasses; (b) *Panicum repens;* (c) *Salvinia* "complex", *Polygonum* sp., *Ludwigia* spp, *Scirpus* sp., *Typha* sp.; (d) *Vallisneria aethiopica, Potamogeton sweinfurthii;* (e) *Potamogeton pusillus;* (f) *Ceratophyllum demersum* and *Chara* sp.

Panicum repens mingles with the terrestrial grasses *Aristida, Heteropogon* and *Rhyncheletrum* on dry soil, occupies most of the soak zone and thrives in water up to 100 cm in depth. *Typha* and *Scirpus* emerge from water up to a depth of about 60 cm. Between 100 cm and 150 cm submerged plants are scattered and usually composed of stands of *Potamogeton pusillus, P. sweinfurthtii* and *Vallisneria aethiopica.* On shores exposed to any degree of wave action only *P. pusillus* maintains this zone. At water depths of between 150 cm and 300 cm, *P. pusillus* is the dominant plant. In the shallow water of the Sengwa cleared area vast beds of *P. pusillus* can occur up to three miles from the shore. At 300 cm a sharp transition occurs with *P. pusillus* giving way to dense stands of *Ceratophyllum demersum* which can occupy water depths of up to 750 cm. Although *Ceratophyllum* does occur sporadically in shallow water the plants do not appear to be permanent. Between Milibizi and Sinamwenda *Lagarosiphon* spp. are largely replacing

P. pusillus in the shallow water of the sheltered areas. Although not visible from above, *Chara* has been recorded in the Sengwa cleared area at 12 m (G. W. BEGG, pers. comm.) and from the gut contents of *Tilapia melanopleura* captured in 7 m of water. It seems that this plant occupies the innermost boundary of the limnetic zone (ODUM, 1963 : 300).

TILAPIA HABITAT PREFERENCES

Tilapia, both *melanopleura* and *mossambica*, in Lake Kariba can be placed in three arbitrary length categories with regard to habitat preferences. Fish of up to 10 cm in total length prefer water depths of up to 30 cm on a gently sloping shoreline. For convenience this zone is termed a "primary" nursery. "Secondary" conditions apply to fish of between 11 and 19 cm in length which usually inhabit waters of between 30 and 60 cm in depth. The areas at these depths and the numbers of fish harboured there are proportional to the gradient of the shoreline.

At between 17 and 19 cm in length and at an age of one year *Tilapia* tend to leave these nurseries for the adult habitats even though they are not sexually mature until at least a year later (DONNELLY, in preparation).

Above 20 cm in length *T. mossambica* occupy a variety of habitats up to about 15 m in depth with some seasonal fluctuations (COKE, 1967). *T. melanopleura* on the other hand are rather less catholic and confine themselves to the *Ceratophyllum* and *P. pusillus* beds with a preference for the latter. However, adult *T. melanopleura* do enter shallow water for breeding purposes or during a rise in lake level to feed on decomposing grasses.

Although *Tilapia* breeding occurs throughout the year to some extent there are spawning peaks for both *T. mossambica* and *T. melanopleura* from October to December. Nesting sites are ecologically distinct. During this period *T. melanopleura* nests are easily observed along the lake margin in water of between 60 and 100 cm in depth. Observations indicate two types of nest with one instance of colonial nesting where eighteen shallow, adjacent scrapes attended by an estimated six pairs of adults were recorded. These are incubation nests as the parents later deposit the alevins in the pitted type nest as described by DE BONT (1949).

T. mossambica nests on the other hand have not been seen by the writer but underwater fishermen confirm that nesting takes place in deeper water at about 4 m in depth.

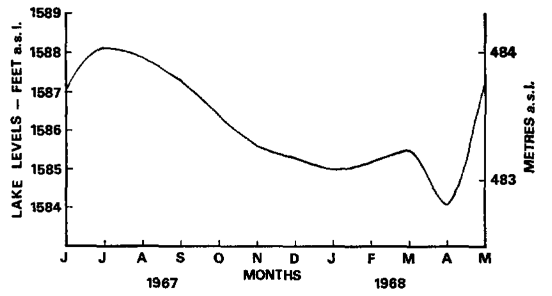

Fig. 3. Kariba Lake levels from June 1967 to May 1968.

Influences of lake fluctuation

Figure 3 gives lake levels recorded during the study period. This shows that levels fell from 484.0 m (1588 ft) a.s.l. in August to 482.8 m (1584 ft) a.s.l. in April, subjecting the lake to a receding shoreline for 8 months of the year. During this period changes to the marginal nursery vegetation are slow but nevertheless distinct. The narrow *Salvinia* mat is gradually stranded and begins to dry out (Pl. 1). *Ludwigia stolonifera* and *Polygonum* invade the stranded mat over the soak zone and encroach lakewards over that portion still floating as do members of the Cyperaceae and *Typha*, if not already present on the mat (Pl. 2). *Ludwigia erecta* creeps over the dried *Salvinia* mat on the shore while terrestrial grasses *Aristida*, *Heteropogon* and the aquatic grass *Panicum repens* spring up in their respective positions on the newly exposed ground.

Of the submerged aquatics only *Potamogeton pusillus* shows any adverse response to the lowering water level. From October to April this plant gradually dies back leaving a bare, sandy floor despite being covered by water, as lake levels drop over the *Potamogeton* zone (Fig. 2B). At the deeper parts of its depth range the plants remain unaltered.

The rising water from April to July, apart from promoting growth in *P. pusillus* has the profound effect of floating the *Salvinia* mat "complex" (Pl. 3). The "complex" further extends lakewards by incorporating fresh *Salvinia* mats which blow up against the raft and in certain localities this growth has advanced over water up to 2 m in depth.

Seepage through the raft inundates the aquatic and terrestrial grasses and appears as a sheet of open, calm water (Pl. 4). The terrestrial grasses immediately begin to break down while *P. repens* survives until the water depth overtops its extremities. In areas with well developed rafts these enclosed lagoons can remain uninhabited by fish until up to 4 weeks after inundation. Any wave action

Plate 1. Sanyati East cleared area, October. Lake level falling and reducing nursery area situated in the foreground.
Plate 2. Sanyati East cleared area, April. Lake level low, *Salvinia* mat stranded, regeneration of invader species, shallow nursery non existant.

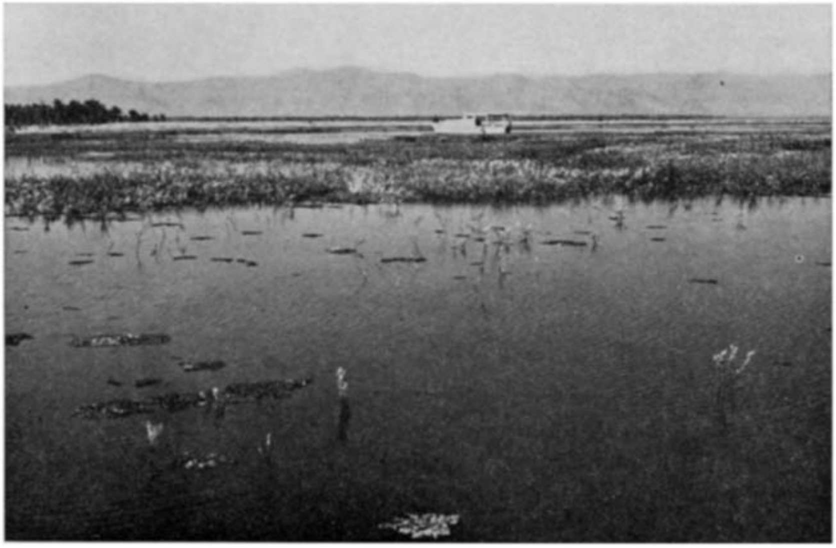

Plate 3. Sanyati East cleared area, May. Lake level rising, onset of shallow nursery conditions.
Plate 4. Sanyati East cleared area, July. Peak lake level producing shallow nursery conditions in foreground with *Salvinia* "complex" floating in the middle distance.

from the lake is so severely cushioned by the raft, reinforced by invader root systems, that it does not initially allow mixing with lake water. Fish attempting to inhabit these shallows prematurely have been seen gasping at the surface, indicating a low dissolved oxygen tension, probably derived from the decay of drowned vegetation.

Undoubtedly the most favourable conditions for young *Tilapia* in the shallows occur during the 5 month period when the lake is rising. The rotting vegetation, emergent Cyperaceae and *P. repens* provide ample protective cover and there appears to be a bloom of animal and plant life over the fresh soil. However, as the shoreline recedes it has the effect of gradually forcing the young fish back through the *Salvima* "complex" which for a time affords cover but eventually shades out the shallow water (Fig. 2B). At this stage most fish retreat to the deeper *Potamogeton* and *Ceratophyllum* beds where they remain until the following lake level rise.

Thus the "shallow" nurseries are "temporary" and do not effectively function from November to April. The *Ceratophyllum* and *Potamogeton* beds then act as "deep" and "permanent" nurseries.

THERMAL PROPERTIES

While little work has so far been undertaken on the chemical aspects of "gradient" shorelines on Lake Kariba some indications of the thermal properties have been obtained.

In July, the middle of winter, lake temperatures are in the region of 22° C with a daily fluctuation in the nurseries, at 10 cm depth, ranging between 16.6° C and 28.8° C. In October at the onset of the hot months a range of between 22.2° C and 35.6° C at 10 cm has been recorded when lake temperatures are 27° C.

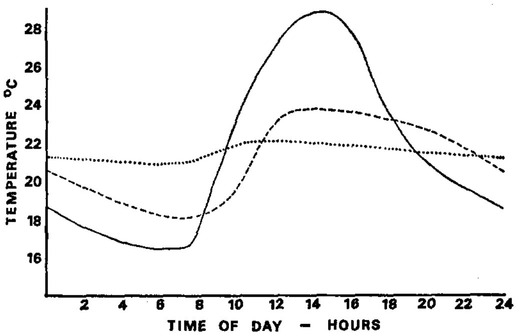

Fig. 4. 24 hour temperature fluctuations in "primary" and "secondary" nurseries recorded in July at 10 cm. depth (unbroken line), 30 cm. (broken line) and 100 cm. (dotted line).

The upper limits of these temperature ranges conform reasonably well with the preferential temperature range of 27.0° to 33.5° C in *Tilapia mossambica* as found by BADENHUIZEN (1967 : 553). In addition to the considerable resistance of *Tilapia* to high temperatures, their ability to withstand a 24 hour amplitude of at least 13.4° C in Lake Kariba would appear more remarkable. However, as was found by WELCOMME (1964 : 24) on the beaches of Lake Victoria, a decline in *Tilapia* numbers occurs at night when diurnal gradient conditions are reversed.

Figure 4 illustrates the gradient nature of a typical nursery shoreline in July. By 18.00 hours most young *Tilapia* have departed from the "primary" nurseries to deeper water and from the "secondary" nurseries by 23.00 hours, when temperatures drop below 22—23° C. Reinvasion of the shallows takes place about 10.00 hours onwards when temperatures rise above 22° C, giving occupation times of approximately 8 hours in "primary" and 12 hours in "secondary" nurseries. In the hot months this period would no doubt be extended. However, during these potentially optimum conditions lake levels are for the most part falling with the young fish seeking cover in deeper water.

Water covered by *Salvinia* is usually about 2° C cooler than open water at equivalent depths. It has been noted that loose mats of *Salvinia* in nurseries insulate against warming but seems not to retain heat under cooling conditions.

PREDATORS

The presence of an active predatory species within a fish population has the effect of altering the behaviour of prey species. In some Rhodesian highveld dams where the only potential predator is *Clarias gariepinus*, *Tilapia* shoals of all size groups can be found intermingled at various depths, though segregating out when they come into the warmer shallow water. The predatory habits of *Hydrocynus vittatus* in Lake Kariba do not allow such freedom and young *Tilapia* do not venture far from cover until a total length of between 17 and 19 cm is attained. This is most certainly a *Hydrocynus* induced phenomenon.

The largest *Tilapia* taken in a "shallow, secondary" nursery measured 19 cm, while the smallest *Tilapia* obtained in open water outside any nursery influence measured 17 cm. These results coincide directly with the size of the largest *Tilapia*, 18 cm, recorded from an examination of 2,300 *Hydrocynus* stomachs. Above this length they can be considered "safe" and move with relative impunity among *Hydrocynus* of 60 cm and larger. This agrees accurately with the results obtained by JACKSON (1961 : 603) from Bangweulu, Mweru and the Middle Zambezi before inundation. MUNRO (1966 : 403) gives a smaller "safe" length of 16 cm for *Tilapia* on Lake McIlwaine, Salisbury. However, he states that "*H. vittatus* larger than 40 cm total length are uncommon".

On steeply shelving shores young *Tilapia* find cover individually among loose rocks with the shoaling habit a rare feature in this type of habitat. Alevin shoals however, frequently base their foraging around a single drifting *Salvinia* plant while it remains in shallow water. If this is removed the fish "freeze" on the bottom relying on cryptic colouration and prefer to be scooped out in the hand rather than escape into deeper water as would be the case in impoundments lacking swift predators. In the "shallow" nurseries *Tilapia* invariably seek refuge under *Salvinia* mats while in "deep" nurseries the fish hide in the foliage of *Ceratophyllum* and *Potamogeton.*

FRYER (1961 : 4) discusses the advantages of the shallow habitat as a protection from predators. In Lake Kariba this is exhibited by the fact that *Hydrocynus* seldom enter water shallower than about triple their own length. *Hydrocynus* of up to 10 cm in length taken in "primary" nurseries are generally still feeding on invertebrate life while those of 20 cm in length patrolling "secondary" nurseries are in contact with *Tilapia* too large to feed upon. In contrast, a steeply shelving shoreline allows even the largest *Hydrocynus* almost direct contact with the narrow *Tilapia* margin.

Apart from the phobia of entering water shallower than a certain depth *Hydrocynus* also exhibit great reluctance to enter any sort of submerged vegetation (JACKSON 1961 : 612). Shoals of *Hydrocynus* patrol in open water over the *Ceratophyllum* and *Potamogeton* beds and along lanes and gaps within the plants themselves. Gill nets set among this vegetation seldom yield *Hydrocynus* except where the nets emerge into open water or extend above plant height.

While *Hydrocynus* is here considered a diurnal predator, feeding mainly during the early mornings and evenings, when young *Tilapia* are adjusting to temperature changes, three nocturnal predators warrant consideration. These are all relatively slow moving species which are unlikely to impose behavioural changes in prey fish. Observations at night have shown that *Clarias gariepinus* and *Eutropius depressirostris* swim alongside small *Tilapia* without causing concern. Results to date show that *Clarias* of up to 70 cm in length nightly enter "primary" nurseries especially during inundation. An examination of stomach contents has revealed that Cladocerans, Odonata nymphs, *Caradina* and terrestrial insects with an occasional Cichlid to be the object of the invasion. *Eutropius* stomachs have yielded a higher proportion of Cichlids but this data requires further examination. *Mormyrops deliciosus* confines its foraging to the "deep" nurseries where it appears to actively enter the submerged vegetation for its prey. However, this species occurs in such small numbers that its overall impact on *Tilapia* is considered negligible.

Discussion

The advantages of a shallow sloping shoreline as a prerequisite for *Tilapia* nurseries are well documented by Welcomme (1964) and Fryer (1961). In Lake Kariba the value of this type of habitat is complicated by the presence of *Salvinia auriculata*. When this plant is afforded protection from wind and wave action it accumulates to cover wide areas potentially suitable for *Tilapia* nurseries. The fringe benefits of cover from predation are far outweighed by the effects of nutrient depletion, low oxygen tensions and retardation of planktonic and submerged aquatic vegetation growth necessary to maintain *Tilapia* nurseries. Had *Salvinia* been absent from the impoundment, essential marginal and submerged vegetation would have existed over a wider area than at present and would have contributed more effectively towards the *Tilapia* fishery. Fortunately, as mentioned by Bowmaker (1968 : 6) the ultimate breakdown of emergent drowned trees will further reduce the area of *Salvinia* coverage.

The combination of an active predator such as *Hydrocynus* and a fluctuating water level has enhanced the importance of submerged aquatic plants in Lake Kariba. This aspect of cover and the behavioural reluctance of *Hydrocynus* to enter vegetation and shallow water will prove to be major factors in predator/prey relations.

Summary

Young *Tilapia* on Lake Kariba show a marked preference for shallow water but this is complicated by fluctuating lake levels, the floating weed *Salvinia auriculata* and the Tigerfish *Hydrocynus vittatus*.

Tilapia nurseries found to date occur on shallow sloping shores predominently in the bush cleared areas and overlie Lower Karroo and Marly Sandstones. They are characterised by having a minimum of *Salvinia* coverage and a diversity of emergent and submerged aquatic plant growth arranged in fairly definate zones.

Rising lake levels provide the most favourable conditions for young *Tilapia* in the shallow, temporary nurseries. Receding water levels force the fish into *Ceratophyllum* and *Potamogeton* beds of the deeper water.

Tilapia do not leave cover until a length of between 17 cm and 19

cm is attained. Above this size they are considered reasonably safe from *Hydrocynus*. The impact on *Tilapia* of three nocturnal predators is considered insignificant at the present time.

Salvinia has the effect of causing lower oxygen tensions and retardation of essential submerged aquatic vegetation and is considered detrimental to the *Tilapia* fishery. Submerged aquatic plants are highly desirable to protect young *Tilapia* from predation during receding water levels.

ACKNOWLEDGEMENTS

I should like to thank Mr. M. I. VAN DER LINGEN and Mr. G. W. BEGG of the Lake Kariba Fisheries Research Institute for their numerous discussions and comments relating to these observations.

Thanks are due to Mr. R. A. JUBB, Albany Museum, Grahamstown, for his constant assistance and advice and to Mr. D. S. MITCHELL of the University College of Rhodesia for identifying many of the plants.

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