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OBSERVATIONS ON THE BALANCE IN FISH POPULATIONS IN A SMALL RESERVOIR IN GHANA

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ABSTRACT

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This paper examines the fish populations in a small reservoir located in the coastal savanna to the east of Accra, Ghana, to evaluate their balance. The main forage fishes were the cichlid, *Sarotherodon galilaeus* (*E* value 88.2%), and the prawn, *Macrobrachium vollenhovenii* (*E* value 7.8%). The carnivores were represented by the catfish, *Clarias senegalensis*, and the cichlid, *Hemichromis bimaculatus*, with *E* values of 2.6 and 0.2%, respectively. The F/C and Y/C ratios were 34.92 and 1.79, respectively, which suggests unbalanced populations, presumably due to overcrowding by stunted forage fish, mainly *S. galilaeus*. The A_T value of 50.81%, however, might suggest balanced populations, but this index may have been over-estimated and the populations may be incapable of producing harvestable crops.

INTRODUCTION

The utilization of impoundments for the production of fish, besides other primary uses, has become a common practice in many countries, especially the industrialized ones, where a number of impoundments are managed for the production of annual harvestable fish crops (Byrd and Moss, 1957; Davies, 1973).

The recent significant increase in the surface area of inland waters in Ghana, primarily for the generation of electricity, domestic water supply and irrigation, promises to be of great advantage in fish production. These new man-made lakes contain fish populations that are already exploited by fishing communities attracted by the initial increase in fish production. Increased and uncontrolled fishing pressure often leads to over-exploitation of the fish stocks.

Various management practices have been suggested (Swingle, 1964) for use in impounded waters with the view to increasing fish production. These

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include the elimination of undesirable species and stocking with desirable fish, fertilization and liming, combined feeding and selective feeding of fish. Studies on the existing species composition and the state of balance between fish populations in a water body are essential in predicting the possibility or otherwise of the populations yielding annual harvestable crops (Swingle, 1950). Such predictions provide the necessary basis for improved management of impoundments (Tang, 1970).

This work examines the interactions between fish populations in Dawhenya Reservoir in Ghana, especially their probable state of balance and the ecological status of the major forage and carnivorous species. It is envisaged that this investigation would aid future attempts at achieving and maintaining harvestable yields of fish in the reservoir.

THE STUDY SITE

Dawhenya Reservoir occurs in the coastal savanna about 35 km east of Accra, the capital city of Ghana. It is a shallow lake of about 48 ha surface area, created in 1974 to irrigate the surrounding plains for agriculture. Surface water temperatures vary from 25.0 to 31.0°C throughout the year, and transparency ranges between 20.0 and 30.0 cm. Oxygen concentrations in the surface waters measure 7.0—10.0 p.p.m., while the pH ranges from 7.2 to 8.0. The locality experiences seasonal rainfall patterns. Precipitation in 1979 was 0—8.73 mm, with peaks in June (8.73 mm) and October (8.32 mm), but high water levels occurred from July to December and low levels from January to June.

MATERIALS AND METHODS

Fish hauls were obtained at 3-month intervals between February 1979 and March 1980 with a hand drawn drag net (5.5 m long, 54.8 m wide and 1.5 m deep between the head and foot ropes). The net comprised 3 meshes of 70, 40 and 12 mm at the anterior, middle and pocket, respectively. A few samples were obtained from gill-nets and wire-mesh traps.

The total weight of each sample was measured and it was then sorted into various species groups. Each group was weighed separately. On the basis of their food habits, fish were classified as forage (F) species, in this instance planktivorous, detritivorous and macrophytophagous feeders, and carnivorous (C) species, which refers to piscivores. Lengths of fish ingested by predators were measured to determine the maximum size of prey fish. The total length (*TL*), standard length (*SL*) and weight (*W*) of fish were measured. Prawns were measured for length (*L*), from the orbit to the tip of the telson, and body weight (*W*). Lengths and weights were measured to the nearest 0.1 cm and 0.1 g, respectively. Gonads were examined in *Sarotherodon galilaeus* to estimate fecundity and maturity size, but in *Macrobrachium vollenhovenii*, only maturity size was determined.

The E value, F/C and Y/C ratios, and A_T value derived by Swingle (1950), were calculated for the combined samples during the study period. These indices are defined below.

RESULTS

Species composition and E *values*

The E value of a species is defined as the percentage by weight of the species relative to the weight of the entire fish population.

Nine fish species and 3 species of prawns were sampled in the reservoir. The E value of the principal species are given in Table I. The cichlid, *S. galilaeus*, comprised a very high proportion of the total fish biomass (E value = 88.2%). The next important species was *M. vollenhovenii*, but this had an E value of only 7.8%. All other species had relatively low percentages.

TABLE I

Percentage composition by weight (E values) of principal fish species in Dawhenya Reservoir

Total weight of fish (kg)	E values						
	Sarotherodon galilaeus	*Tilapia zillii*	*Hemichromis bimaculatus*	*Marcusenius brachystius*	*Clarias senegalensis*	*Meterotis niloticus*	*Macrobrachium vollenhovenii*
39.528	88.2	0.4	0.2	0.2	2.6	0.7	7.8

F/C *ratio*

This is defined as the ratio of the total weights of forage (F) species to carnivorous (C) species. On the basis of their food habits, 10 species were

TABLE II

The food of forage (F) and carnivorous (C) species in Dawhenya Reservoir

Species	Stomach contents
Foragers	
Sarotherodon galilaeus	Diatoms, green algae, blue-green algae, flagellates
Sarotherodon heudeloti	Diatoms, green algae, flagellates
Tilapia zillii	Macrophytes, filamentous algae, diatoms
Heterotis niloticus	Copepods, Nemata, Foraminifera, macrophytes, algae
Marcusenius brachystius	Detritus
Barbus senegalensis	Macrophytes, detritus, algae
Pellonula miri	Copepods, cladocera
Macrobrachium vollenhovenii	Detritus, diatoms, desmids, blue-green algae
M. felicinum	Detritus, diatoms, desmids
M. macrobrachion	Detritus, diatoms, zooplankton
Carnivores	
Clarias senegalensis	*Sarotherodon*, *Tilapia*, shrimp, snails, bivalves, insect larvae
Hemichromis bimaculatus	Insects, fish scales

classified as forage and 2 as carnivorous fishes (Table II). The ratio was estimated as 34.92 (Table III), and is outside the range of 1.4—10.0 observed for balanced populations (Swingle, 1950).

TABLE III

F/C ratio, Y/C ratio and A_T value of fish populations in Dawhenya Reservoir

Total weight of fish (kg)	Weight of F species (kg)	Weight of C species (kg)	Weight of Y group (kg)	Weight of harvestable fish (kg)	$\frac{F}{C}$	$\frac{Y}{C}$	A_T
39.528	38.410	1.100	1.971	20.083	34.92	1.79	50.81

Y/C ratio

This is the ratio of the total weight of all prey-size forage fish (Y) to the total weight of the average-size carnivore (C). Examination of stomach contents of the carnivorous catfish, *Clarias senegalensis*, showed that forage species in the 4-cm group and smaller represented prey-size fish and were therefore in the Y-group. The ratio was estimated to be 1.79 (Table III).

A_T value

This refers to the percentage of the total weight of a fish population composed of individuals which have attained harvestable size. The value in this population was estimated as 50.81 (Table III), which is within the balanced range of 33—100% (Swingle, 1950).

TABLE IV

Length and weight ranges of fish species in Dawhenya Reservoir

Species	N	TL range (cm)	Modal length (cm)	W range (g)
Foragers				
Sarotherodon galilaeus	758	2.7—20.0	6.0	0.3—175.0
S. heudeloti	*	—	—	—
Tilapia zillii	25	4.5—13.4	7.0	1.9— 49.5
Heterotis niloticus	4	26.5—31.0	—	170.9—280.0
Marcusenius brachystius	14	9.7—12.8	11.0	10.6— 20.5
Barbus senegalensis	4	3.9— 5.7	—	0.7— 1.8
Pellonula miri	7	5.1— 6.4	—	0.9— 2.4
Macrobrachium vollenhovenii	222	3.3—11.2	6.0	0.6— 65.0
M. felicinum	*	—	—	—
M. macrobrachion	*	—	—	—
Carnivores				
Clarias senegalensis	21	12.2—28.1	19.0	20.0—160.0
Hemichromis bimaculatus	26	4.3— 9.0	—	3.0— 15.0

N = number of fish; TL = total length; W = body weight. *Less than 4 specimens.

TABLE V

The monthly percentage composition (by weight) of fish in Dawhenya Reservoir[1]

Date		Total weight of fish (kg)	Composition (%)				
			Sarotherodon galilaeus	*Sarotherodon heudeloti*	*Tilapia zillii*	*Heterotis niloticus*	*Clarias senegalensis*
1978	Jan.	75.870	97.03	—	2.02	0.94	—
	Feb.	81.810	99.50	—	0.50	—	—
	Mar.	57.825	99.14	—	0.54	0.31	—
	Apr.	52.965	98.05	0.59	0.85	0.34	0.17
	May	28.270	92.20	0.64	1.27	—	5.89
	June	3.915	77.01	—	—	—	22.99
	July	21.060	93.80	—	1.49	—	4.70
	Aug.	16.290	97.79	—	0.28	—	1.93
	Sep.	21.420	100.00	—	—	—	—
	Oct.	36.765	93.15	—	4.04	0.24	2.57
	Nov.	28.485	93.52	—	6.48	—	—
	Dec.	15.300	82.65	—	17.35	—	—
1979	Jan.	34.200	93.03	—	3.68	1.58	1.71
	Feb.	49.365	93.71	—	—	3.10	3.19
	Mar.	40.230	91.83	—	—	3.02	5.15
	Apr.	23.805	86.39	—	1.89	6.99	4.73
	May	—	—	—	—	—	—
	June	19.620	61.01	—	—	28.67	10.32
	July	35.910	75.44	—	1.25	19.05	4.26
	Aug.	30.330	83.09	—	0.15	16.02	0.74
	Sep.	38.340	86.50	—	0.47	7.16	5.87
	Oct.	27.180	89.74	—	—	1.49	8.77
	Nov.	48.195	94.49	—	—	1.68	3.83
	Dec.	47.590	92.83	—	—	4.63	2.53

[1] Commercial fishery.

Tables IV and V summarize the lengths and weights of fish species and the monthly compositions of species in commercial catches in the reservoir, respectively.

Observations on the biology of the major foragers

Sarotherodon galilaeus

The length—frequency distribution, length—weight relationship, food, fecundity and length at first maturity were studied. The relationship between length and weight (Fig. 1a) is represented by the equation

$$W = 0.0206L^{2.9557} \quad (r = 0.98)$$

where W is the body weight in grams, and L is the total length in centimeters.

The length distribution in 758 specimens (Fig. 1b) showed a modal length in the 6.0—6.9-cm group. The specimens measured 2.7—20.0 cm.

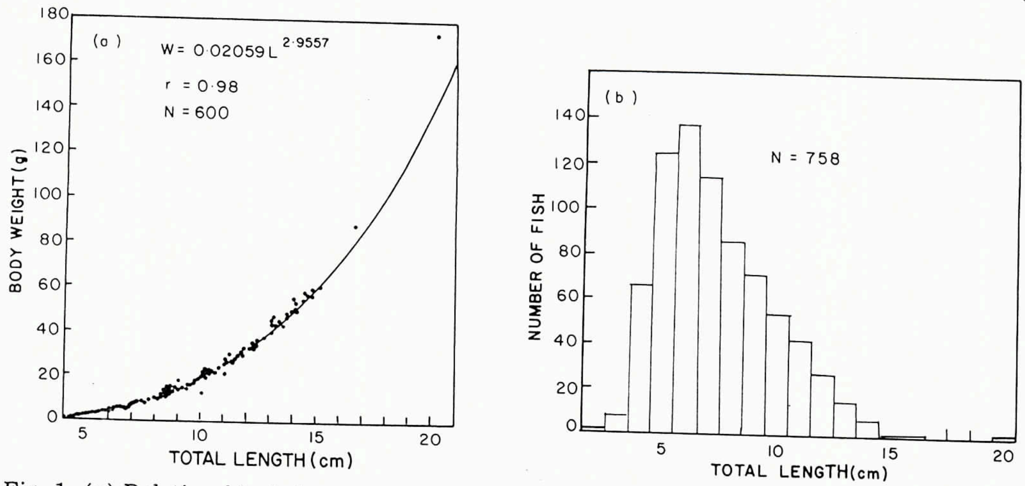

Fig. 1. (a) Relationship between weight and length. (b) Length frequency distribution in *S. galilaeus*. N = number of fish; r = correlation coefficient.

The species fed mainly on planktonic algae and protozoan flagellates. The food organisms and their percentage compositions are illustrated in Fig. 2. The most exploited alga was the diatom *Melosira granulata*, which comprised 62.3% of the total food consumed. *M. granulata* similarly accounted for 65.0% of the total plankton counts in water samples. This might suggest considerable stenophagism for this alga by *S. galilaeus*.

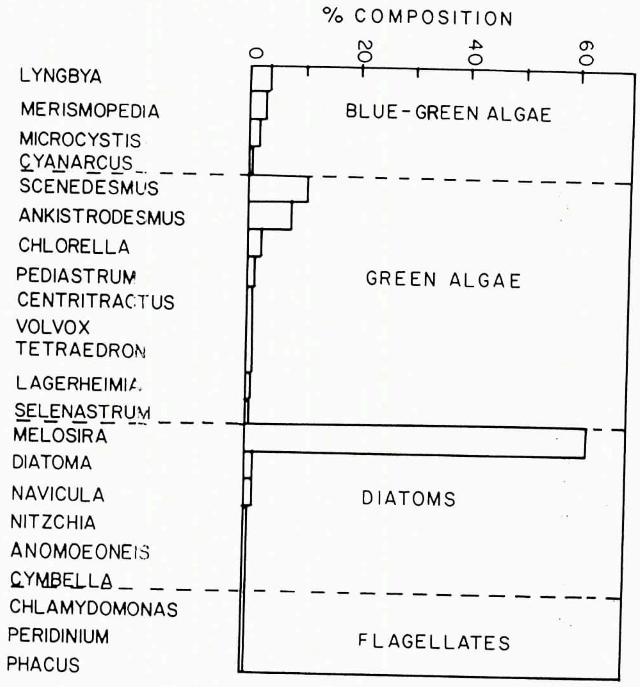

Fig. 2. The percentage composition of food items in the stomachs of *S. galilaeus*.

Fecundity was determined by counting all mature eggs in the ovary. Counts of 143—411 (mean = 247) were made in 32 specimens of lengths from 9.6 to 15.0 cm and weights from 17.1 to 60.0 g. The relationships between fecundity and total length, and fecundity and body weight (Fig. 3a, b) are described by the equations

$$FEC = 47.3265TL - 314.0390$$

and

$$FEC = 5.4136W + 77.9942$$

where FEC is fecundity, TL is total body length in centimeters, and W is the body weight in grams.

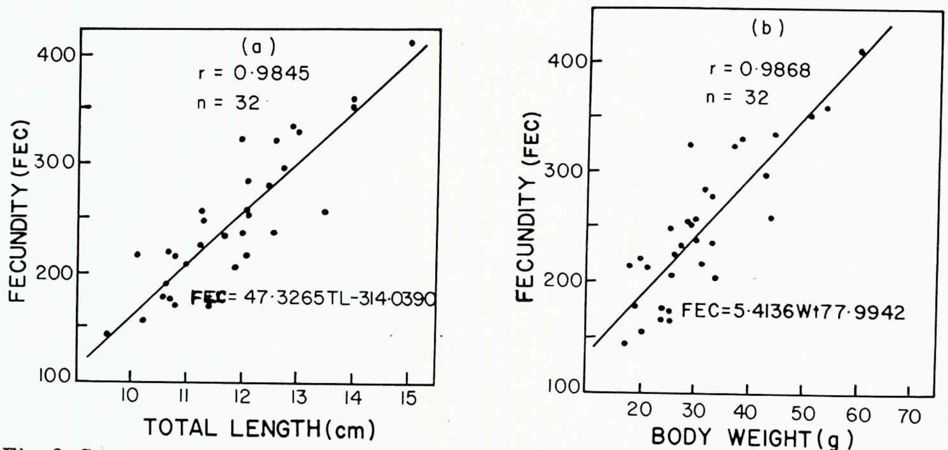

Fig. 3. Scatter diagrams showing relationships between (a) fecundity and total length, and (b) fecundity and body weight in *S. galilaeus*. n = number of fish.

In the males, the smallest mature individual was 9.0 cm, while the majority were mature at 10.5 cm. The smallest mature female measured 9.6 cm, but 50% were mature when they attained a length of 11.5 cm.

Macrobrachium vollenhovenii

Aspects of the biology investigated were the relationship between length and weight, length distribution, maturity size and food habits.

The length—weight relationship in all specimens, including berried females (Fig. 4a), is described by the equation

$$W = 0.0336L^{3.0}$$

where W is the body weight in grams and L is the body length in centimeters.

The modal length of 222 prawns, ranging in length from 3.3 to 11.2 cm, was in the 6.0—6.9-cm group (Fig. 4b). The smallest berried female was 6.2 cm in length, but most were mature at a size of 8.0 cm.

The food organisms found in the stomachs of the prawns were diatoms,

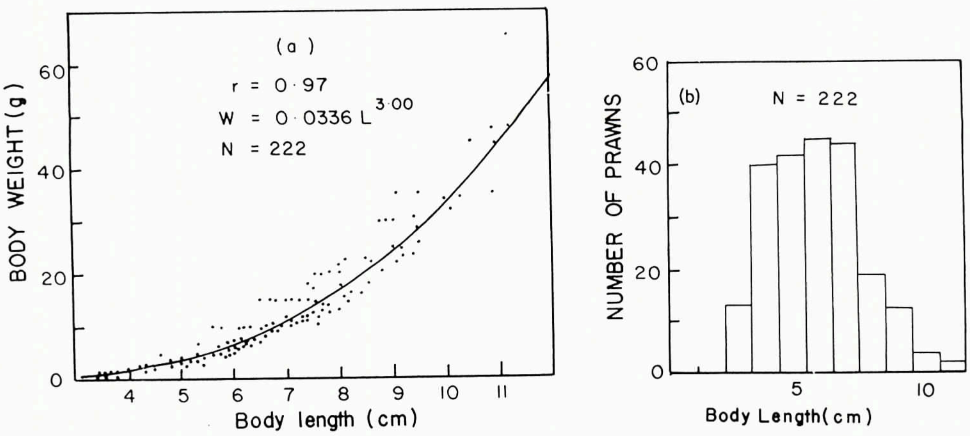

Fig. 4. (a) Relationship between weight and length. (b) Length frequency distribution in *Macrobrachium vollenhovenii*. N = number of prawns.

desmids and blue-green algae, but detritus formed 60% of the total food consumed. The composition of diatoms was as follows: *Melosira granulata*, 15%; *Synedra fasciculata*, 10%; *Diatoma vulgaris*, 2%. The desmids, *Closterium* spp., formed 3% of the food, while blue-green algae had a composition of 10%. The significant representation of detritus in the food of the prawns is probably related to their benthic life.

DISCUSSION

Studies on the fish populations in reservoirs and natural waters to evaluate their balance are of great importance in fishery management practices (Swingle, 1950; Byrd and Moss, 1957; Tang, 1970; Davies, 1973). According to Swingle (1950), fish populations may be balanced or unbalanced depending on whether they are capable of producing yearly harvestable crops or not. Earlier investigations, using the F/C and Y/C ratios, the A_T value and other relationships in estimating the balance between fish populations, were carried out in the United States of America and China (Swingle, 1950, 1954; Swingle and Swingle, 1967; Hayne et al., 1967; Tang, 1970).

In Dawhenya Reservoir, the species representation of fish shows that foragers are more abundant than carnivores. Although forage fish are represented by 10 species, the cichlid, *Sarotherodon galilaeus*, and to a lesser extent the palaemonid prawn, *Macrobrachium vollenhovenii*, were the most significant, as suggested by their respective E values. The E value of a species is influenced by its reproductive potential, food habits, growth and adaptation to the environment (Swingle, 1950). The very high E value (88.2%) observed in *S. galilaeus* suggests that it has the ability to maintain a high abundance under the prevailing conditions in the lake. This may be the result of its high reproductive capacity. *Sarotherodon* and *Tilapia* species are known to be protracted breeders, spawning about 3—4 times a year (Fryer and Iles, 1972; Payne, 1975). This index, however, is of significance only if a large proportion of surviving individuals attain harvestable size yearly (Swingle, 1950).

The A_T value which deals with the percentage of the fish population composed of harvestable individuals was estimated to be 50.81, suggesting a balanced population. The index in this study may have been over-estimated because the minimum harvestable size of fish and prawns were based on the size at which they first mature. If this index was determined on the basis of the size at which 50% of the fish and prawns mature, it would be less than the estimated value of 50.81. This is because there would be fewer numbers and reduced total weights of fish considered to be harvestable. As a result of their high *E* values in the population, *S. galilaeus* and *M. vollenhovenii* were largely responsible for the observed A_T value. Their respective maturity sizes were 10.5 and 8.0 cm. *S. galilaeus* has been reported to mature at 19.8 cm (Petr, 1968) and 18.0 cm (Iles and Holden, 1969) in some water bodies. The variations in maturity size in the different habitats is attributed to the prevailing environmental conditions, and hence ecologically determined. Although *M. vollenhovenii* in Dawhenya Reservoir matured about 2.0 cm longer than the economically exploited specimens in Liberia (Miller, 1971), its modal and maximum lengths were smaller, and only 34% of the sample could be considered harvestable.

It can therefore be inferred that the high *E* values of *S. galilaeus* and *M. vollenhovenii* do not reflect their true importance in the fishery, as their lengths do not suggest economic sizes. In the Volta Lake in Ghana, marketable sizes of *S. galilaeus* range from about 19.0 to 34.0 cm (Lelek and Wuddah, 1968). In spite of their small lengths (mode 6.0—6.9 cm; maximum length 20.0 cm), this fish is the mainstay of the fishery in Dawhenya Reservoir, with a monthly composition of 61—100% of the total catch of local fishermen (Table V).

The F/C ratio of 34.92 suggests an unbalanced fish population in the reservoir, probably due to low predation by the existing carnivorous fishes. This could lead to overcrowding by forage fish and stunted growth. This assumption is illustrated by *S. galilaeus*, which comprised 88.2% of the fish population by weight. Stunting is a common phenomenon in *Tilapia* and *Sarotherodon* species, in which they attain sexual maturity at a smaller size when overcrowded in small environments (Hickling, 1962; Fryer and Iles, 1972; Eyeson, 1983), but mature at a larger size in larger water bodies. The maturity sizes of *S. galilaeus* in the reservoir are similar to those attained by specimens in captivity without intensive management (Iles and Holden, 1969; Blay, 1981).

Underpredation of forage species by the carnivorous fishes, *Clarias senegalensis* and *Hemichromis bimaculatus*, may be due to the occurrence of alternative food sources. The former do not feed exclusively on forage fish, but also on small gastropods (*Gyraulus* sp.), bivalves and insect larvae. Although fish scales were occasionally observed in stomachs of the latter, the small sizes of this fish (4.3—9.0 cm) might suggest its ineffectiveness as a predator in the lake. It is also possible that low predation by these carnivores was the result of their low E values, which rendered any predation on forage fish insignificant.

The ratio of the weights of prey-size to carnivorous fish (Y/C ratio) occurred in the range (1.0—3.0), which is observed to be the best for balanced populations (Swingle, 1950), although in some instances, a ratio in the range 0.06—3.0 depicts unbalanced populations because of the presence of large weights of stunted forage fishes due to underpredation. As shown earlier, the F/C ratio indicates low predation by carnivorous fishes on foragers, and this might therefore be the paramount reason for overcrowding in forage fishes.

It would appear from the foregoing that the fish populations in Dawhenya Reservoir are in an unbalanced condition and corrective measures might be necessary to effect an improvement in the fish yields. The F/C ratio could be reduced to the desired range of 3.0—6.0 (Swingle, 1950) to establish the best balance between forage and carnivorous fish in mixed populations. This may be achieved through intensive manual cropping of forage fish, mainly *S. galilaeus*, or by controlling their reproduction through the introduction of suitable sizes and biomass of the existing carnivores. In view of the current observations on the role of the existing carnivores, the introduction of more voracious carnivores such as *Lates niloticus*, *Hydrocynus* spp., *Hepsetus odoe* and *Hemichromis fasciatus*, either singly or in combination, may be considered for the control of populations of *S. galilaeus*.

SUMMARY

The condition of balance in the fish populations of Dawhenya Reservoir in Ghana has been investigated. Ten forage species and 2 carnivores were recognised on the basis of their food habits. *Sarotherodon galilaeus*, and to a lesser extent, *Macrobrachium vollenhovenii*, were the best represented groups, as evidenced by their respective percentage compositions in the total fish biomass. The carnivorous catfish, *Clarias senegalensis*, and the cichlid, *Hemichromis bimaculatus*, were less important. The F/C and Y/C ratios, and the A_T value were the indices used to determine the state of balance between the fish species. Underpredation, overcrowding, and stunted growth in forage fish, exemplified by *S. galilaeus*, seem the most plausible reasons for the unbalanced condition observed in the populations. Aspects of the biology of the principal forage fishes necessary for explaining their roles in the level of balance of the fish populations were studied. Suggestions have been made on methods for improving the balance in the populations.

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