

The utilization of terrestrial plants as a food source by the fish stock of a gently sloping marginal zone in Plover Cove Reservoir, Hong Kong

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Synopsis

A study of the feeding habits of the fish stock of a gently sloping marginal zone of Plover Cove Reservoir, Hong Kong, has been carried out. Analysis of the stomach contents of five species of fish revealed that, after a rise in water level which led to the inundation of considerable quantities of terrestrial vegetation, such plants were the major dietary item of the animals collected. This finding was consistent whether the points, occurrence or dominance methods of gut content analysis were used. Additionally, statistical analysis of these data strongly suggested that the fish migrated into the marginal zone to feed upon the flooded material thus raising the possibility that these animals are normally food limited. A discussion of the findings of this study indicated that the fish in Plover Cove Reservoir played an important role as agents of transmission and conversion of the input of allochthonous carbon compounds from the surrounding terrestrial environment.

Introduction

During 1977 and early 1978 a prolonged drought caused water levels in Plover Cove Reservoir (Hong Kong) to fall with the result that, on many areas of the exposed shoreline and particularly in sheltered coves, terrestrial vegetation sprouted and flourished. This phenomenon has been recorded elsewhere, both in tropical and temperate regions (MacLachlan 1974, Baxter 1978). The main species involved in Hong Kong were sedges (*Fimbristylis* spp.) and certain Polygonaceae, but grasses such as *Echinochloa* sp. were important in localities where the substrate was relatively dry. In some parts of the exposed marginal zone standing stocks of up to 124.26 g dry weight metre^{-2} were recorded. In early May 1978 the onset of monsoon rains caused a rise

in reservoir water levels and the terrestrial plants were flooded, inundation of the previously exposed marginal zone being complete by mid-June. The subsequent disappearance of these plants was extremely rapid with biomass dropping to less than 10 per cent of the pre-inundation levels in three weeks. The remaining portions of the plants were high in ash and low in organic material. Detailed accounts of these changes as well as the physical and chemical characteristics of the study area are in preparation.

The rate of disappearance of the inundated terrestrial macrophytes was considerably greater than recorded rates of breakdown of allochthonous leaf litter in temperate streams (e.g. Kaushik & Hynes 1971, Peterson & Cummins 1974, Blackburn & Petr 1979), where invertebrate shredders (sensu Cummins 1973) interact with other invertebrates and microorganisms in processing this energy

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source. However, as such invertebrate consumers are largely absent from Plover Cove Reservoir other explanations for the rapid disappearance of the inundated macrophytes were sought.

The possibility that freshwater fish may ingest significant quantities of allochthonous plant material has been investigated by a number of workers. While strictly carnivorous taxa may consume no detritus, estimates for other species range from slightly over half (Berner 1951) to almost the entire diet (Knöppel 1970, Bowen 1979) comprising such material. These studies were carried out in widely separated geographical regions including North America, Africa and the Amazon thus indicating the cosmopolitan nature of the phenomenon. Indeed, many taxa in the Amazon are nutritionally dependent upon allochthonous detritus (Fittkau & Klinge 1973). Further evidence for the importance of detritus as fish food comes from investigations of the River Thames in England (Mann 1965). With these studies in mind an attempt was made to assess the importance of terrestrial plants in the diet of fish inhabiting an area of the recently flooded marginal zone of Plover Cove Reservoir. It was considered that extensive consumption of such material by the large fish stock of this habitat (Man & Hodgkiss 1977a) might explain the rapid decline in plant biomass observed soon after inundation of the previously exposed shoreline.

Methods

In order to assess the importance of terrestrial plants in the marginal zone as a food for the fish stocks of the reservoir a sample of fish was collected from a newly inundated area of the habitat in early June 1978. A fine meshed gill net was stretched along the lower boundary of the newly flooded region and fish driven from the shoreward side into the net with the aid of a rowing boat. The catch was immediately packed in ice and on return to the laboratory the fish were identified, measured, and the intestinal system of each animal dissected out and placed in 10% neutral formalin. The analysis of stomach or foregut contents (in species where the stomach region is not clearly defined) was carried

out using a stereomicroscope and followed the points, occurrence and dominance methods discussed by Hynes (1950). According to his recommendations the use of points, assigned to each fish on the basis of 'stomach' fullness, was emphasized. The contents of the 'stomach' were allotted points according to their occurrence by volume; a full 'stomach' was assigned 20 points and a maximally distended one 30 points. The dominance method was used to indicate the percentage of animals caught with a given food category as the dominant item in the 'stomach'. The occurrence method simply noted the percentage of fish of each species with a certain type of food in the 'stomach' contents. To facilitate comparison between species and individuals the points were converted to percentages of the total points after analysis was carried out. This aided comparisons of results from fish with half-full, full and distended 'stomachs'.

Results

Five species of fish were collected, i.e. *Carassius auratus* (L.), *Hemiculter bleekeri* Warpachowsky, *Culter erythropterus* Basilewsky, *Cirrhinia molitorella* (Cuv. and Val.) (Cyprinidae) and *Sarotherodon mossambicus* (Peters) (Cichlidae), and analysed for stomach contents (Table 1). In all of the species studied terrestrial macrophytes were present in at least 67% of the individuals examined, and in all but one of these species (the predatory carp *Culter erythropterus*) over 60% of the fish collected had this foodstuff as the dominant component of the 'stomach' contents. In the case of *Sarotherodon mossambicus* all of the fish examined had terrestrial macrophytes as the dominant food material. On the basis of points assessment terrestrial plant material was the single most important food category in all five species of fish examined.

Discussion

During the extremely rapid reduction in terrestrial plant biomass after inundation of the previously exposed marginal zone of Plover Cove Reservoir,

Table 1. Table showing the occurrence of different food materials in the 'stomach' contents of fish collected from a recently inundated portion of a gently sloping marginal zone of Plover Cove Reservoir, Hong Kong, as analysed by three different procedures. P = points method, O = occurrence method, D = dominance method.

Species	<i>Carassius auratus</i>			<i>Hemiculter bleekeri</i>			<i>Culter erythropterus</i>			<i>Sarotherodon mossambicus</i>			<i>Cirrhina molitorella</i>		
No. of fish	6			10			3			7			25		
Size range (mm)	160–190			110–170			180–260			110–150			135–160		
Method of assessment	P	O	D	P	O	D	P	O	D	P	O	D	P	O	D
Terrestrial vegetation	53.0	83.3	66.7	48.8	80	60	67	67	33	62.3	100	100	58.0	100	80
Seeds from terrestrial vegetation	26.5	66.7	16.7										0.9	4	0
Aquatic macrophytes (<i>Vallisneria</i>)				28.1	20	20				1.8	14.3				
Algae				4.9	60	0				3.5	28.6	0	0.6	8	0
Detritus	23.5	83.3	0	9.1	100	0	3	33	0	27.2	100	0	29.0	100	20
Sand + mud										5.2	28.6	0	11.6	72	0
Animal material							30	100	67						
Terrestrial insects				9.1	30	20									
% of fish with empty stomachs	16.67	16.67	16.67	0	0	0	0	0	0	0	0	0	0	0	0
Average no. points per fish	11.67			16.4			11.3			16.3			14.0		
Average no. points per fish excluding those with empty stomachs	14.0			16.4			11.3			16.3			14.0		

it was found that terrestrial macrophytes were the most important item in fish 'stomach' contents. In those species which were most abundant in the catch (*Cirrhina molitorella* and *Sarotherodon mossambicus*) it was the major food item. This observation is of some importance as *S. mossambicus* is the dominant fish in the Plover Cove community (Man & Hodgkiss 1977a). The significance of terrestrial macrophytes to the reservoir fishes as a whole is not known but it has been suggested that these animals are food limited (I.J. Hodgkiss, personal communication), and this is supported by the deteriorating condition of *S. mossambicus* in Plover Cove over the period 1972–1973 (Hodgkiss & Mann 1977). Such a change may be due to the general decrease in productivity observed during the post-filling stage of many man-made lakes (McLachlan 1974). The suggestion that terrestrial plants may be a valuable food source in Plover Cove is supported by an earlier study on the diet of *S. mossambicus* (Man & Hodgkiss 1977b) in

which 'vascular plants' were found in considerable quantities in the foreguts of fish collected during the months of July and August 1973, just after a rise in water level. These findings acquire additional significance in the light of reports that certain species of freshwater fishes (especially Cyprinidae) possess enzymes capable of breaking down cellulose (Prejs & Blaszczyk 1977) thus allowing these animals to assimilate more of this kind of material than was previously thought possible. It will be apparent therefore that during the summer months flooding of terrestrial plants caused by rising water levels makes available to the reservoir fishes a significant quantity of food material, the actual amount depending on the duration and extent of the winter (dry season) fall in water level. This seasonal input comes at a time when the fish are feeding heavily since Man & Hodgkiss (1977b) have shown that, within the range experienced in Plover Cove Reservoir, feeding and digestive activities in *S. mossambicus* are positively related to temperature.

Stems and leaves, as well as seeds, of the flooded terrestrial plants were found in the 'stomachs' of the fishes examined and, in view of the absence of soft-bodied insects as a source of food in Plover Cove (Dudgeon, personal observations) and the relative unpalatability (Man & Hodgkiss 1977b) of the large stocks of benthic molluscs in the reservoir, it is probable the seasonal input of terrestrial plants represents an important source of food for *S. mossambicus* as well as *C. molitorella*. Diatoms (Bowen 1978), blue-green algae (Moriarty 1973), bacteria (Bowen 1976) and detritus (Bowen 1979, 1980, 1981) have been recorded as important components of the diet of *S. mossambicus* and related species. The findings of Man & Hodgkiss (1977b) indicate that they are of importance in the diet of *S. mossambicus* (and possibly *C. molitorella*) in the absence of terrestrial macrophytes.

While obtaining specimens from the flooded marginal zone in this study, the nets were aligned so that fishes entering and leaving the area were captured and thus both groups of animals were represented in the resultant collection. Assuming that terrestrial plants were an important food source for the reservoir fishes, then those animals entering the study area would have partially or completely empty 'stomachs' containing little or no allochthonous material. Obviously, inclusion of findings from the analysis of the 'stomach' contents of such animals with those from actively feeding fish would lead to an underestimate of the importance of terrestrial vegetation as a source of food. In order to determine whether those fish which had been feeding actively had, in fact, been consuming terrestrial plants, the fullness of the 'stomach' in the animals captured was plotted against the percentage (by volume) of the stomach contents made up by terrestrial macrophytes (Fig. 1). A significant positive correlation between these two variables was noted ($P < 0.05$) indicating that at low levels of 'stomach' fullness terrestrial plants were the missing food category, thus providing strong evidence for the extensive utilization of this material by fish feeding in the marginal zone of Plover Cove Reservoir. Additionally this relationship implies that fish migrate into the marginal zone in the summer months to feed and, on the basis of

the low levels of 'stomach' fullness observed in individuals which had consumed little or no terrestrial plant material, this contribution from the terrestrial environment is clearly of some importance. Such movements into areas of available resources have also been reported for fish populations in a North American lake (Gascon & Legett 1977).

The importance of flooding of terrestrial material in other man-made lakes is indicated by the work of Donnelly (1969) who considers that shore areas of man-made lakes may serve as important nursery areas for small fish. In natural systems, it is known that fish migrate into flooded areas of the igapo forests during the high water season in Amazonia, and certain parts of the inundated vegetation are sought after by specialized species of fish (Sioli 1975). In central Africa a variety of species in the Kafue and Zambezi River system spawn during the rainy season in newly flooded flat areas (Kapetsky 1974). Lowe-McConnell (1979) states that the high-water season is the main feeding and growing time for many tropical riverine fishes which then lay down fat stores to last through the ensuing dry season when they have to retreat to the main rivers where there is little food.

Relating the findings of the present study to the ecology of Plover Cove as a whole, the consumption of terrestrial plants by reservoir fishes represents a transfer of material from the terrestrial to

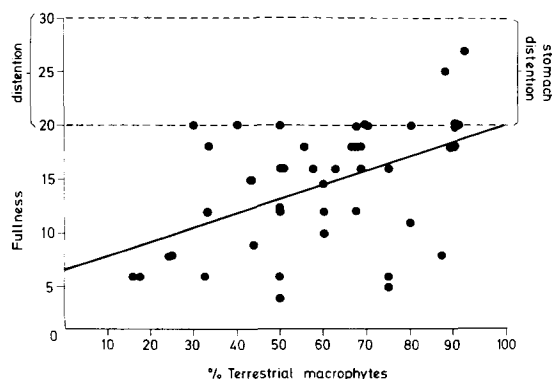


Fig. 1. Graph showing the relationship between the fullness of the 'stomach' and the percentage of terrestrial macrophytes in the food intake of five species of fish collected from a recently inundated portion of a gently sloping marginal zone of Plover Cove Reservoir, Hong Kong.

the aquatic environment. Similar processes are recorded by McLachlan (1974) in tropical African man-made lakes. The macrophyte-derived faeces of the fish may serve as a food source for benthic macroinvertebrates in Plover Cove and their deposition in the reservoir (possibly far from the feeding site) possibly represents a 'sharing' of the allochthonous energy source between the marginal zone and the rest of the aquatic habitat.

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