that Rb would be used to mark long-lived clams in culture because of the rapid decline in detectable amounts of Rb, but Rb might well be used over shorter time periods before body burden of Rb levels off. Substituting similar non-radioactive trace elements for Rb, these basic techniques for labelling clams could be used to trace energy flow in clam culture systems.

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MOLLUSKS AS PREY OF ARIID CATFISH IN THE FLY RIVER

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Reasons for the examination of the contents of fish stomachs have varied over the years and with the interests of the people involved. In the early 1800's, fish stomachs were a common source of deep-water marine mollusks not easily obtained by other means at that time. Commercial fishermen were encouraged to save stomachs when they gutted their fish at sea and the boats were eagerly met as they came into port. The literature of that period often records decriptions of new species with the type locality given as the stomach of a fish caught off Gloucester or some other point.

In recent years there has been considerable interest in the feeding habits of fish, including those found in freshwater. This is evidenced, for example, in the fish section of the Zoological Record for 1971, which references 74 authors under the heading *Mollusks as food* and covers 53 families of which 27 are either anadromous or freshwater. Though many papers have been published on the biology and feeding of freshwater fish, few do more than mention the relative importance of mollusks as food or, at best, identify the mollusk to genus. Bottom feeding freshwater fish such as the ariid catfish are an excellent source of mollusks and often allow one to obtain material from large rivers which otherwise would be difficult to collect. For example, the most abundant fish in the mainstream rapids of the lower Congo (now Zaire) River, is the cichlid *Steatocranus gibbiceps* Boulenger 1889 which feeds mainly on the small gastropods clinging to the rocks. It ingests the little-known assimineid *Septariellina congolensis* Bequaert and

Clench without crushing them so that perfect specimens may be taken from their stomachs. Both the fish and the mollusk are endemic to these rapids (Bequaert and Clench, 1936; Roberts and Stewart 1976). In the introduction to their paper on the rheophilous mollusks of the channel, Bequaert and Clench stated that:

1) the Congo River between Matadi and Boma courses through the narrow rocky channel at speeds ranging from 5 kilometers (low water) to 20 kilometers (high water) per hour; 2) the 6 species of snails found were all collected in February when the river was at its lowest; 3) "not withstanding this favorable circumstance, the search for minute snails, with hand-lens in bright sunlight, on the moist surface of rocks, was most tedious and not without danger. Of the six species of snails, three were taken in single specimens only." and 4) "it may therefore be safely predicted that many other unusual finds await the skill and efforts of the malacologist in the Matadi-Boma channel of the Congo." It is obvious that fish adapted to feed on these snails have a much easier time collecting and are a good source of specimens.

Species of the pangasiid catfish genus *Helicophagus* Bleeker 1858 inhabit the large rivers of Thailand and Sumatra, and, according to Smith (1945), the genus is well named. He reported that, though his specimens were collected at different places and different times, they all "had entire shells of small univalves in their stomachs." Unfortunately, the snails were not identified.

The present paper, concerned with the molluscan prey of the ariid catfish *Cinetodus froggatti* (Ramsay and Ogilby 1887) in the Fly River, New Guinea, demonstrates the value of collaboration between ichthyologists and malacologists. *Cinetodus* is a monotypic genus endemic to the rivers of southern central New Guinea. *Cinetodus froggatti* (Plate 1) occurs in the lowland riverine habitats of the upper, middle and lower Fly River (Plate 2) and has also been taken in the Kikori River (Kailola, 1975). Its feeding habits were unknown until Roberts collected a total of 16 specimens during an ichthyological survey of the Fly River in 1975 (Roberts, in press).

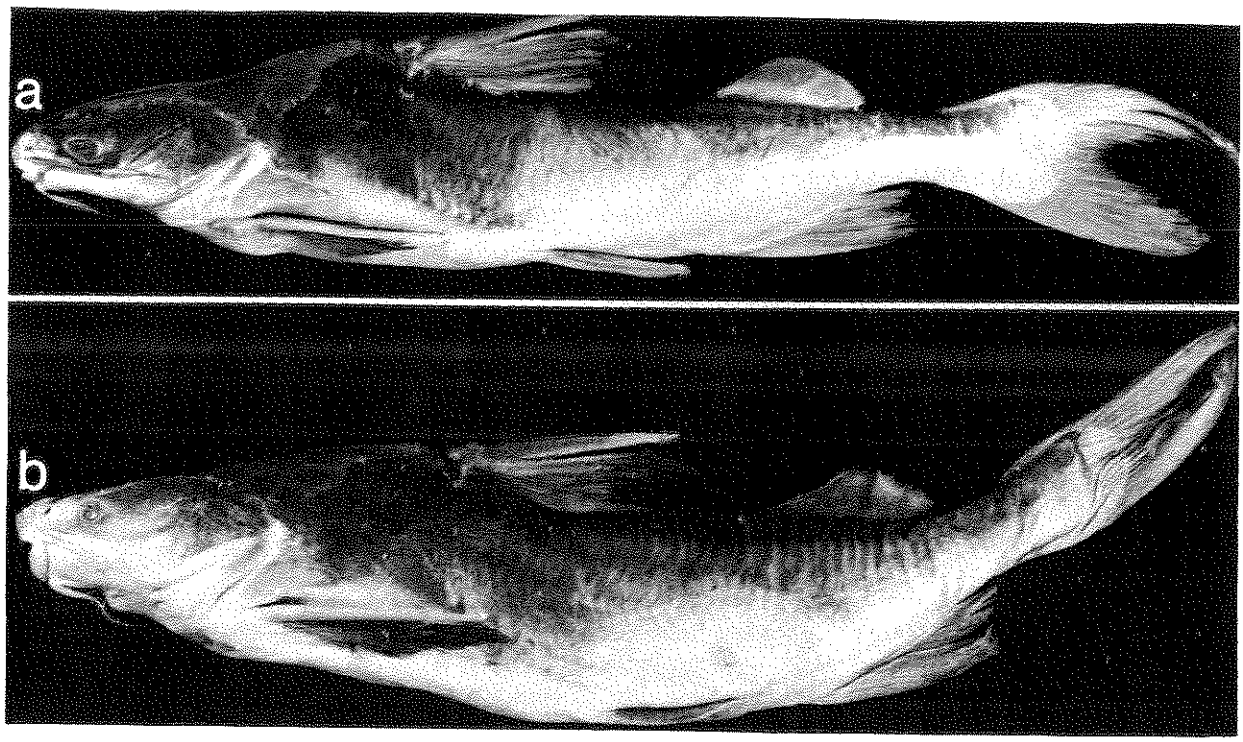

Plate 1. Cinetodus froggatti, Fly River station 26, USNM 217080. a: with normally developed lips and barbels (standard length 350 mm); b: with thickened lips and barbels (standard length 320 mm). (from Roberts, in press).

TABLE 1
Species of Mollusks taken from
the stomachs of *Cinetodus froggatti*

	Station	No. of Specimens	Plate	fig.
Gastropoda				
Family Neritidae Lamarck 1816				
Nentodryas simplex (Schepman 1919)	1	3	3	1-3
	26	1		
Family Viviparidae Gray 1847				
Bellamya decipiens (Tapparone-Canefri 1883)	6	12	3	6-9
	25	1		
	26	1		
Larina sp.?	1	6	3	10-13
	20	+40		
Family Hydrobiidae Troschel 1857				
Clenchiella sentaniensis Jutting 1963	26	28	3	4-5
Family Bithyniidae Walker 1927				
Gabbia lacustris Jutting 1963	1	13	3	14-16
	26	14		
Family Assimineidae H. & A. Adams 1858				
Acmella parvicostata Jutting 1963	25	1	5	5
Family Thiaridae Gray 1847				
Thiara scabra (Muller 1774)	20	13	4	11-17
	25	1		
Melanoides flyensis (Tapparone-Canefri 1883)	1	6	4	6-8
	25	+35		
Melanoides tuberculatum (Muller 1774)	1	+60	4	1-5
Tarebia granifera (Lamarck 1822)	1	1	4	18-19
Family Planorbidae Rafinesque 1815				
Amerianna carinata (H. Adams 1861)	26	9	5	4
Physastra vestita (Tapparone-Cenfri 1883)	26	7	3	17-18
Hippeutis (Helicorbis) umbilicalis (Benson 1836)	26	2	5	1-3
Bivalvia				
Family Erodonidae Winckworth 1932				
Erodona sp.	26	26 valves	6	1-6

TABLE 2 - STATION DATA

Data are from Tyson Roberts' field notes. Station numbers (e.g. Fly 75-1) are those used for the fish collection, the 75 indicating the year of collection. We used only the last numbers on the map (Plate 2).

Fly 75- 1. Date: Oct. 1975.
Fish: *Cinetodus froggatti*, [USNM 217078].
Mollusks: *Neritodryas simplex, Larina* sp., *Gabbia lacustris, Melanoides flyensis, M. tuberculatus, Tarebia granifera.*
Location: Mainstream of Upper Fly River near Kiunga, 828 km. upriver from mouth of Fly, 6°07.7'S, 141°17.0'E. Water temp: 25.0-25.5°C; pH 7.1-7.4 on November 15, 1975.

Fly 75- 6. Date: Oct. 1975.
Fish: *C. froggatti.* [not preserved]
Mollusks: *Bellamya decipiens.*
Location: Ox-bow lake from mainstream of Fly River 3 km downstream from Kiunga.

Fly 75-17. Date: Nov. 23, 1975.
Fish: *C. froggatti* [USNM 217079]. 2:330-391 mm.
Mollusks: None – stomach empty.
Location: Mouth of Binge River, a large strongly flowing tributary of the Middle Fly, 675 km upriver from mouth of Fly, 6°32.5'S, 140°55.0'E.

Fly 75-20. Date: Nov. 27, 1975.
Fish: *C. froggatti.* [not preserved]
Mollusks: *Larina* sp., *Thiara scabra.*
Location: Mainstream of Middle Fly River near Boset, 509-512 km upriver from mouth of Fly, 7°14.0'S, 141°08.3'E.

Fly 75-25. Date: Dec. 6-7, 1975.
Fish: *C. froggatti.* [not preserved]
Mollusks: *Bellamya decipiens, Acmella parvicostata, Thiara scabra, Melanoides flyensis.*
Location: Grassy side channel and mainstream of Strickland River 2-3 miles downstream from Massey Bakers junction (junction with Herbert R.).

Fly 75-26. Date: Dec. 8, 1975.
Fish: *C. froggatti.* [USNM 217080]. 10:230-367 mm.
Mollusks: *Neritodryas simplex, Bellamya decipiens, Clenchiella sentaniensis, Gabbia lacustris. Americanna carinata, Physastra vestita, Hippeutis (Helicorbis) umbilcalis, Erodona* sp.
Location: Mainstream of Lower Fly River near Elangowan Island, 298 km upriver from mouth of Fly (about 50 km above uppermost influence of tides), 7°49.4'S, 141°39.0'E.

Fly 75-29. Date: Dec. 12, 1975.
Fish: *C. froggatti* [USNM 217081]. 1:423 mm.
Mollusks: None. Gut filled with mud.
Location: Lower 5 km of Burei Creek, a large tributary of the Lower Fly, 206-211 km upriver from mouth of Fly. 8°11.8'S, 142°00.7'E. Water clear, reddish brown.

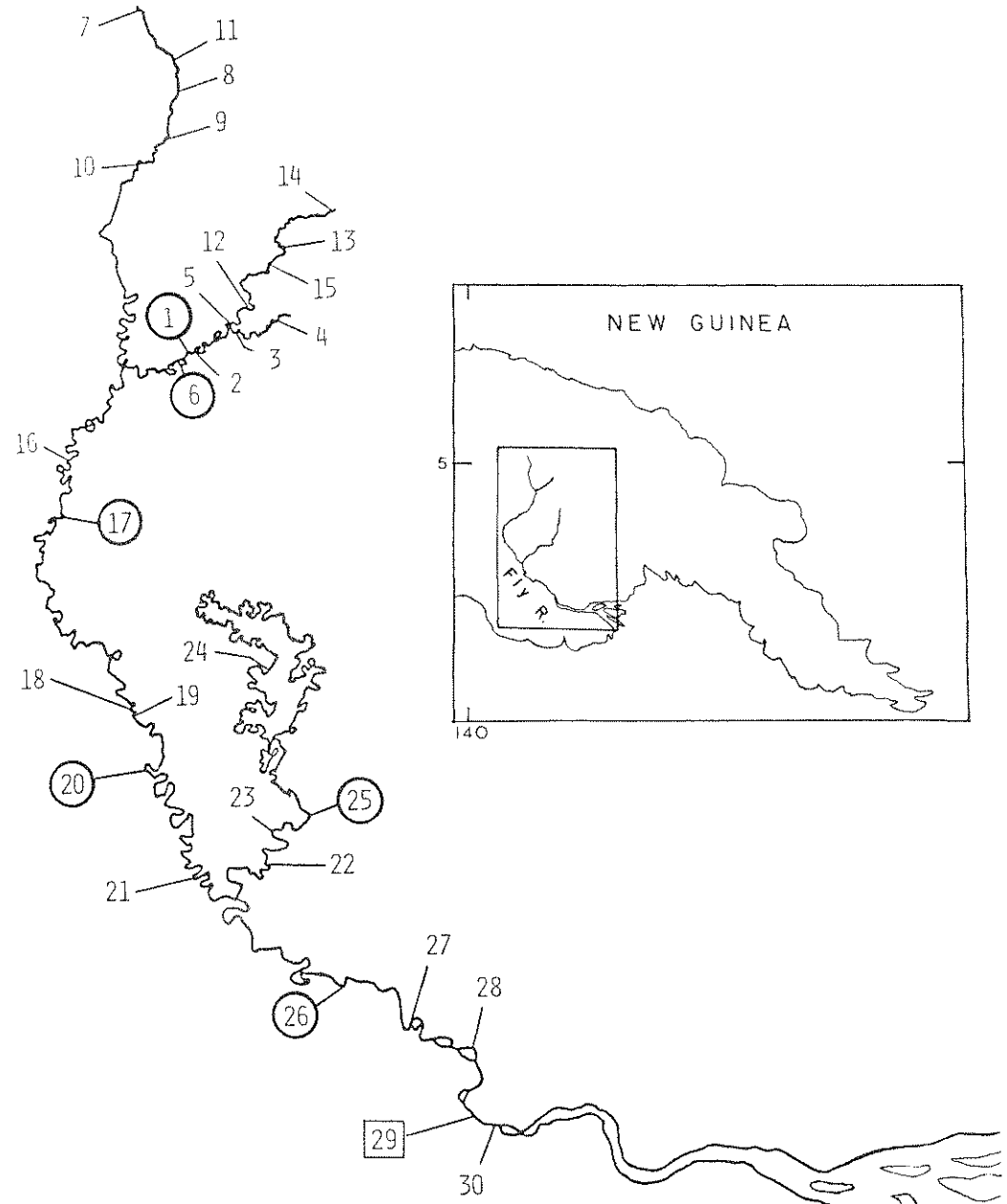

Plate 2. Map of Fly River, New Guinea; inset showing its location in New Guinea. The numbers are the collecting stations of Tyson Roberts. Those in circles indicate stations at which *Cinetodus froggatti* containing mollusks were collected. The number in a square indicates *Cinetodus* with mud-filled stomach (after Roberts, in press).

The contents of the digestive tracts of all specimens were examined and preserved, most of them while still in the field. Thirteen specimens had ingested numerous shelled mollusks, the shells of which were still intact, but little or no substrate; the guts of two were empty; and one, from station 29, had the stomach and anterior portion of the intestine filled with a thick, silty mud, devoid of macroscopic organic material. No other food items were observed.

Cinetodus froggatti apparently feed only on mollusks. However, as all collections were made from October through December, it is possible that at other seasons their diet could vary. The only other Fly River catfish feeding heavily on mollusks is the plotosid *Tandanus ater*. Unlike *Cinetodus* it crushes the shells it ingests and also feeds on insects, prawns and worms.

Cinetodus froggatti are typically found in the mainstream and large tributaries of the Fly River where there is a moderate to strong current, muddy bottom and a shoreline densely vegetated with grasses and other aquatic or semi-aquatic macrophytes. This was not true at station 29, on lower Burei Creek, the only site where the specimen's stomach was full of mud; here vegetation was lacking and the water was clear and reddish brown. Station 26 was 298 km from the mouth of the Fly River and about 50 km above the uppermost influence of the tides. At station 1, on November 15, the water temperature was 25.0 - 25.5° C and the pH 7.1 - 7.4. Reference should be made to Roberts (in press) for further ichthyological and ecological data on the Fly River.

Cinetodus froggatti is a small-mouthed ariid, distinguished from all other members of the family in having the ventral portion of the gill membranes broadly joined to a flat, broad isthmus, so that the gill openings are restricted to the sides of the head, possibly an adaptation to its diet. The gill rakers, gill arches, and pharyngeal folds or valves seem to be morphologically generalized, without evident specializations for malacophagy, though the shape of the oral tooth bands is very distinctive (Roberts, in press). All but one of the *C. forggatti* collected have rather thin lips and barbels (Plate 1, Fig. a). However, a 320 mm specimen from station 26 has the entire lips and basal portions of the chin barbels markedly thickened and all of the barbels slightly shortened (Plate 1, Fig. b). In all other characters it agrees with typical *C. froggatti*. It is noteworthy that this was the only specimen which had bivalves in its stomach, and it apparently fed exclusively on this bivalve (Plate 6).

Fourteen species of mollusks representing 13 genera in 8 families were obtained from the fish and of these 8 were found at Station 26. The single species of bivalve belongs in the Erodonidae, genus *Erodona* Bose 1801. Though erodonids are rare in collections, the single, thick-lipped specimen of *froggatti* from Station 26 apparently had no trouble collecting them. It is possible that this small *Mya*-like bivalve is common in the muddy bottom of large deep rivers. Erodonids, so far as known, are brackish water bivalves. Their presence at Station 26, which is said to be 50 km above the influence of the tides, may be accounted for by the fact that: 1) there is a salt water creep on the bottom, 2) this is a new species of freshwater erodonid, or 3) the fish had fed further down stream. The largest gastropod re-

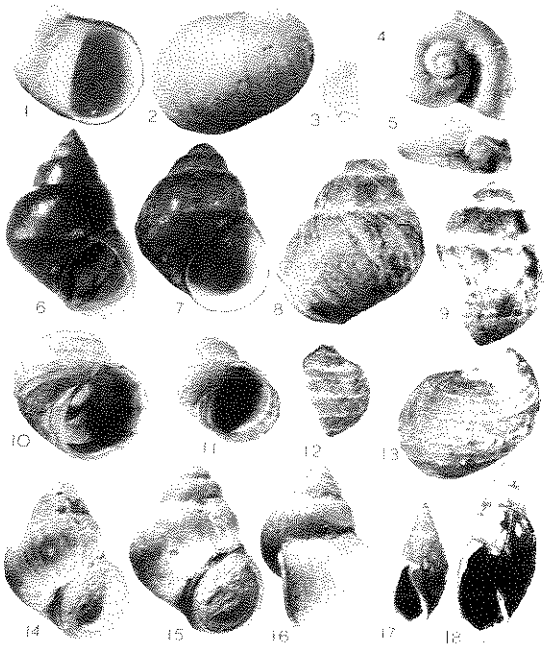

Plate 3. Figs. 1-3: Neritodryas simples (Schepman). Sta. 1, (5X). *Figs. 4-5: Clenchiella sentaniensis* Jutting. Sta. 26, (12X). *Fig. 6: Bellamya decipiens* (Tapparone-Canefri). Sta. 25 (2X). *Figs. 7-9: Bellamya decipiens* (Tapparone-Canefri). Sta. 6, (2X). *Figs. 10-13: Larina* ? sp. Sta. 20, (3X). *Fig. 14. Gabbia lacustris* Jutting. Sta. 26, (10X). *Figs. 15-16 Gabbia lacustris* Jutting. Sta. 1, (10X). *Figs. 17-18 Physastra vestita* (Tapparone-Canefri). Sta. 26 (2X).

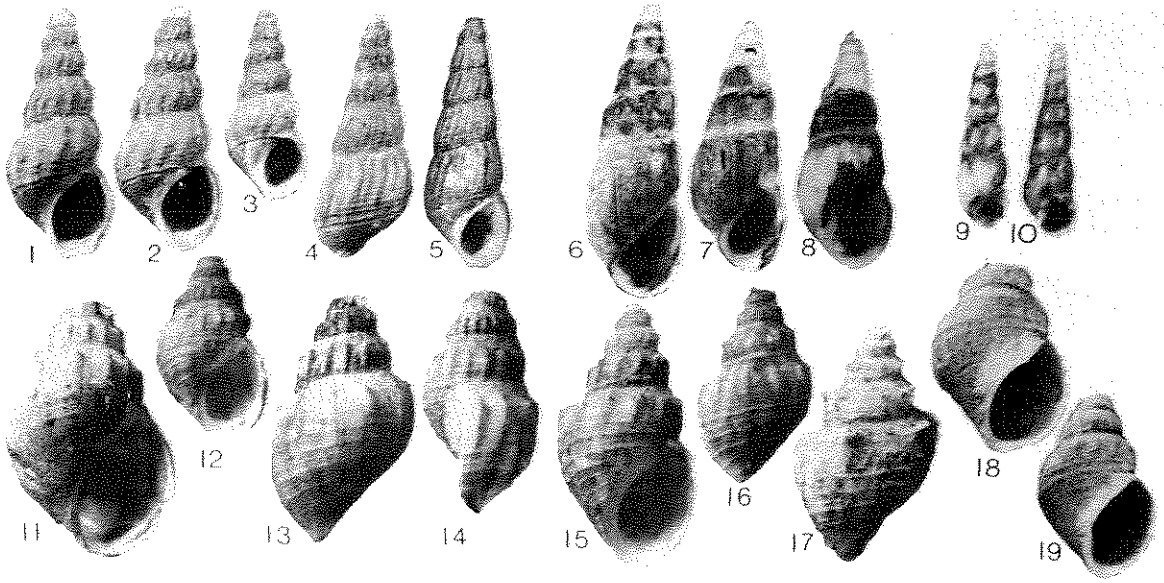

Plate 4. Figs. 1-5: Melanoides tuberculatus (Muller). Sta. 1, (2X). *Figs. 6-8: Melanoides flyensis* (Tapparone-Canefri). Sta. 25, (2X). *Figs. 9-10: Melanoides* sp. Sta. 25, (2X). *Figs. 11-14: Thiara scabra* (Muller). Sta. 20, (5X). *Figs. 15-17: Thiara scabra* (Muller). Sta. 25, (5X). *Figs. 18-19: Tarebia granifera* (Lamarck). Sta. 1, (5X) (young).

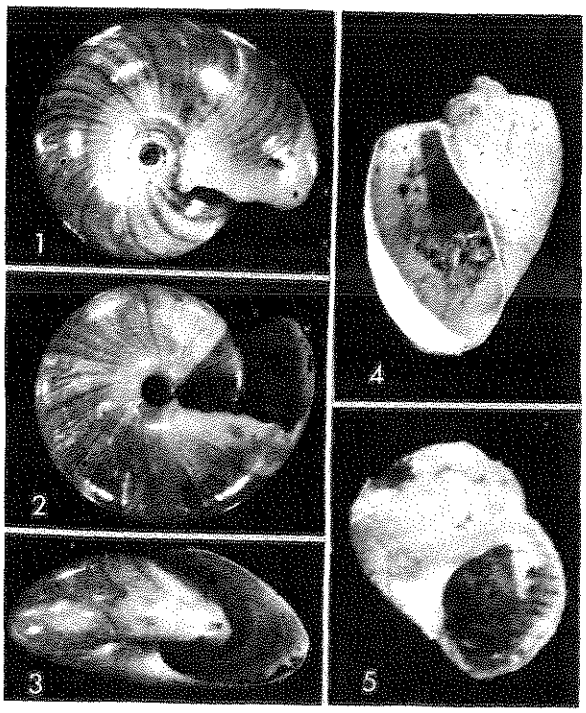

Plate 5. Figs. 1-3: Hippeutis (Helicorbis) umbilicalis (Benson). Sta. 26, (10.5X). *Fig. 4: Amerianna carinata* (H. Adams). Sta. 26, (10X). *Fig. 5: Acmella parvicostata* Jutting. Sta. 25, (32X) (young).

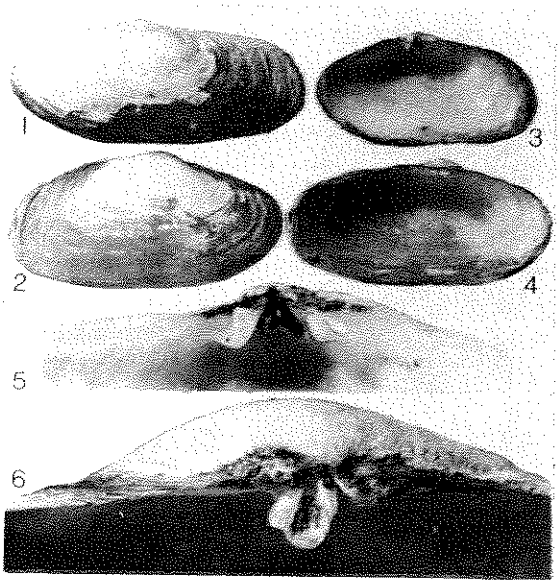

Plate 6. Erodona sp. *Fig. 1:* Outer view of left valve, (2X). *Fig. 2:* Outer view of right valve, (2X). *Fig. 3:* Inner view of right valve, (2X). *Fig. 4:* Inner view of left valve, (2X). *Fig. 5:* Close-up of hinge area of right valve, (4X). *Fig. 6:* Close-up of hinge area of left valve, (4X).

moved from a fish was 22 mm in length. The most common species found in *Cinetodus* stomachs were *Melanoides tuberculata, Melanoides flyensis, Bellamya decipiens, Larina* sp. and *Clenchiella sentaniensis*. All of these gastropods are known freshwater species.

Based on fish stomach contents, the impression that lowland streams in the Amazon and Congo basins are poor in mollusks compared with those of southeast Asia (Roberts, 1972) was reinforced by additional field work in the Congo in 1973 (Roberts and Stewart, 1976) and in Borneo in 1976. The present work suggests that mollusks are more diverse, more abundant and more important as fish food in the lowlands of the Fly River than in either the Amazon or Congo.

Table I lists the mollusks found in *froggatti* stomachs, the stations at which the fish were collected, the number of specimens, and a reference to the illustrations.

Table II gives station data for those stations at which *Cinetodus froggatti* were collected.

ACKNOWLEDGEMENTS

The 1975 ichthyological survey of the Fly River was carried out while the junior author was Research Associate of the Smithsonian Tropical Research Institute, as part of the Papua New Guinea Program of the Smithsonian Institution's International Environmental Science Program. We are grateful to Ross Johnston for making the map and reading manuscript, and to Anthony Martins and Sally Kaicher for many photographs.

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CORBICULA FLUMINEA (BIVALVIA: SPHAERIACEA): THE FUNCTIONAL MORPHOLOGY OF ITS HERMAPHRODITISM

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INTRODUCTION

Evidence has been presented earlier (Kraemer and Lott, 1977) to show that *Corbicula* is evidently a simultaneous hermaphrodite. On the one hand, that finding corresponds to the known hermaphroditism of other sphaeriaceans, the freshwater fingernail clams, *Sphaerium* and *Musculium* (Heard, 1977). On the other hand, comprehensive investigations (van der Schalie, 1970) revealed that hermaphroditism is rare in indigenous species of unionacean freshwater mussels. In the U.S., many of the latter species are dwindling and/or being replaced by the introduced Asian clam, *Corbicula*. Clues to the phenomenal spread of *Corbicula* across the U.S. thus may logically be sought in studies of its hermaphroditic reproductive processes.

In a discussion of methods for assessing the reproductive cycle in (marine) bivalves, Seed (1976, p. 20) lists five procedures before concluding, "Probably the most reliable information is that obtained from microscopic preparation of the gonad." The present, primarily histological study was undertaken for the purpose of discovering and evaluating maturational and seasonal changes not only in the reproductive organs of *Corbicula*, but in other organs related to the animal's reproductive process, as