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A comparison of fish surveys made in 1908 and 1998 of the Potaro, Essequibo, Demerara, and coastal river drainages of Guyana

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In 1908, Carl H. Eigenmann traveled within Guyana to study its fishes. In 1998, we resampled fishes in the areas visited by Eigenmann. We sampled 11 of the 18 localities surveyed in 1908 and five localities near the remaining seven. Eigenmann reported a total of 336 species from Guyana, of which 258 were represented by voucher specimens and were taken from areas in which we sampled. We collected a total of 270 species. The comparison of species richness detected by each survey revealed nearly identical results at almost all sites, except near Georgetown where fewer species were detected in 1998. The lower species richness around Georgetown may be attributed to environmental degradation associated with a nearby urban population. Except for the Georgetown area, environmental degradation was localized, and species diversity was similar to that in 1908. This study increases the number of freshwater fish species known from Guyana by 47, and potentially by 73. An examination of species distributions in the Potaro and Essequibo Rivers revealed an upstream limit to more than 40 % of all fish species at Tumatumari cataract.

Introduction

In 1908, Carl H. Eigenmann, one of the pre-eminent ichthyologists of his time, traveled by boat into the interior of Guyana [= British Guiana] to collect and study fishes in the Essequibo River basin. He recorded the localities and collections of fishes made on the journey in his 1912 book *The Fishes of British Guiana*. In the book are descriptions of 360 nominal species of fishes of

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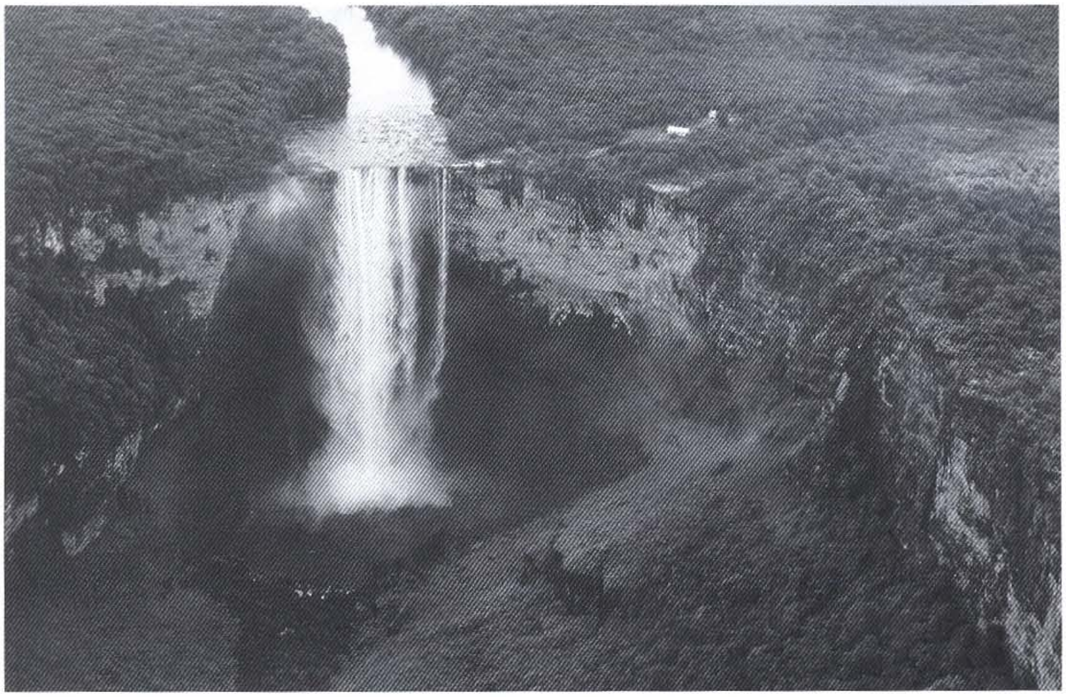

Fig. 1. Guyana: Kaiteur Falls. These waterfalls pose an upstream limit to approximately 25 % of fish species reported from Potaro River. Photograph by L. M. Page.

which 128 were diagnosed as species new to science (Eigenmann, 1912). 336 of the 360 species are currently considered valid.

In 1998, we repeated Eigenmann's journey, collecting in the same drainages and often at the same localities in an effort to provide more information on the poorly known fishes of Guyana. The primary objectives of our trip were to resample the fishes and detect changes in diversity in areas visited by Eigenmann 90 years earlier, search for species not reported in 1908, and add new distributional information to the growing body of knowledge on South American fishes. We also wanted to compare environmental conditions now with those observed by Eigenmann. Although Guyana is one of the least developed countries in South America, gold and diamond mining is widespread. Mining can be devastating to aquatic environments because the process releases large amounts of sediment and toxic substances (e.g., mercury).

Material and methods

The drainage basins we sampled were the same as those visited by Eigenmann (see Table 1 for a summary of Eigenmann's collection sites): Coastal Streams (referring to small river systems near Georgetown draining into the Atlantic Ocean), Demerara River, Essequibo River, Lower Potaro River, and Upper Potaro River. The Upper and Lower Potaro rivers are separated by Kaiteur Falls, the highest single-drop falls (226 m) in the world (Fig. 1).

Our collecting efforts, measured by the number of sites visited in each drainage basin, were similar to the activities of Eigenmann (Table 2). We sampled 11 of the 18 localities sampled by Eigenmann and five localities near the remaining seven (Fig. 2). We were unable to collect at some of the localities visited by Eigenmann because of permit restrictions related to lands owned by Amerindians, and we were not permitted to collect in Kaiteur National Park (called Savannah Landing by Eigenmann). Unlike Eigenmann, we did not sample the Essequibo River upstream of its confluence with the Potaro River.

Fig. 2. Localities sampled in Guya

Eigenmann collected fishes
60 m in length and by poison
natural ichthyocide extracted f
(Derris elliptica), a plant native
American Indians have, presum
of years, used hiari to catch fis

We relied almost exclusively
we accompanied Amerindians
while they collected fishes usin
of our collections were made wi
now seines with 3.2 mm mesh
bag seines with 4.8 mm mesh
were sampled by dragging se
and into the side of a stream ba
or gravel bar. Riffles and rapids
holding a minnow seine in plac
otherwise dislodging stones ar
materials a short distance upst
Floodplain pools and other sma
were sampled with dipnets. A
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ited at the Illinois Natural Histo
Auburn University (AU), and
Study of Biological Diversity at
Guyana (UG/CSBD). The Catal

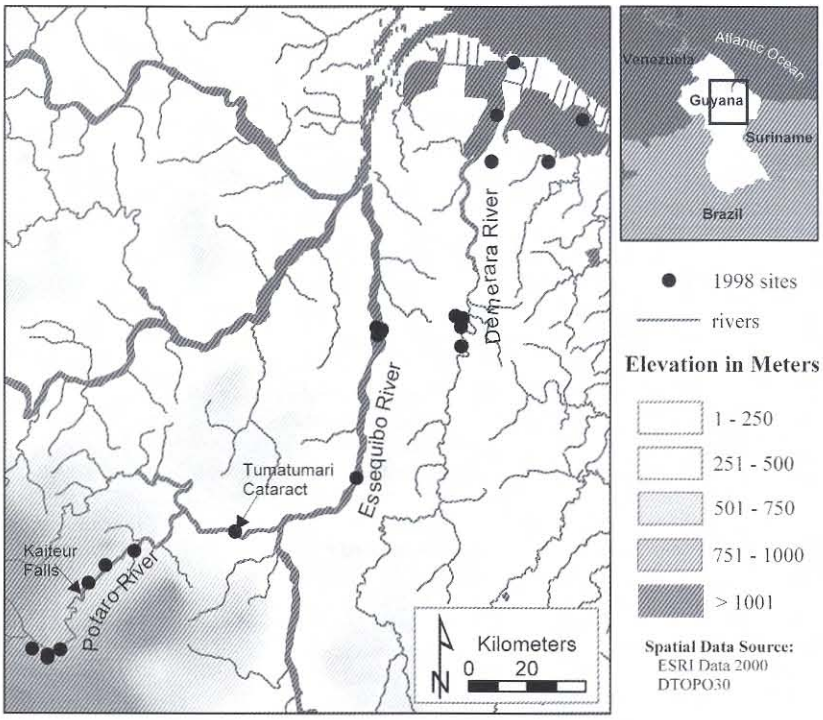

Fig. 2. Localities sampled in Guyana, 1998.

Eigenmann collected fishes with seines up to 60 m in length and by poisoning fishes with a natural ichthyocide extracted from roots of hiari *(Derris elliptica)*, a plant native to Guyana. South American Indians have, presumably for hundreds of years, used hiari to catch fishes.

We relied almost exclusively on seines, although we accompanied Amerindians near Chenapou while they collected fishes using hiari root. Most of our collections were made with 3.0 × 1.5 m minnow seines with 3.2 mm mesh or with 9.0 × 1.8 m bag seines with 4.8 mm mesh. Pools and runs were sampled by dragging seines downstream and into the side of a stream bank or onto a sand or gravel bar. Riffles and rapids were sampled by holding a minnow seine in place while kicking or otherwise dislodging stones and other substrate materials a short distance upstream of the seine. Floodplain pools and other small bodies of water were sampled with dipnets. All individuals collected were identified to species and were deposited at the Illinois Natural History Survey (INHS), Auburn University (AU), and the Centre for the Study of Biological Diversity at the University of Guyana (UG / CSBD). The Catalog of Fishes (Eschmeyer, 1998) was used to provide the taxonomy on which this study was based.

Eigenmann's specimens are located in several museums. Many of his type specimens are housed at the Field Museum of Natural History (FMNH). In making our identifications, we examined all of his characiform types and many other specimens at FMNH, and specimens at the Academy of Natural Sciences of Philadelphia and the California Academy of Sciences. Eigenmann purchased a large number of specimens in markets in Georgetown. We purchased only a few because localities where the specimens had been captured usually could not be confirmed with certainty.

For our comparison of species richness in the two surveys, we did not include 5 species reported in the 1908 survey that were found only at sites we did not sample, (e.g., Essequibo River sites upstream of its confluence with the Potaro River; Konawaruk and Warraputa Cataract). Furthermore, we did not include 23 species in the 1908 list that were not represented by voucher specimens because their identifications or localities could not be verified.

Table 1. Summary of collections reported in Eigenmann (1909, 1912) including approximate locations, habitats sampled, sampling methods, primary collectors and dates. [1] Information from Eigenmann (1909: 5). [2] Eigenmann did not sample Aruataima Cataract himself due to heavy rains; species collected in the cataract were described in Eigenmann (1909).

geographic region, site names (numbered) and collection localities (*italics*)	habitat and sampling efforts (if specified)	primary collector	date (1908 unless specified)
Coastal streams and lower Demerara River			
1. Lama Stop-off, Maduni Stop-off, and Cane Grove Corner	Seined canal, below dams on Lama and Maduni Creeks, and Lama Water Conservancy (reservoir)	Eigenmann	Sep. 15-19
2. Georgetown Trenches			
Georgetown trenches	Seined vegetated trenches and canals (freshwater) and muddy pond (occasionally brackish)	Eigenmann	Sep. 9-14
Botanic Garden	Collected in trenches, drained one of water	Shideler	Between Oct. 19 – Dec.
3. Georgetown Market and Harbor	Presumably specimens from mouth of Demerara River, estuaries and coast near Georgetown	Eigenmann	Sep. 9-14 and Nov. 11 – Dec.
4. Northwest Coast			
Multiple localities near Morawhanna including Mora Passage, Aruka River, Koriabo Rubber Plantation, and Issorora Plantation	Presumably collected in coastal swamps, sloughs, trenches and canals (fresh and brackish water)	Shideler	Between Oct. 19 – Dec.
Upper Demerara River			
5. Kumaka, Wismar, Christianburg			
Christianburg, Wismar (including Freiheit[1])	Collected in Demerara River at Christianburg and Wismar, Christianburg canal, and local creeks	Eigenmann	Between Sep. 24-29, Oct. 3
Kumaka	Poisoned creek	Eigenmann	Between Sep. 24-29, Nov. 10
6. Malali	Collected in Demerara River in or near cataract	Shideler	Between Sep. 24-29
Essequibo River			
7. Bartica	Not specified	Shideler	Between Oct. 19 – Dec.
8. Rockstone, Gluck Island			
Rockstone	Seined Essequibo River in rocks of stelling, environs of Rockstone including large beach and slough downstream	Eigenmann	Sep. 29 – Oct. 2
Gluck Island	Collected in small forest creek on large island in Essequibo River channel using fish fence and poison	Eigenmann	Sep. 30
9. Crab Falls	Seined and poisoned above, in, and below falls of Essequibo River at night	Eigenmann	Nov. 4-7
10. Konawaruk	Poisoned backwater pool opposite mouth of Konawaruk River	Eigenmann	Nov. 6
11. Warraputa	Poisoned small, rocky branch of Warraputa Cataract (Essequibo River)	Eigenmann	Nov. 6
12. Packeoo (or Pacu Falls in the Rupununi)	Not specified	Grant	1908-1910[1]

13. Rupununi, Twoca Pan
Multiple localities including Rupununi opposite Massara Landing and Twoca Pan (betwee… Rupununi and Pununike)

Lower Potaro River
14. Tumatumari
15. Potaro Landing
16. Kangaruma
17. Erukin
18. Amatuk
19. Waratuk
20. Tukeit
Shrimp (Orimetuk) Creek

Upper Potaro River
21. Savannah Landing
22. Holmia
Two hours below Holmia[1]
23. Aruataima

Amazon Basin
24. Maripicru (branch of Ireng River between Wontyke and Karakara above Karona Falls
25. Chipoo Creek (tributary of Ireng River between Karakar… and Rupununi)
26. Nickaparoo (or Nickaparu Creek, a branch of the Ireng River, location unknown)

Additional sites
Papan, near Eworora
Creek between Rapoo and lower falls
Gattuck Creek, Potaro Highland…
Yakeatonuk Fall, Potaro River

13. Rupununi, Twoca Pan *Multiple localities including Rupununi opposite Massara Landing and Twoca Pan (between Rupununi and Pununike)*	Not specified	Grant	1908-1910[1]
Lower Potaro River			
14. Tumatumari	Seined Potaro River in cataract and on sand bars above and below cataract, and creek entering Potaro River from north below the cataract	Eigenmann	Oct. 7-9
15. Potaro Landing	Poisoned creek near landing	Shideler	Oct. 11
	Not specified, probably in creek near landing[1]	Shideler	Between Oct. 19 – Dec.
16. Kangaruma	Incidental fishing in Potaro River	Eigenmann	Oct. 14-15
17. Erukin	Night fished Erukin Creek near confluence with Potaro River	Eigenmann	Oct. 15
	Poisoned Erukin Creek	Eigenmann	Oct. 31
18. Amatuk	Seined Potaro River on sand bar below Amatuk Cataract	Eigenmann	Oct. 16
	Poisoned above Amatuk Cataract on island and in rocky branch of Potaro River below cataract	Eigenmann	Oct. 30-31
19. Waratuk	Not specified	Eigenmann	Oct. 16
	Poisoned small branch of Waratuk Cataract	Eigenmann	Oct. 30
20. Tukeit	Collected in Potaro River	Eigenmann	Oct. 17
	Poisoned creek below landing	Eigenmann	Oct. 29
Shrimp (Orimetuk) Creek	Poisoned small, high gradient creek or seep	Grant	Oct. 30
Upper Potaro River			
21. Savannah Landing	Not specified, probably collected in Potaro River	Eigenmann	Oct. 18-19
	Poisoned creek and collected in swamp above landing	Eigenmann	Oct. 27-29
22. Holmia	Poisoned small creek below camp and received specimens taken locally by Amerindians	Eigenmann	Oct. 20-26
Two hours below Holmia[1]	Collected sand bank in Potaro River	Eigenmann	Oct. 20-26
23. Aruataima	Poisoned two creeks below Aruataima Cataract	Eigenmann	Oct. 20-26
	Collected in Aruataima Cataract	Grant	1908-1909[2]
Amazon Basin			
24. Maripicru (branch of Ireng River between Wontyke and Karakara above Karona Falls)	Not specified	Grant	1908-1910[1]
25. Chipoo Creek (tributary of Ireng River between Karakara and Rupununi)	Not specified	Grant	1908-1910[1]
26. Nickaparoo (or Nickaparu Creek, a branch of the Ireng River, location unknown)	Not specified	Grant	1908-1910[1]
Additional sites			
Papan, near Eworora	Not specified	Grant	1908-1910[1]
Creek between Rapoo and lower falls	Not specified	Grant	1908-1910[1]
Gattuck Creek, Potaro Highland	Not specified	Grant	1908-1910[1]
Yakeatonuk Fall, Potaro River	Not specified	Grant	1908-1910[1]

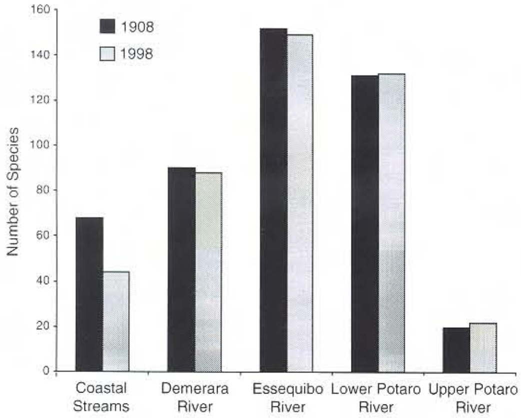

Fig. 3. Comparison of species richness for the five river basins surveyed.

Table 2. Localities surveyed in Guyana and numbers of species collected in 1908 and 1998.

drainage	number of species 1908	1998	difference [% of 1908]
Coastal Streams	68	44	65%
Georgetown Canals	40	10	25%
Lama + Maduni Rivers	46	36	78%
Demerara River	90	88	98%
Linden (river, nearby creeks)	94	60	67%
Malali	24	–	–
Madewini River	–	34	–
Land of Canaan	–	15	–
Essequibo River	152	149	98%
Rockstone	131	132	100%
32mi. SSW Rockstone	–	58	–
Crab Falls	77	–	–
Lower Potaro River	131	132	101%
Tumatumari	82	98	120%
Potaro Landing	39	–	–
Kangaruma	15	–	–
Erukin	24	–	–
Amatuk	42	31	76%
Waratuk	16	42	263%
Tukeit	32	20	63%
Upper Potaro River	20	22	110%
Savannah Landing	14	–	–
Chenapou (Holmia)	16	4	25%
Chenapou Cataract (Aruataima)	15	12	80%
Oung and Chenapou Creeks	–	9	–
Arnick Creek	–	11	–
Total number of species	258	270	105%
Total number of sites	18	16	89%

Results

Species collected in 1908 and 1998 are listed by family and drainage basin in Table 3. In terms of the total number of species collected in each of the drainages, both surveys recovered similar results (Table 2; Fig. 3). At the drainage scale, the only large difference was found between samples from Coastal Streams, where Eigenmann collected 68 species and we collected 44 species (a drop of 35 %). Numbers of species from the Demerara River (90 in 1908, 88 in 1998), Essequibo River (152 in 1908, 149 in 1998), Lower Potaro (131 in 1908, 132 in 1998) and Upper Potaro (20 in 1908, 22 in 1998) were nearly identical.

Discussion

Eigenmann reported a total of 336 species from Guyana that are currently considered valid. Another 73 species were added in our 1998 samples, of which 47 were described, bringing the total number of described fish species reported for Guyana from these two studies to 383. The 26 undescribed species suggest a total of 409 (Table 3). The possible 22 percent increase of the recent survey suggests that additional inventories of the region are likely to further increase the number of species. Most of the species added were characiforms (characins), siluriforms (catfishes), and gymnotiforms (knifefishes).

As represented by voucher specimens, 258 species were collected by Eigenmann in the areas we sampled (Table 3). We collected 270 species, an increase of nearly 5 percent. However, an examination of all specimens collected by Eigenmann, which we did not do, and comparison to the current taxonomy might reveal additional species in his samples. Eigenmann collected 74 species in 1908 that we did not collect in 1998 (Table 3). Single specimens represent 24 (32 %) of these and 41 species are represented by 3 specimens or fewer, so at least 55 % of the 74 species unique to the 1908 survey could be considered rare or uncommon. Of the remaining 33 species, more than half are catfishes, most notably members of Loricariidae and Pimelodidae. Our collecting efforts should have detected many of these fishes. Of the 86 species reported as unique to the 1998 survey, 13 were also collected by Eigenmann from areas of Guyana not sampled in 1998

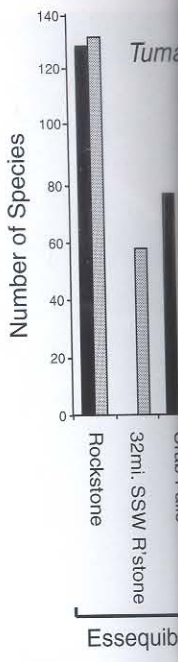

Fig. 4. Comparison of 1908 and
dramatic truncation of species ric
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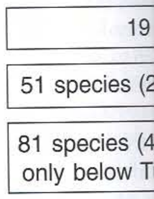

Fig. 5. Distribution of fish speci
Kaiteur Falls.

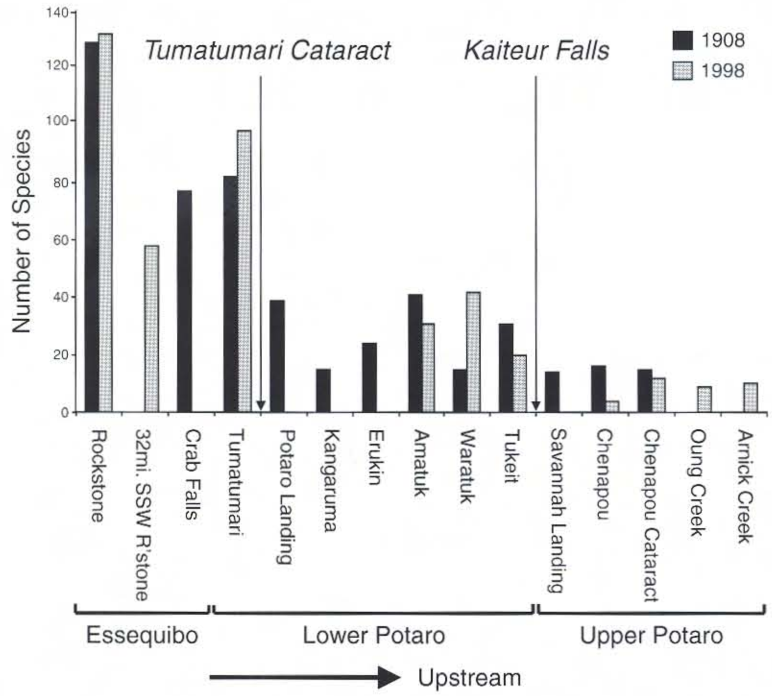

Fig. 4. Comparison of 1908 and 1998 species richness by site for the Potaro-Essequibo River drainage. Most dramatic truncation of species richness within Potaro River appears to correspond to Tumatumari Cataract, rather than Kaiteur Falls.

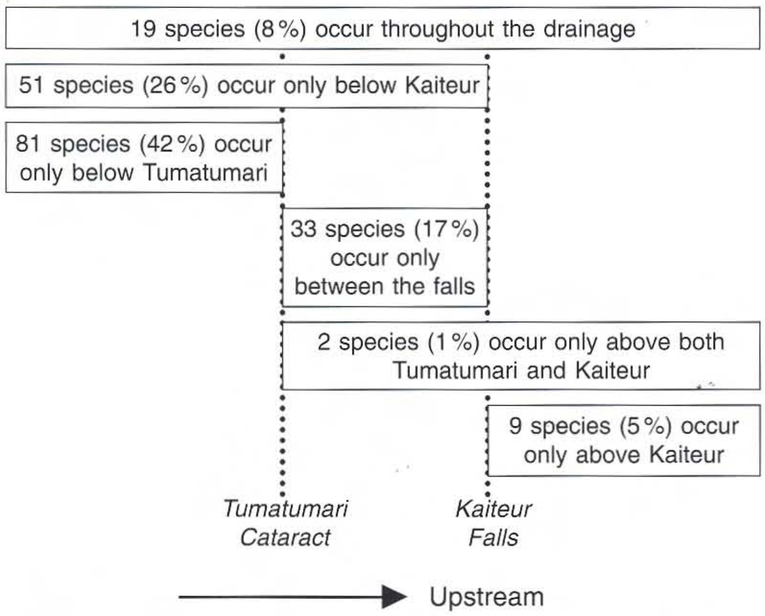

Fig. 5. Distribution of fish species within the Potaro River, with limits corresponding to Tumatumari Cataract and Kaiteur Falls.

Fig. 6. Tumatumari Cataract, as seen from the north bank. This cataract poses an upstream limit to 42 % of fish species reported from the Potaro River. Photograph by M. Hardman.

and, as such, represent range extensions. Of the remaining 73 species, 19 (26 %) were represented by single specimens and 33 species were represented by three specimens or fewer, so at least 45 % of the 73 species unique to the 1998 survey could be considered rare or uncommon. The similarity between the proportions of rare and uncommon species suggests the two surveys were able to detect them with equal efficacy, and that this source of discrepancy may be attributed to sampling error. The remaining discrepancy is likely an artifact of a small sample size, but could represent natural fluctuations in stream-fish communities. In summary, Eigenmann's survey contained 74 species that we did not detect, and did not contain 73 species that our survey did. If actual changes in fish communities of Guyana have taken place since 1908, their net effect has been very slight as judged by species richness.

The number of species found in a stream generally increases as the size of the stream increases (Vannote et al., 1980); thus, the usual pattern in species distributions is to find fewer species in smaller creeks and headwaters than in larger rivers. In agreement with this pattern, the numbers of species collected in the Potaro-Essequibo River basin were lower at upstream localities (Fig. 4). The 226 m single-drop waterfall at Kaiteur (Fig. 1) appears to impose an upstream limit to approximately one-quarter of all fish species reported from the Potaro River. However, the importance of Kaiteur Falls as a limiting feature to the dispersal of fishes is eclipsed by the rather unexpected observation that over 40 percent of all fish species in this drainage have not been found above the cataract at Tumatumari (Figs. 4-6).

Geographic features such as large cataracts and waterfalls can prevent the dispersal of organisms living either side of those features and function as important barriers to gene flow. Using data from 1908 and 1998, we examined the distributions of species in the Potaro River drainage for distributional limits corresponding to the cataract at Tumatumari (Fig. 6) and waterfalls at Kaiteur (Fig. 1). As can be seen in Figure 5, of the 195 species now reported from the Potaro River, 81 were distributed only below Tumatumari Cataract. Fifty-one species are limited upstream by Kaiteur Falls, and nine of the 29 species above the

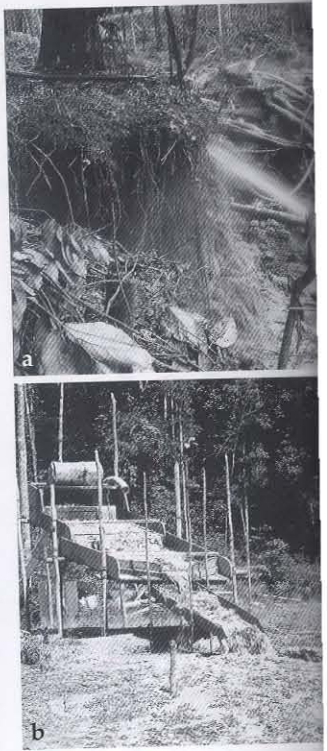

Fig. 7. Land-based mining ope
impregnated sluice filters adsorb
stream. Photographs by M. Har

falls have not been found bel
occur throughout the Potaro
species appear to be limited t
Tumatumari Cataract and Ka
have distributions that are
by Tumatumari Cataract, bu
above Kaiteur Falls.

Except for the area aroun
ronmental degradation in the
relatively localized. The nu
of the fish species of the D
Lower Potaro, and Upper Po
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species in coastal drainages
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1998). Much of the coastal

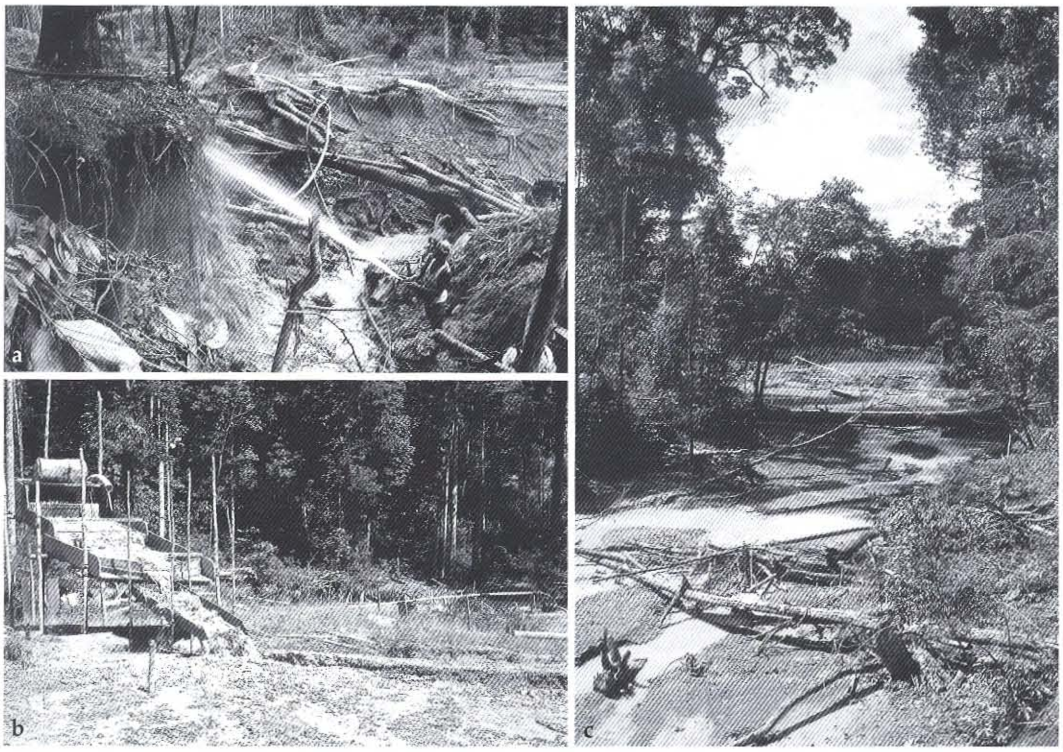

Fig. 7. Land-based mining operation. **a**, High-pressure hoses used to erode and suspend soils; **b**, mercury-impregnated sluice filters adsorb gold particles from soil suspension; **c**, processed soil-suspension is returned to stream. Photographs by M. Hardman.

falls have not been found below them. 19 species occur throughout the Potaro River drainage. 33 species appear to be limited to the river between Tumatumari Cataract and Kaiteur Falls. 2 species have distributions that are downstream limited by Tumatumari Cataract, but which also occur above Kaiteur Falls.

Except for the area around Georgetown, environmental degradation in the areas surveyed was relatively localized. The numbers and identities of the fish species of the Demerara, Essequibo, Lower Potaro, and Upper Potaro Rivers found in this study are very similar to those reported by Eigenmann. In contrast, the lower numbers of species in coastal drainages near Georgetown in 1998 appear to be a consequence of development and environmental degradation. In 1908, the population of Guyana was approximately 250,000 (Swan, 1958). In 1998, the population had grown to approximately 800,000, and most of the population was centered about Georgetown (Anonym, 1998). Much of the coastal area has been developed for agriculture, and little natural landscape remains. Canals in this region appeared to be heavily polluted with runoff from streets and crop fields.

Environmental degradation in some areas of the interior was severe. Land-based mining operations (Fig. 7) involved the use of high-pressure water hoses, diesel engines, and mercury-impregnated screens to remove gold from local soil. Small streams draining the mining areas ran milky white and were devoid of fishes. Larger streams receiving these effluents and streams in which mining was undertaken with dredges were also negatively affected. However, the volume of water in the larger streams seemed to dilute the impact from siltation, and the effluents did not appear to affect fishes for large distances. However, the long-term impact from the chronic release of mercury into the streams of Guyana may not be realized for years to come. We were not in areas with extremely large mining operations, such as the one on the Essequibo River at Omai,

Table 3. Composite list of freshwater fishes reported by Eigenmann (1908) and the present study (1998) in Coastal Streams, Demerara River and Potaro-Essequibo River drainages of Guyana. Species are arranged by family according to Nelson (1994) and Ferraris & de Pinna (1999).

	drainage basin				
	Coastal Streams	Demerara	Essequibo	Lower Potaro	Upper Potaro
Dasyatidae					
Paratrygon aiereba[2]			E[2]		
Potamotrygon histrix[1]			E[1]		
Osteoglossidae					
Osteoglossum bicirrhosum		D[1]	E[2]		
Engraulidae					
Anchoviella guianensis			E		
Anchoviella sp.[2]			E[2]	L[2]	
Pterengraulis atherinoides[2]		D[2]			
Clupeidae					
Rhinosardinia amazonica[2]		D[2]			
Hemiodontidae					
Argonectes scapularis[2]			E[2]		
Bivibranchia protractila			E		
Hemiodopsis microlepis[2]			E[2]		
Hemiodopsis quadrimaculatus				L	
Hemiodopsis semitaeniatus[1]			E[1]		
Hemiodus unimaculatus	C	D	E	L	
Curimatidae					
Curimata cyprinoides	C	D	E[2]		
Curimatopsis crypticus	C	D	E		
Cyphocharax festivus		D[1]	E	L	
Cyphocharax microcephalus[2]		D[2]	E[2]		
Cyphocharax spilurus		D	E	L	
Prochilodus rubrotaeniatus			E	L[1]	
Psectrogaster ciliata			E		
Psectrogaster essequibensis			E	L[2]	
Anostomidae					
Anostomoides laticeps[1]			E[1]		
Anostomus anostomus			E[1]	L	
Anostomus plicatus[1]			E[1]	L[1]	
Caenotropus labyrinthicus[2]			E[2]		
Caenotropus maculosus			E	L[1]	
Chilodus punctatus			E		
Laemolyta sp.[2]			E[2]		
Leporinus pellegrini[1]			E[1]	L[1]	
Leporinus arcus				L	
Leporinus fasciatus				L	
Leporinus friderici		D	E	L	
Leporinus granti[2]				L[2]	
Leporinus maculatus				L	
Leporinus nigrotaeniatus		D	E	L	
Pseudanos trimaculatus			E		
Schizodon fasciatus[1]				L[1]	
Erythrinidae					
Erythrinus erythrinus		D[1]	E	L	U
Hoplerythrinus unitaeniatus	C[1]		E		U[1]
Hoplias macrophthalmus		D[2]	E[1]	L[1]	
Hoplias malabaricus	C	D	E	L[1]	U[1]
Lebiasinidae					
Copella carsevennensis[2]	C[2]				
Nannostomus beckfordi	C[1]	D	E[1]	L	
Nannostomus eques[2]			E[2]		
Nannostomus harrisoni		D	E[2]		
Nannostomus marginatus	C[1]	D	E[1]		
Nannostomus trifasciatus			E	L	
Nannostomus unifasciatus			E	L[1]	
Pyrrhulina filamentosa	C	D	E	L	U
Ctenoluciidae					
Boulengerella cuvieri			E		
Gasteropelecidae					
Carnegiella strigata	C[1]	D[1]	E		
Gasteropelecus sternicla[1]		D[1]			
Characidae					
Acanthocharax microlepis			E	L	
Acestrorhynchus falcatus	C[1]	D	E	L	
Acestrorhynchus falcirostris	C[1]	D[1]	E		
Acestrorhynchus microlepis	C	D	E	L	
Acestrorhynchus nasutus[1]			E[1]		
Agoniatus halecinus[2]			E[2]		
Ammocryptocharax lateralis[1]				L[1]	
Ammocryptocharax vintonae			E[2]	L[1]	
Aphyocharax erythrurus		D[2]	E		
Aphyocharax melanotus[1]			E[1]		
Astyanax bimaculatus	C	D			U[1]
Astyanax guianensis			E	L[1]	
Astyanax mutator[2]				L[2]	
Brittanichthys myersi[2]	C[2]		E[2]		
Brycon falcatus			E	L[1]	
Brycon pesu		D[1]	E	L[1]	
Bryconamericus hyphesson			E[2]	L	
Bryconops affinis		D	E	L	U
Bryconops caudomaculatus		D[1]	E	L	U
Bryconops giacopinii[2]				L[2]	
Bryconops melanurus	C	D			
Catoprion mento[1]			E[1]		
Chalceus macrolepidotus			E	L	
Characidium fasciatum[2]				L[2]	
Characidium pellucidum[1]			E[1]		
Characidium pteroides		D[1]	E[1]	L[2]	
Characidium steindachneri[1]			E[1]		
Characidium tenue[1]		D[1]	E[1]	L[1]	
Characidium zebra[2]				L[2]	
Characidium sp. 1[2]				L[2]	
Characidium sp. 2[2]				L[2]	
Characidium sp. 3[2]				L[2]	
Characidium sp. 4[2]			E[2]		

Characidium sp. 5[2]	
Charax gibbosus	C
Charax hemigrammus[1]	
Creagrutus melanzonus	
Crenuchus spilurus	C
Ctenobrycon spilurus	C
Cynodon gibbus	
Cynopotamus essequibensis	
Dermatocheir catablepta[1]	
Deuterodon potaroensis	
Gnathocharax steindachneri[2]	
Hemigrammus analis	
Hemigrammus bellottii[2]	
Hemigrammus cylindricus	
Hemigrammus erythrozonus	C[1]
Hemigrammus iota	C[2]
Hemigrammus ocellifer	
Hemigrammus orthus	
Hemigrammus rodwayi	C
Hemigrammus stictus	C
Hemigrammus unilineatus	
Hemigrammus cf. *iota*[2]	
Hemigrammus sp.[2]	
Hydrolycus armatus[2]	
Hydrolycus tatauaia[2]	
Hyphessobrycon eos	
Hyphessobrycon gracilis	
Hyphessobrycon minimus	C
Hyphessobrycon minor[2]	
Hyphessobrycon rosaceus[1]	
Jupiaba abramoides	
Jupiaba essequibensis	
Jupiaba mucronata[2]	
Jupiaba pinnata[2]	
Jupiaba polylepis	
Jupiaba potaroensis	
Jupiaba cf. *minor*[2]	
Leptocharacidium sp.[2]	
Melanocharacidium blennioides	
Melanocharacidium sp.[2]	
Metynnis argenteus	
Metynnis hypsauchen	
Metynnis luna[2]	
Metynnis maculatus[1]	[illegible]
Microschemobrycon casiquiare[2]	
Moenkhausia browni	
Moenkhausia chrysargyrea	
Moenkhausia colletti	
Moenkhausia copei	
Moenkhausia cotinho	
Moenkhausia dichroura	
Moenkhausia georgiae[2]	
Moenkhausia grandisquamis	
Moenkhausia lepidura	
Moenkhausia megalops[1]	
Moenkhausia oligolepis	
Moenkhausia shideleri	
Moenkhausia cf. *dichroura*[2]	
Moenkhausia cf. *lata*[2]	

Characidium sp. 5[2]				L[2]	
Charax gibbosus	C	D	E	L	
Charax hemigrammus[1]			E[1]		
Creagrutus melanzonus			E[1]	L	
Crenuchus spilurus	C	D	E[1]		
Ctenobrycon spilurus	C	D[2]	E[2]		
Cynodon gibbus		D[1]		L[2]	
Cynopotamus essequibensis			E	L[1]	
Dermatocheir catablepta[1]				L[1]	
Deuterodon potaroensis				L	
Gnathocharax steindachneri[2]		D[2]	E[2]		
Hemigrammus analis		D[1]	E	L[2]	
Hemigrammus bellottii[2]		D[2]			U[2]
Hemigrammus cylindricus			E	L	
Hemigrammus erythrozonus	C[1]			L	
Hemigrammus iota	C[2]	D[2]	E		
Hemigrammus ocellifer		D[2]	E		
Hemigrammus orthus			E	L	
Hemigrammus rodwayi	C	D[2]			
Hemigrammus stictus	C	D	E[1]		
Hemigrammus unilineatus		D			
Hemigrammus cf. *iota*[2]			E[2]		
Hemigrammus sp.[2]		D[2]			
Hydrolycus armatus[2]			E[2]	L[2]	
Hydrolycus tatauaia[2]			E[2]		
Hyphessobrycon eos				L	
Hyphessobrycon gracilis			E		
Hyphessobrycon minimus	C[1]		E[2]	L[2]	
Hyphessobrycon minor[2]			E[2]		
Hyphessobrycon rosaceus[1]			E[1]		
Jupiaba abramoides		D	E[1]	L	
Jupiaba essequibensis			E	L	U[2]
Jupiaba mucronata[2]				L[2]	
Jupiaba pinnata[2]				L[2]	
Jupiaba polylepis		D[1]	E	L	
Jupiaba potaroensis				L	
Jupiaba cf. *minor*[2]				L[2]	
Leptocharacidium sp.[2]				L[2]	
Melanocharacidium blennioides			E[1]	L	
Melanocharacidium sp.[2]				L[2]	
Metynnis argenteus			E	L	
Metynnis hypsauchen			E		
Metynnis luna[2]			E[2]		
Metynnis maculatus[1]	C[1]		E[1]		
Microschemobrycon casiquiare[2]			E[2]	L[2]	
Moenkhausia browni				L	U
Moenkhausia chrysargyrea		D[1]	E	L[1]	
Moenkhausia colletti		D	E	L	
Moenkhausia copei		D	E	L[2]	
Moenkhausia cotinho		D	E	L	
Moenkhausia dichroura			E	L	
Moenkhausia georgiae[2]				L[2]	U[2]
Moenkhausia grandisquamis		D[1]	E	L	
Moenkhausia lepidura		D[1]	E	L	
Moenkhausia megalops[1]			E[1]		
Moenkhausia oligolepis				L	U[1]
Moenkhausia shideleri				L	
Moenkhausia cf. *dichroura*[2]				L[2]	
Moenkhausia cf. *lata*[2]				L[2]	
Moenkhausia cf. *lepidura*[2]				L[2]	
Myleus rhomboidalis				L	
Myleus rubripinnis[2]		D[2]			
Parapristella aubynei	C	D[2]			
Phenacogaster megalostictus			E	L	
Phenacogaster microstictus		D[2]	E	L	
Piabucus dentatus[1]		D[1]			
Poecilocharax bovallii				L	U[1]
Poptella orbicularis	C[1]	D	E	L	
Pristella maxillaris			E[1]	L[2]	
Pristella riddlei	C	D			
Pygoprystis denticulatus	C	D[2]			
Roeboides thurni		D[1]	E[2]		
Serrasalmus eigenmanni[2]		D[2]	E[2]	L[2]	
Serrasalmus gymnogenys[1]		D[1]	E[1]	L[1]	
Serrasalmus rhombeus		D	E	L	
Serrasalmus serrulatus[1]		D[1]	E[1]		
Tetragonopterus chalceus		D	E	L	
Triportheus elongatus[2]			E[2]		
Triportheus rotundatus		D	E	L[2]	
Ariidae					
Arius passany	C				
Doradidae					
Acanthodoras cataphractus	C[1]		E	L	
Acanthodoras spinosissimus[2]			E[2]		
Amblydoras hancockii	C	D	E	L	
Doras carinatus	C[1]		E	L	
Doras micropoeus	C[1]	D			
Hassar notospilus[1]			E[1]		
Hemidoras microstomus	C[1]	D[1]	E[2]	L[2]	
Leptodoras linnelli	C[1]	D	E[1]	L[1]	
Opsodoras leporhinus[1]				L[1]	
Physopyxis lyra[2]			E[2]		
Platydoras costatus[1]			E[1]		
Auchenipteridae					
Ageneiosus brevifilis[1]	C[1]				
Ageneiosus marmoratus[1]				L[1]	
Ageneiosus ucayalensis		D[1]	E[2]	L[2]	
Auchenipterichthys thoracatus[2]			E[2]		
Auchenipterus brevior			E[2]	L	
Auchenipterus demerarae		D			
Parauchenipterus galeatus	C	D			
Pseudauchenipterus nodosus[1]		D[1]			
Tatia aulopygia		D[1]		L	
Tatia intermedia[2]		D[2]	E[2]	L[2]	
Trachycorystes obscurus[2]			E[2]		
Tympanopleura piperata[2]			E	L[2]	
Pimelodidae					
Brachyglanis frenata				L	U[2]
Brachyglanis melas[1]			E[1]		
Brachyglanis phalacra[1]				L[1]	
Brachyplatystoma vaillanti			E		
Goeldiella eques			E		
Heptapterus brevior				L	
Heptapterus longior				L[1]	U[2]
Hypophthalmus edentatus[1]		D[1]			
Leptorhamdia essequibensis[1]			E[1]		

	Coastal Streams	Demerara	Essequibo	Lower Potaro	Upper Potaro
Megalonema platycephalum [1]				L[1]	
Microglanis poecilus [2]			E[2]		
Myoglanis potaroensis [1]				L[1]	
Pimelodella cristata		D	E	L	
Pimelodella macturki	C[1]	D[2]			
Pimelodella megalops			E[2]	L	
Pimelodus blochii	C	D	E	L	
Pimelodus ornatus		D	E[1]	L	
Pinirampus pirinampu [2]			E[2]		
Pseudopimelodus albo-marginatus [1]				L[1]	
Pseudopimelodus villosus		D[1]	E[2]	L	
Pseudoplatystoma fasciatum		D[1]	E		
Rhamdia holomelas [1]	C[1]				
Rhamdia quelen	C[1]	D	E	L[1]	U
Cetopsidae					
Helogenes marmoratus		D[2]	E[2]	L	U
Hemicetopsis macilentus [1]				L[1]	
Hemicetopsis minutus [1]				L[1]	
Aspredinidae					
Bunocephalus verrucosus			E		
Dysichthys chamaizelus [1]			E[1]	L[1]	
Dysichthys coracoideus [1]			E[1]		
Platystacus cotylephorus [2]		D[2]			
Trichomycteridae					
Ituglanis gracilior [1]				L[1]	
Trichomycterus conradi [1]				L[1]	
Trichomycterus guianense					U
Vandellia beccarii [2]				L[2]	
Callichthyidae					
Callichthys callichthys		D[1]	E[2]		U
Corydoras melanistius brevirostis [2]			E[2]		
Corydoras melanistius melanistius [2]			E[2]		
Corydoras potaroensis [2]				L[2]	
Corydoras punctatus [1]		D[1]	E[1]	L[1]	
Hoplosternum littorale [1]	C[1]				
Hoplosternum sp.	C				
Megalechis personata			E		
Megalechis thoracata	C[1]	D[1]	E		
Loricariidae					
Ancistrus gymnorhynchus [1]			E[1]		
Ancistrus hoplogenys			E		
Ancistrus lithurgicus [1]			E[1]		
Corymbophanes andersoni					U
Corymbophanes kaiei [2]					U[2]
Farlowella nattereri			E		
Farlowella rugosa [2]			E[2]		
Hemiancistrus megacephalus [1]				L[1]	
Hemiodontichthys acipenserinus [1]			E[1]		

Column heading: drainage basin

	Coastal Streams	Demerara	Essequibo	Lower Potaro	Upper Potaro
Hypoptopoma guianense [2]			E[2]	L[2]	
Hypostomus hemiurus [2]		D[2]	E[2]	L[2]	U[2]
Hypostomus plecostomus [1]	C[1]	D[1]			
Hypostomus watwata [1]	C[1]				
Limatulichthys punctatus [2]			E[2]		
Lithoxus lithoides			E	L[1]	
Loricaria cataphracta [1]		D[1]	E[1]		
Loricariichthys brunneus [1]	C[1]	D[1]	E[1]	L[1]	
Loricariichthys microdon			E		
Loricariichthys platyurus [1]				L[1]	
Loricariichthys sp. [2]		D[2]			
Parotocinclus britskii [2]			E[2]		
Parotocinclus collinsae [2]				L[2]	
Pseudancistrus barbatus [1]			E[1]		
Pseudancistrus nigrescens [1]				L[1]	
Rineloricaria fallax [2]		D[2]	E[2]	L[2]	
Rineloricaria stewarti			E		
Astroblepidae					
Lithogenes villosus					U
Sternopygidae					
Distocyclus cf. *conirostris* [2]				L[2]	
Eigenmannia lineatus [2]		D[2]	E[2]	L[2]	
Eigenmannia macrops			E	L	
Eigenmannia virescens	C	D[1]		L[1]	
Rhabdolichops electrogrammus [2]				L[2]	
Sternopygus macrurus	C[1]	D[1]	E[1]	L	
Rhamphichthyidae					
Gymnorhamphichthys cf. *hypostomus*				L	
Gymnorhamphichthys cf. *rondoni* [2]				L[2]	
Gymnorhamphichthys cf. *rosamariae* [2]				L[2]	
Rhamphichthys rostratus [1]		D[1]		L[1]	
Hypopomidae					
Brachyhypopomus beebei [2]					U[2]
Brachyhypopomus brevirostris	C	D			
Brachyhypopomus sp. 1 [2]			E[2]		
Brachyhypopomus sp. 2 [2]			E[2]		
Hypopomus artedi	C[1]	D[1]	E[1]	L[2]	
Hypopygus lepturus [2]	C[2]	D[2]	E[2]	L[2]	
Hypopygus neblinae [2]	C[2]				
Steatogenys elegans		D		L[2]	
Apteronotidae					
Apteronotus albifrons [1]				L[1]	
Apteronotus leptorhynchus			E[1]	L	
Porotergus gymnotus				L	
Gymnotidae					
Gymnotus anguillaris [2]			E[2]	L[2]	
Gymnotus carapo	C[1]		E[1]	L	U[1]
Gymnotus cf. *pedanopterus* [2]				L[2]	
Electrophoridae					
Electrophorus electricus [1]				L[1]	
Mugilidae					
Agonostomus monticola [2]		D[2]			
Belonidae					
Potamorrhaphis guianensis	C[1]	D[1]	E	L	

Aplocheilidae	
Rivulus breviceps	C
Rivulus frenatus [1]	
Rivulus holmiae	
Rivulus lanceolatus [1]	
Rivulus stagnatus	
Rivulus waimacui	
Anablepidae	
Anableps anableps [2]	
Poeciliidae	
Poecilia parae	C
Poecilia picta	C
Poecilia reticulata	C
Poecilia vivipara	C
Poecilia sp.	C
Poecilia cf. *reticulata*	C
Tomeurus gracilis	
Synbranchidae	
Synbranchus marmoratus	C
Sciaenidae	
Bairdiella sanctaeluciae [2]	
Ophioscion punctatissimus [2]	
Pachypops fourcroi [1]	
Pachyurus grunniens	
Stellifer rastrifer	
Nandidae	
Polycentrus schomburgki	
Cichlidae	
Aequidens geayi [1]	
Acarichthys heckeli	
Acaronia nassa	
Aequidens potaroensis	
Aequidens tetramerus	
Apistogramma ortmanni	
Apistogramma steindachneri	
Biotodoma cupido	
Chaetobranchus flavescens [1]	
Cichla ocellaris	
Cichlasoma bimaculatum	
Cleithracara maronii	
Crenicara punctulata [1]	
Crenicichla alta	
Crenicichla johanna	
Crenicichla lugubris	
Crenicichla reticulata	
Crenicichla saxatilis	
Crenicichla wallacei	
Geophagus surinamensis	
Guianacara cf. *geayi* [2]	
Heros cf. *appendiculatus*	
Krobia guianensis [2]	
Mesonauta guyanae	
Nannacara anomala	
Pterophyllum scalare [1]	
Satanoperca leucosticta	
Tilapia rendalli [2]	

Aplocheilidae					
Rivulus breviceps	C			L^1	
Rivulus frenatus ^{1}			E^1		
Rivulus holmiae				L^2	U
Rivulus lanceolatus ^{1}			E^1		
Rivulus stagnatus		D^1		L^2	
Rivulus waimacui				L	
Anablepidae					
Anableps anableps ^{2}		D^2			
Poeciliidae					
Poecilia parae	C	D			
Poecilia picta	C				
Poecilia reticulata	C				
Poecilia vivipara	C				
Poecilia sp.	C				
Poecilia cf. *reticulata*	C				
Tomeurus gracilis		D			
Synbranchidae					
Synbranchus marmoratus	C^2		E^1	L^2	
Sciaenidae					
Bairdiella sanctaeluciae ^{2}		D^2			
Ophioscion punctatissimus ^{2}		D^2			
Pachypops fourcroi ^{1}		D^1			
Pachyurus grunniens			E^2	N^1	
Stellifer rastrifer	C^1	D^2			
Nandidae					
Polycentrus schomburgki	C	D			
Cichlidae					
Aequidens geayi ^{1}			E^1	L^1	
Acarichthys heckeli			E		
Acaronia nassa	C	D	E	L^2	
Aequidens potaroensis			E^1	L	U
Aequidens tetramerus	C^1	D	E		
Apistogramma ortmanni			E^1	L^2	
Apistogramma steindachneri	C	D	E	L	
Biotodoma cupido	C^1		E	L^1	
Chaetobranchus flavescens ^{1}	C^1		E^1		
Cichla ocellaris	C^1	D^2	E	L^1	
Cichlasoma bimaculatum	C	D^2			
Cleithracara maronii		D			
Crenicara punctulata ^{1}			E^1		
Crenicichla alta			E	L	U
Crenicichla johanna	C^1	D^1	E	L	
Crenicichla lugubris			E	L^1	
Crenicichla reticulata			E		
Crenicichla saxatilis	C	D	E	L^2	
Crenicichla wallacei			E	L^1	
Geophagus surinamensis		D	E	L^2	
Guianacara cf. *geayi* ^{2}		D^2			
Heros cf. *appendiculatus*		D^2		L	
Krobia guianensis ^{2}		D^2			
Mesonauta guyanae	C	D	E^1		
Nannacara anomala	C				
Pterophyllum scalare ^{1}			E^1		
Satanoperca leucosticta	C^1	D	E	L	
Tilapia rendalli ^{2}	C^2				
Eleotridae					
Eleotris amblyopsis ^{1}	C^1				
Achiridae					
Achirus achirus ^{2}			E^2		
Achirus lineatus ^{1}	C^1		E^1	N^1	
Soleidae					
Soleonasus finis ^{1}				N^1	
Tetraodontidae					
Colomesus psittacus ^{2}		D^2	E^2		
Total number of species per drainage:	**81**	**129**	**208**	**183**	**28**
Total species per drainage in 1908:	74	92	150	128	20
Number of species unique to 1908:	37	41	57	51	6
Total species per drainage in 1998:	44	88	151	133	22
Number of species unique to 1998:	7	37	58	57	8

Total number of species:	**340**
Total number of species reported in 1908:	248
Number of species unique to 1908:	68
Total number of species reported in 1998:	272
Number of species unique to 1998:	92

Aus bus = species reported in 1908 and 1998
Aus bus ^{1} = species reported in 1908 only
Aus bus ^{2} = species reported in 1998 only
C,D,E,L,U = presence reported in 1908 and 1998
C^1,D^1,E^1,L^1,U^1 = presence reported in 1908 only
C^2,D^2,E^2,L^2,U^2 = presence reported in 1998 only

but rural Guyanese described water quality and fishing success around such operations as poor.

One possibly taxon-specific impact of mining was the lower diversity of loricariid catfishes observed in the Potaro River. In particular, Eigenmann collected 87 specimens of *Lithoxus lithoides* from the Potaro River at Amatuk, where we were unable to find any. These catfishes are dorsoventrally flattened and live under rocks in swift water, which makes them difficult to collect with seines. Eigenmann used hiari root at Amatuk and described how *L. lithoides* was secured with the poison. Although our inability to collect *Lithoxus* may have been at least partially a result of not using poison, it seems that our effort should have detected this species, given that Eigenmann's sample suggested a large population. The absence of any specimens in 1998 suggested that the population of *L. lithoides* at Amatuk has dramatically decreased during the past 90 years.

Lithoxus feeds primarily on aquatic insect larvae and, like other loricariids, also feeds on the nutrient-rich biofilm that covers submerged objects. The mercury from gold mining is likely to be deposited in biofilm, and substrate-scraping fishes such as *Lithoxus* may be the first to suffer from its toxic effects through ingestion.

Other fishes notable for their absence in 1998 were doradid catfishes below Tumatumari Cataract. Eigenmann collected 28 individuals of *Leptodoras linnelli*. The absence of this sand-dwelling species from our 1998 sample at Tumatumari suggests that the population has been lost or has been drastically reduced. We spent two days and nights at Tumatumari, and during this time several barge dredges worked continually below the cataract. Small barge dredges can process 1.4 cubic meters of sediments per minute and collectively can influence the streambed to such an extent as to threaten navigation (Biller, 1994). Large mounds of stream substrate were piled along the shoreline and it seems probable that dredging activity in this area has adversely affected the local doradid diversity.

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Literature cited

Anonym. 1998. The Dorling Kindersley world reference atlas. Second Edition. Dorling Kindersley, New York, 731 pp.

Biller, D. 1994. Informal gold mining and mercury pollution in Brazil. Policy Research Working Paper 1304.: 1-36. World Bank, Washington.

Eigenmann, C. H. 1909. Reports on the Expedition to British Guiana of the Indiana University and the Carnegie Museum, 1908. Report No. I. Some new genera and species of fishes from British Guiana. Ann. Carn. Mus., 6: 4-54.

— 1912. The freshwater fishes of British Guiana, including a study of the ecological groupings of species and the relation of the fauna of the plateau to that of the lowlands. Mem. Carn. Mus., 5: 1-578, 103 pls.

Eschmeyer, W. N. 1998. Catalog of Fishes. California Academy of Sciences, San Francisco, 2905 pp.

Ferraris, C. J. & M. C. C. de Pinna 1999. Higher-level names for catfishes (Actinopterygii: Ostariophysi: Siluriformes). Proc. Cal. Acad. Sci., 51: 1-17.

Nelson, J. S. 1994. Fishes of the world. Third edition. Wiley, New York, 600 pp.

Swan, M. 1958. British Guiana, The land of six peoples. Her Majesty's Stationary Office, London, 235 pp.

Vannote, R. L., G. W. Minshall, K. W. Cummins, Z. J. R. Sedell & C. E. Cushing 1980. The river continuum concept. Can. J. Fish. Aquat. Sci., 37: 130-137.

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