The fish fauna of the Iwokrama Forest

GRAHAM WATKINS
Iwokrama International Centre, 77 High Street, Kingston, Georgetown, PO Box 10630, Guyana—gwatkins@iwokrama.org

WILLIAM SAUL
Department of Ichthyology, Academy of Natural Sciences, 1900 Benjamin Franklin Parkway, Philadelphia PA 19103-1195, U.S.A.

ERLING HOLM
Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada, M5S 2C6—erlingh@rom.on.ca

CYNTHIA WATSON
University of Missouri, St. Louis MO 63121-4400, U.S.A.

DEOKIE ARJOON
Centre for the Study of Biological Diversity, Georgetown, Guyana

JAKE BICKNELL
Bina Hill Institute, Annai District, Region 9, Guyana—jbicknell@iwokrama.org

ABSTRACT—Fishes were collected from the rivers in and around the Iwokrama Forest during January–February and November–December 1997. Four hundred species of fish were recorded from forty families in ten orders. Many of these fishes are newly recorded from Guyana and several are thought to be endemic. The number of species recorded for the area is surprising given the low level of effort and suggests that this area may be particularly important from a fish diversity perspective. This paper focuses on species of particular interest from a management perspective including those considered economically important, rare or endangered. The paper is also the basis for developing fisheries management systems in the Iwokrama Forest and Rupununi Wetlands.

INTRODUCTION

Fish are key components of Amazonian rain forest ecosystems (Barthem and Goulding 1997; Goulding 1983; Goulding et al. 1995; Lowe-McConnell 1995; Lundberg 2001). They are linked to forests through nutrient flows into wetlands and by migrations of fish through inundated forest ecosystems. In addition, fish are often critical traditional food sources that define human-forest relationships (Robinson & Redford 1991). Fish communities respond to changes in the physical and chemical characteristics of wetlands; in this context, human impacts through timber harvesting, road building, and mining can transform fish communities. Padoch et al. (1999) describe the effects of "boom and bust" natural resource economic cycles on varzéa (flooded forests) and express the need for forest management to include sustainable fishing, habitat conservation and management of long range fish migrations.

The aquatic systems within and around the Iwokrama Forest are key components of the Iwokrama Forest ecosystem. Local people have been long aware of the linkages between seasonal flooding and the feeding and spawning cycles of fishes in the Iwokrama Forest and Rupununi Wetlands (Forte et al. 1999). In addition, fishes are important resources for the indigenous communities of the North Rupununi (Forte, Janki et al. 1999) and several fishes (*Arapaima gigas*, *Cichla ocellaris*, and pimelodid catfishes) are sold commercially. These wetlands and their fish fauna are integral to deriving economic and social benefits from the Iwokrama Forest. Unfortunately, there have been few studies of the wetland resources in the Iwokrama Forest, or in Guyana as a whole (see Eigenmann 1912, Hardman et al. 2002; Lowe-McConnell 1964, 1967, 1969).

The Iwokrama Forest is drained by the Essequibo River and two smaller rivers, the Burro-Burro and Siparuni, that are briefly confluent before joining the Essequibo. It is bordered to the east by the Essequibo River and to the north and west by the Siparuni River. The Burro-Burro River runs through the central part of the Iwokrama Forest (Fig. 1).

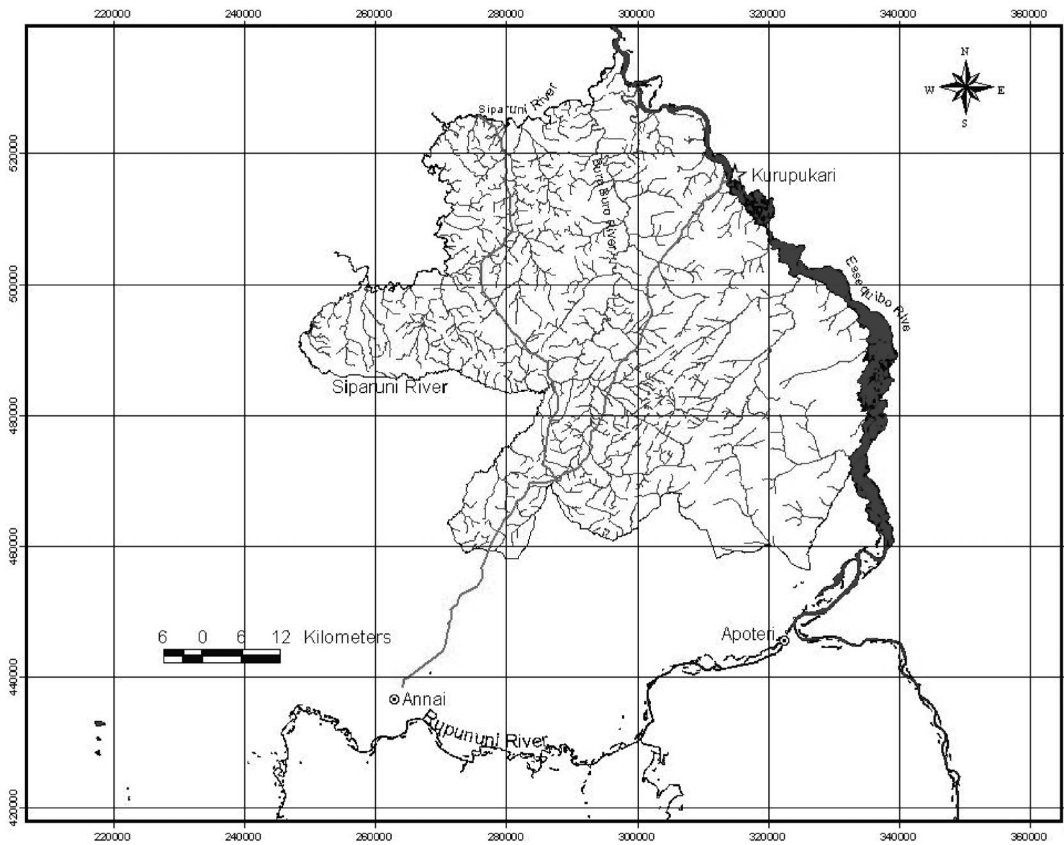

Fig. 1. The river systems in and around the Iwokrama Forest (coordinates in UTM).

Approximately, 1500 km^2 of the Iwokrama Forest drain directly to the Essequibo River, 1500 km^2 to the Burro-Burro and 900 km^2 to the Siparuni River (Hawkes & Wall 1993).

In the vicinity of the Iwokrama Forest the Essequibo River has main channels 250–500 metres wide and is at most approximately 1 km wide. It is characterized north of Kurupukari Falls by extensive sand bars that are visible during low water. In several places throughout the Iwokrama Forest, it is crossed by volcanic dykes that form rapids. The Essequibo has a probable maximum depth of 40 m (Hawkes & Wall 1993), and its banks are not high except where scouring has occurred (Hawkes & Wall 1993). The Essequibo drainage is seasonally linked to the Amazon drainage when the flooded savannas form a continuous expanse of water between the tributaries of the Rio Branco and the Rupununi River. The Burro-Burro and Siparuni Rivers are much smaller rivers with maximal widths of 100 m and 150 m respectively. As in the Essequibo, rapids are formed where the rivers cross over volcanic dykes. Both the Burro-Burro and Siparuni rivers are steep-sided, deep rivers with few sandbars, and little exposed shoreline. The Essequibo River has far more sand and silt substrates than do either the Siparuni or Burro-Burro. The Burro-Burro River floods extensively into the forest during the rainy season.

Amazonian and other South American river systems are often categorized as white, black, or clear waters. Similarly, Carter (1934) describes the rivers of Guyana as either black water or white water. Black waters are acidic, with high carbon dioxide and low oxygen content. White waters are turbid, with low carbon dioxide, high silica, and low acidity. The rivers near the Iwokrama Forest do not neatly fall into these categories. The Essequibo has high sediment loads and can be considered a white water river along its borders with the Iwokrama Forest. This is partly due to the fact that the white water Rupununi River drains into the Essequibo just south of the Iwokrama Forest. Secchi disc visibility ranges from approximately 0.2–1.0 m in the main channels. Despite this, water colour and turbidity change seasonally and spatially, with the result that the river sometimes appears much like what is considered to be black water. For example, south of the confluence between the Rupununi and Essequibo rivers, the upper Essequibo is considerably darker than the lower Essequibo. Changes in the relative contributions from the different tributaries can substantially alter the waters of the Essequibo near the Iwokrama Forest. The Burro-Burro and Siparuni are predominantly black water rivers, with the Siparuni being slightly darker; however the transparency of these rivers is highly variable. All of the main rivers are fed by small third order creeks which are more readily defined either as black, white, or clear waters.

Mean annual rainfall at Kurupukari is approximately 3000 mm per year (Hawkes & Wall 1993). Annai and Apoteri have recorded mean annual rainfall of 1600 mm and 1900 mm respectively (Hawkes & Wall 1993). The Iwokrama Forest therefore has a rainfall gradient that decreases from north to south. Rains peak at both Kurupukari and Annai from May to September. However, in Annai there is generally only one rainy season—Kurupukari is affected by coastal weather patterns with a second shorter rainy season from December to January.

Essequibo River levels respond to seasonal patterns of rainfall over the whole Essequibo drainage of 50,000 km^2. The Burro-Burro and Siparuni however, have more immediate responses to local rainfall and extreme rises are restricted to the lower reaches of these rivers. River levels in the Siparuni and Burro-Burro are almost certainly affected by both rainfall in their catchments and changes in the levels of the Essequibo River. Waters in the Essequibo generally rise from April, and recede from August to October. In total, an average water-level change of six-metres occurs on an annual basis. These changes undoubtedly effect the migration, spawning, and feeding behaviour of fish communities in the Essequibo and possibly even in the systems of the Rupununi (Lowe-McConnell 1995) and Amazon (Barthem & Goulding 1997).

METHODS

Fishes were collected during two expeditions to the rivers in and around the Iwokrama Forest during January–February and November–December of 1997. During January–February, the Essequibo and Burro-Burro drainages were surveyed; in November–December the Essequibo, Burro-Burro, and Siparuni drainages were surveyed. In addition, data from earlier collections by the Royal Ontario Museum were used to develop a species list for the area.

Several survey methods were used (see Plate 1) and mostly included stationary and moving gill nets, seines, dip and hoop nets, hook and line, and chemo-fishing (Noxfish Fish Toxicant Liquid Emulsion—Rotenone). Hook and line were used extensively to record larger species. Rotenone was used for smaller species in the steep sided, deep sections of the Burro-Burro and Siparuni Rivers where seines proved ineffective.

Due to time constraints and difficulty of access, only 41 sites were surveyed in the Burro-Burro and Siparuni drainages, while 84 were surveyed in the Essequibo. Sampling was restricted to the lower order rivers and creeks.

Specimens from collections were deposited at the Centre for the Study of Biological Diversity, University of Guyana, and the Academy of Natural Sciences, Philadelphia. Specimens collected in 1990 by personnel of the Royal Ontario Museum and Youth Challenge International were deposited at the Royal Ontario Museum. Several species were not collected because they were too large or protected in Guyana. These were *Brachyplatystoma vaillantii*, *Brachyplatystoma filamentosum*, *Zungaro zungaro*, and *Arapaima gigas*.

The Abundance-based Coverage and Incidence-based Coverage Estimators of species richness from the computer programme EstimateS.5 (Colwell 1997) were used to estimate fish species richness for the areas surveyed.

RESULTS

Four hundred species of fish were recorded (Appendix 1) from forty families in ten orders. Many of these fishes are newly recorded for Guyana and several are thought to be endemic.

Twenty percent of the sites surveyed contained over 30 species, and three sites contained over 50 species. The majority of these species-rich sites were either small creeks or sand bars in the Essequibo River.

EstimateS.5 (Colwell 1997) was used to estimate fish species richness for the areas surveyed. The Abundance-based Coverage Estimator of species richness estimates that the surveyed area contains 462 species; the Incidence-based Coverage Estimator estimates 747 species. Figure 2 represents the accumulated number of species found in collection lots (a lot is a set of specimens of the same species collected at any one field site over a specific time period), and supports estimate calculations as the number of species continues to increase throughout. The step-wise pattern of species accumulation in Figure 2 suggests the appearance of new species communities in newly sampled habitats.

DISCUSSION

Why So Many Species?

Fish species richness is unusually high in the rivers near the Iwokrama Forest. This is especially apparent when compared with other much larger Amazonian

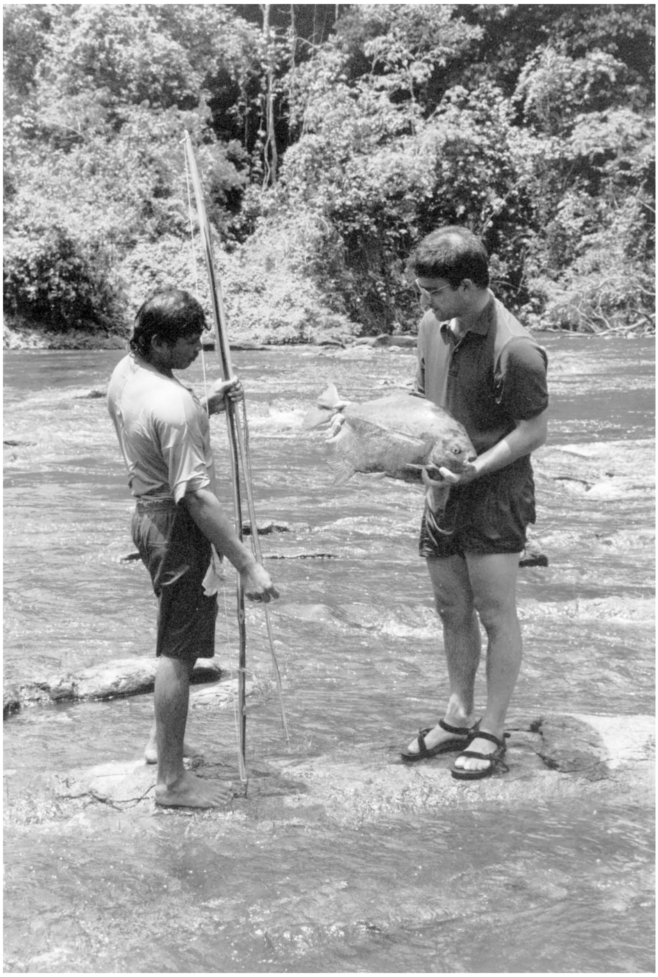

Plate 1. Iwokrama field expedition members Errol McBirney (left) and David Agro with a recently captured fish and the bow and arrow used by Errol in its capture, September 1997. Photography by Robert M. Peck.

drainages (Rio Negro: 450 species, (Goulding 1988) Madeira River: 398 species, (Revenga et al. 2000)).

Two factors potentially cause this elevated diversity. The first factor is the wide range of habitats represented within the sampling area. This was suggested by Lowe-McConnell (1964) as a major cause of the high species richness in the Rupununi savannas. In the area, the large variety of habitats (flooded forests and savannas, rivers, creeks, ponds and oxbow lakes) can support a diverse assemblage of fishes. The second factor is that the Essequibo River is situated between three major ichthyofaunal regions: the Orinoco, eastern Guiana Shield, and Amazon. Flooding during the annual high water period enables an exchange in fish species between these three systems.

Distribution and Migration

The Siparuni, Burro-Burro and Essequibo Rivers are physically and chemically distinct, though variable, and many creeks have distinct origins. Water transparency is an important predictor of fish community structure in Orinoco floodplain lakes (Rodriguez & Lewis 1997). In general, fish with sensory adaptations to low light such as Gymnotiformes and Siluriformes tend to be dominant in turbid lakes, whereas visually oriented fish such as Characiformes, Clupeiformes, and Perciformes tend to be dominant in transparent lakes. Similar patterns have been described in Amazonian systems (Lowe-McConnell 1995) and the Rupununi (Lowe-McConnell 1964). Turbid waters in the rivers near the Iwokrama Forest were dominated by catfish- 78 species of catfish were almost exclusively found in white waters as opposed to 18 species that were found most frequently in black and clear waters. Auchenipterids, pimelodids, loricariids, and doradids were regularly found in samples from white waters, while they were almost absent from black and clear waters. Seventy percent of the 63 species that were most frequently encoun-

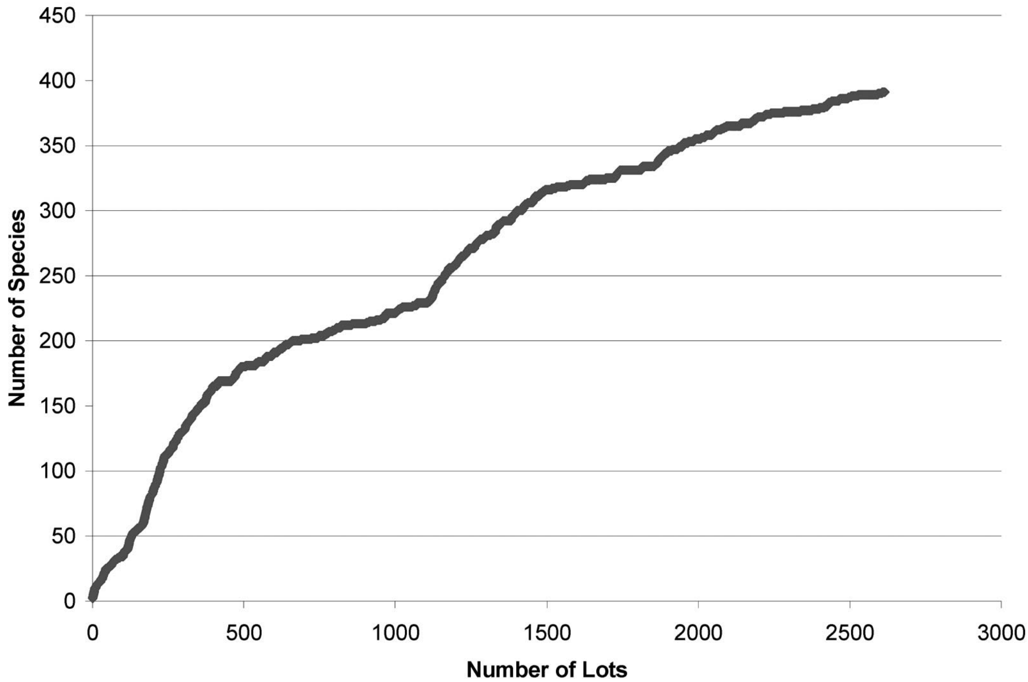

Fig. 2. Number of species recorded as the number of lots increases over time.

tered in black and clear waters were characoids or gymnotids.

As with Amazon and Orinoco fish communities, the key to understanding the Iwokrama Forest fish fauna is the migration, feeding, and spawning patterns that are controlled by seasonally changing water levels and availability of oxygen (Lowe-McConnell 1964, 1995; see Table 1). Many of the fish species in the Iwokrama Forest undertake trophic dispersals and spawning migrations based on changes in water levels. These changes in water levels seasonally modify the available habitats in the area (Table 1).

The majority of fishes in the Iwokrama Forest migrate in response to changing water levels. The dry season and the lower water levels have been described as a "physiological winter" for fish (Lowe-McConnell 1967). A general characteristic of lowland, low-nutrient forest waterways is that allochthonous fruit and leaves form the major food base. Food availability for fishes therefore increases in high water when flooded areas become accessible. To deal with this, fat reserves are built up during the rainy season in preparation for the dry season (Lowe-McConnell 1964). Oxygen levels and available habitats also decrease substantially during the dry season. Some species migrate back to the larger ponds and main rivers to avoid these harsh conditions; despite this many fishes are trapped in drying ponds. Consequently, several species have adaptations, such as air breathing (*Arapaima*, *Electrophorus*) and terrestrial locomotion (e.g., *Erythrinus*, *Hoplerythrinus*, and *Hoplosternum*). These drying ponds, particularly in the savannas, are thought to be ecologically important as a food base for wild cats, birds and other scavengers (personal observation, Watkins).

Lowe-McConnell (1964) observed upstream migrations of several species towards spawning sites in the headwaters of small creeks, at the confluences of rivers and creeks, and in the flooded savannas. These migrations occur when waters rise at the beginning of the rainy season. Fishes begin returning from the flooded areas at the end of the rainy season as waters recede. Exact migration movements are currently unknown, but it is thought that fish travel from the main rivers in the dry season, to adjacent ponds and creeks in the wet season.

The Rupununi River and the surrounding savannas are likely to be vital for the healthy maintenance of fish populations in the nutrient poor Essequibo. It is likely that food availability in the flooded Rupununi savanna drives much of the spawning and feeding movements in the Essequibo. Flooding along the Essequibo is much less extensive than in the Rupununi savannas; thus fishes moving into the Rupununi during the high water periods, unlock a much greater resource than is available in the Essequibo.

Fisheries Management

Several species in the Iwokrama Forest have economic and social values. Certain species have been

Table 1. Seasonal cycles in the Rupununi and Iwokrama Forest (after Lowe-McConnell 1977).

Month	Jan–Feb	Mar–Apr	May–July	Aug–Oct	Nov–Dec
Rainfall	Dry season		Rains		Dry season
Water levels	Low		High		Low
Land covered with water	Small	Expanding	Maximal	Declining	Low
Food levels		Nutrients washed in by first rains increase food and plant growth for cover	Access to flooded forest areas for food		
Reproductive strategy		Spawning and the growth of young	Feeding and growing	Beginning high mortality	Stranding and predation; de-oxygenation of pools
Fish movements	Confinement to pools	Lateral and longitudinal migrations up rivers and creeks	Dispersal on floodplains	Movements back to the river	Confinement to pools
Fishing	Catch fish in ponds—that are normally dry season refuges	Catch upstream migrants—before spawning	No fish available	Catch again as fish move back	Catch fish in ponds—that are normally dry season refuges

used locally for subsistence and commerce. For some, there is an urgent need to develop management systems, and there is now potential to develop other uses for fish including sport fishing and aquarium fisheries. The major commercial species in the area is Arapaima (*Arapaima gigas*). Populations of this species have declined dramatically since the 1960s when harvesting began in earnest for sale to Brazil. *Arapaima* is found mainly in lakes and large creek pools and is more abundant in the Rupununi and the Essequibo near the south-eastern border of the Iwokrama Forest. The Arowana (*Osteoglossum bicirrhosum*) is also an important subsistence and commercial fish that is relatively abundant in the area. It is important both for food and for the aquarium trade and is considered under some conservation threat in the area. The freshwater drum or Basha (*Plagioscion squamosissimus*) is also an important commercial species that lives in deeper water and near falls and is thought to be declining close to villages. The erythrinids including Haimara (*Hoplias macrophthalmus*), Huri (*Hoplias malabaricus*), Yarrow (*Hoplerythrinus unitaeniatus*), and Bush Yarrow (*Erythrinus erythrinus*) are also important species for local subsistence, and the Haimara is also sold commercially. Of the pimelodid catfish, the Skeete or Banana Fish (*Phractocephalus hemioliopterus*), Lao-Lao (*Brachyplatystoma filamentosum*), Blinka (*Brachyplatystoma vaillantii*), Siana (*Zungaro zungaro*) and Jon-Jon (*Pinirampus pirinampu*) are the largest, but commercially exploited at lower levels than the Long Head Cullet (*Pseudoplatystoma tigrinum*) and the Short Head Cullet (*Pseudoplatystoma fasciatum*). The Baiaras (*Cynodon gibbus*, *Hydrolycus armatus*, *Hydrolycus tatauaia* and *Roestes ogilviei*), Lukanani (*Cichla ocellaris*), Yakutu (*Prochilodus rubrotaeniatus*), and Boots (*Trachycorystes trachycorystes*) are also important food fishes.

Many of the fish species found in the Iwokrama Forest play important and complex ecological roles. Whereas little is known about the role of fishes in Guianan terrestrial ecosystems, Goulding (1983) has argued that characoids and catfish play important roles in Amazonian flooded forests as fruit eaters and dispersers; and fish distributions could readily affect forest plant distributions, in particular palms and other key flooded forest species. Characoids tend to be seed predators because of their well developed teeth, whereas catfish tend to be good seed dispersers. In particular, characoid genera such as *Myleus*, *Serrasalmus*, *Pygocentrus*, *Brycon*, *Leporinus* and *Triportheus* may be important seed-eaters and dispersers. The Siluriformes like *Phractocephalus*, *Oxydoras*, *Trachycorystes*, *Pimelodus*, *Pimelodella*, and *Zungaro* are seed-dispersers in Amazonian waterways (Goulding 1983) and are likely to be so in the Iwokrama

Forest. Clearly, gaining an understanding of the biology, in particular diet and seed-dispersal capacities, of these species in the Iwokrama Forest will help in making sound management decisions.

CONCLUSIONS

The Iwokrama Forest has a fish fauna of global significance. The high diversity and pristine condition of the ecosystem makes this area a refuge for large numbers of Amazonian fishes threatened elsewhere. Due to the long distance migrations of fish in the Burro-Burro, Siparuni and Essequibo River watersheds, management of fisheries in the Rupununi wetlands is likely to be important to the management of fisheries in the Iwokrama Forest. Clearly, fish migration, spawning, and feeding strategies are complex and may have far reaching terrestrial and aquatic ecosystem consequences. Successful management of the fisheries of the Iwokrama Forest will therefore require effort to understand migration, spawning and feeding. For example, the major fish harvest periods currently include the spawning runs and the periods when ponds are drying.

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Appendix 1. Fish of the Iwokrama Forest showing numbers recorded at different locations. Nomenclature follows Reis et al. (2003).

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
ELASMOBRANCHII				
MYLIOBATIFORMES				
POTAMOTRYGONIDAE				
Potamotrygon orbignyi	(Castelnau, 1855)	1	0	0
Potamotrygon sp		1	0	1
OSTEICHTHYES				
OSTEOGLOSSIFORMES				
OSTEOGLOSSIDAE				
Arapaima gigas	(Cuvier, 1829)	1	1	1
Osteoglossum bicirrhosum	(Cuvier, 1829)	1	1	1
CLUPEIFORMES				
CLUPEIDAE				
ENGRAULIIDIDAE				
Anchoviella jamesi	(Jordan & Seale, 1926)	1	0	0
Anchoviella guianensis	(Eigenmann, 1942)	1		1
Anchoviella sp		1	1	1
Jurengraulis sp		1	0	0
CHARACIFORMES		0	0	0
ACESTRORHYNCHIDAE		0	0	0
Acestrorhynchus falcatus	(Bloch, 1794)	1	1	1
Acestrorhynchus falcirostris	(Cuvier, 1819)	1	1	0
Acestrorhynchus heterolepis	(Cope, 1878)	1	0	0
Acestrorhynchus microlepis	(Schomburgk, 1841)	1	1	1
Acestrorhynchus nasutus	Eigenmann, 1912	1	0	0
Acestrorhynchus sp		0	1	1
ANOSTOMIDAE				
Anostomus anostomus	(Linnaeus, 1758)	0	1	1
Anostomus plicatus	Eigenmann, 1912	1	0	1
Anostomus ternetzi	Fernández-Yépez, 1949	1	0	0
Laemolyta proxima	(Garman, 1890)	1	0	0
Leporinus alternus	Eigenmann, 1912	1	0	0
Leporinus arcus	Eigenmann, 1912	1	1	1
Leporinus fasciatus	(Bloch, 1795)	1	0	1
Leporinus friderici	(Bloch, 1794)	1	1	1
Leporinus maculatus	Müller & Troschel, 1844	0	1	1
Leporinus nigrotaeniatus	(Jardine, 1841)	1	1	1
Leporinus pellegrini	Steindachner, 1910	1	1	1
Pseudanos irinae	Winterbottom, 1980	1	0	0
Pseudanos trimaculatus	(Kner, 1858)	0	1	0
Schizodon fasciatus	Spix & Agassiz, 1829	1	0	0
CHARACIDAE				
Acanthocharax microlepis	Eigenmann, 1912	1	0	0
Agoniates halecinus	Müller & Troschel, 1845	1	1	1
Aphyocharax erythrurus	Eigenmann, 1912	1	0	0
Aphyocharax sp		1	0	0
Aphyodite grammica	Eigenmann, 1912	1	0	0
Aphyodite sp		1	0	0
Astyanax bimaculatus	(Linnaeus, 1758)	0	0	1
Astyanax guianensis	Eigenmann, 1909	1	1	0
Brachychalcinus orbicularis	(Valenciennes, 1850)	0	1	1
Brycon falcatus	Müller & Troschel, 1844	1	1	1
Brycon pesu	Müller & Troschel, 1845	1	1	0
Bryconamericus hyphesson	Eigenmann, 1909	1	0	0
Bryconamericus sp		0	0	1
Bryconops affinis	(Günther, 1864)	1	1	1
Bryconops alburnoides	Kner, 1858	1	0	0
Bryconops caudomaculatus	(Günther, 1864)	1	1	1

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Bryconops melanurus	(Bloch, 1794)	1	1	1
Bryconops sp *1*		1	0	0
Bryconops sp *2*		0	1	0
Catoprion mento	(Cuvier, 1819)	1	0	0
Chalceus macrolepidotus	Cuvier, 1816	1	1	1
Charax gibbosus	(Linnaeus, 1758)	1	1	0
Charax hemigrammus	(Eigenmann, 1912)	1	0	0
Creagrutus melanzonus	Eigenmann, 1909	1	0	0
Creagrutus sp		1	0	0
Ctenobrycon spilurus	(Valenciennes, 1850)	1	1	1
Cynopotamus essequibensis	Eigenmann, 1912	1	0	1
Gnathocharax steindachneri	Fowler, 1913	1	0	0
Hemigrammus analis	Durbin, 1909	1	0	0
Hemigrammus belottii	(Steindachner, 1882)	1	1	1
Hemigrammus cylindricus	Durbin, 1909	1	0	0
Hemigrammus gracilis	(Lütken, 1875)	1	0	0
Hemigrammus guyanensis	Géry, 1959	0	0	1
Hemigrammus iota	Durbin, 1909	1	0	0
Hemigrammus levis	Durbin, 1908	1	0	0
Hemigrammus ocellifer	(Steindachner, 1882)	1	1	1
Hemigrammus ocellifer-gr	(Steindachner, 1882)	1	0	0
Hemigrammus orthus	Durbin, 1909	1	0	0
Hemigrammus schmardae	(Steindachner, 1882)	1	0	0
Hemigrammus sp		1	0	0
Heterocharax macrolepis	Eigenmann, 1912	1	0	0
Hyphessobrycon gr. agulha	Fowler, 1913	1	0	0
Hyphessobrycon bentosi	Durbin, 1908	1	0	1
Hyphessobrycon gr. bentosi	Durbin, 1908	0	1	0
Hyphessobrycon bentosi-rosaceus	Durbin, 1909	1	1	1
Hyphessobrycon eos	Durbin, 1909	1	1	0
Hyphessobrycon minimus	Durbin, 1909	1	0	0
Hyphessobrycon minor	Durbin, 1909	1	0	0
Hyphessobrycon rosaceus	Durbin, 1909	1	0	0
Hyphessobrycon sp		1	0	1
Iguanodectes spilurus	(Günther, 1864)	1	0	1
Jupiaba abramoides	(Eigenmann, 1909)	1	1	1
Jupiaba essequibensis	(Eigenmann, 1909)	1	1	1
Jupiaba pinnata	(Eigenmann, 1909)	0	1	1
Jupiaba polylepis	(Günther, 1864)	1	1	1
Jupiaba potaroensis	(Eigenmann, 1909)	0	0	1
Knodus heteresthes	(Eigenmann, 1908)	1	0	0
Knodus sp		1	1	0
Metynnis argenteus	Ahl, 1923	1	0	0
Metynnis hypsauchen	(Müller & Troschel, 1844)	1	0	0
Metynnis luna	Cope, 1878	1	0	0
Microschemobrycon casiquiare	Böhlke, 1953	1	0	1
Microschemobrycon geisleri	Géry, 1973	0	1	1
Microschemobrycon sp		1	0	0
Moenkhausia chrysargyrea	(Günther, 1864)	1	1	1
Moenkhausia gr. chrysargyrea	(Günther, 1864)	1	0	0
Moenkhausia collettii	(Steindachner, 1882)	1	1	1
Moenkhausia copei	(Steindachner, 1882)	1	1	1
Moenkhausia cotinho	Eigenmann, 1908	1	0	0
Moenkhausia dichroura	(Kner, 1859)	1	0	0
Moenkhausia georgiae	Géry, 1965	0	1	1
Moenkhausia grandisquamis	(Müller & Troschel, 1845)	1	0	0
Moenkhausia lepidura	(Kner, 1858)	1	1	1

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Moenkhausia megalops	Eigenmann, 1907	1	0	1
Moenkhausia oligolepis	(Günther, 1864)	1	1	1
Moenkhausia shideleri	Eigenmann, 1909	0	1	0
Moenkhausia surinamensis	Géry, 1965	0	1	0
Moenkhausia sp *1*		1	0	0
Moenkhausia sp *2*		1	0	0
Moenkhausia sp *3*		1	0	0
Moenkhausia sp *4*		1	0	0
Myleus rhomboidalis	(Cuvier, 1818)	1	1	1
Myleus rubripinnis	(Müller & Troschel, 1844)	1	0	1
Myleus torquatus	(Kner, 1858)	1	0	1
Myleus sp		1	1	1
Oxybrycon sp		1	0	0
Parapristella aubynei	Eigenmann, 1909	1	0	0
Phenacogaster megalostictus	Eigenmann, 1909	1	1	1
Phenacogaster microstictus	Eigenmann, 1909	1	0	0
Phenacogaster sp		1	0	1
Piaractus brachypomus	(Cuvier, 1818)	1	0	0
Poptella compressa	(Günther, 1864)	1	0	1
Pristella maxillaries	(Ulrey, 1894)	1	0	0
Pristobrycon sp		1	0	0
Pristobrycon striolatus	Steindachner, 1908	1	1	1
Pygocentrus nattereri	Kner, 1858	1	0	0
Pygopristis denticulate	(Cuvier, 1819)	1	0	0
Roeboides thurni	Eigenmann, 1912	1	1	0
Serrasalmus rhombeus	(Linnaeus, 1766)	1	0	1
Serrasalmus serrulatus	(Valenciennes, 1850)	1	1	1
Serrasalmus sp		1	1	1
Tetragonopterus argenteus	Cuvier, 1816	1	0	1
Tetragonopterus chalceus	Spix & Agassiz, 1829	1	0	1
Thrissobrycon sp	Böhlke, 1953	1	0	0
Triportheus angulatus	(Spix & Agassiz, 1829)	1	0	0
Triportheus rotundatus	(Jardine, 1841)	1	1	1
Unidentified		1	1	0
CHILODONTIDAE				
Caenotropus labyrinthicus	(Kner, 1859)	1	0	0
Caenotropus maculosus	(Eigenmann, 1912)	1	0	1
Chilodus punctatus	Müller & Troschel, 1844	1	0	0
CRENUCHIDAE				
Ammocryptocharax lateralis	(Eigenmann, 1909)	0	1	1
Amnocryptocharax vintonae	(Eigenmann, 1909)	1	1	1
Characidium gr. fasciatum	Reinhardt, 1866	0	1	1
Characidium pteroides	Eigenmann, 1909	1	0	0
Characidium steindachneri	Cope, 1878	1	0	0
Crenuchus spilurus	Günther, 1864	1	1	1
Leptocharacidium sp		0	1	0
Melanocharacidium blennioides	(Eigenmann, 1909)	1	1	1
Melanocharacidium dispilomma	Buckup, 1993	0	1	1
Microcharacidium eleotrioides	(Géry, 1960)	0	1	1
Microcharacidium sp		1	1	0
CTENOLUCIIDAE		0	0	0
Boulengerela cuvieri	(Agassiz, 1829)	1	0	0
CURIMATIDAE		0	0	0
Curimata cyprinoides	(Linnaeus, 1766)	1	0	0
Curimata roseni	Vari, 1989	1	0	0
Curimata vittata	(Kner, 1858)	1	0	0
Curimatella immaculate	(Fernández-Yépez, 1948)	1	0	0

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Curimatopsis crypticus	Vari, 1982	1	0	0
Cyphocharax festivus	Vari, 1992	1	1	0
Cyphocharax microcephalus	(Eigenmann & Eigenmann, 1889)	1	0	0
Cyphocharax spilurus	(Günther, 1864)	1	1	1
Cyphocharax sp *1*		1	0	0
Cyphocharax sp *2*		1	0	0
Psectrogaster ciliata	(Müller & Troschel, 1844)	1	0	0
Psectrogaster essequibensis	(Günther, 1864)	1	1	0
Steindachnerina bimaculata	(Steindachner, 1876)	1	0	0
Steindachnerina planiventris	Vari & Vari, 1989	1	0	0
CYNODONTIDAE				
Cynodon gibbus	Spix & Agassiz, 1829	0	1	1
Hydrolycus armatus	(Jardine & Schomburgk, 1841)	1	0	0
Hydrolycus tatauaia	Toledo-Piza, Menezes & Santos, 1999	1	1	0
Roestes molossus	(Kner, 1858)	1	0	0
Roestes ogilviei	(Fowler, 1914)	1	0	0
ERYTHRINIDAE				
Erythrinus erythrinus	(Bloch & Schneider, 1801)	1	1	1
Hoplerythrinus unitaeniatus	(Agassiz, 1829)	1	1	1
Hoplias macrophthalmus	(Pellegrin, 1907)	1	1	1
Hoplias malabaricus	(Bloch, 1794)	1	1	1
Hoplias sp		1	1	1
GASTEROPELECIDAE				
Carnegiella strigata	(Günther, 1864)	1	1	1
HEMIODONTIDAE				
Argonectes longiceps	(Kner, 1858)	1	0	0
Bivibranchia bimaculata	Vari, 1985	1	0	0
Bivibranchia fowleri	Steindachner, 1908	1	0	0
Hemiodus argenteus	(Pellegrin, 1908)	1	0	0
Hemiodus gracilis	Günther, 1864	1	0	0
Hemiodus gr. gracilis	Günther, 1864	1	0	0
Hemiodus microlepis	(Kner, 1858)	1	0	0
Hemiodopsis sp *1*		1	0	0
Hemiodopsis sp *2*		1	0	0
Hemiodus quadrimaculatus	Pellegrin, 1908	1	1	1
Hemiodus gr. semitaeniatus	Kner, 1858	0	0	1
Hemiodus unimaculatus	(Bloch, 1794)	1	0	1
LEBIASINIDAE				
Nannostomus eques	Steindachner, 1876	1	1	0
Nannostomus harrisoni	Eigenmann, 1909	0	0	1
Nannostomus marginatus	Eigenmann, 1909	1	1	1
Nannostomus minimus	Eigenmann, 1909	1	1	1
Nannostomus trifasciatus	Steindachner, 1876	1	0	0
Nannostomus unifasciatus	Steindachner, 1876	1	0	0
Pyrrhulina filamentosa	Valenciennes, 1847	1	1	1
Pyrrhulina stoli	Boeseman, 1953	1	0	0
Pyrrhulina sp		1	0	0
PARODONTIDAE				
Parodon guyanensis	Géry, 1959	0	1	1
PROCHILODONTIDAE				
Prochilodus rubrotaeniatus	Jardine & Schomburgk, 1841	1	1	0
SILURIFORMES				
ASPREDINIDAE				
Bunocephalus amaurus	Eigenmann, 1912	1	0	0
Bunocechalus coracoideus	Cope, 1874	1	1	0
Bunocephalus verrucosus	(Walbaum, 1792)	1	1	0

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
AUCHENIPTERIDAE				
Ageneiosus inermis	(Linnaeus, 1766)	1	0	1
Ageneiosus pardalis	Lütken, 1874	1	0	1
Ageneiosus piperatus	(Eigenmann, 1912)	1	0	0
Auchenipterus demerarae	Eigenmann, 1912	0	1	0
Auchenipterus nuchalis	(Spix & Agassiz, 1829)	1	0	0
Centromochlus heckelii	(De Filippi, 1853)	1	0	0
Centromochlus schultzi	Rössel, 1962	1	0	0
Centromochlus sp		1	0	0
Pseudauchenipterus nodosus	(Bloch, 1794)	1	0	1
Pseudauchenipterus sp		1	0	0
Tatia aulopygia	(Kner, 1858)	1	0	0
Tatia creutzbergi	(Boeseman, 1953)	0	1	0
Tatia sp *1*		1	0	0
Tatia sp *2*		1	1	1
Trachyelopterus galeatus	(Linneaus, 1766)	1	0	0
Trachycorystes trachycorystes	(Valenciennes, 1840)	1	0	0
Trachycorystes sp		1	0	0
Unidentified		0	0	1
CALLICHTHYIDAE				
Callichthys callichthys	(Linnaeus, 1758)	1	0	0
Corydoras melanistius	Regan, 1912	1	1	1
Corydoras punctatus	(Bloch, 1794)	1	0	0
Corydoras gr. simulatus	Weitzman & Nijssen, 1970	1	1	0
Corydoras sp		1	0	0
Megalechis thoracata	(Valenciennes, 1840)	1	1	1
CETOPSIDAE		0	0	0
Helogenes marmoratus	Günther, 1863	1	1	1
Pseudocetopsis minuta	(Eigenmann, 1912)	1	0	0
Unidentified		0	1	0
DORADIDAE				
Acanthodoras cataphractus	(Linnaeus, 1758)	1	1	0
Acanthodoras spinosissimus	(Eigenmann & Eigenmann, 1888)	1	0	1
Amblydoras affinis	(Kner, 1855)	1	1	1
Doras carinatus	(Linnaeus, 1766)	1	1	1
Doras micropoeus	(Eigenmann, 1912)	1	0	0
Hassar orestis	(Steindachner, 1875)	1	0	0
Leptodoras hasemani	(Steindachner, 1915)	1	0	0
Leptodoras linnelli	Eigenmann, 1912	1	0	0
Nemadoras leporhinus	(Eigenmann, 1912)	1	0	0
Oxydoras niger	(Valenciennes, 1821)	1	1	0
Physopyxis lyra	Cope, 1871	1	1	1
Platydoras cf. *costatus*	(Linnaeus, 1758)	0	1	0
Trachydoras cf. *brevis*	(Kner, 1853)	1	0	0
Trachydoras microstomus	(Eigenmann, 1912)	1	0	0
HEPTAPTERIDAE				
Brachyglanis frenata	Eigenmann, 1912	1	0	0
Chasmocranus brevior	Eigenmann, 1912	1	0	0
Chasmocranus longior	Eigenmann, 1912	1	1	1
Chasmocranus sp		0	1	0
Goeldiella eques	(Müller & Troschel, 1848)	1	0	1
Heptapterus sp *1*		0	0	1
Heptapterus sp *2*		1	1	0
Heptapterus sp *3*		1	0	0
Pimelodella cristata	(Müller & Troschel, 1848)	1	1	1
Pimelodella macturki	Eigenmann, 1912	1	0	0
Pimelodella megalops	Eigenmann, 1912	1	0	0

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Pimelodella sp		0	1	0
Rhamdia laukidi	Bleeker, 1858	0	1	1
Rhamdia quelen	(Quoy & Gaimard, 1824)	1	1	1
Rhamdia sp		1	0	0
LORICARIIDAE				
Ancistrus hoplogenys	(Günther, 1864)	0	1	0
Ancistrus lithurgicus	Eigenmann, 1912	1	0	1
Ancistrus temmincki	(Valenciennes, 1840)	1	0	0
Ancistrus sp		0	1	0
Cteniloricaria platystoma	(Günther, 1868)	1	1	1
Cteniloricaria sp		1	0	0
Dasyloricaria sp		0	1	0
Farlowella amazona	(Günther, 1864)	1	0	0
Farlowella nattereri	Steindachner, 1910	0	0	1
Farlowella rugosa	Boeseman, 1971	0	1	0
Farlowella sp *1*		1	0	0
Farlowella sp *2*		1	0	0
Farlowella sp *3*		1	0	0
Hemiodontichthys acipenserinus	(Kner, 1853)	1	0	0
Hypoptopoma guianense	Boeseman, 1974	1	0	1
Hypoptopoma sp		1	0	0
Hypostomus hemiurus	(Eigenmann, 1912)	1	0	0
Hypostomus plecostomus	(Linnaeus, 1758)	1	0	0
Hypostomus watwata	(Hancock, 1828)	1	1	0
Limatulichthys griseus	(Eigenmann, 1909)	1	0	0
Limatulichthys sp		1	1	0
Lithoxus lithoides	Eigenmann, 1910	1	1	1
Loricaria cataphracta	Linnaeus, 1758	1	0	0
Loricaria sp *1*		1	0	0
Loricaria sp *2*		1	0	0
Loricariichthys brunnea	(Hancock, 1828)	1	0	0
Loricariichthys sp		1	0	0
Oxyropsis carinata	(Steindachner, 1879)	1	0	0
Parotocinclus britskii	Boeseman, 1974	1	1	1
Parotocinclus collinsae	Schmidt & Ferraris, 1985	1	1	1
Psuedacanthicus leopardus	(Fowler, 1914)	1	0	0
Pseudancistrus barbatus	(Valenciennes, 1840)	1	1	1
Pseudancistrus nigrescens	Eigenmann, 1912	1	0	1
Pseudancistrus sp *1*		1	1	1
Rineloricaria sp *1*		1	0	1
Rineloricaria sp *2*		1	0	0
Rineloricaria fallax	(Steindachner, 1915)	1	0	0
Rineloricaria platyura	(Müller & Troschel, 1848)	1	1	0
Rineloricaria stewarti	(Eigenmann, 1909)	0	1	0
PIMELODIDAE				
Brachyplatystoma filamentosum	(Lichtenstein, 1819)	1	0	0
Brachyplatystoma vaillantii	(Valenciennes, 1840)	1	1	1
Hemisorubim platyrhynchos	(Valenciennes, 1840)	1	1	0
Leiarius marmoratus	(Gill, 1870)	1	1	0
Megalonema platycephalum	Eigenmann, 1912	1	0	0
Phractocephalus hemiliopterus	(Bloch & Schneider, 1801)	1	0	0
Pimelodus albofasciatus	Mees, 1974	1	0	0
Pimelodus blochii	Valenciennes, 1840	0	0	1
Pimelodus blochii- gr. A	Valenciennes, 1840	1	1	1
Pimelodus blochii- gr. B	Valenciennes, 1840	1	1	0
Pimelodus ornatus	Kner, 1858	0	1	1
Pirinampus pirinampu	(Spix & Agassiz, 1829)	0	1	0

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Pseudoplatystoma fasciatum	(Linnaeus, 1766)	1	1	0
Pseudoplatystoma tigrinum	(Valenciennes, 1840)	1	0	0
Sorubim lima	(Bloch & Schneider, 1801)	1	0	0
Zungaro zungaro	(Humboldt, 1821)	1	0	0
PSEUDOPIMELODIDAE				
Batrachoglanis raninus	(Valenciennes, 1840)	1	1	1
Microglanis poecilus	Eigenmann, 1912	1	0	1
Pseudopimelodus sp		0	1	0
TRICHOMYCTERIDAE				
Haemomaster sp		1	0	0
Henonemus punctatus	Boulenger, 1887	1	0	0
Homodiaetus sp *1*		1	0	0
Homodiaetus sp *2*		1	0	0
Ituglanis gracilior	(Eigenmann, 1912)	1	0	0
Ochmacanthus sp *1*		1	0	0
Ochmacanthus sp *2*		1	0	0
Ochmacanthus sp *3*		1	0	0
Stegophilus sp		1	0	0
Trichomycterus sp		0	0	1
Vandellia beccarii	Di Caporiacco, 1935	1	0	0
Vandellia cirrhosa	Valenciennes, 1846	1	0	0
Vandellia sp		1	0	0
GYMNOTIFORMES				
APTERONOTIDAE				
Apteronotus albifrons	(Linnaeus, 1766)	0	1	1
Apteronotus leptorhynchus	(Ellis, 1912)	1	0	0
Apteronotus sp		0	0	1
Porotergus gimbeli	Ellis, 1912	1	0	0
Porotergus gymnotus	Ellis, 1912	1	0	0
Sternarchorhynchus oxyrhynchus	(Müller & Troschel, 1849)	1	0	0
GYMNOTIDAE				
Electrophorus electricus	(Linnaeus, 1766)	1	1	1
Gymnotus anguillaris	Hoedeman, 1962	1	1	1
Gymnotus carapo	Linnaeus, 1758	1	1	1
Gymnotus sp		1	0	1
HYPOPOMIDAE				
Brachyhypopomus beebei	(Schultz, 1944)	1	1	1
Brachyhypopomus sp		1	0	0
Hypopomus artedi	(Kaup, 1856)	0	1	1
Hypopomus sp *1*		0	0	1
Hypopomus sp *2*		1	0	0
Hypopomus sp *3*		1	0	0
Hypopomus sp *4*		1	0	0
Hypopygus lepturus	Hoedeman, 1962	1	1	1
Hypopygus sp *1*		1	0	0
Hypopygus sp *2*		1	0	0
Microsternarchus sp *1*		1	1	0
Microsternarchus sp *2*		1	0	0
Platyurosternarchus macrostomus	(Günther, 1870)	1	0	0
Steatogenys elegans	(Steindachner, 1880)	1	0	1
RHAMPHYCHTHYIDAE				
Gymnorhamphichthys rondoni	(Miranda-Ribeiro, 1920)	1	0	1
Gymnorhamphichthys sp		1	0	0
STERNOPYGIDAE				
Distocyclus conirostris	(Eigenmann & Allen, 1942)	1	0	0
Eigenmannia limbata	(Schreiner & Miranda-Ribeiro, 1903)	0	1	1
Eigenmannia macrops	(Boulenger, 1897)	1	0	0

Appendix 1. (*continued*)

Order, Family, Genus and Species	Authority	Essequibo	Siparuni	Burro-Burro
Eigenmannia virescens	(Valenciennes, 1842)	1	1	1
Eigenmannia sp		0	0	1
Rhabdolichops sp		1	0	0
Sternopygus macrurus	(Bloch & Schneider, 1801)	1	1	1
CYPRINODONTIFORMES				
POECILIIDAE				
Poecilia reticulata	Peters, 1859	1	0	0
RIVULIDAE				
Rivulus waimacui	Eigenmann, 1909	1	0	0
Rivulus sp		1	1	1
BELONIFORMES		0	0	0
BELONIDAE		0	0	0
Potamorrhaphis guianensis	(Jardine, 1843)	1	1	1
Pseudotylosurus microps	(Günther, 1866)	1	0	0
SYNBRANCHIFORMES				
SYNBRANCHIDAE				
Synbranchus marmoratus	Bloch, 1795	1	1	0
PERCIFORMES				
CICHLIDAE				
Acaronia nassa	(Heckel, 1840)	1	0	0
Aequidens tetramerus	(Heckel, 1840)	1	1	1
Apistogramma ortmanni	(Eigenmann, 1912)	1	1	1
Apistogramma steindachneri	(Regan, 1908)	1	1	1
Biotodoma cupido	(Heckel, 1840)	1	0	1
Chaetobranchus flavescens	Heckel, 1840	1	0	0
Cichla ocellaris	Bloch & Schneider, 1801	1	0	1
Crenicichla alta	Eigenmann, 1912	1	1	1
Crenicichla Johanna	Heckel, 1840	1	1	1
Crenicichla lugubris	Heckel, 1840	1	1	1
Crenicichla strigata	Günther, 1862	0	0	1
Crenicichla wallaceii	Regan, 1905	1	0	1
Crenicichla gr. wallaceii	Regan, 1905	0	1	0
Crenicichla sp		1	1	1
Geophagus brachybranchus	Kullander & Nijssen, 1989	1	0	0
Geophagus surinamensis	(Bloch, 1791)	1	1	0
Guianacara geayi	(Pellegrin, 1902)	1	0	0
Guianacara owroewefi	Kullander & Nijssen, 1989	1	1	1
Heros efasciatus	Heckel, 1840	1	0	0
Heros severus	Heckel, 1840	1	0	0
Mesonauta festivus	(Heckel, 1840)	1	0	0
Mesonauta cf. insignis	(Heckel, 1840)	1	0	0
Pterophyllum scalare	(Schultze, 1823)	1	0	0
Satanoperca jurupari	Heckel, 1840	1	0	0
Satanoperca leucosticta	(Müller & Troschel, 1849)	1	1	1
SCIAENIDAE				
Pachypops trifilis	(Müller & Troschel, 1849)	1	0	0
Pachypops sp		1	0	0
Pachyurus sp		1	0	0
Petilipinnis grunniens	(Jardine, 1843)	1	1	0
Plagioscion squamosissimus	(Heckel, 1840)	1	1	1
PLEURONECTIFORMES				
ACHIRIDAE				
Hypoclinemus mentalis	(Günther, 1862)	1	0	0
Soleonasus finis	Eigenmann, 1912	1	0	0
TETRAODONTIFORMES				
TETRAODONTIDAE				
Colomesus asellus	(Müller & Troschel, 1849)	1	1	1