Environmental impacts of bauxite and gold mining in Nassau Mountains, Suriname.

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Description of Nassau Mountains

Nassau Mountains is an isolated, U-shaped mountain ridge (20 x 20 km^2) situated in the northeast of Suriname, between Brokopondo Reservoir to the west and Marowijne River to the east. Nassau Mountains comprises four steep-sided, almost flat-lying, laterite-capped plateaus A, B, C and D at elevations between 500 and 564 meters above mean sea level (m.amsl). The valley of the northeast flowing Paramaka Creek is confined by the four plateaus of Nassau Mountains; its headwater tributary IJskreek drains Plateau C. Prevailing northeastern trade winds blow up-valley for most part of the year. Nassau Mountains lie within the central rainfall belt of Suriname, which receives some of the highest rainfall in the country (2750-3000 mm $year^{-1}$; Amatali 1993, SPS & OAS 1988). Rainfall on Nassau Plateau is significantly greater (> 3000 mm $year^{-1}$) than in surrounding lower lying areas due to orographic effects and mist interception (JHM, personal observations). Highest rainfall is expected on the northeastern, windward edge of the plateau. Most rain falls in the wet season January-July, while the months September-November are relatively dry. Nassau Mountains are covered with largely undisturbed high dry-land forest and small areas of wet palm-swamp forest (*Euterpe oleracea*) in depressions on the plateaus and low 'mountain savanna' forest on the northeastern edge of the plateau (Bánki et al. 2003). The high rainfall at Nassau may have created a stable forest refuge on the plateau during relatively dry Pleistocene ice-age climates when large areas of the Guayana Shield were covered with savanna vegetation (Prance 1982). Soil cover is mostly shallow to moderately thick (0-1 m).

The Nassau, Lely and Brownsberg plateau mountains of eastern Suriname are remnants of an early Tertiary (57-65 Ma) denudation surface or peneplain (King et al. 1964). Nassau and surrounding area are underlain by Lower-Proterozoic (>2000 Ma) rocks of the Trans-Amazonian greenstone belt forming the Marowijne Group (Bosma et al. 1977). Nassau Mountains itself is made up of ocean-floor meta basalts and island-arc meta-andesites, as well as meta-cherts of the Paramaka Formation. A relationship between the geomorphology of the interior and sediment deposition in the coastal plain can be expected because the sediments forming the coastal plain (that can be dated by pollen analysis) are mainly derived from the interior. King et al (1964) described the cyclic development of flat, erosional land surfaces in the interior and contemporaneous sedimentation in the coastal plain. Deep weathering under conditions of a humid tropical climate in the Paleocene resulted in the accumulation of aluminum and iron oxides in pre-bauxite sediments. A change in climate from warm-humid to warm-dry during Middle Eocene to Oligocene favored the formation of laterite and bauxite in both the interior and coastal plain; timing of this 'bauxite hiatus' and contemporaneous climate were documented by pollen from overlying and underlying beds of buried bauxite in the coastal plain of Suriname (Wijmstra 1971). King et al. (1964) correlated the Onverdacht

Formation deposits underlying the coastal bauxite beds with the formation of the Early Tertiary denudation surface in the Interior. This led to the conclusion that all economic bauxites in Suriname (including the Nassau deposits) were formed during one single bauxitization phase in Eocene-Oligocene times (Aleva & Wong 1998). A new period of denudation started at the end of the Oligocene (30 Ma), but the Nassau laterite/bauxite duricrust now protected the area from erosion. Thus the small, 20x20 km^2 Nassau remnant of the early Tertiary planation surface nowadays stands as a high plateau above the lower, rolling country of later planations.

IJskreek, a tributary of Paramaka Creek, is a relatively small stream (catchment approximately 24.4 km^2) which drains the largest of the four main plateaus ('Plateau C') in Nassau Mountains. IJskreek flows in northeastern direction, first along gentle slopes of the flat-lying plateau, but than, after a steep fall at the edge of the plateau, mainly through the valley between the U-shaped mountain ridge where it joins Paramaka Creek (Figure 1). The ground of the headwater basin above the 540 m contour (i.e. 'Plateau C' upstream of BHP-Billiton base camp) is hummocky with numerous shallow depressions and no clear channels. Rainwater accumulated in these depressions either infiltrates into a shallow, unconfined aquifer system (6.5 km^2) within the porous bauxite deposit or flows slowly overland between interconnected ponds until it reaches a tributary of IJskreek (Woodford 2006). During the wet season, IJskreek is fed by numerous ephemeral 'seeps' along the banks of the stream and the water in IJskreek was dominated by surface runoff and interflow (Woodford 2006). The lower reaches of IJskreek are perennial, but upstream of base camp (528 m.amsl) the stream dries up completely in the September-November dry season (Mol et al. 2007). During the dry season, the only contribution of water to the stream would be limited to inflows from perennial springs fed by the shallow aquifer system along the lower reaches of IJskreek, some 500 m downstream base camp (JHM, personal observations). Upstream of base camp, the water level in the aquifer declines to or just below the streambed.

Endemic species of Nassau Mountains

Nassau is known for three endemic (sub)species: two loricariid catfishes (*Harttiella crassicauda* and a recently discovered miniature *Pseudancistrus* (*Guyanancistrus*) species nicknamed 'bigmouth') and a new, fluorescent purple-colored *Atelopus* frog (Mol et al. 2007, Ouboter et al. 2007). Three additional catfishes, two *Lithoxus* species and one *Trichomycterus* species, are in the process of further investigation to determine their status (new species, endemic to Nassau?). A (sub)species of *Epipedobates trivittatus* with orange colored dorsolateral stripes and markings (instead of green or green-yellow colors as in specimens from other areas in Suriname) is probably not endemic to Nassau Mountains (Hoogmoed 1975).

In 1949, fifteen specimens of *Harttiella crassicauda* were collected by Geijskens and Creutzberg in the Nassau Mountains during the 1948-1949 Suriname expedition (Bakker and Lanjouw, 1949; Boeseman, 1953). This unusual catfish species was described in 1953 by Boeseman as a representative of *Harttia*. In a subsequent work, Boeseman (1971) created the genus *Harttiella* to accommodate the species. The monotypic genus

Harttiella (Covain & Fisch-Muller, 2007) was characterised by a depressed body shape, broad head, body, and caudal peduncle, the absence of lateral and predorsal keels, the strongly spiny body plates, the naked belly, and a thick caudal peduncle (Boeseman, 1971). It is the smallest species of the subfamily Loricariinae known so far (Ferraris, 2003). *H. crassicauda* has received considerable interest after both Boeseman (1971) and Isbrücker (1981) hypothesised a basal position for the species within the subfamily Loricariinae. *Harttiella crassicauda* is only known from the Nassau Mountains in Suriname (e.g. Le Bail *et al.* 2000, Mol *et al.* 2007). The restricted distribution of *Harttiella crassicauda*, endemic to the isolated Nassau Mountains plateau, is of interest from a biogeographic/evolutionary perspective.

Mol and Ouboter (2004) mentioned that *H. crassicauda* was at risk of extinction or possibly already extinct because of mining activities in Nassau Mountains. However, recently Mol *et al.* (2007) collected the species for the second time, 56 years after its original collection. At the same time, Mol *et al.* (2007) noted that *H. crassicauda* is still an endangered species due to potential degradation of its habitat by both small and large scale mining, and its restricted distribution in a single mountain stream. *Harttiella crassicauda* will be submitted for inclusion in the IUCN red list of threatened species.

Following the rediscovery of *H. crassicauda* in Nassau Mountains in 2005, subsequent phylogenetic/DNA research by the Museum d'Histoire Naturelle (Geneva, Switzerland), University of Geneva and Anton de Kom University of Suriname has resulted in discovery of four new *Harttiella* species in French Guiana (unpublished results of morphological and DNA analyses); all five *Harttiella* species appear to have a very restricted distribution, i.e. each confined to one or two mountain streams (Table 1; R. Covain, pers. communication).

Table 1. Localities of *H.crassicauda* and four recently discovered *Harttiella* species in French Guiana. (R. Covain, personal communication)

Species	**Mountain/River**	**Country**	**Locality**	**Latitude** (DegMinSec)	**Longitude** (DegMinSec)
H. crassicauda	Nassau / Marowijne	Suriname	Upper Paramaka Creek	04º49'13.7''	54º36'20.6''
Harttiella n. sp.	Tortue / Orapu	French Guiana	Crique Grillon	4º16'840''	52º27'084''
Harttiella n. sp.	Cottica / Lawa (Marowijne)	French Guiana	Unnamed mountain stream	3°90'	54°20'
Harttiella n. sp.	- / upper Mana	French Guiana	Crique Aya, 100m en face du camp Aya, crique Baboon	04°36.090'	53°24.806'
Harttiella n. sp.	- / upper Approuague	French Guiana	Arataï River, Camp Arataï, crique Nourague	4° 5 30	52° 42 0

During a survey in March/April 2006 to map the distribution of *H. crassicauda* in Nassau Mol *et al* (2007) not only found *H. crassicauda* restricted to a single stream (Paramaka Creek), but also collected a new loricariid catfish nicknamed 'bigmouth' (closely related to *Pseudancistrus* (*Guyanancistrus*) *brevispinnis*) and a new, purple-colored *Atelopus* frog. Bigmouth was collected in a single branch of Paramaka Creek. Subsequent analysis of Mt and nuclear DNA of bigmouth and *P. brevispinnis* by Dr Juan Montoya-Burgos of the University of Geneva revealed that *P. brevispinnis* populations from rivers in

Suriname and French Guiana probably have to be considered separate species (with the name *P. brevispinnis* to be restricted to the species of the type locality Nickerie River).

Mining interests in Nassau Mountains

Nassau Mountains is a rather small (appr. 20x20 km2), isolated bauxite plateau (altitude 570 m above mean sea level; Fig. 1) in northeastern Suriname. Suralco (Alcoa) has an old (bauxite) mining concession in the centre of Nassau Mountains (Fig. 1). In collaboration with Newmont, Suralco is also engaged in gold exploration in the northern foot hills of Nassau Mountains (Surgold project). Small-scale gold miners ('porknockers') are active in the northern and western foot hills of Nassau and they were even signaled (by satellite images in GOOGLE Earth) in the lower Paramaka Creek.

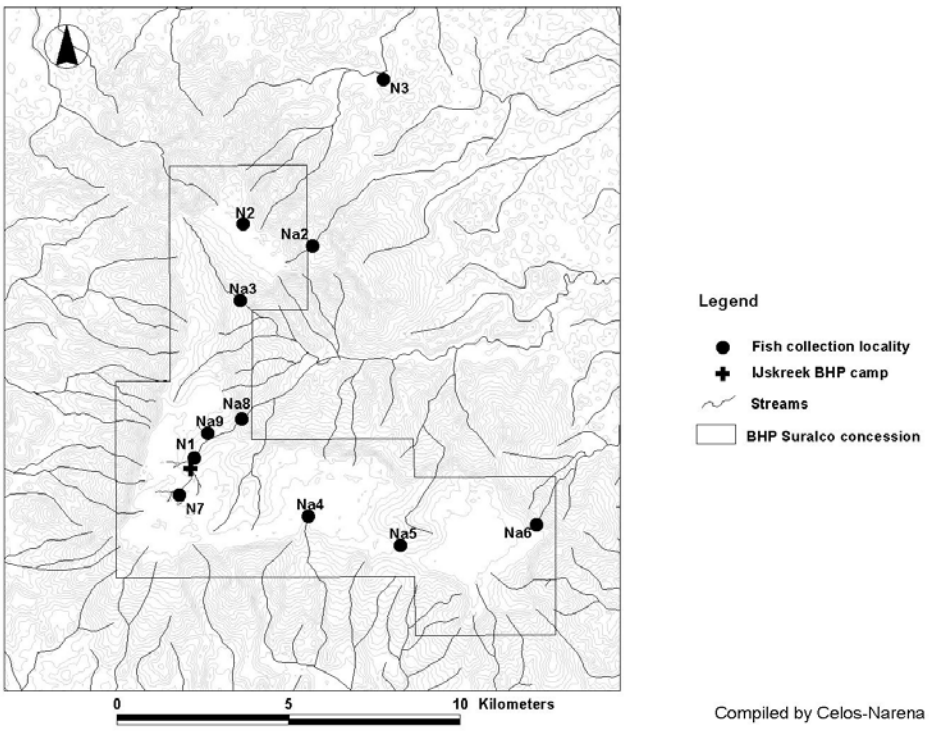

Figure 1. Map of Nassau Mountains showing fish collection localities and Suralco's mining concession. *Harttiella crassicauda* was collected in two branches of Paramaka Creek (sites N1, Na9, Na8 and Na3). Bigmouth was collected at site Na3.

Bauxite deposits in eastern Suriname have mostly been mined (with the exception of the Nassau, Lely and Brownsberg mountains). The mining companies Suralco/Alcoa and BHP-Billiton Suriname (BMS) now look for the large bauxite deposits in western Suriname, i.e. Bakhuis Mountains. In 2003, Suralco and BMS started a Mining Joint Venture MJV (55% Suralco, 45% BMS) in relation to negotiations with Surinamese government about the mining concession for Bakhuis. Within this joint venture BMS would be responsible for exploration and mining and Suralco would take care of bauxite refinery. Thus, BMS recently (in 2005-2007) assessed the bauxite reserves of Suralco's

Nassau Concession and decided they would not mine Nassau because of (1) poor bauxite reserves, (2) logistical problems of bauxite transport and (3) environmental issues (based on report of Nassau/Lely Rap survey). They stated their decision at the launch of CI's RAP report in Paramaribo (May 2007). Suralco's CEO W. Pedersen also stated in a local newspaper that 'the bauxite of Nassau can stay where it is' (De West, 4 June 2007). However, only 6 months later, Alcoa/Suralco informed CI-Washington about their plans to mine bauxite in Nassau Mountains. Alcoa/Suralco subsequently hired ERM consultancies (USA) to execute the ESIA studies concerning mining of the Nassau bauxite. An ESIA for a haul road from Nassau to the Paranam refinery started in September 2008 and reconnaissance work for the Nassau bauxite mine ESIA started in February 2009. Although the projected bauxite mine is clearly of immediate concern, two other mining-related activities are also of some concern to the Nassau endemics: (1) the activities by illegal, small-scale goldminers at the foot of the Nassau Plateau and (2) a projected gold mine by Suralco/Newmont in the northern foot hills of Nassau Mountains (the 'Surgold' project launched in June 2008 by Alcoa/Suralco and Newmont; De Ware Tijd, 18 June 2008).

Chronology

1917. Founding of N.V. Nederlandsche Mijnexploitatie en Exploratie Maatschappij (NENIEM) with 50% of shares owned by Norsk Aluminium Co and 50% of shares owned by N.V. Nederlandsche Handel Maatschappij & West Indische Mail
1918/19. First demonstration of presence of bauxite bauxiet in Nassau Mountains by Douglas (1920) after inventory of NENIEM bauxite deposits
1925. Preliminary survey of Nassau Mountains by Alcoa (N.V. Surinaamsche Bauxiet Maatschappij SBM)
1926. SBM/Alcoa buys shares of 'inactive' NENIEM Company, including the Rorac Concession
1929. Many bauxite concessions of SBM/Alcoa (including Nassau) incorporated in one large area of 377,13 km^2 with concession rights for 60 year (Aleva & Wong 1998).
1949. Biologists of the Dutch expedition 'Natuurwetenschappelijke Expeditie naar Suriname' (Bakker & Lanjouw 1949) collect 15 specimens of a small loricariid catfish in a 'creek in Nassau Mountains'
1951-1953. Bauxite exploration in Nassau Mountains by the 'Geologische Mijnbouwkundige Dienst Suriname' (GMD) in Nassau Mountains (Doeve 1955)
1953. The Dutch ichthyologist Dr M. Boeseman (Natuur Historisch Museum Leiden) publishes a description of the small Nassau catfish under the name *Harttia crassicauda* (Boeseman 1953)
1958. The Brokopondo Joint Venture Suriname gives Suralco/Alcoa bauxite exploration rights in an area of 5000 km^2 (enclosed by Marowijne River, Suriname River and the Atlantic Ocean) for a period of 10 years. This includes an option to obtain mining concessions with a maximum size of 200 km^2 (and a period of 75 year) in the following 10 years. After exploration of the bauxite deposits of Nassau these are considered not favorable for mining because of their isolated location.

1971. M. Boeseman creates a new genus *Harttiella* for the little Nassau catfish because the species has unique characters not present in known *Harttia* species (Boeseman 1971).
2000. At year of the publication of the French 'Atlas des poissons d'eau douce de Guyane. Tome 2. Fascicule II. Siluriformes' (Le Bail *et al.* 2000) based on more than 20 years of ichthyological investigations in French Guiana by a team of French ichthyologists, *Harttiella crassicauda* is still only known from the 15 specimens that were collected in 1949 in Nassau Mountains. *H.crassicauda* is still the only known species in the genus *Harttiella* (Le Bail et al. 2000).
2002. The 'Guayana Shield Priority-Setting Workshop' (5-9 April 2002, Paramaribo; Conservation International 2003) identifies the Maroni Area (including Brownsberg, Nassau and Lely mountains) as an area of high biological importance (and high pressure) with high need for scientific research, based partly on the occurrence of the endemic catfish *H.crassicauda* in Nassau Mountains (Huber & Foster 2003).
2003. Suralco and BHP-Billiton Maatschappij Suriname start a Mining Joint Venture (MJV) to optimize negotiations with Surinamese Government about exploitation of the large Bakhuis bauxite deposits in West Suriname. Within the MJV, BMS is to be responsible for exploration and mining and Suralco is to be responsible for refining the bauxite ore.
2004. Mol & Ouboter (2004) warn that activities by small-scale (illegal) goldminers in the Nassau area threaten *Harttiella crassicauda* with extinction.
2005. During a Rapid Assessment Program (RAP) survey of Conservation International (sponsored by BHP-Billiton Maatschappij Suriname and Suralco) *Harttiella crassicauda* is re-discovered in Nassau Mountains 56 years after its original discovery in 1949; the species is collected in the headwaters of Paramaka kreek ('IJskreek') on plateau C in Nassau Mountains, but it is not collected in Lely Mountains (Mol et al. 2007 in Alonso & Mol 2007).
2005-present. Intensive research into the ecology and (DNA-based) systematics of *Harttiella crassicauda* by the Museum d'Histoire Naturelle Geneva, Geneva University and Anton de Kom University of Suriname.
2006. A follow-up survey in Nassau Mountains aimed at a better understanding of the distribution of the little catfish fails to discover *H.crassicauda* in three other mountain streams; *H.crassicauda* is apparently restricted in its distribution to Paramaka Creek. The survey discovered one new miniature catfish (*Pseudancistrus* 'bigmouth'), also in a headwater tributary of Paramaka Creek and a new purple *Atelopus* frog.
2006. A geohydrology report into groundwater flow in the IJskreek catchment in Nassau demonstrates the 'sponge' functioning of the porous bauxite/laterite rock and its relevance to year-round water flow in IJskreek (Paramaka Kreek) (Woodford/SRK 2006). Removal of the bauxite 'sponge' though mining of the bauxite will probably result in drying out of the IJskreek (and possibly Paramaka Creek) in the dry season.
2007 (May). Results of the CI-RAP expedition to Nassau and Lely mountains and the follow-up expedition by AdeK to Nassau are published in CI's RAP report 43 (Alonso & Mol 2007). At the lauch of the RAP report BHP-Billiton Maatschappij Suriname announces it will not mine bauxite in Nassau Mountains for reasons of (1) disappointing bauxite deposits, (2) logistics of bauxite transport to Paranam refinery, and (3) environmental concerns. Suralco's CEO Warren Pedersen also informs local newspaper De West that 'the bauxite of Nassau and Lely can stay where it is' (Alfaisie, De West, 4

June 2007). BMS Environmental Officer Andy Witcomb, Paul Ouboter (AdeK) and Jan Mol (AdeK) receive an environmental award of BHP-Billiton for their work concerning 'Nassau Environmental Care'.
2008 (February). Alcoa informs CI-Washington about their plans to mine bauxite in Nassau Mountains.
2008 (March). Alcoa's plans for bauxite mining in Nassau are published in local newspaper De Ware Tijd (Cairo & Texel 2008) and on the website of Caribbean Net News (Cairo 2008).
2008 (June). Launch of the Surgold project by Alcoa/Suralco and Newmont with the specific aim to develop a goldmine in the Merian Creek catchment in the northern foot hills of Nassau Mountains (De Ware Tijd, 18 June 2008).
2008 (June). Mol presents the threats to Nassau's endemic fishes to the scientific community at ATBC-2008 annual meeting in Paramaribo. ATBC adopts a resolution that calls for protection of the Nassau and Lely and Brownberg bauxite plateaus.
2008-2009. Follow-up research by Juan Montoya Burgos and Raphael Covain of Geneva University and Natural History Museum of Geneva, respectively, based on DNA sequences of Nassau's endemic fishes leads to the discovery of 4 new *Harttiella* species in French Guiana (all with very restricted distribution, much like *H.crassicauda* of Nassau Mountains) and 7 new *Pseudancistrus* species in the *P.brevispinis* group in Suriname and French Guiana (with *P.brevispinis* now being restricted to its type locality Nickerie River). Investigations into an explanation for the occurrence of the endemic fish species in Nassau by University of Geneva are in progress.
2008 (September). Alcoa/Suralco/ERM starts an ESIA study for a haul road from Nassau to Paranam, related to their plans to mine bauxite in Nassau Mountains. A second specimen of the endemic fluorescent-purple Atelopus frog is collected in Nassau Mountains; tissue samples for analysis of its DNA are taken by AdeK University.
2008 (October). BHP-Billiton announces it will leave Suriname in 2010 and will not pursue further the Bakhuis Mountains Bauxite Mining project (and associated dredging projects in the Corantijn and Suriname rivers).
2009 (January). Zoological Museum of University of Amsterdam (Dr Ronald Vonk, ZMA) and Zoological Museum of Sao Paulo, Brazil (Dr Mario de Pinna) start a research project into the status of a potentially new trichomycterid catfish of Nassau Mountains.
2009 (February). The ATBC Executive Council of the Association for Tropical Biology and Conservations formally approves its resolution 11 that specifically argues against mining in Nassau Mountains and urges for implementation of a protective status for the Nassau Mountains Area. The ATBC resolution is distributed in Suriname to government, the mining companies involved, ambassadors of the USA and the Netherlands in Suriname, the NGOs CI and WWF, and 4 local newspapers.
2009 (February). Alcoa/Suralco/ERM starts reconnaissance work in Nassau Mountains in preparation for the Nassau Mountains Bauxite Mining project ESIA.

References

Aleva, G.J.J. & Th.E. Wong, 1998. History of bauxite exploration and mining in Suriname. In *The history of earth sciences in Suriname* (Wong, Th.E., D.R. De

Vletter, L. Krook, J.I.S. Zonneveld & A.J. Van Loon, eds), p.275-310. Kon. Ned. Akad. Wet. & Ned. Inst. Toegep. Geowet. TNO.

Alfaisie, L., 2007. Wetenschappers ontdekken 24 nieuwe diersoorten in Oost-Suriname. *De West* **4 June 2007**. (in Dutch)

Amatali, M.A. 1993. Climate and surface water hydrology. In *The freshwater ecosystems of Suriname* (Ouboter, P.E., ed.), p. 29-51. Dordrecht: Kluwer.

Bakker, J.P. & J. Lanjouw, 1949. Indrukken van de natuurwetenschappelijke expeditie naar Suriname 1948-49. *Tijdschrift Koninklijk Nederlandsch Aardrijkskundig Genootschap* **66**, 538-557. (in Dutch with English summary)

Banki, O.S., H. ter Steege, M.J. Jansen-Jacobs & U.P.D. Raghoenandan, 2003. *Plant diversity of the Nassau Mountains*. Report of the 2003 expedition. Internal report NHN-Utrecht/BBS-Paramaribo. Utrecht, the Netherlands.

Boeseman, M. 1953. Scientific results of the Surinam expedition 1948-1949. Part II. Zoology. No. 2. The fishes. *Zoölogische Mededelingen (Leiden)* **32**: 1-24.

Boeseman, M. 1971. The 'comb-toothed' Loricariinae of Surinam, with reflections on the phylogenetic tendencies within the family Loricariidae. *Zoölogische Verhandelingen (Leiden)* **116**: 1-56.

Bosma, W., S.B. Kroonenberg, R.V. van Lissa, K. Maas & E.W.F. de Roever, 1977. *Geological map of Suriname (coloured), scale 1:500,000 (two sheets)*. Geologisch Mijnbouwkundige Dienst Suriname.

Cairo, I., 2008. Habitat of newly discovered species in Suriname threatened by mining. *Caribbean Net News* **March 26 2008**. (www.caribbeannetnews.com/news-6806--36-36--.html)

Cairo, I., 2009. Effectenstudie bepalend voor exploitatie Nasasaugebied. *De Ware Tijd* **20 Februari 2009**. (in Dutch)

Cairo, I. & V. Texel, 2008. Habitat nieuwe diersoorten mogelijk bedreigd: Alcoa vraagt mijnadvies Nassaugebergte. *De Ware Tijd* **25 Maart 2008**. (in Dutch)

Conservation International, 2003. *Natuurbehoudsprioriteiten voor het Guiana Schild: 2002 consensus*. Conservation International, Washington D.C. (in Dutch)

Covain, R. & S. Fisch-Muller, 2007. The genera of the Neotropical armored catfish subfamily Loricariinae (Siluriformes: Loricariidae): a practical key and synopsis. *Zootaxa* **1462**, 1-40.

Ferraris, C.J. 2003. Subfamily Loricariinae. . In *Check list of the freshwater fishes of South and Central America*: (Reis, R.E., S.O. Kullander and C.J.. Ferraris, eds), p. 330-350. Porto Alegre, EDIPUCRS..

Hoogmoed, M.S., 1975. *Eindverslag betreffende het veldwerk in verband met een onderzoek naar de in Suriname voorkomende kickers, gedurende 26 Nov. 1974 – 27 Nov. 1975*. Internal report Rijks Museum Natuurlijke Historie (Naturalis), Leiden, the Netherlands.

Isbrucker, I.J.H., 1981. *A treatise of the Loricariidae Bonaparte, 1831, a family of South American mailed catfishes, with emphasis on the subfamily Loricariinae (Pisces, Siluriformes)*. Thèse de doctorat Université Nancy, 224 pp.

King, L.C., D.K. Hobday and M. Mellody. 1964. *Cyclic denudation in Surinam*. Unpublished report Geological and Mining Service of Suriname. Paramaribo: Geologische Mijnbouwkundige Dienst, 16 pp.

Le Bail, P.-Y., P. Keith and P. Planquette. 2000. *Atlas des poissons d'eau douce de Guyane. Tome 2 – fascicule II. Siluriformes*. Paris: Museum National d'Histoire Naturelle.

Miller, P.J., 1996. The functional ecology of small size: some opportunities and consequences. *Symposium Zoological Society London* **69**, 175-199.

Mol, J.H. and P.E. Ouboter. 2004. Downstream effects of erosion from small-scale gold mining on the instream habitat and fish community of a small neotropical rainforest stream. *Conservation Biology* **18**: 201-214.

Mol, J.H., K. Wan Tong You, I. Vrede, A. Flynn, P. Ouboter & F. Van der Lugt, 2007. Fishes of Lely and Nassau Mountains, Suriname. In *A Rapid Biological Assessment of the Lely and Nassau Plateaus, Suriname (with additional information on the Brownsberg Plateau)* (L.E. Alonso & J.H. Mol, eds), p. 107-118. RAP Bulletin of Biological Assessment 43. Conservation International, Arlington, USA

Montoya-Burgos, J.I., 2003. Historical biogeography of the catfish genus *Hypostomus* (Siluriformes: Loricariidae), with implications on the diversification of Neotropical ichthyofauna. *Molecular Ecology* **12**, 1855-1867.

Ouboter, P.E., R. Jairam & K. Wan Tong You, 2007. Additional records of amphibians from Nassau Mountains, Suriname. In *A Rapid Biological Assessment of the Lely and Nassau Plateaus, Suriname (with additional information on the Brownsberg Plateau)* (L.E. Alonso & J.H. Mol, eds), pp. 128-129. RAP Bulletin of Biological Assessment 43. Conservation International, Arlington, USA.

Prance, G.T. (ed), 1982. *Diversification in the Tropics*. Colombia University Press, New York.

Stichting Planbureau Suriname (SPS) & Organization of American States (OAS), 1988. *Suriname Planatlas*. Washington, D.C., SPS/OAS, 48 pp.

Weitzmann, S.H. and R.P. Vari. 1988. Miniaturization in South American freshwater fishes: an overview and discussion. *Proceedings Biological Society Washington* **101**, 444-465.

Wijmstra, T.A., 1971. *The palynology of the Guiana coastal basin*. Thesis, Amsterdam. Oegstgeest, Drukkerij De Kempenaar, 62 pp.

Wijmstra, T.A. & T. Van der Hammen, 1964. Palynological data on the age of the bauxite in British Guiana and Surinam. *Geologie Mijnbouw* **43**, 1-143.

Woodford, A.C., 2006. *Preliminary geohydrological assessment of the IJskreek catchment, Nassau bauxite concession, Suriname*. Report prepared for NV BHP Billiton Maatschappij Suriname by SRK Consulting, Cape Town, South Africa, 29 pp.