Combining ecology and archaeology to decipher the unique functioning of a pre-Columbian Amazonian fishery

Doyle McKey

Rumsaïs Blatrix

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GDR 3353 MOSAIQUE

JOURNÉE SCIENTIFIQUE CEMEB 2018

Montpellier, 13 March, 2018


Humans adapt to their environment in part by modifying the environment to fit their needs

Humans adapt to their environment in part by modifying the environment to fit their needs


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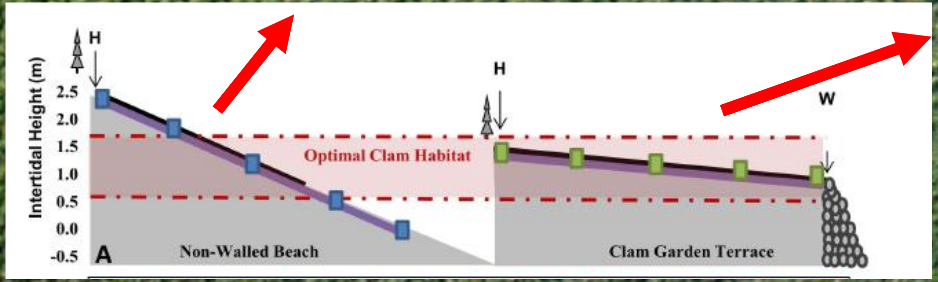
PLOS | ONE

Ancient Clam Gardens Increased Shellfish Production: Adaptive Strategies from the Past Can Inform Food Security Today

Amy S. Groesbeck[1]*, Kirsten Rowell[2], Dana Lepofsky[3], Anne K. Salomon[1]*

1 School of Resource and Environmental Management, Simon Fraser University, Burnaby, British Columbia, Canada, 2 Department of Biology, University of Washington, Seattle, Washington, United States of America, 3 Department of Archaeology, Simon Fraser University, Burnaby, British Columbia, Canada



Niche construction to manage aquatic resources

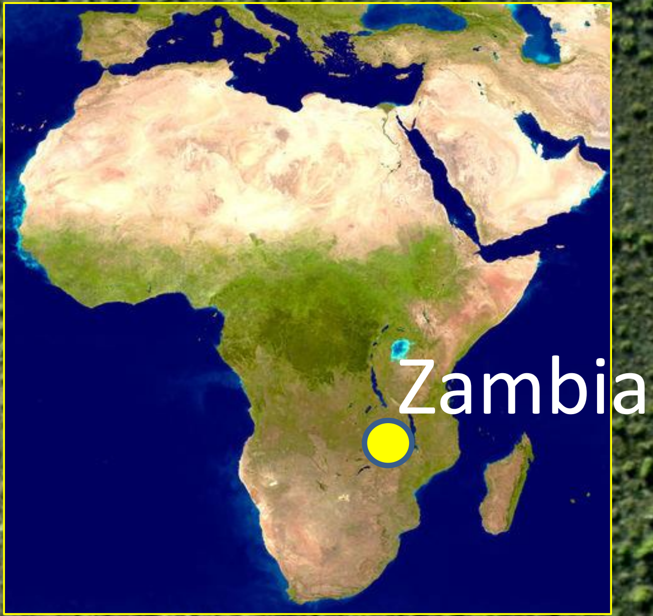
A fishery based on long earthen weirs in a floodplain savanna

Photo © D McKey

Photos © CF Huchzermeyer unless otherwise noted

Life history of floodplain-migratory species: *high fecundity, high juvenile mortality (most die the first dry season), long-lived adults*

A fishery based on long earthen weirs in a floodplain savanna



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Photos © CF Huchzermeyer unless otherwise noted

Life history of floodplain-migratory species: *high fecundity, high juvenile mortality (most die the first dry season), long-lived adults*

Fishway gaps

Most adult fish leave the floodplain when water level is high, before traps are set

Most fish caught are juveniles


Photo © CF Huchzermeyer


Photo © CF Huchzermeyer


Photo © D McKey

Most adult fish leave the floodplain when water level is high, before traps are set

Most fish caught are juveniles

Age class with very low reproductive value (most would die in any case during the first dry season)

→ *High harvest levels can be sustained*

McKey et al. (2016), *PNAS*

A pre-Columbian fishery based on long earthen weirs in a floodplain savanna

An artificial landscape-scale fishery in the Bolivian Amazon

Clark L. Erickson *Nature* (2000)

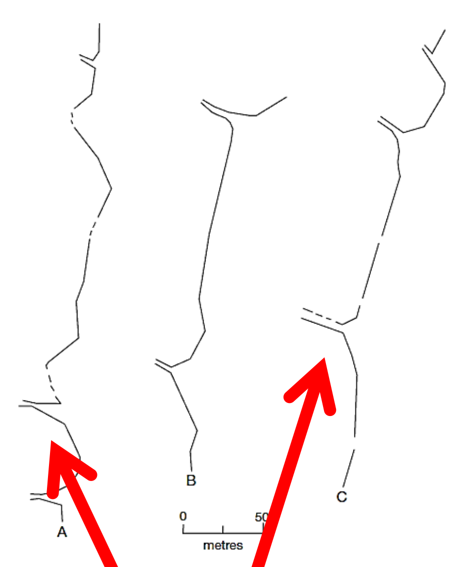


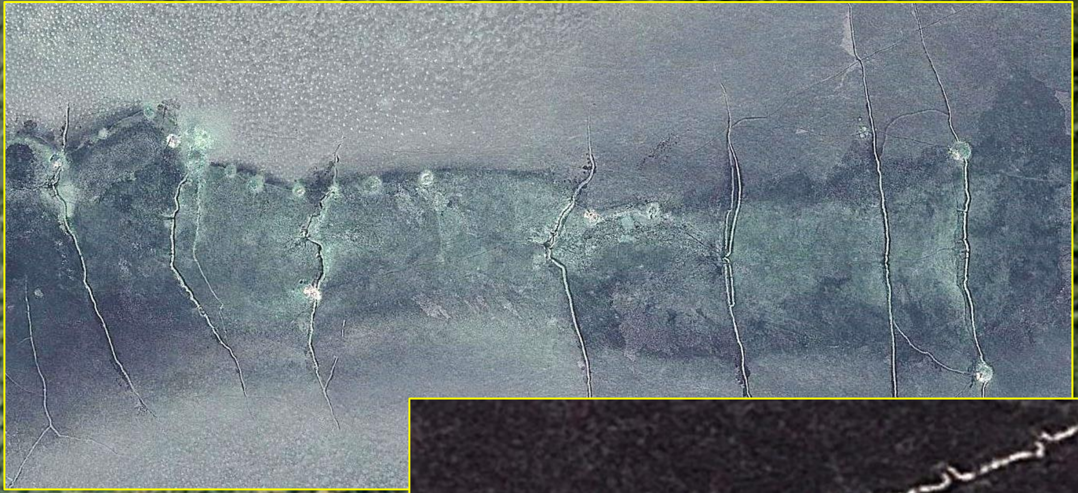
Figure 5 Plans of fis weirs (zigzag structures) mall parallel openings in the weirs are present every 50–200

« V » - shaped fishway gaps

Similar earthworks in similar environments

Bolivia, pre-Columbian

Zambia, present-day



PNAS

Present-day African analogue of a pre-European Amazonian floodplain fishery shows convergence in cultural niche construction

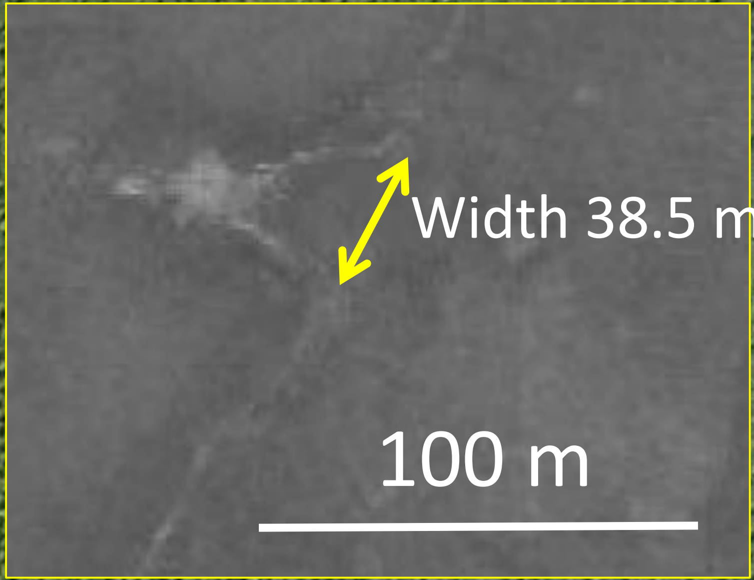
Doyle B. McKey[a,b,1], Mélisse Durécu[a], Marc Pouilly[c], Philippe Béarez[d], Alex Ovando[e], Mashuta Kalebe[f], and Carl F. Huchzermeyer[g]

'V'- shaped fishways

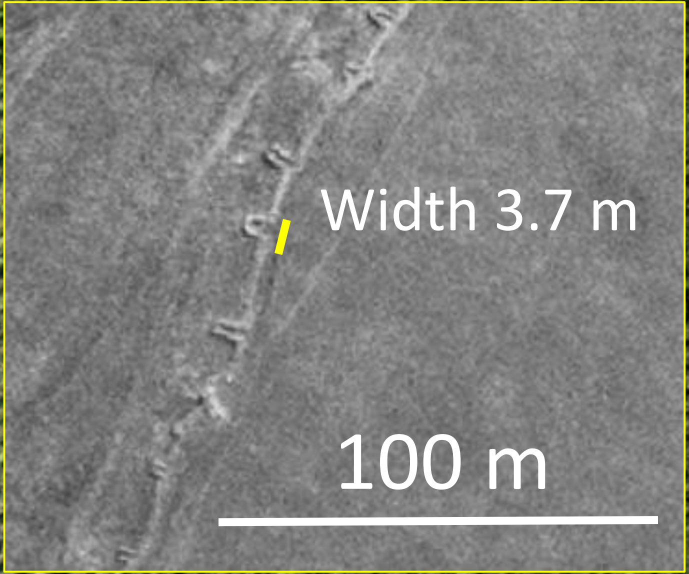
But the two landscapes also present some remarkable differences

Bolivia, pre-Columbian

Zambia, present-day



Size of V-shaped structures



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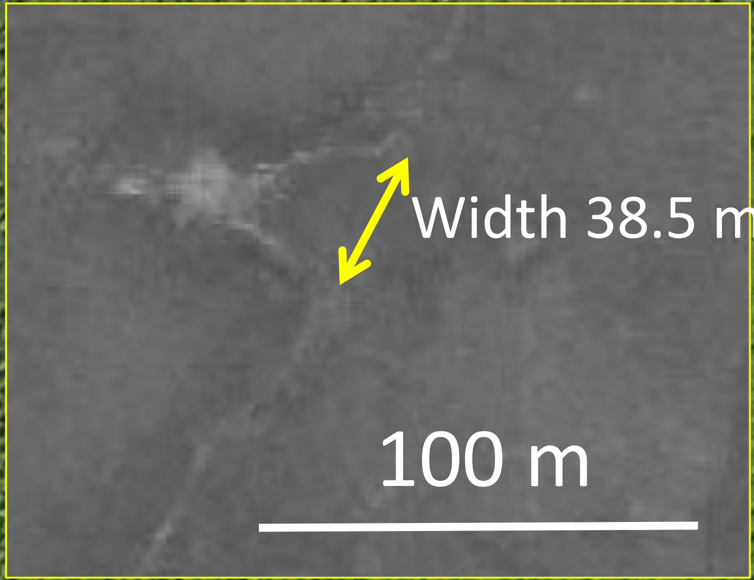

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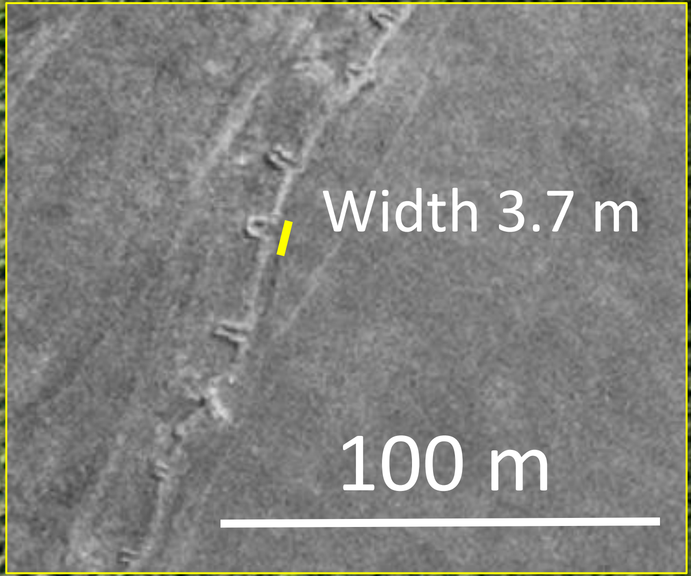

Numerous ponds

No ponds

But the two landscapes also present some remarkable differences

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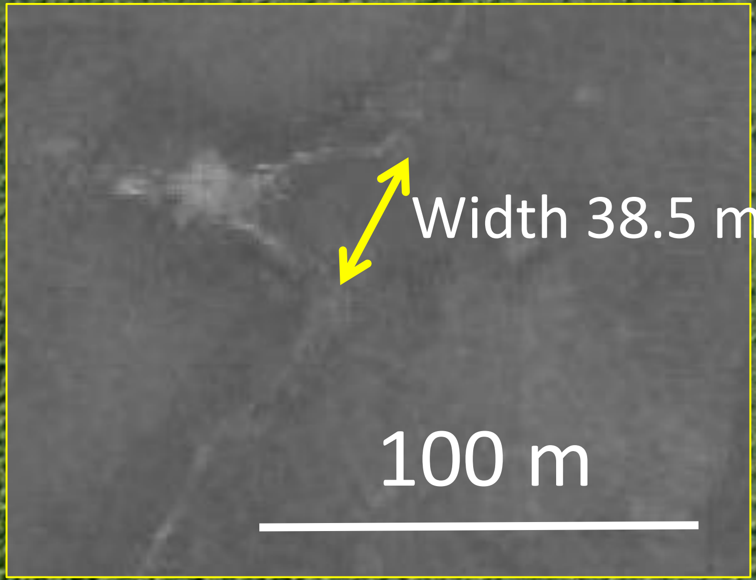
Zambia, present-day



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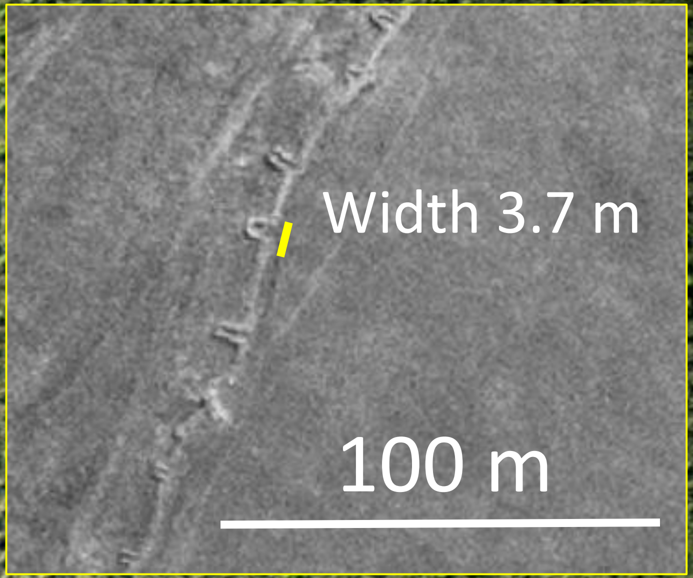


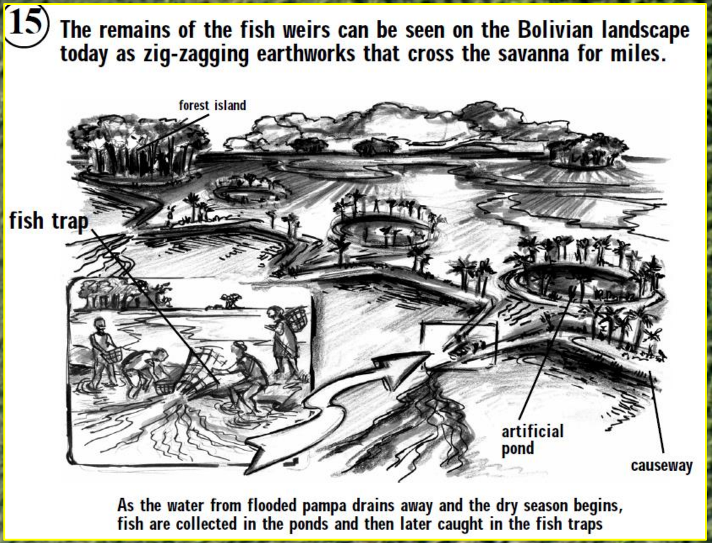
Numerous ponds

No ponds

These differences suggest different modes of functioning

Erickson postulated that weirs and ponds worked together

But how they may have done so is unclear



Erickson & Brinkmeier (2007)

Weirs upstream of ponds

Ponds upstream of weirs

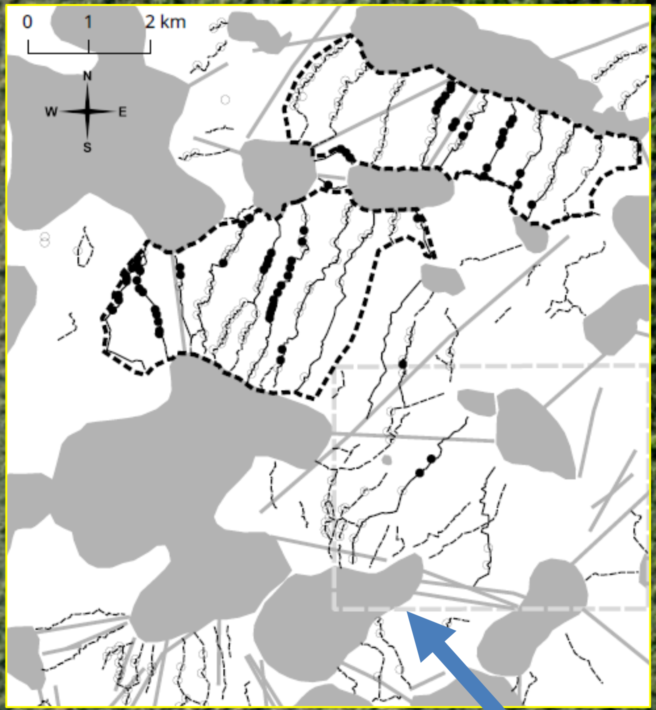
Objective: Understand the functioning of the pre-Columbian fishery

- Describe in detail:
  - Earthen weirs
  - V-shaped structures
  - Ponds
- Characterize topographical variation in the landscape
- Analyze the spatial relationships between ponds and weirs to try to infer how they may have worked together

Results reported here:

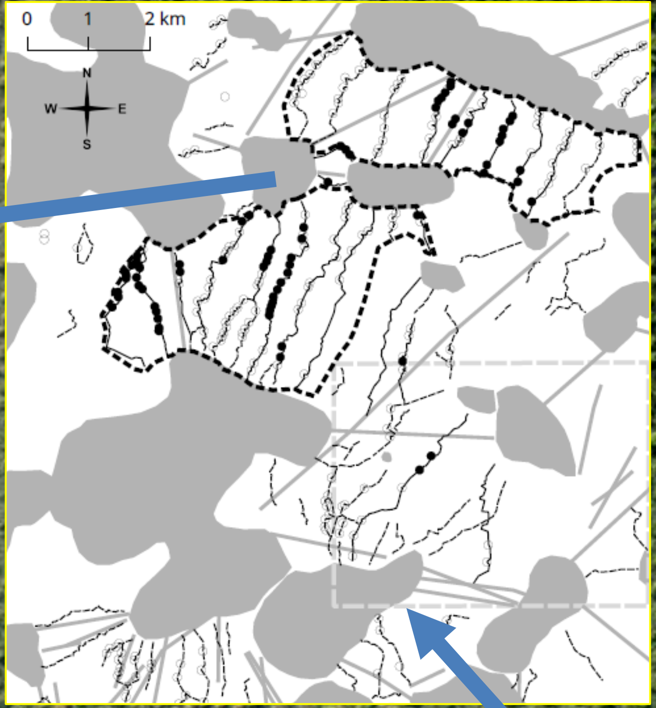
Blatrix R, B Roux, P Béarez, G Prestes-Carneiro, M Amaya, JL Aramayo, L Rodrigues, U Lombardo, J Iriarte, JG de Souza, M Robinson, C Bernard, M Pouilly, M Durécu, CF Huchzermeyer, M Kalebe, A Ovando, D McKey. The unique functioning of a pre-Columbian Amazonian floodplain fishery. *Scientific Reports* (in revision)

Choosing the field site and getting there



Grey rectangle: area Erickson surveyed exhaustively

Choosing the field site and getting there



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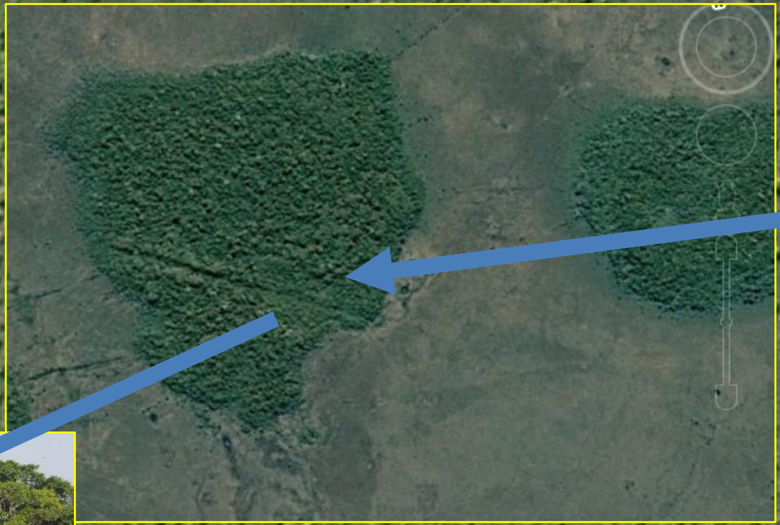

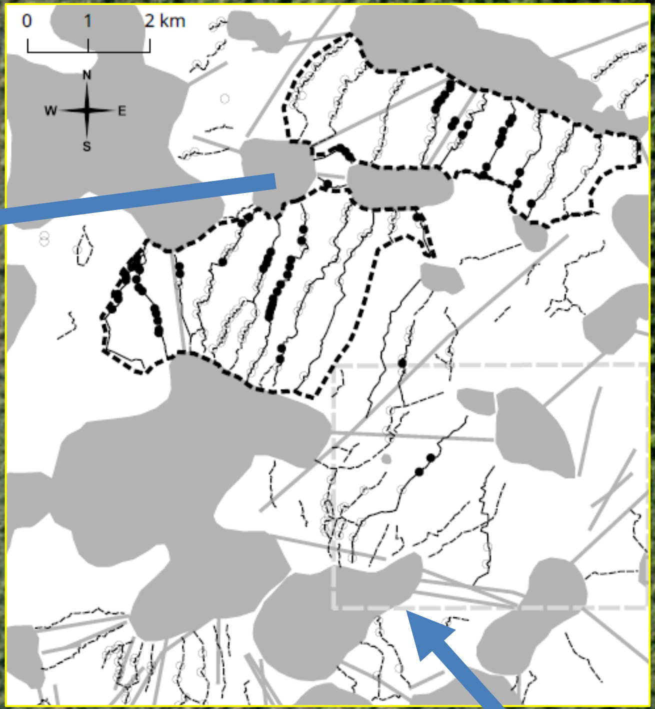

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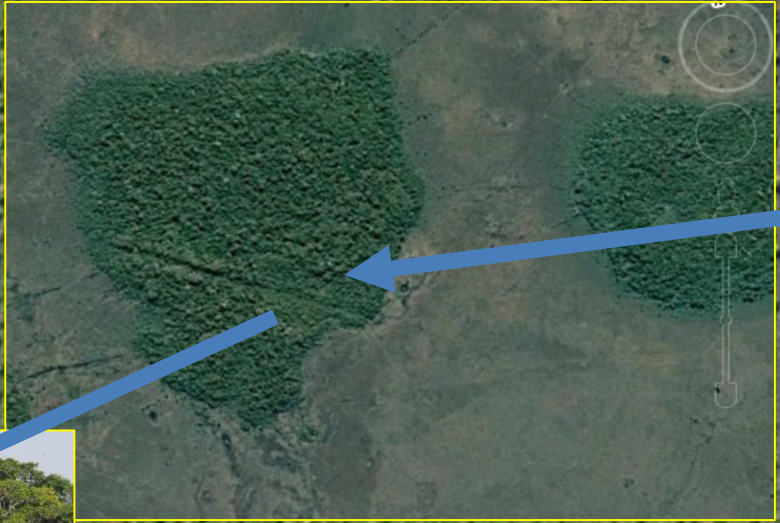
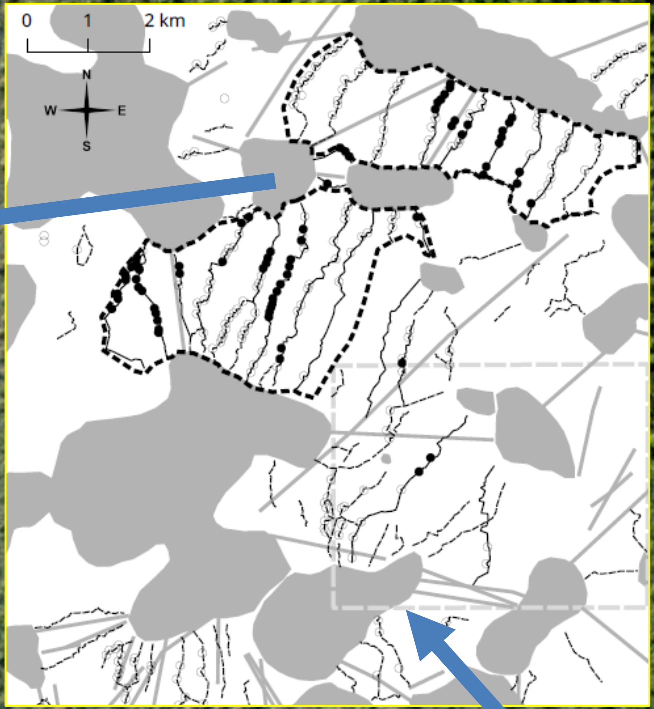




Grey rectangle: area Erickson surveyed exhaustively

Photos © D McKey

All the conveniences of home

Photos © D McKey

Causeways

Photo © B Roux

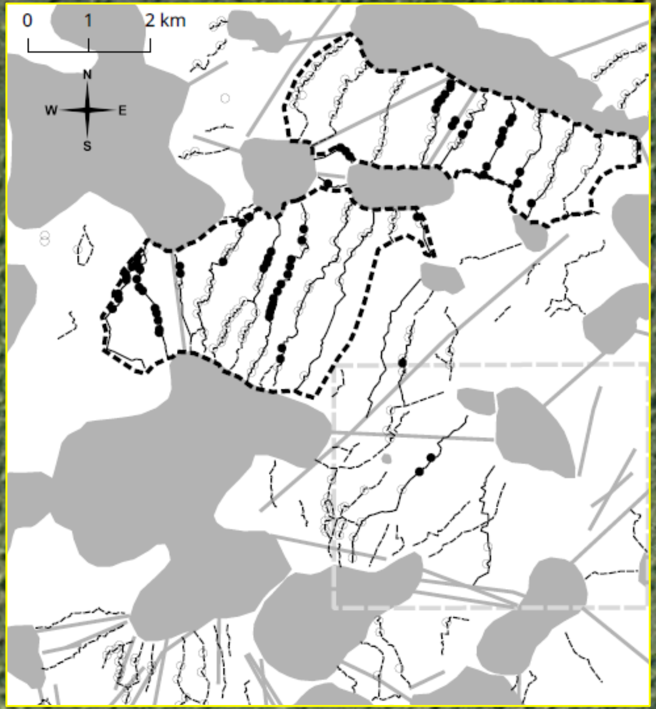
Photos © D McKey unless otherwise noted

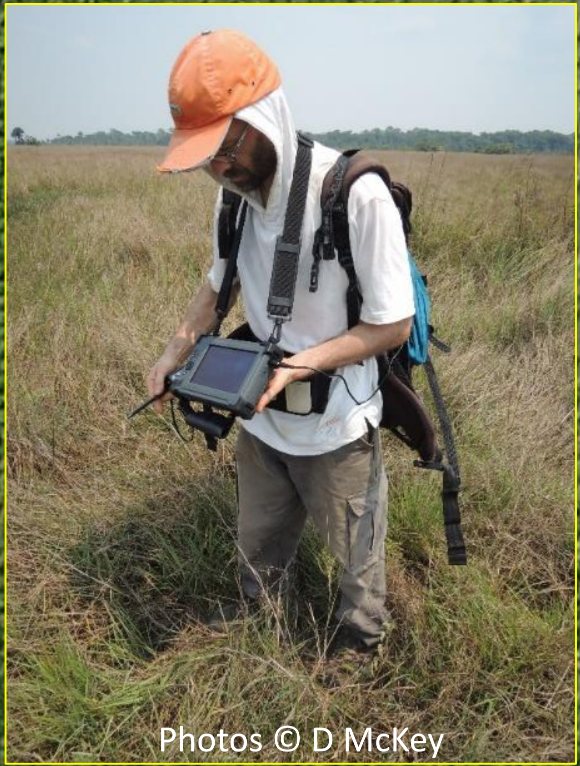
Weirs and ponds

Photo © B Roux

Photos © D McKey unless otherwise noted

Orienting in the field using satellite imagery stored in a tablet

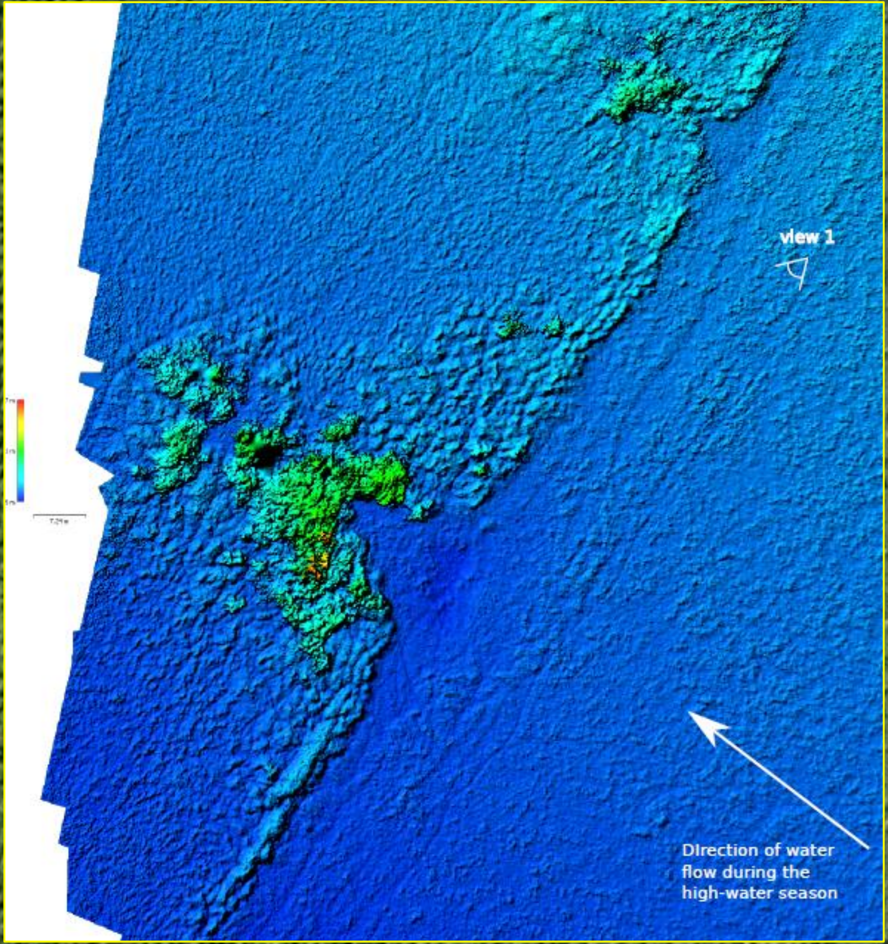




Rapid measurement and characterization of

- 270 V-shaped structures
- 382 ponds (89 ground-truthed)

Stereophotogrammetry using a kite-borne camera



illustration© B Roux

Photos © D McKey unless otherwise noted

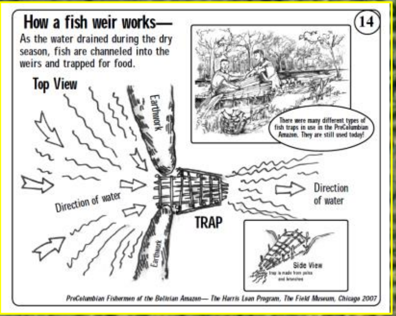
Bruno Roux, l’Avion Jaune

Surprising result: no fishway gaps in the V's

Zambian fishery: numerous fishway gaps

Pre-Columbian Bolivian fishery:

Erickson postulated fishways



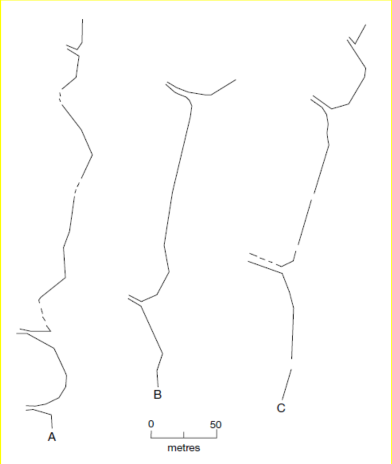
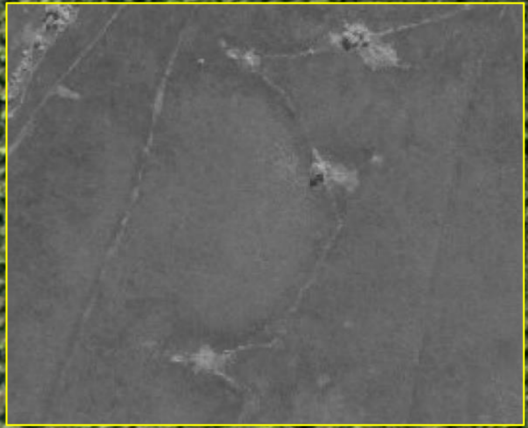


Figure 5 Plans of fish weirs (zigzag structures). Small parallel openings in the weirs are present every 50–200 m.

Our results: fishways usually absent



The tips of the V's are in fact the *highest* parts of the weir!

Woody vegetation, always on higher ground

Arm of a V

Photo © D McKey

The berm of each pond (higher ground marked by palms and other trees) is only on the *downstream* side

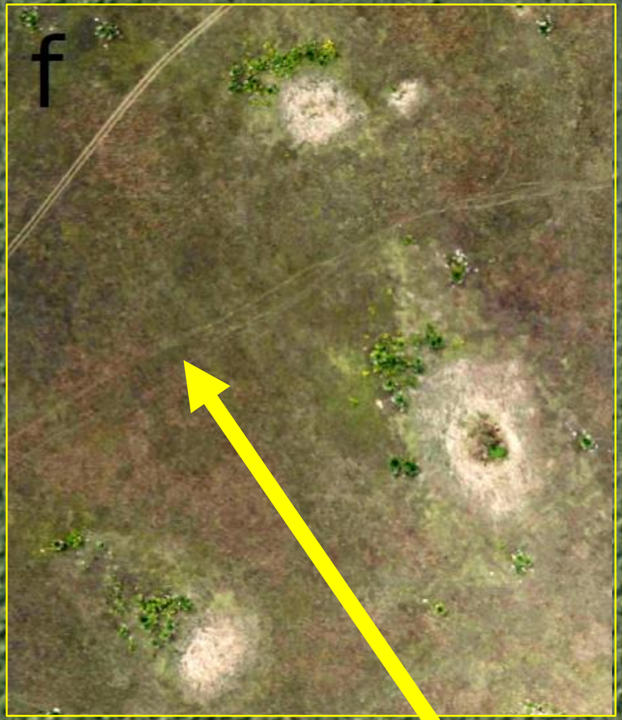
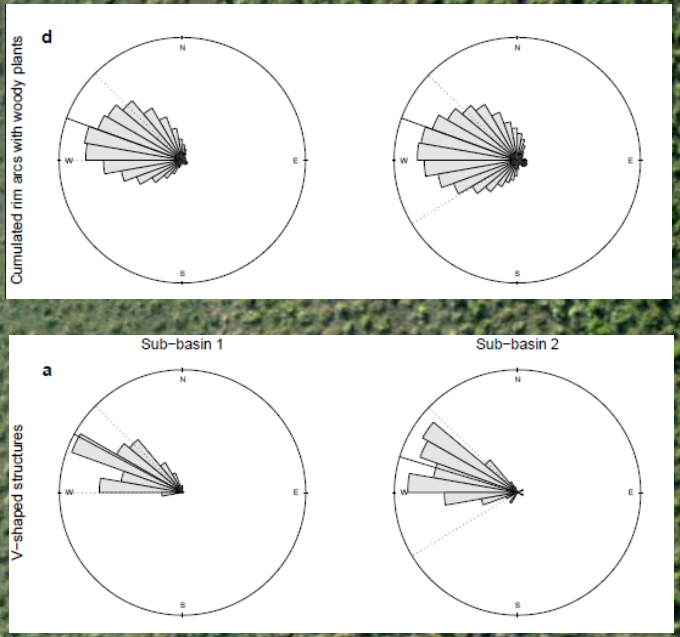


Photo © B Roux



Direction of water outflow

Regular spatial organization of ponds in relation to V's of weirs

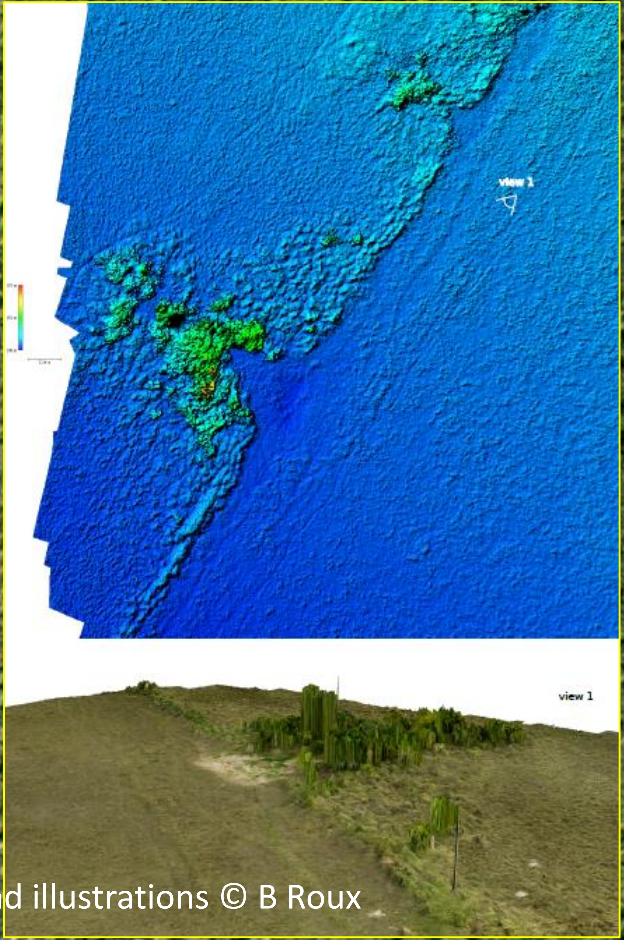


Photo and illustrations © B Roux

Most ponds are just upstream of a V,
and the berm of the pond merges with the V

Weirs concentrate fish in ponds; the pond serves as the trap

As water recedes, fish follow current downstream, swim along the weir until reaching a pond, where they find deeper, slower water

As water level drops, fish are trapped in ponds and increasingly concentrated there

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Zambian weir fishery: fish must be harvested daily from traps in fishways or rot: commercial fishery done by specialists

Are ponds artificial (Erickson 2000)?

Seemingly adaptive design: humans placed excavated soil only on the downstream side, to enhance trapping effectiveness

Easy for fish to swim into the pond (upstream shore, no berm) and difficult for fish to swim out (downstream shore, high berm and wall of the V)

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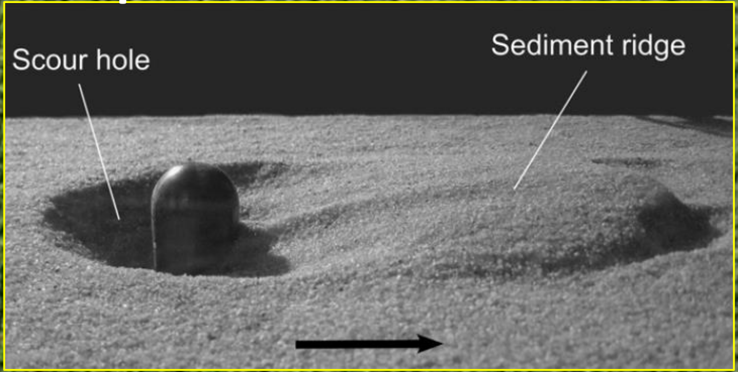
But there is a plausible alternative hypothesis

Floodplains in all this part of the Mojos show depressions and ‘forest humps’ aligned in the direction of stream flow

Such structures appear to be produced by scour and deposition induced by obstacles to water flow



Euler & Herget (2012), *Catena*

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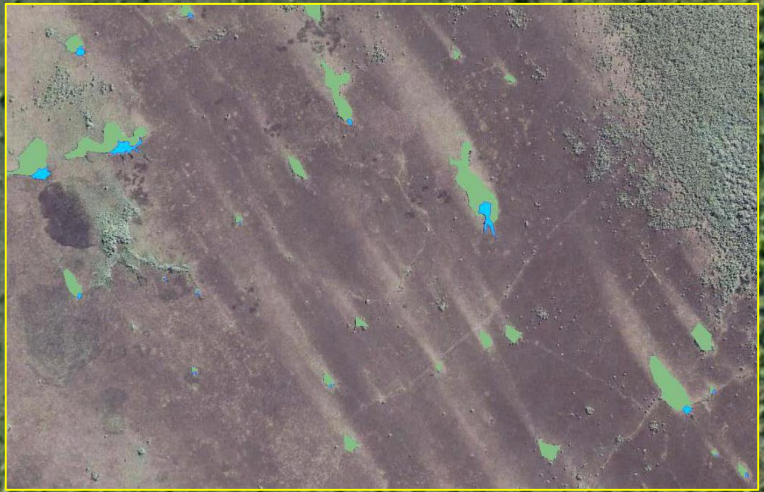

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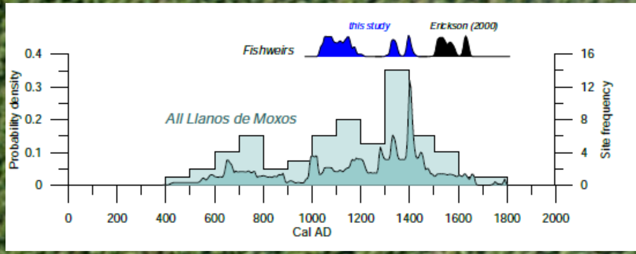
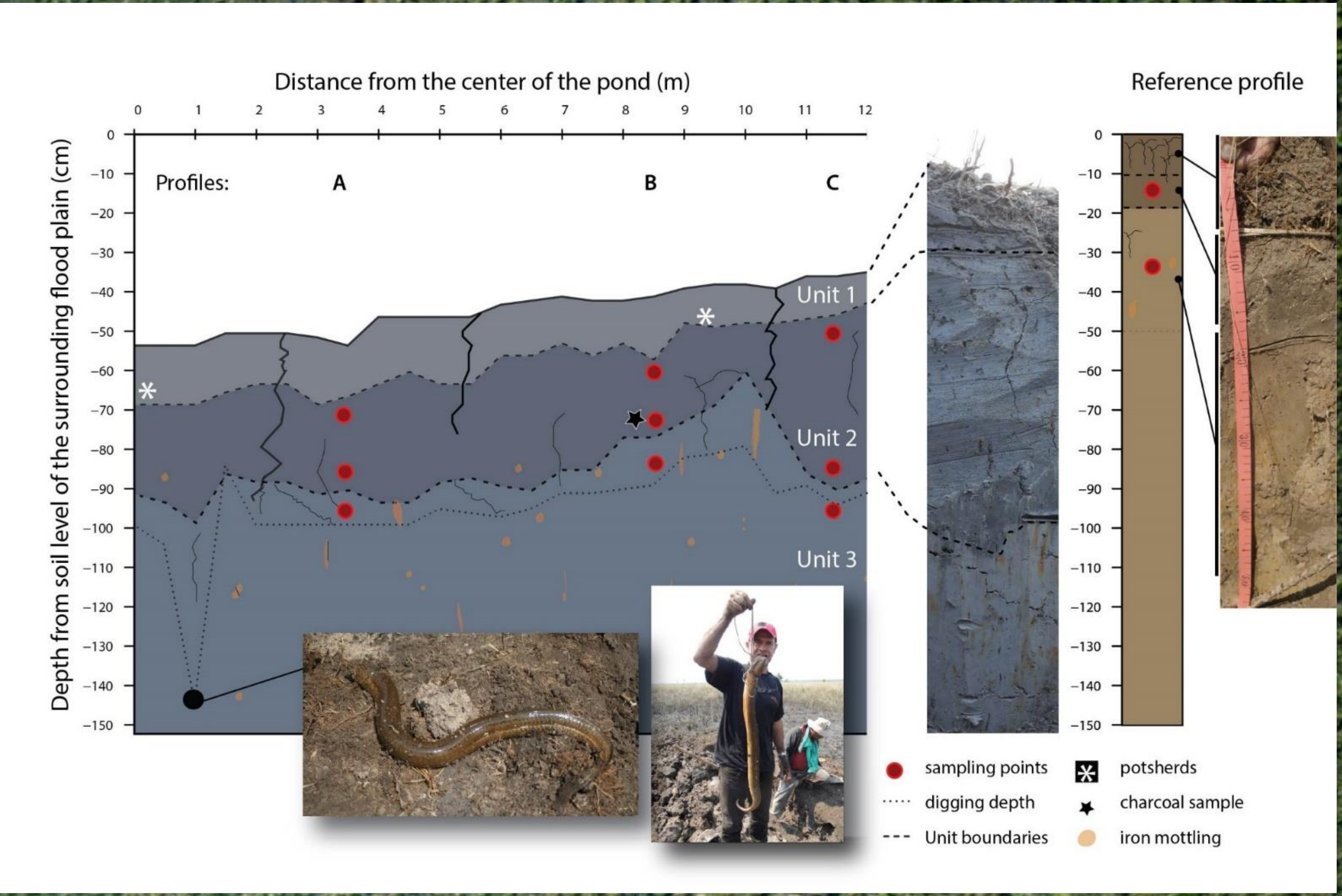
Euler & Herget (2012), *Catena*

Fishermen may have enhanced natural features (downstream pond berm) with artificial structures (weirs) to make a more effective trap

Excavation of a pond within a V-shaped structure of a weir

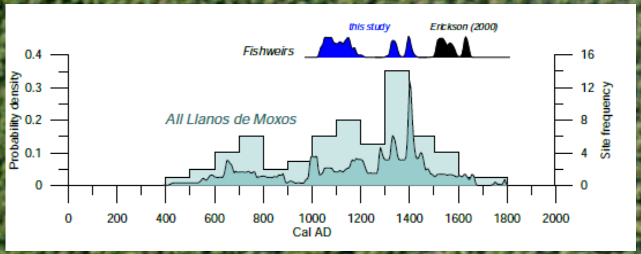


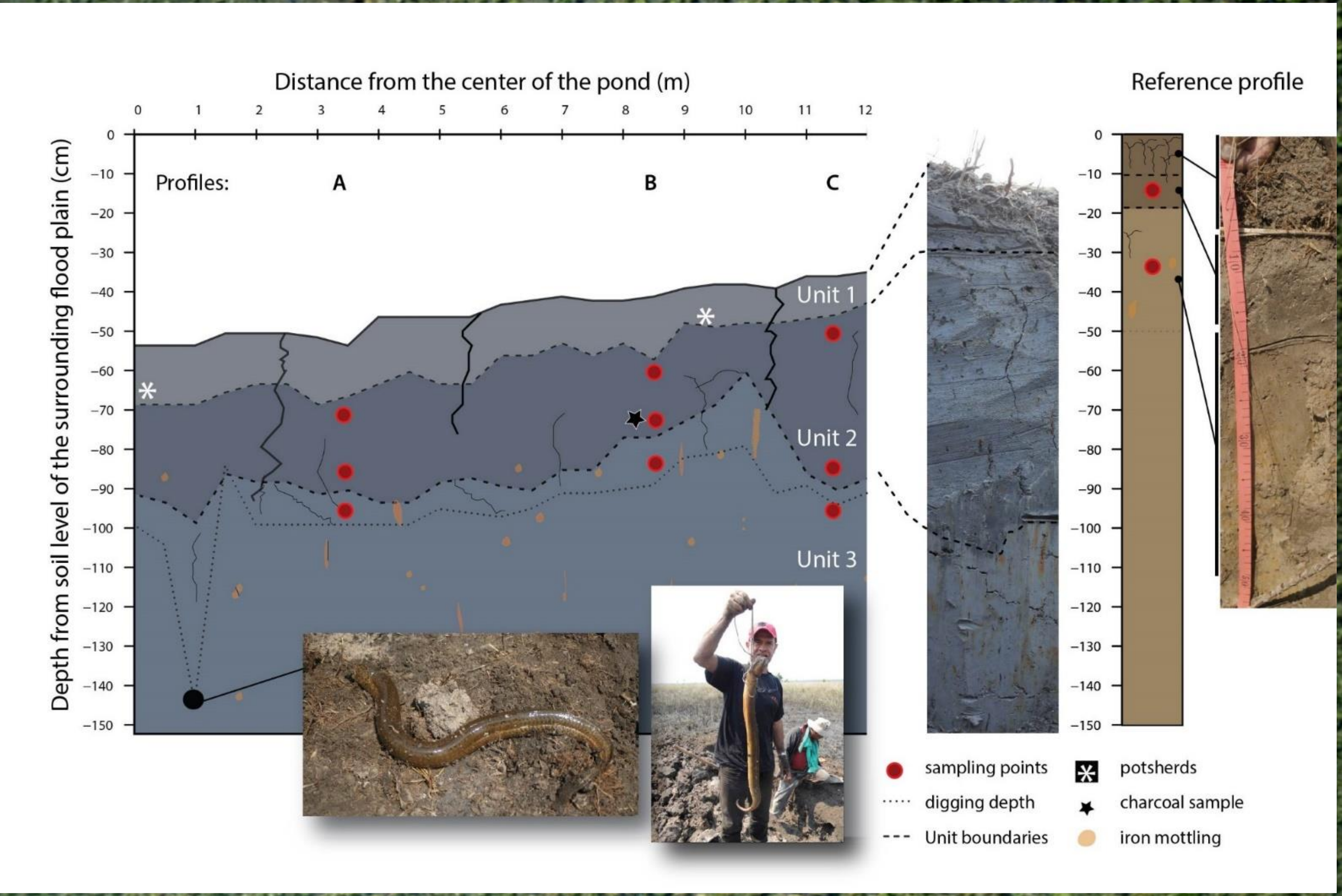


Charcoal ~ 1200 AD

Photos © D McKey

Excavation of a pond within a V-shaped structure of a weir





Charcoal ~ 1200 AD

And a fish!

Photos © D McKey

As Erickson postulated, ponds permitted ‘live storage’ of fish into the dry season

Synbranchus sp. (swamp eel), estivating in the mud of a pond

As Erickson postulated, ponds permitted 'live storage' of fish into the dry season

With ponds integrated, resident species could also be captured, throughout the year

Synbranchus dominates archaeoichthyological remains in the region – but is not consumed today!

Synbranchus sp. (swamp eel), estivating in the mud of a pond

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Synbranchus dominates archaeoichthyological remains in the region – but is not consumed today!

Many migratory species are known from the region, and their life histories are convergent with those in Zambia. Did weirs capture these? *Next field trip!*

Synbranchus sp. (swamp eel), estivating in the mud of a pond

Why study historical ecology and environmental history?

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Because it’s fun

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Because it may be useful

Amazonian fisheries today function very differently than they once did: new gears, new people, new markets

Current fishing practices are not sustainable

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Amazonian fisheries today function very differently than they once did: new gears, new people, new markets

Current fishing practices are not sustainable

The past offers examples of other ways of fishing

Most commercially important fish in Amazonia are large species, and older, bigger fish are selectively harvested

http://www.faunagua.org/proyectos/divulgacion-de-informacion-sobre-peces-pesca-y-las-amenazas-que-enfrentan-en-la-amazonia-boliviana

Pacú (*Colossoma macropomum*, Characidae)

Surubí (*Pseudoplatystoma* spp., Pimelodidae)

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Pacú (*Colossoma macropomum*, Characidae)

Surubí (*Pseudoplatystoma* spp., Pimelodidae)

In many areas, fisheries are clearly unsustainable

Giant Amazon fish 'locally extinct' due to overfishing

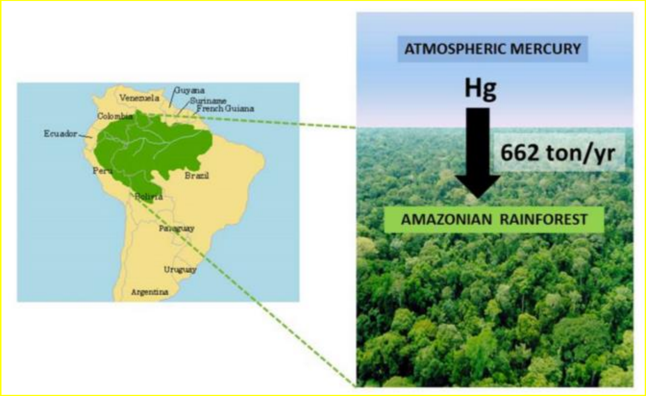
By Zoe Gough
Reporter, BBC Nature

DAVID GIBBS MCGRATH

Arapaima can weigh more than 28st (180kg) and are highly prized by fishermen

Methylmerury is a problem in Amazonian rivers

Atmospheric deposition and storage in soils



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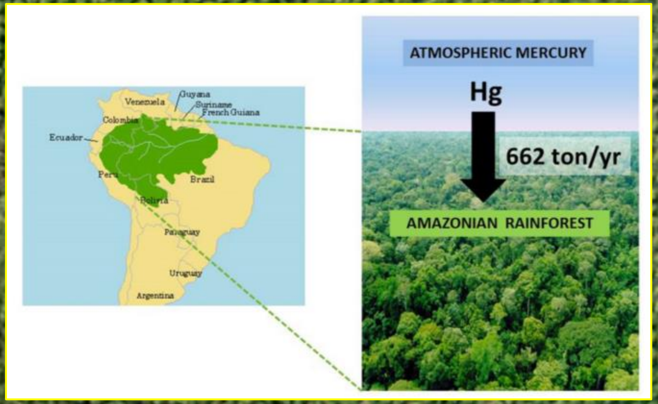
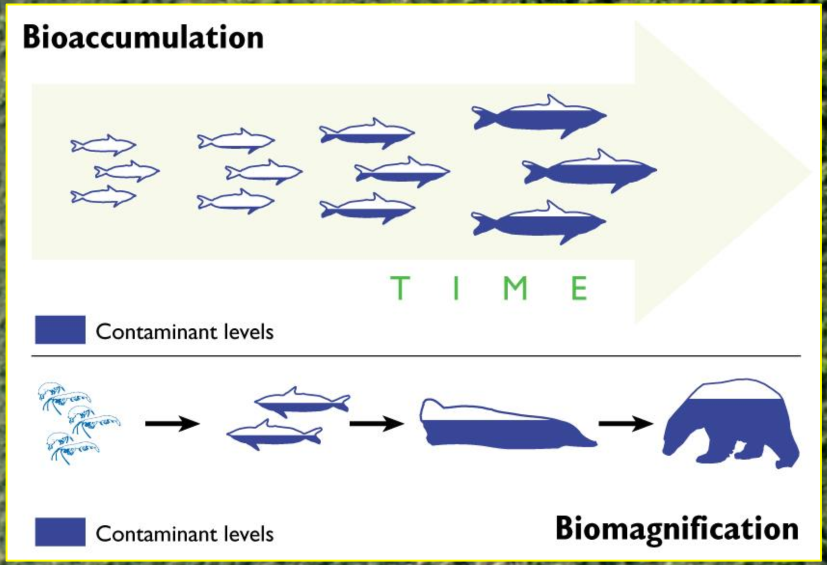


Eating older, bigger fish increases exposure to methylmercury

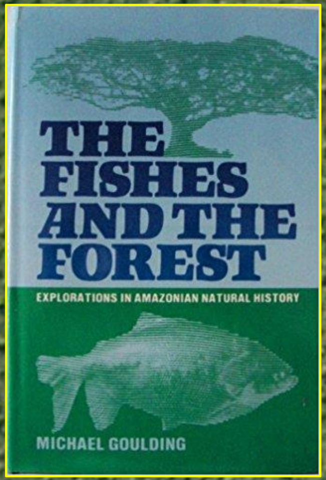
bioaccumulation

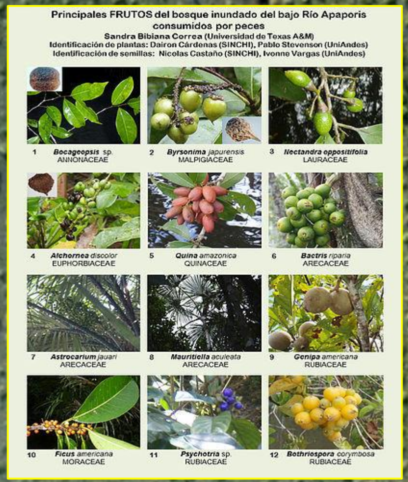


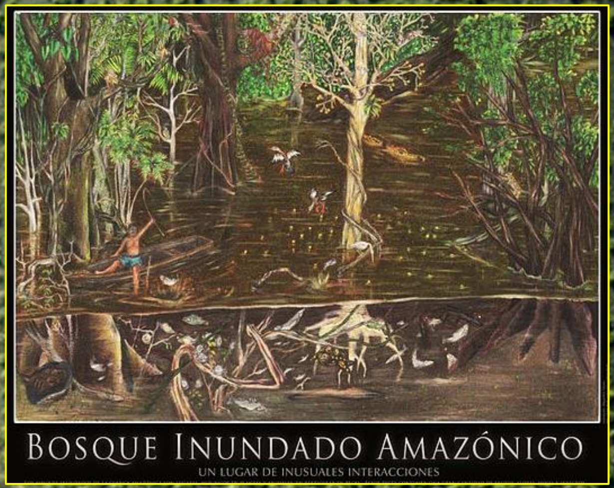
http://mercurypolicy.scripts.mit.edu/blog/

Some commercial fish species are omnivores (e.g., pacú), some are piscivores (e.g., surubi): biomagnification

Fish seed-dispersal mutualisms are crucial to many Amazonian trees







http://macorrea97.wixsite.com/sbcphd/resources

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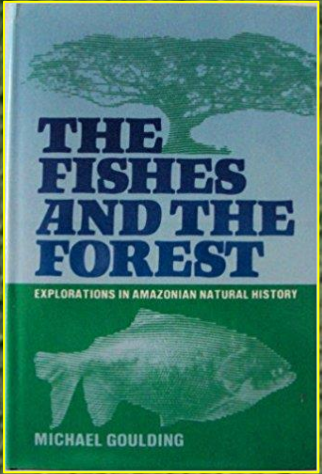
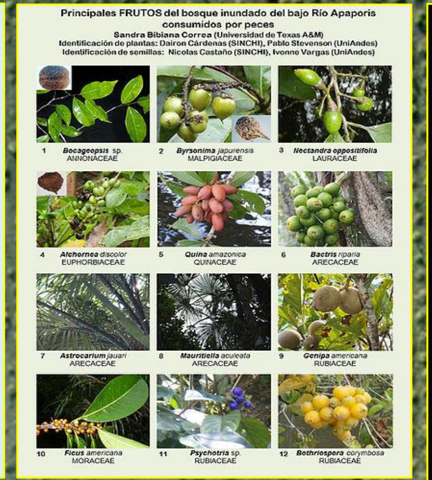
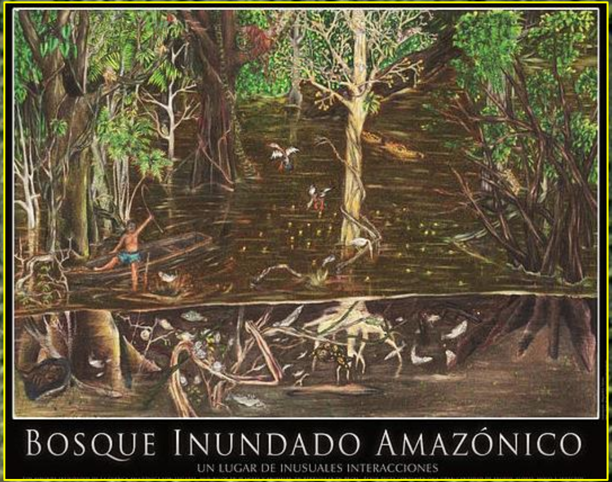






http://macorrea97.wixsite.com/sbcphd/resources

Overfishing and downsizing are leading to their collapse


Biological Conservation 191 (2015) 159–167

Contents lists available at ScienceDirect

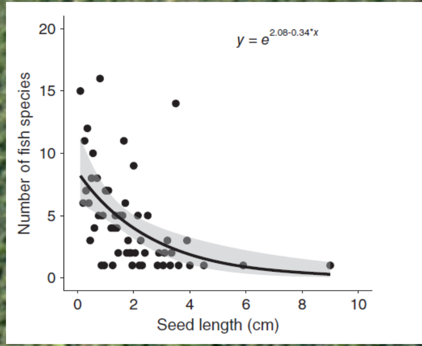
Biological Conservation

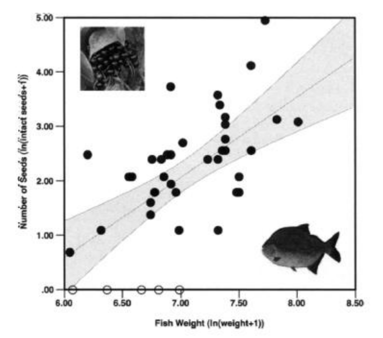
journal homepage: www.elsevier.com/locate/bioc

ELSEVIER

Overfishing disrupts an ancient mutualism between frugivorous fishes and plants in Neotropical wetlands

Sandra Bibiana Correa [a], Joisiane K. Araujo [b], Jerry M.F. Penha [b], Catia Nunes da Cunha [b], Pablo R. Stevenson [c], Jill T. Anderson [a,*]





Correa et al. (2008), *Biological Reviews*

Galetti et al. (2008), *Biotropica*

Big fish are the best dispersers:

- Disperse a greater diversity of seeds
- Are the ONLY dispersers for large-seeded tree species
- Excrete more seeds intact
- Retain seeds longer, disperse them further

Next step: field mission in May 2018

Archaeologists from University of Exeter, UK:

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Mark Robinson

Jonas Gregorio de Souza

Ichthyologist from the Museo Ictícola del Beni (Trinidad, Bolivia): Takayuki Yunoki

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Archaeoichthyologist from Universidade Federal do Oeste do Pará (Santarem, Brasil): Gabriela Prestes-Carneiro

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