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Gender-Differentiated Impacts of the Belo Monte Hydroelectric Dam on Downstream Fishers in the Brazilian Amazon

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Abstract

The Belo Monte Hydroelectric dam on the Xingu River in the Brazilian Amazon will be the third largest dam in the world in power generating capacity (11 GW). Its construction has brought negative socioeconomic and environmental impacts for local fishers that far outweigh the benefits. We used a qualitative case study approach to explore perceptions among fishers in a community downstream from the dam of the impact of Belo Monte on their livelihoods and their fisheries. We found that fishers, who, although they were not displaced were neither consulted nor compensated, have been severely impacted by the dam, and that fishermen and fisherwomen are differentially affected. More attention needs to be given to downstream communities and the impacts they experience.

Keywords Hydroelectric dams · Socio-ecological impacts · Downstream communities · Gender · Amazon fishers · Xingu River · Brazil

Introduction

The increasing demand for energy needed by human populations and for economic development has resulted in growing use of fossil fuels and emissions of greenhouse gases (Arvizu *et al.* 2011). In response, many countries have begun to promote a transition towards renewable energy sources, among them hydropower (Yüksel 2010). Hydropower currently provides 16.3% of the electricity in the world, generates the largest quantity of renewable energy (IEA 2015), and is gaining favor in many nations in the southern hemisphere as a renewable alternative to fossil fuels (Abril *et al.* 2005; Fearnside 1995; Winemiller *et al.* 2016).

After China, Brazil has the largest developed hydropower capacity (IHA 2015; REN21 2015), producing more than 65.2% of the country's energy supply (EIA 2015). The Amazon region has the highest hydropower potential in the country (IHA 2015), and according to Zarfl *et al.* (2014), 84 dams were in the planning stage in the Brazilian Amazon by 2014. These developments are not without consequences for local residents, their livelihoods, and the environment.

In the Amazon, fish are the main source of protein and the most important source of livelihood for communities (Bayley and Petrere 1989; McGrath *et al.* 1993; Silvano *et al.* 2005). There are serious concerns about the potential impacts of dams on fish ecology, production, and biodiversity, and on the livelihoods of fishing communities.

The Belo Monte Hydroelectric dam has generated significant controversy because of its size and predicted socio-ecological impacts (Fearnside 2006). After delays of more than 20 years, construction was approved by Presidential fiat in 2010 and began in 2011 (Fleury and Almeida 2013). The project will be completed in 2019 when all 24 turbines will be operational, at which time it will generate an expected 11 GW of energy per hour, making it the third largest hydroelectric dam in the world (von Sperling 2012). That energy is destined for large cities along the coast of Brazil and industries in the southeast rather than for local communities near the dam.

It is estimated that more than 472 million people around the world are negatively affected by living downstream from large dams (Richter *et al.* 2010). In Brazil, riverine populations living downstream from dams are not considered "directly affected" by designers of hydroelectric projects and consequently they are not included in the consultation processes prior to construction or compensated for subsequent negative impacts

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on their livelihoods. This was the case with Belo Monte downstream fishers.

Hydroelectric Dams and Their Social, Ecological, and Economic Impacts

According to the International Energy Agency (IEA) hydroelectric dams and their associated reservoirs provide the flexibility to generate energy on demand, since large reservoirs retain months or years of average water inflows (IEA 2012). Hydroelectric dams can potentially supply energy to communities that lack access (REN21 2015), generate jobs, instigate infrastructure improvements (Koch 2002), and may reduce seasonal flooding (IPCC 2014). However, they also generate negative socio-ecological and economic impacts (Table 1).

Dam construction generates a change from a lotic to a lentic system,[1] decreasing the quantity of dissolved oxygen and reducing fish populations (Agostinho *et al.* 2008; Fearnside 2014). In the Amazon, dams change the geomorphology of rivers causing an alteration in the flooded forests upstream and increasing rates of deforestation and habitat fragmentation downstream, among other impacts (Alho *et al.* 2015; Fearnside 2015; Hallwass *et al.* 2013; Stenberg 2006; Winemiller *et al.* 2016). For example, the Tucuruí Hydroelectric dam caused high fish mortality and generated socio-ecological impacts associated with the changes in river flow levels (Manyari and de Carvalho 2007). Two years after the construction of Tucuruí dam the quantity of fish caught downstream was one third of the harvest before its construction (Fearnside 1999). This caused a change in residents' diet (Agostinho *et al.* 2008; Fearnside 2014, 2016; Stenberg 2006). After the dam, 11 species of fish disappeared from the area (WCD 2000). In another study conducted in the same dam zone 22 years after construction, fishermen reported an overall decrease in fish abundance, deterioration of water quality, changes in water levels, and fish trapped above the dam (Hallwass *et al.* 2013) (Table 2).

Fishing Differences by Gender

Natural resource knowledge varies among individuals based on experience, gender, age, class, and occupation and is also influenced by power dynamics (Haraway 1991; Kelkar 2007). Gender is embedded in people's experiences and management of natural resources (Frausin *et al.* 2014), thus men and women use resources according to their assigned cultural roles (Agarwal 1997; Bechtel 2010; Cavendish 2000; Sunderland *et al.* 2014).

In the case of fisheries, there is a lack of knowledge of the role of women because most research is focused on the catching sector, which is male dominated (Bennett 2005). However, there is ample evidence that women participate as active fishers in different regions of the world (Bennett 2005; Deb *et al.* 2015; Harper *et al.* 2013; Kebe 2009; Weeratunge *et al.* 2010). Research shows that not only knowledge, practices and management differ between men and women fishers, but also their perceptions, attitudes, behavior patterns, priorities, concerns, opportunities, and needs (Agarwal 1997; Cavendish 2000; Sunderland *et al.* 2014).

The negative impacts of large-scale development disproportionately burden the rural poor and create more pressure on women compared to men (Braun 2011; Tilt *et al.* 2009). This is because women have unequal rights and access to land (or fishing spots and gear), are poorly protected by law, and lack access to education and employment opportunities (Adams 2009; Barry 1997).

The Belo Monte Hydroelectric Dam

Belo Monte has been a controversial project due to its predicted socio-ecological impacts, the restriction of river discharge during the annual dry season, and the high cost of construction (Stickler *et al.* 2013). The provisional environmental license for the construction of the dam was issued by IBAMA (the Brazilian Environmental Agency) in 2010 under direct orders from the President. According to Sousa Junior and Reid (2010), this licensing process remains controversial due to the lack of consultation with inhabitants of the region and because the environmental impacts were underestimated or ignored. The failure of the dam construction company to meet the legal requirements of addressing and improving local water and sanitation systems under Brazil's Basic Sanitation Law did not prevent the issue of the license to operate the dam in 2016 (Gauthier *et al.* in review).

We present our research on the impact of the Belo Monte Hydroelectric dam on the livelihoods of fishermen and fisherwomen in Vila Nova, a community downstream from the dam. We conducted fieldwork in 2016, when four of the 24 turbines were in operation, giving an early indication of likely changes downstream. To the best of our knowledge, this is the first study looking at the socio-ecological impacts perceived by fishing communities living downstream from a hydroelectric dam in the Brazilian Amazon basin using a gendered approach.

Vila Nova is a community in the Xingu river that attracted our attention because both women and men fish. While this may not be unusual elsewhere in the world, it is highly unusual in the Brazilian Amazon since fishing has typically been a male activity and women were traditionally banned from it because they allegedly brought *panema* ("bad luck") to the fishermen (first noted by Wagley 1953, and by others

[1] Lotic and lentic systems are freshwater habitats with slow and rapid water movements, respectively.

Table 1 Main socio-ecological and economic impacts of dams

	Positive	Negative	References
Increase in human migration		X	(von Sperling 2012)
Increase in criminality, drugs, prostitution		X	(von Sperling 2012)
Increase in teenage pregnancy		X	(von Sperling 2012)
Increase in disease transmission		X	(Fearnside 1999; Grisotti 2016; Koch 2002; Soito & Freitas 2011; Trussart et al. 2002; von Sperling 2012; WCD 2000)
Displacement of human populations		X	(Fearnside 1999; IPCC 2014; Junk & Mello 1990; Trussart et al. 2002; von Sperling 2012)
Population resettlement with little consultation		X	(Boanada Fuchs 2016)
Health services overwhelmed by population increase		X	(Grisotti 2016; Moran 2016)
Job opportunities	X		(Arvizu et al. 2011; Koch 2002; von Sperling 2012; WCD 2000)
Low operating and maintenance cost	X		(IHA 2003)
Loss of social cohesion		X	(WCD 2000)
Energy supply for people who lack access	X		(REN21 2015)
Improved roads and infrastructure	X		(Koch 2002)
Poor sanitation and water quality during construction		X	(Grisotti 2016)
Increasing cost of electricity		X	(Tilt et al. 2009)
Water supply for irrigation	X		(IHA 2003; Yüksel 2009, 2010)
Enhanced water quality	X		(von Sperling 2012)
Generates "clean energy"	X		(Bartle 2002)
Produces greenhouse gases		X	(Abril et al. 2005; Fearnside 1995)
Reduces CO_2 emissions	X		(Arvizu et al. 2011; von Sperling 2012)
Loss of biodiversity		X	(Stenberg 2006; Trussart et al. 2002)
Increases deforestation rates		X	(Alho et al. 2015; Fearnside 2015; Hallwass et al. 2013; Winemiller et al. 2016)
Depletion of forest resources		X	(Tilt et al. 2009)
Reduced seasonal flooding	X	X	(IPCC 2014)
Change in river geomorphology		X	(Stenberg 2006)
Decline in agricultural productivity		X	(Tilt et al. 2009)

consistently thereafter, e.g., Galvao 1955, Moran 1974, Smith 1981, Marques 2001, Witkoski 2010). Attention to the role of women fishers is overdue, since they are in general overlooked by policy makers, managers, and researchers (Branch and Kleiber 2017; Koralagama *et al*. 2017).

Materials and Methods

Study Area

Vila Nova (2°52′31.57"S, 51°53′36.34"W) is a community located on the Xingu River in the municipality of Senador José Porfírio in the State of Pará-Brazil. Its inhabitants are riverine people, called *ribeirinhos*. As in other riverine communities in the state of Pará, fish is their most abundant protein source. According to Vila Nova' s health workers and the school director, in the summer of 2016, the community had 752 inhabitants living in 156 domestic units (Fig. 1).

Data Collection

Fieldwork was done between June and August of 2016. We conducted a total of 26 in-depth interviews with fishers to explore their livelihoods, knowledge, and the changes they perceived during the construction and the early operation of Belo Monte. Participants were chosen based on their willingness to participate, their availability and 10 or more years of experience fishing in the area. Thirteen of the interviewees were fisherwomen, twelve were fishermen and we also conducted one interview with a married couple who both fished. We recorded the conversations with consent. The names of all participants have been changed to protect their identities.

Table 2 Socio-ecological and economic impacts of hydroelectric dams on fisheries

	Positive	Negative	References
Generates obstacles in river navigation		X	(Baran and Myschowoda 2009; IPCC 2014; Orr et al. 2012; Trussart et al. 2002)
Change in river geomorphology		X	(Stenberg 2006)
Alters hydrological regimes		X	(Alho 2011; IPCC 2014; Trussart et al. 2002; Yüksel 2010)
Increases the rates of deforestation		X	(Alho et al. 2015; Fearnside 2015; Hallwass et al. 2013; Winemiller et al. 2016)
Increases habitat fragmentation		X	(Alho 2011)
Reduction in dissolved oxygen		X	(Agostinho et al. 2008; Alho 2011; Fearnside 2014)
Loss of biodiversity		X	(Stenberg 2006; Trussart et al. 2002)
Reduces water quality in the reservoir by increasing eutrophication		X	(Fan, He, & Wang 2015)
Blocks fish migration		X	(Baran and Myschowoda 2009; IPCC 2014; Orr et al. 2012; Trussart et al. 2002; von Sperling 2012)
Reduces fish production		X	(Baran and Myschowoda 2009; Orr et al. 2012)
Reduction of primary productivity (reduction of photosynthesis) affecting secondary production (e.g. fish)		X	(Alho 2011)
Changes in the diet of population		X	(Agostinho et al. 2008; Fearnside 2014, 2016; Stenberg 2006)
Loss and alteration of flooded forest		X	(Fearnside 2016; Manyari and de Carvalho 2007; von Sperling 2012)
Increased fish mortality when fish pass below the dam (turbines)		X	(Zhong and Power 1996)

We navigated the area used by fishers to observe and discuss with them their fishing activities and the impacts generated by the dam (e.g., fishing spots, gear, captured species, distances, challenges, etc.). We accompanied two fishermen and one fisherwoman on fishing trips, and they took us to their fishing spots. We recorded GPS coordinates with a Garmin GPS and we also took pictures with a GPS-enabled camera (a Panasonic Lumix).

In addition, we conducted 10 participatory mapping activities, in which fishers drew fishing areas, with six individual men, three individual women and one group of four fisherwomen. The participatory mapping allowed us to obtain information about property rights, seasonal trends in fisheries, and how they fished before and during the construction of the dam.

Data Analysis

We followed Miles *et al.* (2014) data analysis process, which is an interactive and continuous system for data collection, condensation, display, and conclusions. We conducted the analysis of data in two main phases: during and after fieldwork. During fieldwork, we followed the process of fieldnote writing proposed by Bernard (1995): writing every day about each data collection and writing-up fieldnotes.

After fieldwork, our local research assistant transcribed the interviews verbatim; we then reviewed the transcripts and compared them to the recordings of each of the interviews. Next, we began the *data condensation* stage. We used inductive codes to analyze our data, then we organized and summarized each of the codes into displays.

Results

Fishers from Vila Nova use the fisheries resources differently depending on their gender. Fishers recognized ecological changes in the water, the flooded forest, and subsequently in the fishery resources, and the consequent changes in their livelihoods caused by the construction of the dam. We first discuss the fishing seasonality in Vila Nova, and then describe the ecological changes perceived by fishers, including changes in mobility and fishing spots for both fisherwomen and fishermen since the dam construction. Finally, we present the social and economic impacts of the Belo Monte dam on fishers' lives and how these differ by gender.

Seasonality of the Fisheries

Fishers in the Amazon basin visit different fishing spots, use different gear and catch different fish species depending on the season. In Vila Nova fishers identify two seasons: the rainy season and the dry season. Maria, a fisherwoman, explained the dynamic of the flooded forest:

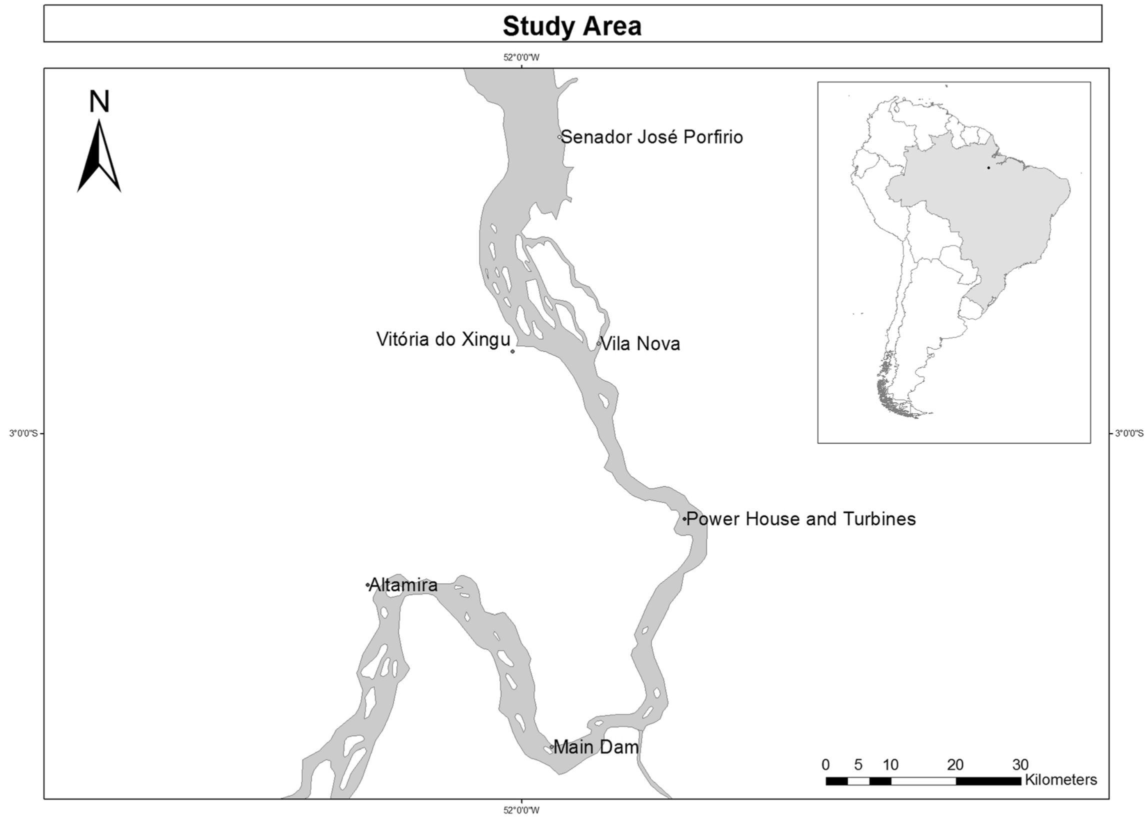


Fig. 1 Map of the study area

"November is when, because of the rain, fishing starts to change. The water of the river starts to rise and other fish arrive…fish enter the *igapo* [the flooded forest] …It is the time of the year when fish such as *Pescada (Plagioscion squamosissimus)* are fat." The seasonality described by fishers corresponds to the records for montlhy average rainfall (see Fig. 2).

The rainy season is the time of the year when the forest, the islands, and even the community are flooded. It starts in November, when the river level starts to rise, and lasts until June, when monthly precipitation drops to below 100 mm. According to fishers most of the regional fish spawn during the rainy season. The flooded forest (*igapo*) plays an important role, providing a protected space for fish to spawn and the fruits and seeds on which they feed. During this season most fishermen use their fishing nets in the Xingu River to harvest larger fish such as *Filhote* (*Brachyplatystoma filamentosum*) and *Pescada*. They also fish in the lakes and the flooded forest with handlines. By contrast, most fisherwomen use handlines to fish *Pescada* and *Piau* (*Leporinus* sp) in lakes and the flooded forest. Fisherwomen describe the flooded forest as an important environment where they fish and collect seeds and fruits to use as bait. For example, Carmen, a fisherwoman, noted that "fish eat many fruits from the igapo… *Envira*, *Jauari,* and *Urucurana.*"

In the dry season (June to November), fishermen mainly use nets to fish *Curimatã* (*Prochilodus nigricans*) and *Ariru* (*Semaprochilodus brama*) on the shore of the Xingu river's islands. Some dive to harvest *Tucunaré* (*Cichla melaniae*), the fish with the highest economic value in the region. Fisherwomen use handlines with *Minhoca* (earthworms), and wet *farinha*[2] as bait, just as they do during the wet season (Table 3).

Ecological Changes Perceived by Fishers

Fishers identified two specific events during the construction of the dam that caused changes in the river ecosystem and in their livelihoods. The first ocurred during the removal of land and vegetation when Norte Energia (the construction company) was dynamiting rocks in the river and using a lighting system to allow the construction crews to work 24 h a day (the lights were comparable to a well-lit football stadium, according our observations and confirmed by the manager of Norte Energia). The second occurred when they began to fill the reservoir.

[2] Farinha is flour made from manioc root, a traditional Brazilian side dish and the chief carbohydrate consumed in the Amazon, often eaten with fish.

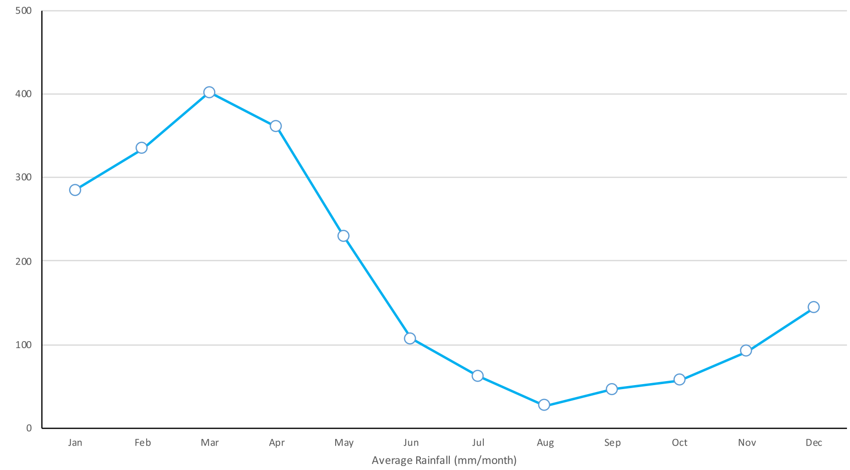


Fig. 2 Average rainfall data for the city of Altamira from the National Institute of Meteorology (Brazil) 1990–2016

Land and Vegetation Removal

All fishers pointed out that before the construction of the dam, the water of the Xingu river was clear and crystaline, and they could see fish and rocks in the water. When the dynamite explosions and land and vegeration removal began, fishers perceived a change in the color and turbidity of the water. This, in turn, led to a decrease in the availability of fish. Jairo, a fisherman, described how the impacts began:

> Before they [Norte Energia] started to use the lights at night and exploded the dynamite, the water was clean, fish were easily caught on the hook with bait. Two years after they started with the construction the water didn't rise: the water was muddy. The water was in no condition to support fish: it was dirty. The fish were not used to those explosions so the fish didn't stay in the region. The noise of the explosions scared the fish. During the first year, there was a lot of machinery and the noise of the charges. Also, the lights that they used were like an eviction notice to fish to leave the area. That was then when the problems for the people close to the dam began.

Half of the fishers interviewed mentioned that fish are dying and disappearing due to the decrease in water quality, as noted by another fisherman:

> Now the water is ugly, it looks like 'tucupi[3];' it is yellow. Fish are dying; we found dead fish in the middle of the river. The water used to be clean and clear; we could see through the water. Now the water is bad, we cannot drink it… Sometimes the water also has a bad smell. -Lorenzo

Most women find that the color and aspect of the water affects the fish in the region. Half of them are also concerned about the possible health effects on them and their families. This group has stopped drinking water from the river.

> That dam finished everything. The fish that came from upstream are dying. We have found dead fish… They [Norte Energia] have heavy machinery with mountains of dead fish. They are throwing the fish everywere. The water is dirty; we cannot drink it anymore. Before we didn't need to bring a drop of water; we drank natural water. Now we cannot: the water is too dirty. It is so dirty, if it is killing the fish, what will happen to the human beings?- Angela.

Before Belo Monte, they used to drink water from the river while fishing. Now, they drink water from a community well that only works when there is power. Some residents are no longer bathing in the river. Nevertheless, most of the women continue washing clothes and dishes and cleaning fish in the river.

The use of stadium lights in the construction area generated a full-moon effect, and fishers do not fish during full-moon nights. They prefer darker nights because fish cannot see the gillnets and are easier to catch. One fisherwoman and two of the fishermen noted the effects of the light:

> … we navigated the river with that light. Everything was illuminated. I think that was what scared the fish. Fish disappeared. I use a 120 meter fishing net and I used to catch lots of fish. Now we are using more than 120 meters in the river and we are just catching between 2 and 3 fish in the net. Fish are disappearing because of that… We [fishers] know the area; we move around and we know the fisheries… I find that everything is empty now, there are no more fish. The fish are running away, perhaps they left to go to the Amazon [referring to the river]. Now, it is bad for a fisherman to live here. – Rafael.

[3] Tucupi is a yellow liquid extracted from manioc root and used as a cooking ingredient in regional dishes

Table 3 Fisheries seasonality by gender

Season	Gender	Mobilization	Fishing gear	Main species	Fishing spot	Bait
Rainy or "inverno"	Women	Canoe & paddle	Hand lines	Piau	Flooded forest, Lakes (less than 5 km from Vila Nova)	Tree fruits and seeds. Igapo.
	Men	Motorized canoe, canoe & paddle	Fishing net (Gillnet)	Pescada, Filhote, Dourada, Curimata, Marapá	Xingu river, lakes	N/A
			Hand lines	Pacu	Flooded forest, lakes	Tree fruits and seeds
Dry or "verão"	Women	Canoe & paddle	Hand lines	Piau Cara Traira	River bank	"Piabinha" little fish (river bank), earthworm (quintal), wet farinha
	Men	Motorized canoe, canoe & paddle	Fishing net (Gillnet)	Cará, Curimatã, Ariru	Xingu river and lakes	N/A
			Hand lines	Ariru, Tucunare	Xingu river and lakes, river bank	"Piabinha" littlefish (river bank)
			Trident, bow and arrow	Curimatã, Piau	Xingu river and lakes, river bank	N/A

Reservoir Filling

All fishers identified the river flow alteration as one of the most evident changes caused by Belo Monte. Before the construction of the dam, the flooded forest zone was usually inundated at least four months of every year. Fishers first perceived a reduction in the river flow during the rainy season of 2015–2016 when Norte Energia began to fill the reservoir. In fact, they noticed that the *igapo* did not flood during that rainy season. Since the flow of the river did not rise to the usual level and the forest did not flood, fish did not enter the igapo or spawn. The impact of the change in the river flow level on fish reproduction was noted by all fishers:

> This year [2016] was when fisheries became bad because the water didn't rise. This year was more than bad… Every year fish enter the igapo to lay their eggs, but this year the river was not in any condition to let the fish lay the eggs: the river didn't have water. –Caio.

Fisher Mobility Patterns and Loss of Fishing Spots

Due to the land and vegetation removal and the filling of the reservoir there was a loss of fishing spots in the region. The area fished by men is larger than that of the women for a variety of reasons. Most women fished by themselves or with a partner almost every weekday, leaving early in the morning and returning before noon to do household chores. They generally paddled canoes to their fishing spots. Fishermen have motor boats that allowed them to go farther and they fished for 10 h a day.

Because of the river flow change, fishers were no longer able to access some fishing spots once the construction started. Women were forced to fish during the rainy season along the river banks when they used to fish only during the dry season (Fig. 3). They also reported a reduction in their fishing spots.

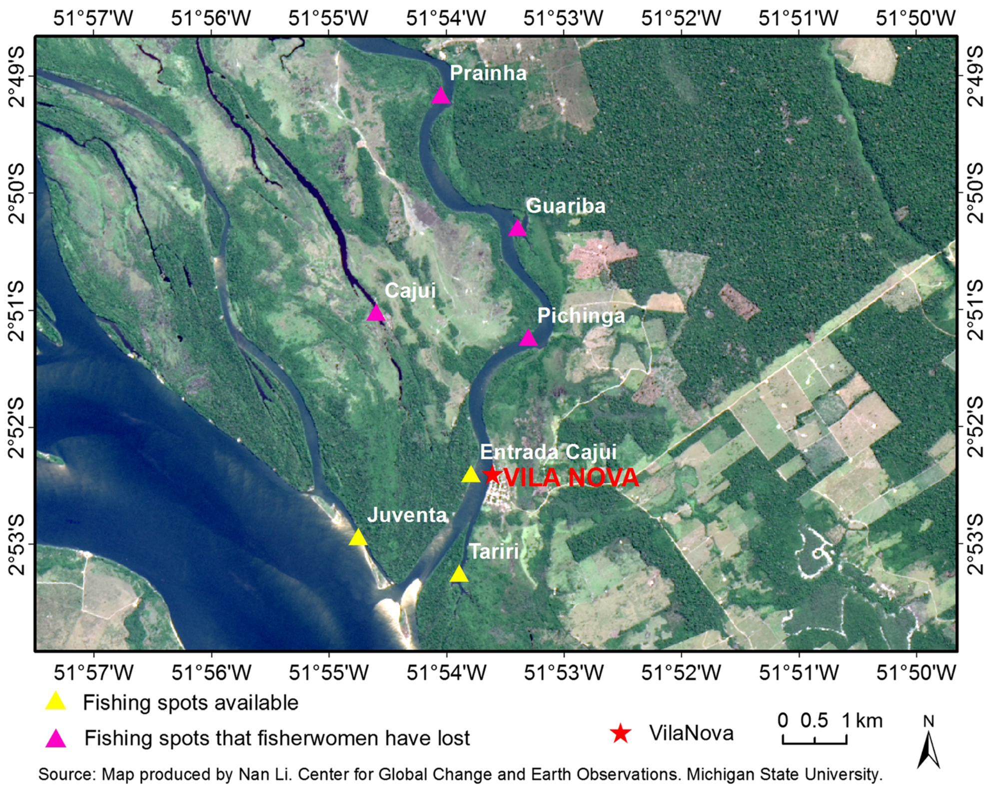
Due to the change in fisherwomen mobility patterns and the loss of fishing spots, women claimed that they fish fewer days per week and for a shorter time each day. With the changes in the fisheries, they find that it is no longer rewarding given the lower fish productivity. As a result, they report spending more time at home.

Men who traditionally fished in spots located further from Vila Nova and who provide income to their households reported the loss of fishing spots along the Xingu river. In particular, they stressed the loss of three catfish species of high economic importance, *Filhote, Marapá* (*Hypophthalmus* sp) and *Dourada* (*Brachyplatystoma rousseauxii*), as most significant to them. Fishermen have increased their time fishing because they must travel longer distances in order to find fish (Fig. 4). Despite additional efforts, fishermen reported lower catches than before the dam construction.

Social and Economic Impacts of the Dam on Fishers by Gender

While men are concerned with the decrease in fisheries and income, women are worried about the decrease in food access and quality for their families (Table 4). Some women also

Fig. 3 Fisherwomen's fishing spots. The pink fishing spots are the ones that are no longer accessible due to the river flow change



mentioned how the dam affects other household activities such as bathing or drinking water due to water quality concerns. Women have also noticed a significant increase in the price of purchased food products. An elderly fisherwoman explained: "That dam ran out the fish and if we want to buy 1kg of farinha, we need to sell 3 kg of fish…1 kg of farinha

Fig. 4 Fishermen's fishing spots. The pink the fishing spots are the ones that are no longer accessible due to the river flow change

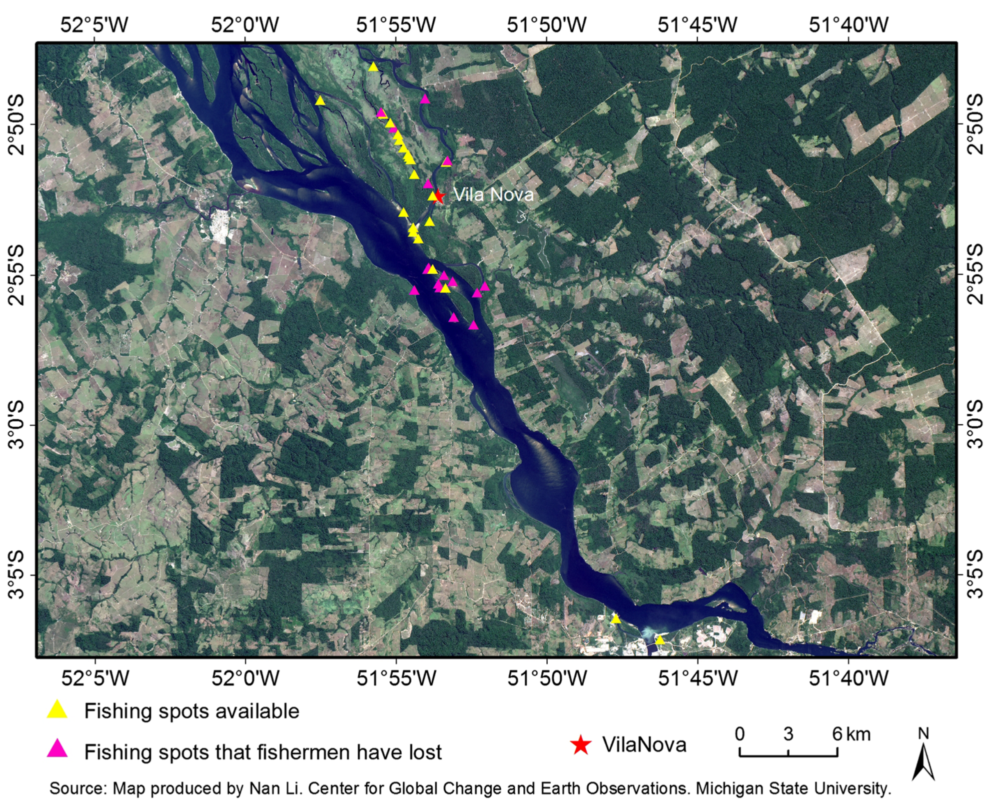


Table 4 Changes caused by the impacts of the Belo Monte dam on fishers' lives

Changes caused by the social, ecological and economic impacts of the Belo Monte Dam on fishers' lives.

	Women	Men
Loss of fish of economic importance		X
Loss of fishing spots	X	X
Increased distance to fishing spots from Vila Nova		X
Increase in fishing expenses prices		X
Limited food access	X	
Increase in food prices	X	
Reduced water quality	X	
Reduction in time fishing	X	
Increase in time fishing		X

costs 7, 6, 8 real [$2.56 USD]." –Blanca. The price of beans, a basic food product, has also increased.

> Nowadays, everything is really expensive. Oh my God, while we are talking the price of beans is R$ 13 [$4.80 USD]. Things got expensive really fast, really fast… When I arrived in the community [11 years ago] the price of one kilogram of farinha was R$1.50 [$0.50 USD] now the price is R$7 [$2.56 USD].- Angela.

The dam has impacted fishermen as well: they are no longer catching the species with the highest economic value and they are traveling farther, reducing their net returns. Adding to their difficulties, the price of gasoline has doubled since the construction of the dam, so they have had to fish more to cover their costs and sustain their families. In 2016, the price of a liter of gasoline in Vila Nova ranged from R$5 to R$6 ($1.90 - $2.20 USD).

> We are certain that the dam affected the fish. We used to fish really close [to the community], it was calm; everyone fished without having to travel farther. Nowadays, if you want to fish… there are fishermen who travel between 3 and 4 hours until they find fish. People are traveling farther away… Sometimes we get to one fishing spot, and we don't catch anything, then we travel from fishing spot to fishing spot looking for fish until we catch something to sell. Our life is like that now, but before it was different. –Pedro.

Discussion

We found that fishermen and fisherwomen have different perceptions of the ecological and socioeconomic impacts of the dam and these differences are explained by the gender roles in fishery households. Both groups recognized that the quality and color of the water changed as soon as dam construction began and these changes affected people's lives. The deterioration of water quality has also been reported by previous studies as one of the impacts of dams on downstream areas (Hallwass *et al*. 2013).

Undoubtedly, the main environmental change perceived by fishers occurred during the reservoir filling process. As other studies have reported (Alho 2011; IPCC 2014; Trussart *et al*. 2002; Yüksel 2010), Vila Nova fishers identified an alteration in the hydrological regime: a reduction in the river flow, which later led to the loss of flooded forests (Fearnside 2016; Manyari and de Carvalho 2007; von Sperling 2012), the most important habitat for fisheries in the Amazon (McGrath *et al*. 1993). This led to a decrease in fish availability (Baran and Myschowoda 2009; Orr *et al*. 2012; Stenberg 2006; Trussart *et al*. 2002).

Our results indicate that the reduction in fish abundance is affecting the local economy–a situation also reported in the Lower Tocantins River (Brazilian Amazon) after the impoundment of the Tucuruí reservoir (Hallwass *et al*. 2013). In the past, women split their time between fishing and their household responsibilities. Now they have reduced their fishing efforts because they are not finding enough fish. This change in women's access to fish affects not only the family's food security, but also the autonomy of the women. Before the construction of the dam, women kept some fish for the household and sold any surplus fish to intermediaries, providing some cash for other household expenses. Now women have become completely dependent on men and what they catch. A similar result is found by Lahiri-Dutt (2012), indicating that women's domestic burden increases with the construction of a dam.

As noted earlier, prices for food and gasoline have also increased, making the food security of these families a concern. It seems that the dam is creating an "inflationary" bubble that is clearly affecting the communities living nearby. This situation is exacerbated by the fact that there is no tradition in Vila Nova of cultivating crops, a legacy of the rubber boom eras (1870–1912 and 1939–45) when rubber barons prevented rubber tappers from planting crops, forcing them to buy supplies from the rubber buyer to ensure their long-term service and keeping them in perpetual debt (Moran 1974; Wagley 1953). In the past, riverine people depended on rubber extraction and fishing for their subsistence, selling the rubber to get other basics such as *farinha*, sugar, salt, and kerosene (Dean 1987).

Conclusions

Our research addresses the knowledge and perceptions of local fishers impacted by the Belo Monte dam in a downstream Brazilian Amazonian community. We followed a gendered approach, highlighting how fishermen and fisherwomen are differentially affected by dam construction. Scientists have stated that the populations suffering more from large-scale dam construction are those that are displaced, forced to resettle because their livelihoods were destroyed, their homes flooded, and they receive few benefits from the projects (Adams 2009). Although this study does not contradict that conclusion, it shows how communities not displaced and not included in consultation processes are also severely impacted by the construction of dams. Downstream communities often have been overlooked in previous discussions of dam impacts.

In this study we have shown how these impacts differ by gender. Fishermen are concerned about the decrease in fisheries, in particular fish of economic importance and the subsequent income reduction, the increase in the distance they now have to travel to fish, and the rising cost of fuel. In contrast, fisherwomen are concerned about the loss of access to fishing spots and the low returns for their fishing efforts, making them less independent and less able to ensure food security for their households. They are also worried about the rising prices of basic products in the market and the lower net returns from fishing efforts by their male counterparts.

Fishers may need to identify new strategies to cope with this situation. These strategies will likely differ by gender, but beyond that, it seems difficult to foresee what strategies will be adopted. Years ago, when the inhabitants of this region extracted rubber as their main economic activity, they had fishing and hunting as complementary activities. The problem now is that they do not yet recognize any viable economic alternatives to supplement fishing. Hunting has been disrupted by the deforestation associated with dam construction; fishing is depleted and likely to remain so for a decade or two; rubber has long ceased to be an important activity except in some exceptional areas like Acre at the other end of the Amazon; and they lack the land titles or traditions to become successful farmers. Documenting the impacts they have perceived (as we have done in this study) is important because policy makers need to be aware of the challenges communities living downstream from dams are facing and that compensation for these populations should be a priority.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent This study was deemed exempt, category 2 research by the Internal Review Board on Human Subjects (IRB No. IRB# ×16-729e) at Michigan State University. Informed consent was used to ensure voluntary participation and confidentiality.

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