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Dams: Implications of Widespread Anthropic Flooding for Primate Populations

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Introduction

As part of a volume dedicated to non-human primates that inhabit flooded ecosystems, it is important to acknowledge that some species live in habitats that were only recently inundated at the hands of humans. While the majority of non-human primates (hereafter primates) discussed in this book have had time to adapt in various ways to flooded environments, the primates discussed in this chapter have been forced to make significant changes virtually overnight as a result of the construction of a dam and inundation of an associated reservoir.

Over 45,000 large dams (≥15m tall) have been built worldwide (Nilsson *et al*., 2005; World Commission on Dams [WCD], 2000). These dams and other man-made diversions affect the flow of approximately 60% of the world's 227 largest rivers (Worldwide Fund for Nature [WWF], 2004). All of the dams reviewed in this chapter [Table 1] are considered large dams and two are among the largest in the world, Brazil's Tucuruí Dam and Venezuela's Guri Dam (WCD, 2000).

People build dams for many reasons including irrigation, production of hydroelectricity, flood control, ensuring water supplies, and improving river navigation ability (Liao, Barghava & Das, 1988; WWF, 2004). Most large dams are built for the purpose of generating electricity; indeed in 2004, WWF reported that almost 20% of the world's electricity was being provided by dams.

Hydroelectric dams have long been touted as a clean alternative for energy production, when compared to fossil fuels (Moore, Dore & Gyawali, 2010). However, recent evidence suggests that, for many years, hydroelectric dams can produce nearly as much, just as much, and sometimes even more greenhouse gas emissions than fossil fuel methods of energy production (Abril *et al*, 2005; Fearnside 2002, 2009; Fearnside & Pueyo, 2012; Kemenes *et al*., 2007, 2011). Today, experts debate whether dams are indeed clean energy producers and, therefore, whether the benefits of damming truly outweigh the costs (Fearnside, 2011; Poff *et al*., 2003).

Though dam construction peaked in the 1950's through the 1980's, they slowed in the 1990's as studies of their impact became available. Even with this information available, 1,600 new large dams were under construction in 2004 (WWF, 2004) with many more constructed since: a dramatic spike in dam construction is anticipated over the next ten to twenty years (Tundisi *et al*., 2014), and a high proportion of these are in primate range countries. Finer and Jenkins (2012), for example, report on plans for 151 new dams in the Amazon basin – 60% would impact river connectivity and, "More than 80% would drive deforestation due to new roads, transmission lines, or inundation." WWF (2004) estimates that of the world's remaining 64 large free-flowing rivers at least 17 are in danger of being dammed by 2020, including several within primate habitat countries in South America and Southeast Asia.

Regardless of where the dam occurs, economic, social and environmental assessments are typically conducted prior to construction. Environmental Impact Assessments (EIA's) are perhaps the most common tool used to evaluate environmental effects of dam construction and reservoir flooding (Robinson, 1992). While their use is not required in all countries (Pack, 1996) and the timing of incorporating EIA studies has often been too late to influence dam construction and design decisions (McAllister *et al*., 2001; Rodrigues, 2006), efforts to incorporate EIA findings into dam design and environmental impact mitigation planning are improving (Robinson, 1992; Tullos, 2008). Still, many countries that conduct pre-construction EIA studies fail to fully implement plans to minimize biodiversity losses (Schneider, 2001; Alho, 2011).

This chapter will highlight results of a literature review focusing on how primates are impacted by man-made dams. Particular attention will be given to a few well-documented case studies in South America and Southeast Asia. The impacts observed at these dam sites will not only inform the discussion, they will also form the basis for a concluding suite of recommended future actions that could help minimize and mitigate adverse effects of dam construction and reservoir inundation on primates.

Overview of Impacts

The initial impact of damming on primates occurs well before the reservoir itself is flooded. Sites are cleared, roads are built, construction crews move in, animal translocations are sometimes undertaken, and the noisy, dusty business of dam-building begins. Collectively, these anthropogenic actions cause noise, air pollution, habitat loss and fragmentation, result in human population increases and relocations, and may either deplete wildlife (via hunting) or increase wildlife population densities (due to animals fleeing from the flood zone or being translocated: Woodford & Rossiter, 1993; Schneider, 2001; Rodrigues, 2006).

During flooding, more terrestrial and riverside habitats are lost. Once the dam is completed and the reservoir begins to fill, animals in the flood zone either escape to higher ground, are rescued, or perish. In most cases, it is unknown how many animals die as a result of reservoir flooding events (Rodrigues, 2006). Animals that survive and move into or are translocated to new habitats face challenges associated with unfamiliarity of surroundings, increased population densities, and competition for limited resources (Rodrigues, 2006). Rescue operations that sometimes take place are controversial for several reasons, but can also form the basis of important empirical studies (Schneider, 2001).

After flooding, when the total amount of habitat loss is realized and populations that may have temporarily faced high densities decline and return to pre-dam sizes, further impacts continue to occur (Benchimol & Peres, 2015a,b; Gibson *et al*., 2013). Most of the lasting effects on the primate populations are due to habitat fragmentation. Whether caused by roads, new human settlements, or islands created within the flood zones themselves, habitat fragmentation can impact primate behavior, ranging patterns, diet, population densities and ultimately their ability to successfully reproduce.

The following sections will focus in on some of the most significant impacts of damming on primate populations including drowning, habitat loss, the influx of human populations, rescue operations, movement into adjacent habitats, and habitat fragmentation [Figure 1].

Drowning

Once a dam is built and the reservoir begins to fill, animals in the flood zone meet one of three fates: flee to higher ground, be rescued, or drown. The likelihood of survival is apt to be directly impacted by the depth of the reservoir, the speed at which it is filled, and the amount of prior vegetation clearing, especially for primates and other animals that can move across shallow bodies of water from tree to emergent tree. Whereas the sites of some reservoirs, such as the one at Na Hang, Vietnam have significant topographic relief (Lang, 2002), others like Balbina (Cabral, Mattos, & Rosas, 2008) and Samuel (de Sá, 2004; Fearnside, 2005) dams in Brazil are very shallow. Because the trees at the latter two sites did not fully submerge, the chance of surviving inundation would likely have been higher because primates had the ability to disperse into adjacent habitat (Granjon *et al*., 1996).

In most cases, the loss of wildlife due to being trapped in a reservoir flood zone is unknown. The eerie sight of trees poking out of flooded reservoirs is common (Terborgh *et al*., 1997); as are haunting stories of mammalian skeletons being found clinging to the tree-tops during the first dry season after flooding (Luis Balbás, 1996, personal communication to AHL). Kingston (1986) suspected that a significant portion of the estimated 100,000 primates that were stranded in the Tucuruí flood zone in Brazil either drowned or starved to death on emergent trees. During rescue operations after flooding at Chiew Larn Dam in Thailand, 40 primates were found dead [152 were rescued alive] (Nakhasathien, 1989). Most of the primate deaths at Cheiw Larn were the result of starvation and drowning. Although the drowning is a heart-wrenching negative impact of damming, it may not be the most significant in the long term.

Habitat Loss

Authors agree that, in most cases, habitat loss is the most important negative impact of dam construction and reservoir inundation on primates (Alho, 2011; de Sá, 2004; Enari & Sakamaki-Enari, 2014; Gribel, 1993; Liao, Bhargava & Das, 1988; Vié, 1999). The amount of habitat remaining after flooding largely depends on the topography of the region [Figure 2]. Areas with significant topographic relief end up with small, deep lakes (Na Hang: Lang, 2002). Flood zones with intermediate topography result in hundreds or thousands of land-bridge islands dotted throughout the reservoir (Tucuruí: Bastos *et al.*, 2010; Guri: Terborgh *et al.*, 1997) and the outcome of inundation in the flattest regions is a flooded contiguous forest (Balbina: Fearnside, 1989; Samuel: de Sá, 2004 and Fearnside, 2005). Even the partially submerged forests at Samuel, with protruding green treetops, however, died within a few years after flooding (de Sá, 2004). While many riparian forest trees annually tolerate up to 10 months inundation and can even withstand two to three years of consecutive flooding, longer than this will kill them (dos Santos Junior *et al.*, 2013; Ferreira *et al*., 2013).

While the area inundated is an important contributor to total habitat lost, it is not the only factor. Nearby habitats are often cleared near the dam site to build lodging for construction workers. Land is also cleared to meet the housing and agricultural needs of local people displaced by the reservoir but the additional habitat loss from these re-settlement activities is rarely estimated or included in EIA's (Moore, Dore & Gyawali, 2010; Tan & Yao, 2006). However, at Balbina Dam approximately 311km^2 of an indigenous peoples' reserve was in the flood zone, forcing one third of the surviving members of the tribe to relocate (Fearnside, 1989).

Influx of Human Populations

For some primate populations, impacts related to habitat loss and drowning are less important than those resulting from the large increase in human populations. In addition to resettled human populations and the influx of construction workers, roads are built to provide access to the dam site. These roads provide humans an entrée into regions that may have previously been quite remote (Boyle, 2008; WCD, 2000). One major consequence of access roads is increased traffic. An average of 360 trucks passed through Na Hang each day during the peak of dam construction in early 2003 (Martin, 2004) [Figure 3]. Inside those trucks are people who are likely to cause increases in both legal and illegal trade in wildlife and other forest products (Martin, 2004; Thach Mai Hoang, 2010; Wolters, 2004). Construction and large truck traffic also increase dust and silt in the atmosphere and affect the amount of silica layered on leaves which, in turn, may contribute to dental abrasion and primate mortality (Covert *et al.*, 2008).

The number of workers required for dam construction varies widely from site to site, but laborers typically number in the thousands at peak construction times. An estimated 7,000 laborers immigrated into Na Hang, Vietnam, during dam construction – more than doubling the size of the local human population (Martin, 2004). Years after a dam is completed, many construction villages become permanent towns with ever-increasing human populations.

With these new pockets of human population it is not unusual to see increased hunting and extraction of timber and non-timber forest products. Both are thought to have led to substantial impacts on wildlife, including primates (Boyle, 2008; Kingston, 1986; WCD, 2000). At Na Hang Dam, for example, hunting is thought to have been a significant contributing factor in the abrupt decline of the already critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) (Covert, Le Khac Quyet & Wright, 2008; Martin, 2004). There were 130 monkeys living at Na Hang before construction. In fact, this relatively large population was suspected to be the best hope for conservation of the species (Mittermeier *et al*., 2009). However, surveys conducted just 13 years after dam construction estimate that only 40 monkeys remain at Na Hang (Thac Mai Hoang, 2010). Because the global population of *R. avunculus* was approximately 300 individuals in 2006 (Mittermeier *et al*., 2009), a loss of an approximately 90 individuals at Na Hang is devastating. An EIA conducted in Vietnam prior to the construction of the Na Hang Dam predicted this severe population decline (Scott Wilson Asia Pacific Ltd. [SWAPL], 2000), but as the dam was built, few of the recommended mitigation measures were implemented.

While there is no direct evidence documenting dam-related hunting at Na Hang, such evidence does exist elsewhere. Forty primates were found dead during rescues at the Chiew Larn Dam in Thailand. Several had bullet wounds that were thought to have been the cause of death (Nakhasathien, 1989) – a clear demonstration that hunting was occurring during inundation.

Rescue Operations

At some dam sites, wildlife rescue operations are undertaken before, during and/or after flooding. The number of primates involved varies from hundreds to tens of thousands but for the most part, rescues are poorly documented (Fournier-Chambrillon *et al*., 2000; Schneider, 2001). Five operations in the Southeast Asian and South American tropics kept careful records of the number of primates rescued: 152 were rescued alive at Chiew Larn in Thailand (Nakhasathien, 1989), 225 at Petit Saut in French Guiana (de Thoisy *et al*., 2001), 528 at Afobaka in Suriname, (Walsh, 1967), 1,352 at Samuel in Brazil (Fearnside, 2005), and 27,007 at Tucuruí in Brazil (Mascarenhas & Puorto, 1988; Peres & Johns, 1991). Most often, primates and other animals were captured and within hours released to adjacent habitat. At Afobaka (Suriname), for example, the goal was to maintain animals in captivity long enough to restore activity levels before releasing them into nearby forest (Walsh, 1967). However, at Samuel in Brazil, primates were sent to a nearby reserve (de Sa, 2004), and some primates rescued from Brazil's Balbina reservoir were transferred to captive colonies (Fearnside, 1989).

It is tempting to think of these rescues as success stories, but because little was known about population densities in areas that were flooded or pre-existing primate densities at most release sites, it is unknown what proportion of these individuals actually survived in the long term (de Sá, 2004; Peres & Johns, 1991). Based on estimates of primate population densities before inundation, what is known – at least at Tucuruí – is that larger-bodied primates (such as *Alouatta*, *Cebus* and *Sapajus*) were more likely to be recovered than smaller ones (such as *Mico*, *Saguinis* and *Saimiri*), while cryptic species (such as *Aotus*) were almost never rescued (Peres & Johns, 1991). At Afobaka, 94% of monkeys rescued were howlers and although eight species inhabit the surrounding forests, only four (howlers, squirrel monkeys, tamarins and white-faced capuchins) were among those rescued. It is unclear why no sakis, brown capuchins or spider monkeys were rescued (Walsh, 1967).

Still, rescue operations allow researchers to collect and test biological samples, conduct health evaluations, and place tracking devices on primates (de Thoisy *et al*., 2001; Peres & Johns, 1991). They have therefore formed the basis of some interesting scientific studies. Perhaps one of the best-studied dam sites with respect to its impact on primates is the Petit Saut Dam in French Guiana. A total of 124 howlers (*Alouatta*), six sakis (*Pithecia*), and 95 tamarins

(*Saguinus*) were rescued and each received health evaluations. All primates captured at Petit Saut during flooding were found to be in good condition. The rescue operation continued post-flooding, however, and one year after flooding began, eleven rescued howlers showed signs of severe nutritional stress (de Thoisy *et al*., 2001).

Some prior rescue operations, such as the one undertaken at Tucuruí, are thought to have been linked more to public relations than wildlife conservation (Alho, 2011; Fearnside, 2001). It is pleasing to hear that a rescue operation is saving hundreds or thousands of animals, but if not sent to a captive rescue center (Kingston, 1986), and not subject to a follow-up field study, then the fate of relocated animals remains unknown (Rodrigues, 2006), and many suspect that most released primates ultimately perish. Some animals likely die due to unfamiliarity of the habitat or competition with conspecifics already inhabiting release sites (Alho, 2011; de Sá, 2004; Griffith *et al*., 1989; Kingston, 1986). At Tucuruí, reserves created as release sites were immediately invaded by loggers and hunters (Fearnside, 2001). In addition, increase in local population densities may increase disease transmission (IUCN, 1987**;** Woodford & Rossiter, 1993; Magnusson, 1995). However, if rescues and releases are carefully planned, they can contribute significantly to our understanding of the impact of damming on primate populations (de Sá, 2004; de Thoisy, *et al*., 2001; Peres & Johns, 1991).

Moving Into Adjacent Habitat

Regardless of whether primates move into new habitat as a result of land clearing, construction noise (Martin, 2004), increased hunting pressure due to the presence of new access roads (Alho, 2011; Martin, 2004), flooding (Alvarez, 1986; de Sá, 2004), or they are rescued and translocated, primates face myriad challenges. They may encounter overcrowded habitats and competition with conspecifics or they may be at a disadvantage due to habitat unfamiliarity (Fischer & Lindenmayer, 2000; Schneider, 2001; Rodriques 2006).

When a primate is not familiar with its surroundings, it may have difficulty finding food, water, shelter, and mates, and it may be at a higher risk of disease and predation. Research from an island in Venezuela's Guri Reservoir suggests that primates rely heavily on memory to find resources (Cunningham & Janson, 2007). At Chiew Larn (Nakhasathien, 1989), Petit Saut (de Thoisy, *et al*., 2001) and Balbina [Figure 4] primates were found malnourished, injured, infected with parasites, and otherwise stressed during post-inundation rescue operations, much of which is hypothesized to have been a consequence of habitat unfamiliarity.

Primate mortality due to habitat loss, overcrowding and habitat unfamiliarity were thought to have been more significant than drowning at the Samuel Dam (de Sá, 2004). In 2004, de Sá found that *Callicebus*, *Pithecia* and *Samiri* species were among the most frequently captured during rescue operations at the Samuel Dam in Brazil. A temporary increase in population density for these three primates was observed in adjacent habitat just after release, but populations decreased in subsequent years, probably due to dispersion or mortality. However, at Santo Antonio Dam in Brazil, telemetry tracking indicated that only 7% of translocated pygmy marmosets (*Cebuella pygmaea*) three months post-release (Dias *et al*., 2015).

Tracking rescued, released primates has become more common in recent years. While most published post-release studies are short-term (and considering many dam-linked projects are consultancies; therefore, biologists may not be given permission to disseminate outcomes when translocations fail) some promising results have been published. Although a 1997 study linked to Brazil's Novo Ponte Dam attempted to radio-track 15 translocated *Callicebus personatus*, authors were unable to follow the animals due to technical difficulties (Neri *et al*., 1997). Since that time, however, several teams have successfully followed primates post-translocation. For example, in Belize, a group of translocated Central American black howlers (*Alouatta pigra)* survived at least one year and established territory (Ostro *et al.*, 2000). Marques *et al*. (2011) used radio-telemetry to follow black-tailed marmosets (*Mico melanura*) translocated as part of a study of wildlife affected by flooding the Manso River reservoir in western Brazil. Of the five animals monitored, two pairs survived at least 8 months, successfully established territories, and appeared healthy. And in northern Brazil, during the formation of the reservoir on the Madeira River created by the Santo Antônio Hydroelectric Dam, two groups of pygmy marmoset (*Cebuella pygmaea*) were translocated into near-by protected, open tropical rainforest. A three-month post-release monitoring study with radio-telemetry found group members remained together and settled in stable home ranges near their release sites (Dias *et al*., 2015).

Similarly, some of the primates rescued at Petit Saut were fitted with telemetry devices. Six sakis and 14 howlers were tracked for an average of about one year after translocation (Richard-Hansen *et al*., 2000; Vié, Richard-Hansen & Fournier-Chambrillon, 2001). Sakis and howlers established home ranges within one year and both were also observed integrating with resident groups. Mortality rates were difficult to discern because telemetry collars contributed to individual deaths (mainly due to screw worm larvae infections). However, Vié and colleagues (2001) and Richard-Hansen *et al*. (2000) indicated that sakis and howlers may both benefit from future, well-planned translocation efforts. So although forced movement into new habitat may ultimately lead to primate deaths, this evidence supports the idea that translocations can serve to rescue a large number of primates, as long as translocations are well-planned (Konstant & Mittermeier, 1982; Fischer & Lindenmayer, 2000).

None of the studies listed above were of sufficient duration to establish if the translocations had long-term success. However, some translocated animals do appear to survive and reproduce. Oklander *et al.* (in press) found that populations of southern black howlers (*Alouatta caraya*) showed strong regional genetic structuring across the Argentinian and Paraguayan part of their range. An exception to the pattern was the population in the Chaco National Park, which contained genetic elements from a population 380 km away from the Yaciretá Dam. During dam construction here, many primates were removed from areas to be inundated and transported to other sites, including the park. Similar evidence for regional differences in genetic variability around the Tucuruí Dam will be discussed in the following section.

Habitat Fragmentation

Perhaps the most significant long-term impact of dam construction and reservoir inundation on primates is habitat fragmentation. In the case of damming, habitat fragmentation occurs primarily in two ways: 1) the construction of access roads that bisect habitats, and 2) via flooding, which often results in a reservoir strewn with numerous islands. Roads are widespread anthropogenic contributors to habitat fragmentation around the world. Many of the primates studied in the investigations reviewed here appeared to treat roads as barriers and avoided crossing them (Richard-Hansen *et al*., 2000). And the reservoirs themselves – especially those with intermediate topographic relief – may contain hundreds or thousands of islands once flooding is completed. The islands that remain are true fragments, with the unforgiving surrounding matrix of water (Anderson *et al*., 2007). Consequently, fragmentation can lead to several impacts on primate populations including the challenges of swimming from one fragment to another, changes in food availability, demographics, travel patterns, and rates of social interaction, as well as genetic diversity, and ultimately, faunal collapse.

Most monkeys can swim quite well (e.g. Berman, 1977; Anderson, Peignot & Adelbrecht, 1992; Chaves & Stoner 2010; Gonzalez-Socoloske, & Snarr 2010; Peck *et al*., 2014) but swimming also comes with some caveats. Predation of swimming monkeys may be high: during the filling of the Balbina reservoir, Barnett (unpublished data) saw caiman and jaguars take swimming howlers and eagles swoop at animals as they climbed out onto trees. Harrison-Levine, Norconk & Cunningham (2003) reported predator-sensitive behaviors, such as increased vigilance, nervousness and guarding, in sakis drinking at Guri Reservoir's edge when other water sources had gone dry. In addition, dam-promoted inundation generally disrupts phenology even when areas are not directly flooded (as on hilltop islands: Kozlowski 2002; Maingi & Marsh, 2002; Stave *et al.*, 2005; Ferreira *et al.*, 2013), so although most monkeys can swim, the uncertainty of resource availability on the destination island may be just as psychologically and physiologically stressful as the risk of predation.

When a previously contiguous forest is transformed into islands surrounded by water, the sun, the wind and water erosion can impact the islands' edges. This phenomenon, referred to as the edge effect, can in turn influence forest structure and lead to further reduction in utilizable primate habitat (Laurance *et al*., 1998; Ferreira *et al*., 2012). The edge effect has more significant impact on water-surrounded islands than on mainland habitats surrounded by a matrix such as pasture, which can act as a better buffer than water (Anderson *et al*., 2007; Norconk & Grafton, 2003). Edge-related fire damage was an important factor in small islands at Balbina (Benchimol & Peres, 2015a). Changes in primate travel patterns, diet and food availability may result (Cosson *et al*., 1999; Ferreira *et al*., 2012; Norconk, 2007; Norconk & Grafton, 2003).

Fragmented habitats are often completely isolated from one another and this can have an effect on primate behavior and ranging patterns, as well as cause devastating long-term impacts on the genetic and reproductive viability of primate populations. Years after flooding at Tucuruí, Silva and Ferrari (2009) returned to the dam to compare the behavior of island and mainland groups of bearded sakis (*Chiropotes*). They found that island individuals rest more and travel less than those living on the mainland, and island populations also have lower levels of social interaction. These behavior patterns are attributed to comparatively small home range size and small group size (respectively) on islands, both of which were thought to be the result of isolation.

When primate populations are forced to mountaintops as a reservoir floods, groups remaining on each island may exhibit unusual demographic patterns – including single-sex groups that are unable to breed. At the Guri Dam, post-flooding surveys indicated that at least a few islands contained non-breeding populations of white-faced sakis, *Pithecia pithecia* (Norconk, 1997). Other islands had populations with juveniles that may not be able to disperse from their natal group, as is typical for the species. A population that lacks the ability to disperse will likely face some genetic viability ramifications. Indeed, Norconk and Grafton (2003) reported that, over a ten year period, the sakis on one Guri Reservoir island had not had a single surviving infant.

In 2008, Gonçalves and colleagues reported on a study comparing genetic data collected during the rescue operation at Tucuruí with that collected 15 years later. These authors found that while the genetic diversity of mainland howlers had increased, possibly due to the influx of genetic material from translocated or fleeing howlers, the genetic diversity of howlers on at least one Tucuruí reservoir island was lower than that of mainland howlers. This is additional evidence to support post-flooding genetic viability concerns for island populations.

Land-bridge islands, or landscape fragments that have been isolated by rising water levels with an associated reduction in habitat area (Diamond, 1972; Terborgh *et al*., 1997), are thought to experience a sort of ecological meltdown (Terborgh *et al*., 2001). Terborgh and other authors (Benchimol & Venticinque, 2014; Cosson *et al*, 1999; Wu *et al*., 2004) found that while the population density of some primate species decreases or the primates disappear entirely on smaller islands, the density of other species increases. This decreases primate diversity on the islands compared to the mainland (Cosson *et al*, 1999; Terborgh *et al*., 1997). Similarly, at Balbina Dam, Benchimol and Venticinque (2014) determined that 60% of primate biodiversity was retained on islands larger than 100 hectares. In addition to size, structural complexity of land-bridge islands is also closely related to primate biodiversity at Balbina. Interestingly, these authors note that larger primates were more likely to be found on islands than small ones, possibly due to their ability to more easily swim from island to island. It is also observed by many of these authors that – especially in the absence of top predators – species that exhibit more behavioral and dietary flexibility (such as howler monkeys, capuchin monkeys and some marmosets), can persist longer on island fragments. While habitat fragmentation resulting from anthropogenic damming may have an overall negative impact on less flexible, smaller primate species, more flexible, larger primates do not seem to experience the same types of impact.

Conclusion

Dam construction and reservoir inundation have devastating effects on habitats and primate populations. Drowning, habitat loss, increased human populations and associated increases in primate hunting, movement into already-occupied habitats, and habitat fragmentation are among the most significant impacts, but the degree to which each of these affects primate populations varies from site to site. Ultimately it is habitat loss, the influx of large human populations and habitat fragmentation that result in the most significant dam-related impacts on primates.

In addition, while rescue operations may seem to be a humane alternative to drowning or starvation, and could also offer tremendous opportunities for embarking on studies of post-flooding and post-translocation primate populations, they must only be undertaken under specific circumstances. Those conducting rescues should identify well-researched and appropriate release sites that exhibit comparatively low population density of the species to be relocated. Release sites must be shown to have sufficient resources and minimal anthropogenic threats, such as hunting. The rescue operations themselves should be studied, monitored long-term, and both successes and failures reported (papers like that of Neri *et al*., 1997 being rare)

Going forward, primary aims should be to engage governments in not only permitting but requiring empirical studies as essential components of the dam planning process, and to work with funding institutions to hold back loans unless scientifically-based plans to mitigate implications of dam construction are developed and implemented. WCD (2000) considers that the five main limitations to effective implementation of Environmental Impact Assessment (EIA) process are: 1) resistant attitudes, 2) insufficient structural integration of EIA recommendations into policy and decision-making, 3) insufficient scope of EIAs, 4) inadequate procedural assessments, and 5) poor technical quality of EIAs. Therefore, it is also important for researchers to advocate for the incorporation of scientific findings early in ~~the~~ dam planning processes; this information is critical to consider when decisions on dam building are made, as well as during dam site selection and dam design. As a high-profile group that are comparatively easily studied, primates can play a key role in dam-based EIAs. Therefore, scientists should gather pre-construction baseline data on primates so that post-construction and post-inundation comparisons are possible (McCartney, Sullivan & Acreman 2001). Similarly, comparative studies regarding island and mainland populations are also needed. All primate populations affected by dam construction and reservoir inundation should be part of long-term monitoring programs (McAllister *et al*., 2001) that investigate longitudinal impacts on issues such as behavior, ranging patterns, diet, health status, and genetics.

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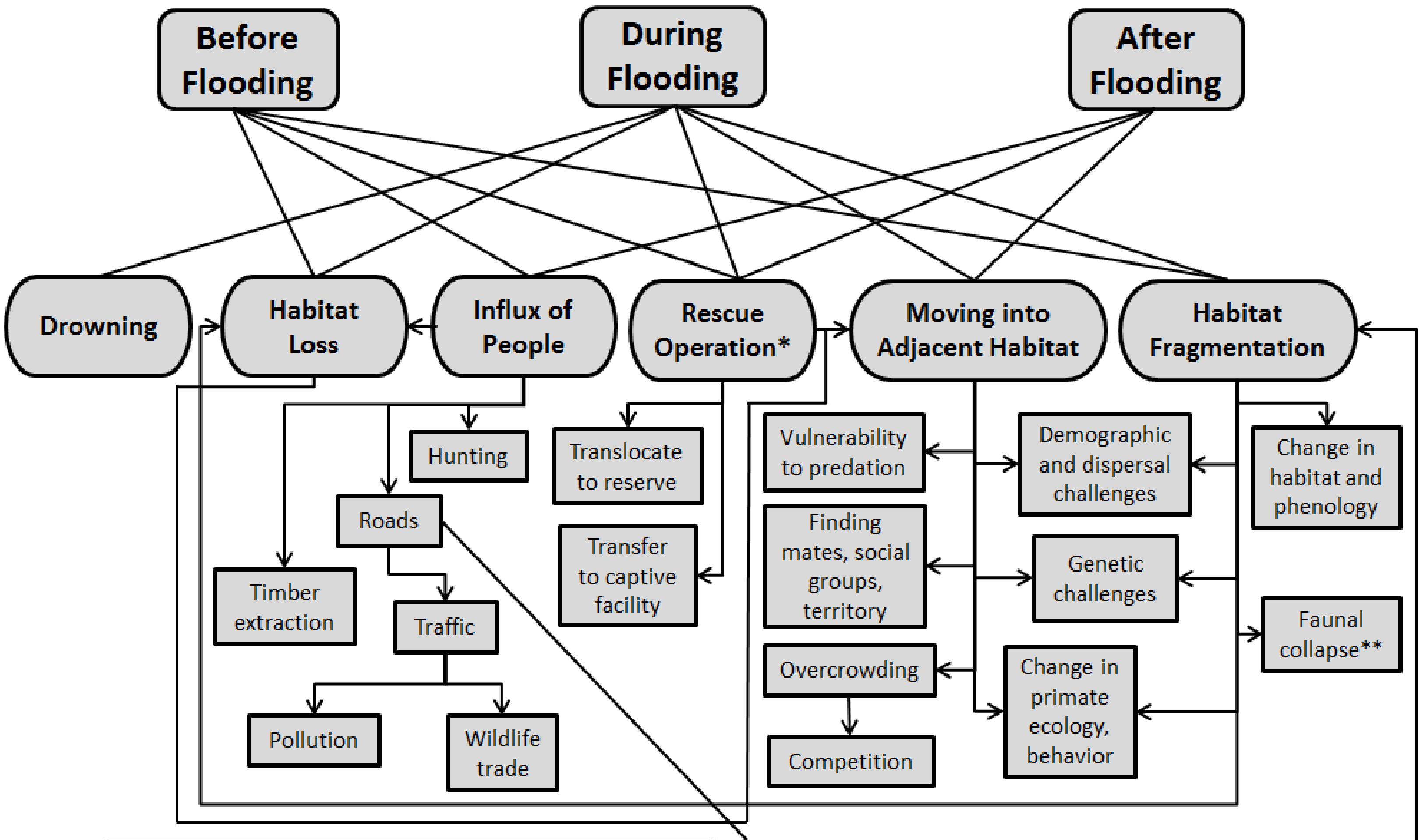
Table 1. Dams, Reservoirs and Rescues

Name of Dam	*Year Reservoir Filled*	*Dam Location*	*Estimated Reservoir Area (km^2)*	*Mean Reservoir Depth (m)*	*Reservoir Volume (km^3)*	*Number of Islands*	*Number of Rescued Primates*	*Rescue Timing*
SOUTH AMERICA								
Afobaka	1964	Suriname	1,683[a]	-	-	-	528 [a]	during flooding [a]
Balbina*	1987	Brazil	2,360[b] 4,437[c] 2,996[e]	7.4[b] 4.8[d]	17.5[c]	1,500[b] 3,299[c]	-	during flooding[b]
Guri	1986	Venezuela	4,240[f]	[<50][g]	135[f]	>100[f]	-	after first phase of flooding[h]
Petit Saut	1995	French Guiana	365[i]	35[i]	-	>200[j]	225[i]	during flooding[i]
Samuel	1988	Brazil	540[d]	8.4[d]	-	-	1,352[k]	during flooding[d]
Tucuruí	1984	Brazil	2,430[l]	20.2[d]	45.5[m]	>1,600[n]	27,007[l]	Before[n] & during[o] flooding
SOUTHEAST ASIA								
Chiew Larn	1986	Thailand	165[p]	-	-	241[p]	152[p]	during flooding[p]
Na Hang	2002	Vietnam	57[q]	-	2.2[r]	-	-	-

[*]Balbina Dam reservoir area estimates and estimated number of islands are highly debated.
[a]Price (2011); [b]Fearnside (1989); [c]Cabral *et al*. (2008); [d]Fearnside (2005); [e]Feitosa *et al*. (2007); [f]Alvarez *et al*. (1986); [g]Terborgh (1997); [h]Konstant & Mittermeier (1982); [i]de Thoisy *et al*. (2001); [j]Cosson *et al*. (1999); [k]Gribel (1993); [l]Fearnside (2001, 2006); [m]Fearnside (2002); [n]Bastos *et al*. (2010); [o]Ferrari *et al*. (2004); [p]Nakhasathien (1989); [q]Lang (2002); [r]Mahabir (2008).

Figure 1. Impacts of Damming on Primate Populations



*Opportunity for empirical research
**Generalists, larger primates persist longer than smaller, specialists

Figure 2. Image of Balbina Dam Reservoir in Brazil (low topographic relief)

Figure 3. Image of Roads and Construction at Na Hang Dam, Vietnam (note the silt in the air)

Figure 4. Image of Bot-Fly Infested, Deceased Howler Monkey (*Alouatta belzebul*) at Tucuruí Dam