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Irrigation demands aggravate fishing threats to river dolphins in Nepal

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ABSTRACT

Riverine species are adapted to natural habitat changes caused by seasonal flood-pulses. However, abrupt river channel changes following flooding events intersect with social systems of land and water management (e.g. agriculture, fisheries) and in turn generate significant consequences for conservation of endangered aquatic species. We investigated tradeoffs between changing river habitat availability and exposure to fishing intensity for a small population of Ganges River dolphins *Platanista gangetica gangetica* in the Karnali basin of Nepal. A major natural flooding event in the Karnali basin in 2010 caused the river channel to shift from the Geruwa (flows through a protected area where fishing is restricted) to the Karnali channel (high fishing activity, agriculture-dominated), where dolphins moved in response. Based on our survey data (2009–2015) and long-term hydrological trends in the basin, we found that irrigation diversions since 2012 had aggravated fishing impacts on dolphins, suggesting that their new habitat had become an 'ecological trap'. Regression models showed that at low river depths, fishing intensity negatively affected dolphin abundance, but at higher depths no effect of fishing was observed. Two records of dolphin bycatch in gillnets confirmed this, as both events corresponded with periods of sudden increase in water abstraction for irrigation. Overall, dolphin distribution shifted downstream and the population declined from 11 in 2012 to 6 in 2015. Effective protection of this river dolphin population from extinction will require the Government of Nepal to prioritize ecologically adequate river flow regimes for implementing efficient irrigation schemes and adaptive fisheries regulations in the Karnali basin.

1. Introduction

Conserving freshwater animal populations is a complex challenge, given their specific ecological requirements, and the high human dependence on river and wetland ecosystems (Arthington et al., 2010; Dudgeon et al., 2006; Dudgeon, 2000). Floodplain river systems are highly dynamic and channel changes are a common feature due to seasonal flooding, precipitation, sediment deposition-erosion processes, and human alterations (Bookhagen and Burbank, 2010; Hofer and Messerli, 2006; Ward, 1998; Junk et al., 1989). Such changes provide new habitats to freshwater species that are evolutionarily adapted to hydrological cues for breeding, migration, and seasonal movements (Dudgeon et al., 2006; Lytle and Poff, 2004; Robinson et al., 2002). Owing to severe human modifications of river flow regimes (Poff and Matthews, 2013; Döll and Zhang, 2010) river channel changes can also influence the exposure of aquatic species to various anthropogenic risks (Dudgeon, 2000). In dynamic floodplain rivers, habitat conditions constantly change and intersect social systems of intensive land and water management (e.g. protected areas, forests, irrigated agriculture, etc.). As a result, freshwater species responding to habitat changes based on environmental cues might face risks that can threaten their survival and conservation in human-dominated environments (Arthington et al., 2010; Robinson et al., 2002; Ward, 1998).

The South Asian River dolphin, *Platanista gangetica*, is an endangered freshwater cetacean species that lives in the highly human-dominated Indus-Ganga-Brahmaputra basin in the Indian subcontinent. The dolphin is threatened throughout its range by declining river water availability and threats from hunting, fisheries by-catch, river pollution, etc. (Sinha and Kannan, 2014; Braulik et al., 2014; Smith and Braulik, 2012; Turvey et al., 2012). For the Gangetic subspecies, *Platanista g. gangetica*, poor dry-season flows and altered flow regimes by dams and barrages threaten their survival in upstream areas of distribution

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(Choudhary et al., 2012; Khatri et al., 2010). Riverine fisheries also result in multiple threats to dolphins, especially through accidental entanglement in gillnets (bycatch) and occasional targeted killing for use as fishing bait (Sinha and Kannan, 2014; Smith and Braulik, 2012; Bashir et al., 2012; Mansur et al., 2008). In general, fishing threats have received greater attention in conservation planning, and are typically addressed in isolation from declining flow regimes (Kelkar and Krishnaswamy, 2014). Especially for isolated small populations of Ganges river dolphins as in Nepal, a combined understanding of the multi-scale interactions between river water availability and fishing impacts is urgently required (Smith and Reeves, 2012).

The Karnali River (which is not yet dammed in Nepal) harbors a small Ganges River dolphin population in Nepal. Rivers are not well represented in Nepal's protected area network (Shrestha et al., 2010) and water availability has been strongly constrained by competing demands for irrigation, hydropower, etc. (Pradhan, 2012; Gumma et al., 2011; Smakhtin et al., 2006). These factors contribute to the significant extinction risk to river dolphins both from various anthropogenic impacts (Paudel et al., 2015a; Smith et al., 1994; Shrestha, 1989). Smith (1993), Smith et al. (1994), and Paudel et al. (2015a, 2015b) estimated 7–9 dolphins to be surviving in the Karnali River. In the plains of Nepal the Karnali bifurcates into two channels, the Karnali or Kaudiyala and Geruwa. For nomenclatural consistency we use the name Karnali for the former channel and Geruwa for the latter, following Paudel et al. (2015a). A major flooding event in 2010 led to the active channel to shift from the Geruwa (which flows through the Bardiya National Park, where fishing is restricted) to the Karnali (high levels of fishing and dominated by agriculture). Following this natural change, dolphins moved from the Geruwa to the now-deeper reaches of the Karnali channel. Further, intensive diversions of water and modernization of community-based irrigation projects began in 2012 and are ongoing, after the construction of the Chisapani irrigation intake (see Section 2.1, study area, for details). This led to continued declines in river depth in both channels till 2015, in which time fishing intensity increased. Thus, the depth cue tracked by river dolphins appears to have forced them into a deeper but more risky habitat (Karnali channel) from a relatively safer but shallow habitat (Geruwa, with better protection from fishing).

This ecological setting offered a great opportunity to assess dolphin responses to natural river dynamics and associated changes in habitat availability and fisheries, which we investigate in this paper. For this we use the conceptual framework of 'ecological traps' (Schlaepfer et al., 2002), that refers to circumstances wherein species first choose habitats based on evolutionarily determined responses to cues associated with habitat quality (e.g. water depth), but land up in risky situations (e.g. pollution) that might impair their survival and persistence in the novel sink habitat. Human activities often increase the mismatch between environmental cues and the evolutionary associations of animals with them such that animals are unable to correctly assess the availability of resources that can affect their fitness (Robertson et al., 2013). This idea emerged from evolutionary biology, but was soon expanded to include anthropogenic threats as proximate impacts on species' population persistence (Kristan, 2003; Schlaepfer et al., 2002). In abruptly and rapidly changing environments such as river floodplains, this concept proves useful for a better understanding of factors that create trap-like situations. This is of significance for adaptive conservation strategies (Battin, 2004) to protect endangered populations of aquatic species.

To answer the question: 'how might hydrological change and declines in river flows affect responses of dolphins to fishing pressure?' we conducted detailed analyses of river dolphin abundance and distribution in relation to changing river depth and fisheries intensity in the Karnali River. For this we analyzed river dolphin population size and distribution in the Geruwa channel (where dolphins were present in 2009) and the Karnali channel (to where dolphins shifted, and surveyed from 2012 to 2015). Fishing intensity was recorded during these time periods by compiling detailed information on the numbers and types of gears, nets and boats used. We tested whether the impacts of higher fishing pressure (e.g. bycatch risk) on river dolphins in the Karnali channel were offset by the availability of greater river depths. We contrast this with river dolphin responses to river depth and fishing intensity (fairly restricted) in the Geruwa channel before the channel shift. Finally, by integrating field survey data and long-term hydrological trends, we discuss scenarios for adaptive water allocations towards ecological flows for dolphin conservation vis-a-vis management of irrigation demand and fisheries regulations.

2. Methods

2.1. Study area

The Karnali is a perennial river that originates from the Tibetan Plateau, flows through the western part of Nepal and drains into the Ghaghara river in India, a tributary of the Ganga (Fig. 1). The eastern channel is called Geruwa (28.60°N, 81.26°E to 28.36°N 81.19° E) and the western channel the Karnali (28.64°N, 81.28° E to 28.41°N, 81.02°E), which bifurcate about 1.5 km downstream of the Chisapani Bridge (Fig. 1). This point forms the natural upstream limit for Ganges River dolphins, as upper reaches have rocky rapids and currents that dolphins avoid (Paudel et al., 2015b; Shrestha, 1989). The Karnali channel enters India at Chaugurjighat (Nepal-India border) and the Geruwa enters India at Kothiaghat, after which these channels meet upstream of the Ghaghra Barrage in India.

Of the eastern arm called the Geruwa (35 km), 25 km flows through the Bardiya National Park (BNP) boundary, where fishing is largely restricted. The remaining 10 km are outside the jurisdiction of the park authority, and subject to multiple human uses, including fisheries. Prior to 2010, the park authorities had provided fishing licenses to traditional fishermen, which allowed them to fish both within and outside the protected river stretch of the Geruwa, with strict restrictions on use of gillnet mesh size enforced by the Department of National Parks and Wildlife Conservation (DNPWC) of Nepal. This kept fishing activity in reasonable check until 2009 at much lower intensities than in 1990, as reported by Smith (1993). However, in 2010 (independent of the flood event), fishing licenses were terminated by DNPWC because a few fishermen were found to be involved in poaching of rhinoceros in the park, and hence fishing restricted to near-complete levels. After 2010, as depth reduced in the Geruwa channel outside the National Park, fishers shifted their activity to the Karnali channel, just as dolphins did after the flooding event. In contrast, the western channel of the Karnali River (Karnali channel, 46 km) flows along the boundary of the Bardiya and Kailali districts, through an irrigated agriculture landscape without any state-declared protected areas.

In the interfluve region of the Karnali and Geruwa channels, the fertile agricultural land is heavily populated with a density of 211 persons/km^2 (<90,000 people; CBS Nepal, 2012). The average annual rainfall in the area is about 1450 mm and average annual discharge is approx.510 m^3/s (Gautam and Regmi, 2013; WECS, 2003; Upreti, 1993). Community-managed irrigation channel diversions account for a dominant proportion of river water withdrawal, especially the Chisapani irrigation intake (part of the Rani Jamara Kulariya Irrigation Project (RJKIP) constructed in 2012, at 100 m downstream of the Chisapani Bridge). A recent study by Paudel et al. (2015a) states that the river flow shifted from Geruwa to Karnali channel following the construction of the Chisapani intake. However, they appear to have missed the information, that the river course had shifted in the major flood of July–August 2010, nearly two years before the construction of the Chisapani intake, which started in 2012 (Stoutjesdijk, 2015). Hence it was the major natural flooding event in 2010 that led to the westward shift in the active flowing stream to move from the Geruwa to the Karnali channel (Table 1). Prior to 2010, the Geruwa had higher discharge and depth than the Karnali, and now it is the opposite