SUSTAINABLE FLOODPLAINS: LINKING E-FLOWS TO FLOODPLAIN MANAGEMENT, ECOSYSTEMS AND LIVELIHOODS. SUSTAINABILITY

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ABSTRACT

SUPPLEMENRTY INFORMATION

Supplementary Table S1: Justification tables for the application of the Bayesian Netwworks as a part of the PROBFLO case study for the Upper Niger River and Inner Niger Delta. These data include all of the socio-ecological system variables or nodes (node names) selected for the models, network variable titles, ranks and associated modelling scores, rank definition and measures for variables and justification for the use of the variables and evidence to describe their use in the risk assessment with references for the evidence used.

Bayesian Network variable title, measure - (BN node name)	Rank (score)	Rank definition and measure for variable	Justification	References
Birds_Mudf_Sed	Zero (25)	Sediment profile is well mixed and ideal to maintain invertebrate and algal food sources for wading birds in the IND.	The IND attracts high diversities and abundances of wading birds that use the IND as a migration stop over and non-breeding area (winter area). A large part of the populations of wading birds are dependent on the availability of benthic invertebrate and algal food within the delta which is largely driven by sediment profile characteristics. For this node the sediment characteristics of invertebrate and algae preferred by wading birds (Glossy Ibis, Ruff, Black-tailed godwit, and other limicoles) have been selected as the indicator. These sediments include well mixed sediments with a larger diversity of fine and mud grain size distributions. The sediment characteristic are influenced by flows and the associated sediment transport into and through the IND. Sheer stress velocities associated with water flows into the IND have been selected as the measure for sediment characteristics in the delta. The measurement in discharge (m3/s) which is linked to the velocities in each RR in the delta via a calibrated hydrodynamic model for the delta that models velocities within the RRs.	Zwarts, Diallo, Maiga, van der Kamp 1999, Van der Kamp, Diallo & Zwarts 2002; Zwarts, Bijlsma, van der Kamp & Wymenga 2009
	Low (50)	Sediment profile is poorly mixed but dominated by fines and mud which is suitable for invertebrate and algal food sources for wading birds in the IND.		
	Moderate (75)	Sediment profile is poorly mixed but dominated by fine and course sand which is poorly suited for invertebrate and algal food sources for wading birds in the IND.		
	High (100)	Sediment profile is sorted and dominated by course sediments that are not suitable for invertebrate and algal food sources for wading birds in the IND.		
Birds_Mudf_Dep	Zero (25)	Ideal depth for wading birds dominates (>50%) RR	The IND attracts high diversities and abundances of wading birds that use the IND as a migration stop over and non-breeding area (winter area). A large part of the populations of wading birds are dependent on the availability of benthic invertebrate within the delta. Water depth, as measure for flood duration, is an important driver for the abundance of bivalves suitable	Zwarts, Diallo, Maiga, van der Kamp 1999, Van der Kamp, Diallo & Zwarts 2002; Zwarts, Bijlsma, van der Kamp & Wymenga 2009
	Low (50)	Ideal depth for wading birds common (10-50%) in RR		
	Moderate (75)	Ideal depth for wading birds uncommon (0-10%) in RR		

	High (100)	Depth preference for wading birds not available in RR	for wading birds. *Corbicula* (also a major prey for fish *Tilapia*) is found only on floodplains covered by water for 6 months, with highest densities on plains covered for 8-9 months. This corresponds roughly with a water depth of 4-5 m. Another important driver is the timing of exposure of the mudflats, depending on maximum flood height (and thus flood duration and water depth). The crucial migration window for migratory birds is from Feb. 1th to 15th of March, when they gain weight to start pre-breeding migration. The lower floodplains should not be exposed before April 1.	
Fish_DTW	Zero (25)	Few people and no aliens.	Disturbances to wildlife include human and alien invasives activity. The extent and intensity of both people and alien species pose a threat to local fisheries. The Inner Delta currently has no invasive fish species, however the potential threat is there. Currently Water hyacinth occurs in the systems and clogs up waterways. This node makes use of the occurrence of people and the type of alien fish (abundances of communities) within the Inner Niger Delta to provide a measure to the disturbance to wildlife. Indicator = Extent and intensity of people and or aliens. Measure = occurrence and type of alien fish and abundance of communities.	Bamba and Samassekou 2004; Zwarts and Diallo 2005; Thieme et al. 2005; Joffre and Laaunie 2008; Smith et al. 2009
	Low (50)	People and no aliens.		
	Moderate (75)	Lots of people and habitat modifying alien spp alone.		
	High (100)	Excessively high abundance of people and many aliens incl. habitat and predatory spp.		
FPFish_Potential	Zero (25)	Habitat naturally not suitable for floodplain spp. No slow flow habitats available.	Indicator - natural potential of ecosystem to maintain ind. Spp. Measure = Habitat availability for ind. Spp.	
	Low (50)	Habitat naturally partially suitable for floodplain spp, dominated by slow habitats.		
	Moderate (75)	Habitat naturally moderately suitable for floodplain spp, dominated by slow habitats.		
	High (100)	Habitat naturally ideal for floodplain spp, dominated by slow habitats.		
FPFish_QFPConnect	Zero (25)	No alteration to discharge required to maintain floodplain connectivity	Approximately 29 species of fish within the IND undertake lateral migrations, particularly juveniles. The main driver of lateral extent as well as species diversity of migrating species, is discharge. *Bagrus* species were selected as the indicator considering their relative contribution to lateral migrator abundance. In addition,	Benech et al 1994, Niare & Benech 1998, Meulenbroek 2013
	Low (50)	Minimal alteration to discharge required to maintain floodplain connectivity		
	Moderate (75)	Moderate alteration to discharge required to maintain floodplain connectivity		

	High (100)	Extreme alteration to discharge required to maintain floodplain connectivity	habitat preferences have been recorded for *Bagrus baja*.	
FPFish_QHabDepth	Zero (25)	No alteration to water column depth required for indicator floodplain species	Bagrus species were selected as the indicator species based on available knowledge. The hydrological model will be used as a measure for depth habitats	Benech et al 1994, Tiare & Benech 1998, Meulenbroek 2012
	Low (50)	Minimal alteration to water column depth required for indicator floodplain species		
	Moderate (75)	Moderate alteration to water column depth required for indicator floodplain species		
	High (100)	Extreme loss or absence of water column depth required for indicator floodplain species		
RFish_Barrier	Zero (25)	no barriers (ranked 4)	Impoundments within a river system can restrict the movement of river fish, which will negatively affect the population's well-being. These impoundments can reduce movements in low flows through the use of small weirs, or large impoundments all year round. Rheophilic species known to frequent fast flowing water can often make it over these barriers if the correct structures are in place to assist them. In this node the intensity and extent of these barriers are used to determine the health of the riverine fish species.	Daget 1959; Quenserie 1994; Smith et al 2009; Agostinho et al. 2008
	Low (50)	impoundments with well-designed fish passages (ranked 3)		
	Moderate (75)	impoundments with poorly designed fish passage (ranked 2)		
	High (100)	impoundments with no fish passage (ranked 1)		
RFish_Food	Zero (25)	See FPInvert_Env_Suit		
	Low (50)			
	Moderate (75)			
	High (100)			
RFish_potential	Zero (25)	River naturally has no fast, deep habitats with rocky substrates, preferred by Rheophillics. Such as floodplain.	The river systems upstream of the IND floodplain naturally has fast deep habitats with rocky substrates. This node makes use of the habitat availability of indicator fish species dependent on theses habitat types, *Hydrocynus* spp. *Gobiocichla wonderi*, *Brycinus caroline*.	Daget 1959; Quenserie 1994; Smith et al 2009
	Low (50)	River naturally has limited fast, deep habitats with rocky substrates, preferred by Rheophillics		
	Moderate (75)	River naturally contains fast, deep habitats with rocky substrates, preferred by Rheophillics		

	High (100)	River naturally dominated by fast, deep habitats with rocky substrates, preferred by Rheophillics		
RFish_QDepth	Zero (25)	No alteration to water column depth required for migrating rheophilic species	Many indicator fishes that occur in the river sections of the upper Niger River (Including the Bani River) are specialist rheophilic species that require instream habitats characterised by fast (>0.3m3/s), deep (>0.3 m) instream habitats associated with hard rocky substrates. Some of these species are migratory and require sufficient water column depth in order to do so. This node represents depth requirements of the indicator taxa. Labeo species were selected as the indicator species.	This study, Schiemer et al., 1989; Muhar and Jungwirth 1998; Bunn and Arthington, 2002; O'Brien et al., 2017, http://www.fishbase.org /summary/2436
	Low (50)	Minimal alteration to water column depth required for migrating rheophilic species		
	Moderate (75)	Moderate loss of water column depth for migrating rheophilic species		
	High (100)	Extreme loss or absence of water column depth required for migrating rheophilic species		
RFish_QSubMobility	Zero (25)	See SubF_Qsedmov		
	Low (50)			
	Moderate (75)			
	High (100)			
RFish_QVDHabitat	Zero (25)	Velocity-depth habitat requirements/preferences of rheophilic indicator fish species dominates river reaches.	Many indicator fishes that occur in the river sections of the upper Niger River (Including the Bani River) are specialist rheophilic species that require instream habitats characterised by fast (>0.3m3/s), deep (>0.3 m) instream habitats associated with hard rocky substrates. This node represents the suitability of instream riverine habitats for these specialist fishes where the average velocity and depth (VD) of habitats have been evaluated using habitat preference information from these rheophilic fishes and similar species. The VD preferences of the Amphillius spp., Chiloglanis spp., Labeo spp. and Labeobarbus spp. were used in the assessment. Hydraulic data is available to represent the instream VD profiles for each reach of river based on discharge (m3/s) which has been selected as the measure for this variable.	This study, Schiemer et al., 1989; Muhar and Jungwirth 1998; Bunn and Arthington, 2002; O'Brien et al., 2017; LHDA 2016;
	Low (50)	Velocity-depth habitat requirements/preferences of rheophilic indicator fish species available at river reaches.		
	Moderate (75)	Velocity-depth habitat requirements/preferences of rheophilic indicator fish species limited in river reaches.		
	High (100)	Velocity-depth habitat requirements/preferences of rheophilic indicator fish species unavailable.		
RFish_WQ	See invert_WQ_SUIT			

SubF_DTW	Zero (25)	Few people and no aliens.	Disturbances to wildlife include human and alien invasives activity. The extent and intensity of both people and alien species pose a threat to local fisheries. The Inner Delta currently has no invasive fish species, however the potential threat is there. Currently Water hyacinth occurs in the systems and clogs up waterways. This node makes use of the occurrence of people and the type of alien fish (abundances of communities) within the Inner Niger Delta to provide a measure to the disturbance to wildlife. Indicator = Extent and intensity of people and or aliens. Measure = occurrence and type of alien fish and abundance of communities.	Bamba and Samassekou 2004; Zwarts and Diallo 2005; Thieme et al. 2005; Joffre and Laaunie 2008; Smith et al. 2009
	Low (50)	People and no aliens.		
	Moderate (75)	Lots of people and habitat modifying alien spp alone.		
	High (100)	Excessively high abundance of people and many aliens incl. habitat and predatory spp.		
SubF_Luse	Zero (25)	Natural conditions, wilderness	Land use can negatively impact the water quality and quantity, this directly effects fish well-being. The intensity and extent of land use activities a will vary per landuse type and risk region in question. This node looks at the intensity and extent of the land use activities affecting river productivity. Indicator - Intensity and extent of land use activities affecting river productivity Measure = occurrence and abundance (% of RR) of concerning land use types.	Ajayi et al. 2012; Warburton et al. 2012
	Low (50)	Well managed land use		
	Moderate (75)	Poorly managed land use		
	High (100)	Very badly managed land use		
SubF_Potential	Zero (25)	Natural conditions, no subsistence fishermen	Many communities along the Niger river depend on fisheries for subsistence living, either directly or indirectly. This node represents the subsistence fishermen evaluated using the occurrence of these communities along the river within the upper Niger River. The abundances of people within each Risk Region will give an estimate on the threat to the fisheries within the Upper Nile River. indicator = occurrence of communities that may have	Bamba and Samassekou 2004; Zwarts and Diallo 2005; Joffre and Laaunie 2008
	Low (50)	Low presence of subsistence fishermen		
	Moderate (75)	Moderate presence of subsistence fishermen		
	High (100)	High presence of subsistence fishermen		

			subsistence fishermen Measure = abundances of people per RR	
SubF_QDuration	Zero (25)	Duration of flood is two weeks	Duration of floods is important for connectivity, spawning and grow out in flood plains for different fish species. The duration of floods will vary between different RR due to their natural topography. This node looks at the duration of the flood events over time. Indicator - duration preferences for spp - see natural hydrograph and spp. Biology/ecology linked to graph. Measure - duration length.	Daget 1959; Quenserie 1994; Smith et al 2009; Lae et al. 2004; Mahe et al. 2013
	Low (50)	Duration of flood is one month		
	Moderate (75)	Duration of floods is two months		
	High (100)	Duration of floods is four months.		
SubF_QSedmov	Zero (25)	<20 000cm/s	Sediment movements are specific to the hydraulics of the Niger system. Barriers within the catchment alter flow velocity and depth profiles which will change the sediment movements. It is important that the right velocities and depth profiles are kept to maintain the flood plain functioning. This node makes use of the discharge profiles and relative sediment movements.	
	Low (50)	20 000-150 000cm/s		
	Moderate (75)	150 000 - 400 000 cm/s		
	High (100)	400 000 plus cm/s		
SubF_QTiming	Zero (25)	Freshets/floods in Spring to Autumn	Many fish species depend on the timing of floods within the system for important biological functioning. When these floods are out of sync to the preferred natural flooding for fish, fisheries will be negatively impacted. This node looks at when these freshets/floods take place on a monthly basis to determine the potential impact that they may have of fishes. +D58	This study; Lae et al. 2004; Mahe et al. 2013
	Low (50)	Freshets/floods early spring or late autumn		
	Moderate (75)	Freshets/floods in winter.		
	High (100)	No Freshets/floods		
SubF_QVelDep	Zero (25)	FD	Fast deep and fast shallow velocity depth profiles are characterised by the high gradient profiles. Shallow deep and Shallow slow velocity depth profiles are characterised by Indicator - CD preferences for all fish Measure = VD distributions	Rowntree and Wadeson 1998; O'Brien 2013
	Low (50)	FS		
	Moderate (75)	SD		
	High (100)	SS		
Presence or absence of humans in the risk regions (WD_AbHumComm)	Zero (25)	0	Human settlements closer to the water bodies within the risk regions will contribute to water quality impairment. Greater densities = greater impariment. Measure is based on the population density figures (people per km2 within 5km buffer) Zero=0ppl/km2, Low=1-35, Mod=35-50, High>50.	Population density GIS information, this project
	Low (50)	1-35		
	Moderate (75)	36-50		
	High (100)	>50		

Effects of the ideal habitat availability for bilharzia vectors (WD_BilhVect_habitat)	Zero (25)	Bedrock dominated, no GSM and limited vegetation	*Bulinus spp* and *Biomphalaria spp* most dominant in muddy substrates. Mud/vegetation is their ideal habitat. Measure is habitat availability based on geomorph	Carmouze et al. 1983 (eds) Lake Chad, Coulibaly and Madsen 1990, Southgate 1997, Sokolow et al. 2015, Sokolow et al. 2013, Jimoh et al 2011, Roberts and Kuris 2016, Kingdom and Hart 2012, Powell 1983, Bidwell 1979, Bidwell 1977
	Low (50)	Minimal silt/mud and vegetation		
	Moderate (75)	Moderate dominance of silt ,mud and veg		
	High (100)	Predominantly Silt/Mud and Vegetation		
Bilharzia infections to the people around the delta (WD_BilhVect_Phys)	Zero (25)	Unsuitable physical conditions for snails	*Bulinus* spp and *Biomphalaria* spp most dominant in muddy substrates. Densities are highest during rainy seasons. But factors such as temperature range, TDS, depth and velocity effect where their populations will be greatest. Measure is a metric combining factors (Temp, TDS, Depth , Vel) broadly for each risk region. Walz et al 2015 indicated threshold values for temps (120-179 degree hors > 27 degrees per week) TDS (> 360mg/l), Depth (>1.5-2m) and Vel (>0.3m/s) for snails. A metric was developed with scores from 1-3 for each category and calculated using available data for each risk region, the scores were summed for each risk region and the following scoring applied for risk: Zero = 0, low = 1-5, mod, 6-10, High >10	Walz et al 2015, Carmouze et al. 1983 (eds) Lake Chad, Coulibaly and Madsen 1990, Southgate 1997, Sokolow et al. 2015, Sokolow et al. 2013, Jimoh et al 2011, Roberts and Kuris 2016, Kingdom and Hart 2012, Powell 1983, Bidwell 1979, Bidwell 1977
	Low (50)	Poor physical conditions - limiting abundance of snails		
	Moderate (75)	Moderately suitable physical conditions allowing for the presence and bundance of snails		
	High (100)	Very suitable physical conditions for thriving snail communities		
Inundation of the floodplain will increase habitat for malaria vectors (WD_Mal_Inundat)	Zero (25)	No rice paddies (agricultural areas) within buffer (0%)	Rice paddies are an excellent habitat for mosquito larvae. Backing up of the water behind the dam wall will cause floodplain inundation upstream of the wall. This will likely create more habitat for mosquito larvae and therefore more malaria infections. Measure is % agric land use (assumed to be predominantly rice farming) within 5km buffer.	Mather 1984 , Dolo et al. 1997 , Mutero et al. 2000, Diuk-Wasser et al. 2004, Diuk-Wasser et al. 2007, Kibret et al 2012, Klinkenberg et al. 2003. Munga, S., Vulule, J. and Kweka, E.J., 2013. Response of Anopheles gambiae sp
	Low (50)	Low proportion of rice paddies (agric area) within 5km buffer (1-25%)		
	Moderate (75)	Moderate proportion of rice paddies (agric area) within 5km buffer (25 -50%)		
	High (100)	High proportion of rice paddies (agric area) within 5km buffer (>50)		
Effect of water velocity on malaria	Zero (25)	High water velocity regions (0-24% SS VD profile)	Mosquito larvae abundance is negatively correlated with water velocity. Mosquito larvae breathe	Overgaard, H.J., Tsuda, Y., Suwonkerd, W. and

vectors (WD_Mal_Qvel)	Low (50)	Medium water velocity regions (25-49)	atmospheric oxygen and so inhabit lentic environments. Measure is proportion of VD profiles - particularly Slow Shallow(SS) category	Takagi, M., 2002. Characteristics of Anopheles minimus (Diptera: Culicidae) larval habitats in northern Thailand. *Environmental entomology*, *31*(1), pp.134-141.
	Moderate (75)	Low water velocity regions (50-75)		
	High (100)	Standing water (75-100)		
Effect of substrate type on Onchocerciasis vectors (WD_OnchVect_sub)	Zero (25)	Predominantly GSM	Simuliid larvae prefer hard substrates such as cobbles, boulders and bedrock to cling on. Artificial flow control structures can provide such substrate. Measure is habitat availability based on geomorphology.	Grillet, M.E. and Barrera, R., 1997. Spatial and temporal abundance, substrate partitioning and species co-occurrence in a guild of Neotropical blackflies (Diptera: Simuliidae). Hydrobiologia, 345(2-3), pp.197-208. Cummins, 1987
	Low (50)	Predominantly GSM with some IC		
	Moderate (75)	Predominantly IC with some GSM		
	High (100)	Predominantly IC		
Effect of water velocity on Onchocerciasis vectors (WD_OnchVect_vel)	Zero (25)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species unavailable (<0.1m/s and <10cm or >0.8m/s and >1.5m)	While they are generally prevalent in fast flowing water conditions in river channels the construction of dams with concomitant regulated/stable flow releases and potential changes to habitat immediately downstream, could result in population booms and outbreaks of the pests and hence disease (Onchocerciasis/River blindness). Measure is velocity depth requirements for rheophilic species	BAMGIRE Project 2016, Eddy Wymenga Model and data assessment BAMGIRE-AW.pdf. Pg8. Grillet, M.E. and Barrera, R., 1997, Thirion 2016
	Low (50)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species limited in river reaches. (0.1m/s and 11-15cm or 0.6-0.8m/s and >1m)		
	Moderate (75)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species available at river reaches (0.2-0.3m/s and 15-30cm)		

	High (100)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species dominates river reaches. (0.4 to 0.6m/s and >30cm)		
Water borne diseases potential (WD_Potential)	Zero (25)	0 people /km2	Where humans are present, there is a risk attached of waterborne diseases. Measure is population density. High risk is where there is more than 1 person	Population Density information (future estimated pop for 2015) http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density-future-estimates/data-download
	Low (50)			
	Moderate (75)			
	High (100)	>1		
Effects of sanitation in spreading diseases (WD_Sanitation)	Zero (25)	High quality sanitation and whole population with access (100%)	Densely populated areas with poor infrastructure will contribute the most to water quality impairment. Measure is based on available literature which suggests less than 50% people in Mali, Guinea and Ivory Coast with access to sanitation. Assumed to be 0% in rural areas. AMCOW reports - sanitation	Ebi, K.L., 2008. Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. AMCOW report - Mali. UN WASH Watch - sanitation map (2017) - Guinea, Mali, Ivory Coast
	Low (50)	Good infrastructure and sanitation (75-100% ppl with access to sanitation		
	Moderate (75)	50-75% population with access		
	High (100)	0-50% access		
Effect of predators on bilharzia vectors (WD_Vect_Pred)	Zero (25)	Regions with high populations of fish and Macrobrachium	Many fish species in the system feed on gastropoda and act as vector control agents along with Macrobrachium. Measure is average percentage between fish wellbeing node and Macrobrachium long access node	Fincke, O.M., Yanoviak, S.P. and Hanschu, R.D., 1997. Howard, A.F., Zhou, G. and Omlin, F.X., 2007. Malaria mosquito control using edible fish in western Kenya: preliminary findings of a controlled study. *BMC public health*, *7*(1), p.199.
	Low (50)	Moderate fish and Macrobrachium populations		
	Moderate (75)	Low fish populations and Macrobrachium distribution affected by dams and barriers		
	High (100)	Fish and Macrobrachium populations very low/absent		
Water quality amelioration	Zero (25)	5-6 Metric score	Open water areas and riparian buffers alleviate the intensity of water pollution. Measure is natural land use	Open water layer and land use layer GIS

measures (WD_WQAmel)	Low (50)	3-4	within 5km buffer and the percentage open water habitats within the whole risk region - combined as a metric (within 5km) each scored on a scale of 1-3 and then summed and a *0.5 weighting applied to Natural land use, as contact with riparian areas is limited when compared to surface area of open water.	(https://eros.usgs.gov/westafrica/data-downloads) information, this project
	Moderate (75)	1-2		
	High (100)	0		
Effects of the inundation area on macroinvertebrate populations associated with the flood plain (FPInvert_InundArea)	Zero (25)	Floodplain Hydrology (inundation area) congruent with pre-anthropogenic conditions (0% reduction)	As the floodplain becomes inundated with water, more habitat/food is made available for invertebrates with faster life cycles to colonise and utilise. Abundance and biomass increase with inundation of temporary/ephemeral wetlands/deltas, while diversity is greater in permanent systems. Production on floodplains can be 1-2 orders of magnitude higher than in the channel. Inundation area models have been developed for the IND by Zwarts et al 2003 for the Crue period, based on water depths at Akka gauging station. A 48% reduction in inundation area for September was anticipated as a result of Fomi dam and 25% in following months. Measure is a % reduction in inundation area derived from hydrology/hydraulic models, Zero Risk = 0% reduction based on historic water levels at Akka, Low = 1-20%, Moderate 21-40% reduction, High >41% reduction in inundation area owing to reduced flows from upstream dams	Gladden and Smock 1990, Zwarts et al 2005, McInerney et al 2017, Novak et al 2015. Hydrology modelling this study.
	Low (50)	Minimal alteration to floodplain hydrology (inundation area) compared to historic average - congruent with pre-anthropogenic conditions with minimal impact to macro-invertebrate community wellbeing (1-20% reduction)		
	Moderate (75)	Moderate alteration to floodplain hydrology (inundation area) with moderate impact to macro-invertebrate community wellbeing (21-40% reduction)		
	High (100)	Large alteration to floodplain hydrology (inundation area) with critical impact to macro-invertebrate community wellbeing (>41% reduction)		
Potential for high diversities and abundances of	Zero (25)	0-1 Negligible open water area or active floodplain present.	The potential for invertebrates associated with floodplains and slower velocity open water to be present will be directly related to the actual area of	Gladden and Smock 1990, Zwarts et al 2005, McInerney et al 2017,

macroinvertebrates relative to the region (specifically floodplains) to occur (FPInvert_Potential)	Low (50)	2-4%	floodplain or open water areas. Measure is open water area (as a proxy for floodplain) calculated as a percentage of total area of risk region.	Novak et al 2015. Hydrology modelling this study.
	Moderate (75)	5-15%		
	High (100)	>15% high percentage of open water area and floodplain present		
Effects of flood duration on seasonal cues for floodplain invertebrates (FPInvert_QDuration)	Zero (25)	Floodplain Hydrology (flood duration) congruent with pre-anthropogenic conditions	The duration of the flood pulse will determine the duration of the seasonal cues required by the invertebrates and therefore interfere with their reproductive cycles. The availability of habitat is dependent on flood duration and inundation area. Measure = period of peak discharge required to maintain habitat. Use duration from Manatee_Duration	Carmouze et al. 1983 (eds) Lake Chad, Mahe et al. 2011
	Low (50)	Minimal alteration to floodplain hydrology (flood duration) with minimal impact to macro-invertebrate community wellbeing		
	Moderate (75)	Moderate alteration to floodplain hydrology (flood duration) with moderate impact to macro-invertebrate community wellbeing		
	High (100)	Large alteration to floodplain hydrology (flood duration) with critical impact to macro-invertebrate community wellbeing		
Effects of flood timing on seasonal cues for floodplain invertebrates (FPInvert_QTiming)	Zero (25)	Floodplain Hydrology (timing of flood pulse) congruent with pre-anthropogenic conditions	The amount of water entering the delta will likely be reduced by dam/s upstream of it. Also, E-flows (steady flows) will interfere with seasonal cues/pulses aquatic invertebrates need start reproduction. Measure is the deviation from time of peak discharge in months. Use duration from Mtee_Qtiming	Carmouze et al. 1983 (eds) Lake Chad
	Low (50)	Minimal alteration to floodplain hydrology (timing of flood pulse) with minimal impact to macro-invertebrate community wellbeing		
	Moderate (75)	Moderate alteration to floodplain hydrology (timing of flood pulse) with moderate impact to macro-invertebrate community wellbeing		
	High (100)	Large alteration to floodplain hydrology (timing of flood pulse) with critical impact to macro-invertebrate community wellbeing		
Effects of pollution inputs and variability on macroinvertebrates (Invert_WQ_Suit)	Zero (25)	0 Metric score. No mines, negligible temperature variability, negligible population density and all natural surrounding land use areas with a high percentage of open water areas	Nutrients are vital in the growth and development of invertebrates especially scrapers and filter feeders. However, too much accumulation from agricultural and urban land use may pose threats leading to algal blooms and eventually depletion of oxygen in water.	Vanni 2002, Goetsch and Palmer 1997. Metric - this study based on various GIS layers:

	Low (50)	1-1.75 possible potential for mines in the region, low population density, low temperature variability, high degree of natural vegetation in surrounding land use areas and high amount of open water areas	The presence of mines can lead to increased turbidity/sediment along with chemical effluents. Higher temperature variation can also lead to physiological stress on invertebrate populations, decreased oxygen saturation and decreased insect diversity to specialist thermally adapted groups. Similarly EC which is often used as a proxy for pollution, may not cause mortalities alone, but when combined with other things such as total dissolved solids, salinity and other toxicants can cause a decline in invertebrate populations. Invertebrates have different tolerance thresholds for EC. Drivers of pollution are mitigated by the potential for processing (natural riparian buffers/land use) and large open water areas for UV processing, filtration and dilution). Measure is a metric that has been developed to calculate and qualitatively score drivers of pollution in relation to area within a 5 km buffer either side of perennial water courses, together with potential for mitigation/processing in each risk region, Zero Risk = metric score of 0, Low Risk = metric score of 1-1.75, Moderate Risk = metric score of 1.76-3.4, High risk = metric score = >3.5	Population Density information (future estimated pop for 2015) http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density-future-estimates/data-download; Water Temperature http://www.fao.org/geonetwork/srv/en/metadata.show?id=24&currTab=distribution; Land Cover https://eros.usgs.gov/westafrica/data-downloads Mines Open water areas and water resources
	Moderate (75)	1.76-3.4 Moderate potential for mines, moderate population density, agricultural and settlement land use, moderate open water		
	High (100)	>3.5 high potential for mines, high population density, high temperature variability, high percentage of land use for settlements and agricultural, limited natural land use and low amount of open water areas		
Effects of biotope availability on aquatic invertebrates (RInvert_Biotope_Avail)	Zero (25)	Predominance of immobile boulders, cobble habitat in addition to GSM, Vegetation and Bedrock ideal for establishment and growth of a large diversity of invertebrate taxa - as per pre anthropogenic impacts	Some invertebrates such as some members of the Ephemeroptera, Plecoptera, Trichoptera, etc. families have special preference for submerged stones. If stones habitat diminishes, these are likely to disappear as well. Some invertebrates such as Polymitarcyiidae burrow into aquatic veg (e.g. Hydrilla verticillata, Cyperus papyrus and in the roots of Pistia stratiotes) and submerged plant stems and roots as well as sediments. Plants also serve as food to most macroinvertebrates, e.g. shredders. This makes both aquatic and marginal vegetation an important biotope for invertebrates. Sediments provide excellent habitat for some	Coulibaly and Madsen 1990, Southgate 1997, Sokolow et al 2015, Sokolow et al 2013, Jimoh et al 2011, Roberts and Kuris 2016, Kingdom and Hart 2012, Powell 1983, Bidwell 1979, Bidwell 1977, Copeland et al 2011, Dallas and Mosepele 2007, Gore,
	Low (50)	Predominance of cobbles, boulders and bedrock with limited vegetation and GSM - ideal for a wide range of invertebrate taxa		
	Moderate (75)	Predominance of vegetation, GSM and bedrock - presenting only partially suitable habitat for a limited suite of invertebrate taxa		

	High (100)	Predominance of highly mobile substrate such as Gravel, Sand and Mud unsuitable for the majority of invertebrate taxa	invertebrates e.g. chironomids, snails and mosquito larvae. Snails prefer mud while chironomids dwell on silt and sand. If the bedrock is covered in silt, few invertebrates may dwell there. Highest abundances and diversity are common stones/riffle habitat, followed by vegetation and then GSM/Bedrock. Measure is semi-quantitative description of available biotopes, Zero = all 3 biotopes available (GSM, impervious cover, Veg), Low Risk only 2 biotopes available (range of impervious cover with limited GSM and Veg), Moderate 2 biotopes available (mostly bedrock with some GSM and veg), high risk 1-2 biotopes= (dominated GSM/bedrock)	J.A., Layzer, J.B. and Mead, J.I.M., 2001. Thirion 2016
Effects of longitudinal access on invertebrate populations - specifically Macrobrachium (Rinvert_Long_Access)	Zero (25)	Ideal depth for indicator species to migrate. Relates to pre-anthropogenic conditions.	Macrobrachium is a dominant taxonomic group within the study area with migratory requirements. Therefore, the maintenance of longitudinal connectivity must be considered within the study area. Accordingly, depth levels must be maintained to allow migratory behaviour. The construction of a dam wall across the river could restrict migration of Macrobrachium vollenhovenii and crabs. Measure is depth, Zero = >150cm, Low = 101-150cm, Mod = 51-100cm, and High = <50cm)	Sokolow et al 2015, Sokolow et al 2013, Jimoh et al 2011, Roberts and Kuris 2016, Kingdom and Hart 2012, Powell 1983, Dallas and Mosepele 2007, Novak et al (2015), O' Brien et al 2017 (Thukela Study)
	Low (50)	Suitable depth for invert migration with minimal impact to indicator species wellbeing		
	Moderate (75)	Moderate alteration of depth with moderate (TPC) impact to indicator species wellbeing		
	High (100)	Significant loss of depth to allow for migration of indicator species resulting in critical impact to species wellbeing		
Potential for high diversities and abundances of	Zero (25)	Low diversity of riverine biotopes present/or absent altogether absent		
	Low (50)			

macroinvertebrates relative to the region to occur (Rinvert_Potential)	Moderate (75)			
	High (100)	High diversity of riverine biotopes available/present		
Physical effects of sediment movement on riverine invertebrates (RInvert_QSedmov)	Zero (25)	No sediment deposition	Macroinvertebrate communities become less diverse and numerically dominated by fine sediment tolerant taxa, when sediment accumulates. Prey items are reduced, drift occurs, interstitial spaces become clogged, and periphyton becomes smothered, effects oxygen uptake or reduces oxygen availability, substrate is altered. Sedimentation occurs when lower threshold velocities are reached and sediments settle out of suspension, but sedimentation can also be increased through increased windblown sand deposits. In the absence discharge data - average gradient of rivers can be used. Measure is, velocity gradient according to which particles of different sizes settle out, Zero risk = flow velocity >5--10m/s, low risk = 1-5m/s, moderate, 0.1-1m/s. High risk <0.1m/s	Hynes 1970, Waters 1995, Wood and Armitage 1997), Hjulström-Sundborg relationship
	Low (50)	Low potential for sediment deposition (higher gradient, higher velocities, limited windblown sands, limited erosion/exposed banks)		
	Moderate (75)	Moderate potential for sediment deposition (moderate velocity, moderate gradient some windblown sands, some exposed banks/moderate erosion)		
	High (100)	High potential for sediment deposition (low velocity/low gradient, windblown sands, exposed banks, high rates of erosion and degradation)		
Physical effects of Velocity and Depth on riverine invertebrates (RInvert_QVelDep)	Zero (25)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species dominates river reaches. (0.4 to 0.6m/s and >30cm)	Certain invertebrates are adapted to fast flowing water and may therefore disappear if the water velocity drops and oxygen content decreases. Higher abundances of invertebrates are found at fast flowing shallower waters (less than a meter). Measure is VD distributions in this case Fast Shallow habitats, Zero = 75-100, Low = 22-75, Mod 3-22, High= 0-3	Dejoux 1989, Gore 1978, Gore et al 2001., Thirion 2016
	Low (50)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species available at river reaches (0.2-0.3m/s and 15-30cm)		
	Moderate (75)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species limited in river reaches. (0.1m/s and 11-15cm or 0.6-0.8m/s and >1m)		
	High (100)	Velocity-depth habitat requirements/preferences of rheophilic indicator invert species unavailable (<0.1m/s and <10cm or >0.8m/s and >1.5m)		

Effects of aquatic vegetation availability on manatee population (Manatee_AquaticVeg)	Zero (25)	Natural abundance of aquatic and emergent vegetation - measure = VEG_SUIT_FP + VEG_SUIT_RIP = MANATEE_AQUATIC_VEG	Manatees that live extremely far inland in rivers in countries such as Senegal and Mali use specific feeding areas where year round aquatic and shoreline plants occur. They spread out onto flood plains during the rainy season to feed on emergent vegetation. African Manatees feed primarily on vegetation, and over 70 species of plants have been documented to date as Manatee food throughout their range. Riparian vegetation risk endpoints will be used as indicator and the measure will be risk endpoints. The river vegetation endpoint will be used for riverine RR and floodplain vegetation endpoint will be used for floodplain RR. Measure will come from vegetation suitability node. VEG_SUIT_FP + VEG_SUIT_RIP = MANATEE_AQUATIC_VEG	Berth 2011, Kienta et al 2008, Keith Diagne 2014, Villiers and Bessac 1948, Powell 1996, Reeves et al. 1988, Akoi 2004, Ogogo et al. 2013, Keith Diagne 2014, Dumont et al 1981, http://www.iucnredlist.org/details/22104/0, Reynolds et al 2018
	Low (50)	Loss of emergent and aquatic vegetation cover albeit minimal - measure = VEG_SUIT_FP + VEG_SUIT_RIP = MANATEE_AQUATIC_VEG		
	Moderate (75)	Moderate loss of aquatic and emergent vegetation - measure = VEG_SUIT_FP + VEG_SUIT_RIP = MANATEE_AQUATIC_VEG		
	High (100)	Severe loss of aquatic and emergent vegetation cover with an extreme of being a complete absence - measure = VEG_SUIT_FP + VEG_SUIT_RIP = MANATEE_AQUATIC_VEG		
Manatee_Barrier	Zero (25)	No barriers	SEE RFISH_BARRIER	Reynolds et al 2018
	Low (50)	Small number of barriers		
	Moderate (75)	Moderate number of barriers		
	High (100)	Large number of barriers with a complete or almost complete loss of connectivity		
Disturbance to Wildlife (Manatee_DTW)	Zero (25)	No people	Due to their larger size, manatees destroy fishing nets of the fishermen and damage rice fields. People kill them as a means to mitigating this problem. Manatees are also hunted illegally by the local people for food. Measure = number/density of people. SEE FISH_DTW	Reynolds et al 2018
	Low (50)	Low density of people		
	Moderate (75)	Moderate density of people		
	High (100)	High density of people		
Effects of fish abundance for manatees as another	Zero (25)	Natural level of diversity and abundance of fish species within the system - i.e. zero risk to fish wellbeing. Measure is fish wellbeing i.e. FPFish_Endpoint	Stable isotope analyses have revealed that fish are an important food source of African manatees. Therefore the maintenance of the fish population wellbeing is vital to maintaining the wellbeing of the manatee	Berth 2011, Kienta et al 2008, (Keith Diagne 2014), (Villiers and Bessac 1948, Powell

food source (Manatee_Fish)	Low (50)	Small loss of abundance and diversity of fish species i.e. low risk to fish wellbeing. Measure is fish wellbeing i.e. FPFish_Endpoint	population. However, the quantity of fish as well as the particular species are not known. Floodplain fish endpoint will be used for all RR as RFish endpoint is based on risk to rheophilic species which is most likely not a dietary component of manatees. SEE SUBF_ENV_SUIT	1996, Reeves et al. 1988, Akoi 2004, Ogogo et al. 2013, Keith Diagne 2014), http://www.iucnredlist.org/details/22104/0, Dumont et al 1981, Reynolds et al 2018
	Moderate (75)	Moderate risk to fish wellbeing. Measure is fish wellbeing i.e. FPFish_Endpoint		
	High (100)	Complete absence of fish within the system i.e. high risk to fish wellbeing. Measure is fish wellbeing i.e. FPFish_Endpoint		
Effects of macroinvertebrate abundance for manatees as another food source (Manatee_Inverts)	Zero (25)	Natural level of diversity and abundance of mollusc species within the system - i.e. zero risk to mollusc wellbeing. Measure is mollusc wellbeing i.e. RInvert_Endpoint and FPinvert_Endpoint	Stable isotope analyses have revealed that molluscs are an important food source of African manatees. Therefore the maintenance of the mollusc population wellbeing is vital to maintaining the wellbeing of the manatee population. However, the quantity of molluscs as well as the particular species, if any, are not documented. Nevertheless, the maintenance of a suitable invertebrate population is required for the species dietary requirements. The river invert endpoint will be used for riverine RR and floodplain invert endpoint will be used for floodplain RR.	Coulibaly and Madsen 1990, Southgate 1997, Reynolds et al 2018
	Low (50)	Small loss of abundance and diversity of mollusc species i.e. low risk to mollusc wellbeing. Measure is mollusc wellbeing i.e. RInvert_Endpoint and FPinvert_Endpoint		
	Moderate (75)	Moderate risk to mollusc wellbeing. Measure is mollusc wellbeing i.e. RInvert_Endpoint and FPinvert_Endpoint		
	High (100)	Complete absence of mollusc within the system i.e. high risk to mollusc wellbeing. Measure is invert wellbeing i.e. RInvert_Endpoint and FPInvert_Endpoint		
Manatee_MDep	Zero (25)	No alteration to channel depth for migration	African manatees are migratory during the wet season and require access to tributaries and lakes during the dry season. Measure = discharge required to maintain suitable depth for migration	Reynolds et al 2018
	Low (50)	Minimal alteration to depth profile		
	Moderate (75)	Moderate change to depth profile		
	High (100)	Absence of suitable depth for migration		
Flood duration to maintain habitats (Manatee_QDuration)	Zero (25)	No people	African manatees require relatively deep habitats with adequate plant growth and molluscs for feeding. The availability of habitat is dependent on flood durations. Measure = period of peak discharge required to maintain suitable habitat	Reynolds et al 2018
	Low (50)	Low density of people		
	Moderate (75)	Moderate density of people		
	High (100)	High density of people		

Effects of depth on manatee wellbeing (Manatee_QVelDep)	Zero (25)	No alteration to natural depth profile	However, although their exact depth-range preference is not known, it is hypothesised that slow-moving water deeper water is preferred, based on their size and feeding ecology. Measure = discharge levels required to maintain relatively deep habitats	Silva and Araújo 2001.
	Low (50)	Minor alteration to depth profile		
	Moderate (75)	Moderate alteration to depth profile		
	High (100)	Extreme loss of relatively deep habitats		
(Mtee_potential)	Zero (25)	River naturally has no habitat for manatees	Indicator - natural potential of ecosystem to maintain manatees Measure = risk of presence based on the % of habitat availability for manatees	
	Low (50)	River naturally has limited habitat for manatees		
	Moderate (75)	River naturally contains habitats preferred by manatees		
	High (100)	River dominated by habitat for manatees i.e. floodplain		
Effects of turbidity (Mtee_Qsedimov)	Zero (25)	No change to discharge required to maintain ideal sediment supply	Turbidity and velocity synergistically influence the growth of aquatic macrophytes which are the primary food source for manatees. N.B. the data used here was extracted from a lab-based study (Birkett, 2004) that evaluated the influence of the aforementioned variables on periphyton. Measure = velocity	Lacoul and Freedman 2006, Carmouze et al. 1983 (eds) Lake Chad, Dallas and Mosepele 200,Corbet 1957, Bidwell 1979; Ajayi 1972, Corbet et al 1973
	Low (50)	Acceptable sediment supply		
	Moderate (75)	Moderate changes to sediment supply		
	High (100)	Large changes to sediment supply		
Veg_Depth_Bourgou	Zero (25)	The optimal depth range for wild Bourgou is from 4-5m.	Different vegetation types show clear zoning and the occurrence of the various plant and tree species is determined by the flooding duration and the water depth when the flood reaches its peak. There are four dominant non-woody vegetation types with distinct maximum flooding depth preferences: Bourgou is dominant where the maximum water depth ranges from 3-5 m, didéré is expected to be dominant where water depth ranges from 2-3 m, wild as well as cultivated rice is found where water depth ranges from 1-2 m, and Vetiver grass occurs in shallow water from 0-1 m (Zwarts et al., 2009; Zwarts, 2012). The zoning of bourgou and other aquatic plants is not fixed however, but changes can take at least one or two years for new habitats to be colonised (Zwarts & Diallo, 2002). The optimal water depth for bourgou is between 4-5 m. Most wild bourgou is found one meter shallower at a water depth of 3-4 m, although bourgou can survive 5-	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Sub-optimal depth range for wild Bourgou is 3-4m where it still does well, but planted Bourgou can occur deeper and frequently occurs within the 5-6m depth range.		
	Moderate (75)	The depth range from 2-3m can sustain Bourgou but due to intense competition with other wetland plants, Bourgou is infrequent in this range, especially since shallower flood waters tend to be more transient.		
	High (100)	Bourgou does not survive in water deeper than 6m, which tend to be open, unvegetated water. It also does not flourish in flooding depths below 2m.		

			6 m below the water surface, but this depth is suboptimal as many bourgou plants drown. Most of the plants at these greater depths occur there due to active planting for end-of-season fodder. Wild bourgou is grazed as floods recede and planted Bourgou (1m deeper to increase production) is harvested for fodder. Part of the bourgou occurring on the floodplain is planted year after year and farmers remove wild rice and didéré from their rice fields as grazing for the estimated two million cattle and four million sheep and goats, which graze the floodplains, especially after flooding (Zwarts, 2012). Deeper flooding improves bourgou fodder yields. The relation between surface of optimal bourgou habitat and maximum water depth at Akka for the range 320-530 cm is given with the equation (Zwarts et al., 2005): y = -0.0007x3 + 0.8506x2 – 331.27x + 41863 (R2 = 0.993) where: y = surface of optimal bourgou habitat (in square km); x = maximum water depth at Akka (in cm)	
Veg_Durat_Bourgou	Zero (25)	To achieve depth preference and periodicity for growth and reproduction 5-7 months is optimal	Flood duration is equally important for plant species distribution patterns and goes hand in hand with flood magnitude. Optimal inundation duration for Bourgou is from 5 to 7 months but planted bourgou which mostly occurs at greater depth can endure inundation for up to 8 months. Floods which last for shorter periods tend to not be deep enough to satisfy bourgou's depth preference and while some growth may occur, production will be retarded or aborted. Duration referred to here is flooding duration of optimal depth ranges.	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Planted bourgou can endure 8 months. If flood duration is slightly shorter than 5 months, bourgou production is likely to remain high.		
	Moderate (75)	Some bourgou growth and production is still likely if floods last from 3-4 months, although other plant species will do better.		
	High (100)	Floods that last longer than 8 months are likely to cause plants to rot in the water column i.e. loss of organic material, while floods that are shorter than 3 months will unlikely facilitate sufficient growth and reproduction will likely fail.		
Veg_Depth_Didere	Zero (25)	The optimal depth range for didéré is from 2-3m.	There are four dominant non-woody vegetation types with distinct maximum flooding depth preferences:	Zwarts & Diallo, 2002; Zwarts, van Beukering,

	Low (50)	Sub-optimal depth range for didéré is 1.4-2m where it still does well, but will compete with wild rice	Bourgou is dominant where the maximal water depth ranges from 3-5 m, didéré is expected to be dominant where water depth ranges from 2-3 m, wild as well as cultivated rice is found where water depth ranges from 1-2 m, and Vetiver grass occurs in shallow water from 0-1 m (Zwarts et al., 2009; Zwarts, 2012). Didéré, together with bourgou is known as bouroutiere, and while flooding depth preferences of didéré are shallower than bourgou, flood duration preference is the same	Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Moderate (75)	The depth range from 1-1.4m and from 3-3.4m can sustain didéré but due to intense competition with other wetland plants, is infrequent in this range.		
	High (100)	Below 1m Vetiver grass is likely to outcompete didéré, and similarly above 3.4m bourgou will dominate		
Veg_Durat_Didere	Zero (25)	To achieve depth preference and periodicity for growth and reproduction 5-7 months is optimal	Even though the flood depth preferences for didéré is shallower than bourgou, its flood duration preference is the same i.e. 5-7 months.	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Planted bourgou can endure 8 months. If flood duration is slightly shorter than 5 months, bourgou production is likely to remain high.		
	Moderate (75)	Some bourgou growth and production is still likely if floods last from 3-4 months, although other plant species will do better.		
	High (100)	Floods that last longer than 8 months are likely to cause plants to rot in the water column i.e. loss of organic material, while floods that are shorter than 3 months will unlikely facilitate sufficient growth and reproduction will likely fail.		
Veg_Depth_Rice	Zero (25)	The optimal depth range for wild and cultivated rice is from 1-2m.	There are four dominant non-woody vegetation types with distinct maximum flooding depth preferences: Bourgou is dominant where the maximal water depth ranges from 3-5 m, didéré is expected to be dominant where water depth ranges from 2-3 m, wild as well as cultivated rice is found where water depth ranges from 1-2 m, and Vetiver grass occurs in shallow water from 0-1 m (Zwarts et al., 2009; Zwarts, 2012). Farmers grow a variety of rice (Oryza glaberrima) on the floodplain where flooding is between 1m and 2m deep and persists for at least 3 month (Zwarts et al, 2006; Zwarts, 2012).	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Sub-optimal depth range for wild and cultivated rice is 0.5-1m or 2-2.5m where it still does well, but planted rice can occur shallower.		
	Moderate (75)	The depth range from 2.5-3m can sustain rice but due to intense competition with other wetland plants, rice is infrequent in this range.		
	High (100)	Rice is unlikely to occur water deeper than 3m, or shallower than 0.5m.		

Veg_Durat_Rice	Zero (25)	The optimal flooding duration for rice to produce a crop is at least 3 months.	Farmers grow a variety of rice (Oryza glaberrima) on the floodplain where flooding is between 1m and 2m deep and persists for at least 3 month (Zwarts et al, 2006; Zwarts, 2012).	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Rice is still likely to produce a crop, albeit reduced output, if flooding duration is from 2.5 months or longer		
	Moderate (75)	Some rice growth and production is still likely if floods last from 2-2.5 months, although production will be markedly hampered.		
	High (100)	Floods that are shorter than 2 months will unlikely facilitate sufficient growth and reproduction will likely fail.		
Veg_Time_Rice	Zero (25)	Floods arrive 1 to 1.5 weeks after the last local rainfall	Cultivated rice: The farmers on the floodplain grow a West-African rice variety Oryza glaberrima, known as riz flottant or floating rice, which is well adapted to grow upwards with the rising water during the crue. However, ideally the seed should have been germinated before the flood arrives. That means that the farmers have to sow the rice grains before the first rainfall, in the hope that the rain comes before the flood and the rice has sprouted before the flood arrives. With the flood the depth of the water column increases by several cm a day. Rice plants are able to grow 3-4 cm a day following the crue. The stems may be as long as 5 metres, but usually they are about 2 metres long. After a flooding period of about 3 months, the rice can be harvested during the décrue. A lot can go wrong in such a system: (Zwarts et al., 2005))	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Floods arrive 1.5 to 2 weeks after the last local rainfall		
	Moderate (75)	Floods arrive >2 weeks after the last local rainfall		
	High (100)	Floods arrive before local rainfall		
Veg_Depth_Vetiver	Zero (25)	The optimal depth range for Vetiver is from 0-1m.	There are four dominant non-woody vegetation types with distinct maximum flooding depth preferences: Bourgou is dominant where the maximal water depth ranges from 3-5 m, didéré is expected to be dominant where water depth ranges from 2-3 m, wild as well as cultivated rice is found where water depth ranges from 1-2 m, and Vetiver grass occurs in shallow water from 0-1 m (Zwarts et al., 2009; Zwarts, 2012).	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Sub-optimal depth range for Vetiver is 1-1.8m where it still does well, but will compete with wild rice		
	Moderate (75)	The depth range from 1.8-2.1m can sustain Vetiver but due to intense competition with other wetland plants, is infrequent in this range.		
	High (100)	Above 2.1m Vetiver will unlikely occur.		

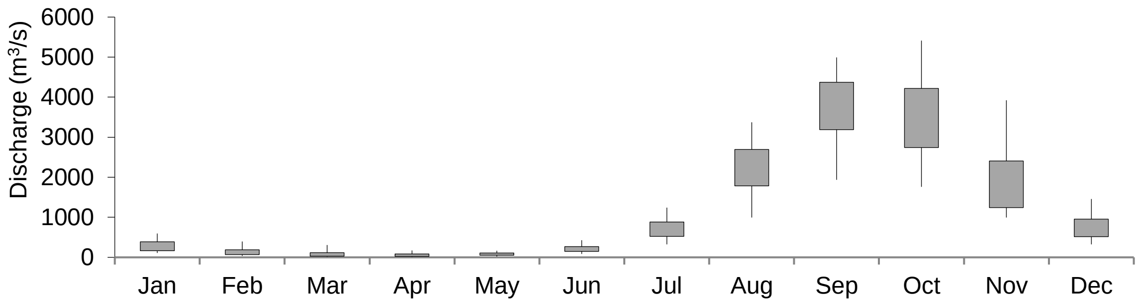
Veg_Durat_Vetiver	Zero (25)	Optimal flooding duration is up to 3 months	Vetiver does better if flooded, but its preference is for shallower flooding for shorter durations. Optimal flooding duration is from 0-3 months and extended flooding will likely reduce productivity.	
	Low (50)	Shorter flooding periods from 0-1 month are likely to have low risk for production		
	Moderate (75)	Extended flooding from 3 to 4 months are likely to reduce productivity		
	High (100)	Absence of flooding or flooding longer than 4 months will likely result in failure		
Veg_Dep_FForest	Zero (25)	The optimal depth range for flooded forest is from 1-2m.	The loss of flooded forests is extensive due to wood removal. In the past, the Inner Niger Delta was surrounded by extensive forests of mainly Acacia seyal, inundated briefly at the peak of flooding, and A. nilotica and F. albida growing on the higher levees. Relicts of these forests still remain at sacred sites where wood is not collected and grazing infrequent or absent (Zwarts et al., 2009). Older people, however, still recall the days that extensive forests occupied the higher grounds and several forests were found in the lower floodplains. Moreover, the vegetation is hugely affected by the two million cattle and four million sheep and goat that graze on the floodplains after the flood has passed. As such, forests have become scarce in the Delta (Zwarts et al., 2012). Some tree species (Acacia kirkii, Ziziphus spina-cristii) grow in floods of up to 3-4 m, but most frequently are flooded by 1-2m of water, similar to the preferences of rice.	Zwarts & Diallo, 2002; Zwarts, van Beukering, Kone & Wymenga (eds.) 2005; Zwarts, 2012.
	Low (50)	Sub-optimal depth range for flooded forest is 0.5-1m or 2-3m where it still does well, if it occurred.		
	Moderate (75)	The depth range from 3-4m can sustain flooded forest, as can slight flooding up to 0.5m.		
	High (100)	Flooded forest is unlikely to occur where flooding is deeper than 4m.		
Veg_Dur_FForest	Zero (25)	The optimal flooding duration is at least 3 months.	Since flooding depth preferences of flooded forest are similar to rice, the inundation duration is taken to also be similar i.e. flooding is between 1m and 2m deep and persists for at least 3 month. Since so little flood forest remains these parameters were quantified	
	Low (50)	2-3 months		
	Moderate (75)	1-2 months		
	High (100)	<1 month		
Veg_Base_wet	Zero (25)	These flows are optimal for flooding riparian zone vegetation, maintaining species and habitat diversity and recharge of soil water.	A range in discharge (Q; m^3/s) at the 50th percentile in the peak wet season (see optimal seasonality below; 3 consecutive months). This is the flow required to activate and flood riparian zone vegetation in the wet season growing months. Although the use of a base flow does not sufficiently describe the flashiness of a flooding regime, it is assumed that the system is large	Hydrology FDC data and simulations
	Low (50)	Reduced wet season flows but still maintain riparian zone functionality and lower delineation i.e. prevent encroachment into the channel.		

	Moderate (75)	Reduced flooding will likely favour woody species encroachment but will also have far reaching consequences for reduced flooding levels and durations on the downstream floodplain.	enough to have less volatile floods with flooding period itself consisting more of a gradual rise followed by recession months later.	
	High (100)	Flooding regime altered to the point where vegetation recruitment is retarded or absent and will result in loss of vegetation in the long term.		
Veg_Base_dry	Zero (25)	These flows are optimal for maintaining more sensitive riparian species and soil moisture levels	A range in discharge (Q; m^3/s) at the 50th percentile in the dry season (see optimal seasonality below). Flows should ideally fluctuate within this range for the duration of the dry season. This is the flow required to activate the more flow sensitive marginal zone species where these exist, or where these are transient non-woody species that quickly colonise wet or moist sands. More importantly however, these flows are required to maintain perenniality of rivers and soil water levels for use by phreatophytic riparian plants, particularly riparian forest species.	Hydrology FDC data and simulations
	Low (50)	Reduced dry season flows but do not pose a high risk of desiccation or encroachment.		
	Moderate (75)	Moderate loss of soil moisture with some desiccation stress and early stages of encroachment		
	High (100)	Flows are reduced to the point where mortality is notable due to desiccation		
Veg_Season_flow	Zero (25)	floods occur in the accepted wet season months	The timing of floods is critical for biological cues and to ensure that ecosystem functions and use and sustainability are protected. The more natural the timing of floods the lower the risk to the resource due to its timing or mis-timing. High risk would be floods in the dry season for example, or the absence of flooding when a natural (defined by failed rainfall, not by overstorage or abstraction) drought is not occurring.	Hydrology data and simulations
	Low (50)	floods occur early or late in the wet season		
	Moderate (75)	floods occur outside of wet season months but also not in the peak of the dry season		
	High (100)	floods occur in the accepted dry season months		

Supplementary Table S2: Flow duration table of monthly average flows representing 1950 Reference flows scenario.

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	595.4	394.7	310.9	175.0	165.6	426.6	1239.4	3374.6	4988.7	5413.1	3924.5	1460.8
1	591.7	358.1	276.6	165.3	163.4	419.7	1208.1	3365.9	4950.9	5267.7	3764.4	1459.6
5	523.5	252.8	208.9	131.3	148.2	371.5	1105.3	3149.3	4860.3	4689.8	3216.7	1455.0
10	470.6	236.3	151.4	114.3	125.9	344.3	1033.9	2923.6	4573.0	4418.0	3002.4	1195.6
15	434.5	200.2	139.5	93.4	115.4	283.0	1006.1	2792.6	4448.4	4355.1	2522.4	1087.9
20	389.7	192.0	119.1	85.8	111.1	266.9	880.7	2697.4	4372.1	4219.3	2405.4	953.3
30	336.4	171.9	101.1	71.8	100.2	222.1	793.7	2585.3	4202.5	3750.9	2081.8	813.9
40	293.3	140.5	90.9	54.7	83.4	206.8	744.9	2310.8	4073.8	3344.4	1843.4	735.9
50	249.0	116.4	67.8	45.0	76.1	191.5	706.5	2221.5	3775.7	3100.7	1634.0	651.9
60	227.6	102.9	57.1	38.1	71.2	168.9	634.0	1996.4	3532.6	2992.5	1513.5	604.3
70	209.4	91.0	42.8	30.9	55.6	162.8	565.8	1836.3	3366.1	2840.3	1359.7	555.4
80	162.0	69.9	28.6	24.0	49.3	146.5	520.0	1782.2	3191.3	2739.4	1239.2	514.3
85	145.5	65.0	26.0	20.4	35.0	139.8	498.7	1659.6	3163.5	2696.8	1224.5	497.3
90	134.6	56.4	22.3	15.9	31.0	122.7	457.1	1531.6	3054.3	2583.8	1194.7	465.9
95	126.5	44.1	18.1	13.9	27.4	88.3	383.2	1414.0	2944.6	2333.2	1150.1	406.2
99	111.1	36.5	15.5	12.4	19.8	83.8	339.4	1081.6	2260.3	1950.0	1046.1	343.7
99.9	106.2	35.5	14.8	12.2	19.1	82.5	322.4	990.3	1932.3	1757.3	991.3	320.9

A.



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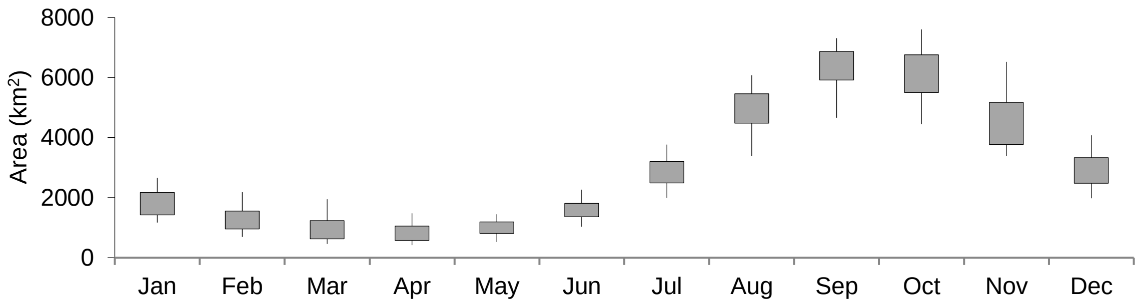

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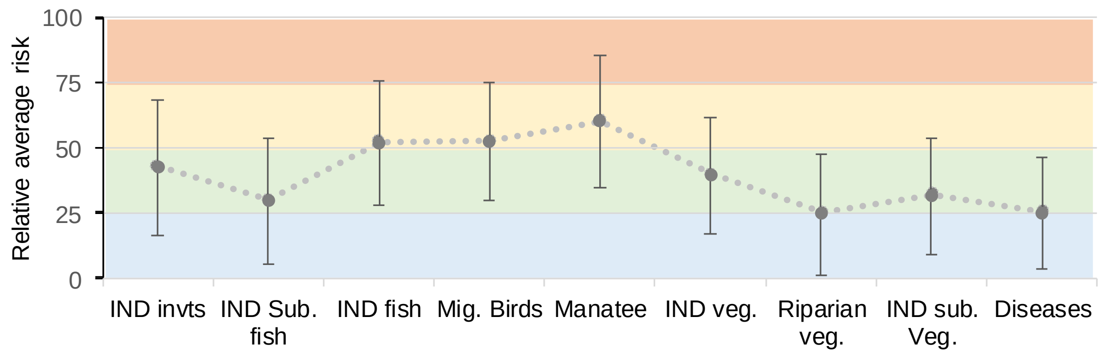
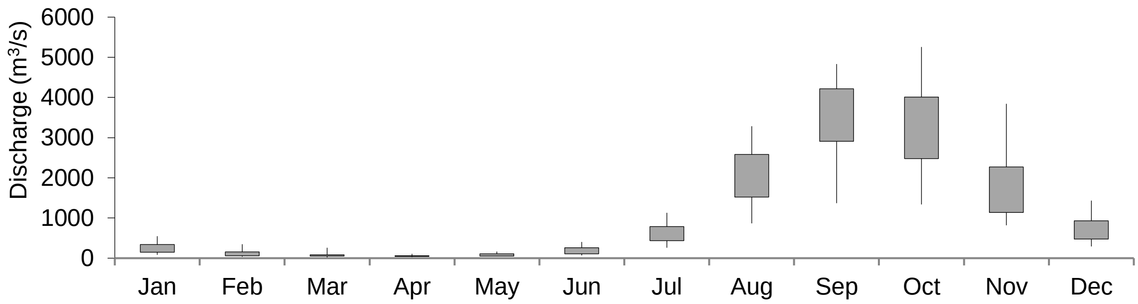


Supplementary Figure S1: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the 1950 Reference flows scenario. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Graph C shows relative risk score ranges overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for each endpoint considered in the study. Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S3: Flow duration table of monthly average flows representing 1950 Reference flows scenario.

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	546.5	347.3	258.0	110.4	166.8	403.4	1127.7	3285.9	4832.8	5258.0	3841.7	1431.3
1	542.8	310.7	225.0	110.0	157.2	390.1	1096.4	3277.1	4795.0	5112.5	3649.2	1429.9
5	474.6	238.9	159.3	94.6	137.9	347.0	993.6	3060.5	4543.6	4534.7	3122.9	1327.8
10	429.6	188.9	126.4	80.4	131.0	292.9	929.7	2834.2	4375.6	4233.1	2923.1	1168.2
15	385.6	172.5	103.1	65.5	111.7	276.9	900.6	2632.8	4229.0	4186.7	2443.1	1060.5
20	340.9	153.8	87.6	61.6	108.2	262.0	790.1	2583.1	4216.1	4011.4	2268.9	926.9
30	302.5	127.3	73.6	53.0	92.9	228.2	688.7	2305.2	3910.1	3595.8	2002.5	760.0
40	252.7	106.7	57.7	51.2	85.4	212.4	631.7	2156.9	3587.1	3092.2	1690.1	671.3
50	224.0	94.7	55.8	50.3	73.8	199.3	606.6	1948.1	3412.0	2886.1	1492.9	611.5
60	192.7	75.6	50.6	50.1	63.7	157.6	556.4	1858.2	3184.6	2697.7	1425.2	558.7
70	167.6	65.7	50.0	49.6	56.9	132.1	482.4	1685.0	3021.6	2562.7	1262.2	519.4
80	148.4	60.9	50.0	43.6	50.1	111.8	437.9	1520.3	2906.2	2478.3	1135.4	475.0
85	142.4	58.3	48.8	39.0	49.3	104.7	419.9	1428.0	2815.5	2409.6	1082.8	438.7
90	128.5	54.8	46.4	37.1	47.8	91.5	358.8	1371.2	2652.8	2247.3	1044.1	420.6
95	115.9	52.3	39.2	30.8	46.5	73.8	277.3	1259.5	2448.6	2142.9	974.2	371.6
99	92.0	41.9	20.7	28.3	45.3	68.6	264.8	924.9	1681.3	1541.7	869.2	309.2
99.9	87.3	37.5	19.1	27.0	45.2	68.4	260.2	868.7	1370.6	1339.0	818.6	289.9

A.



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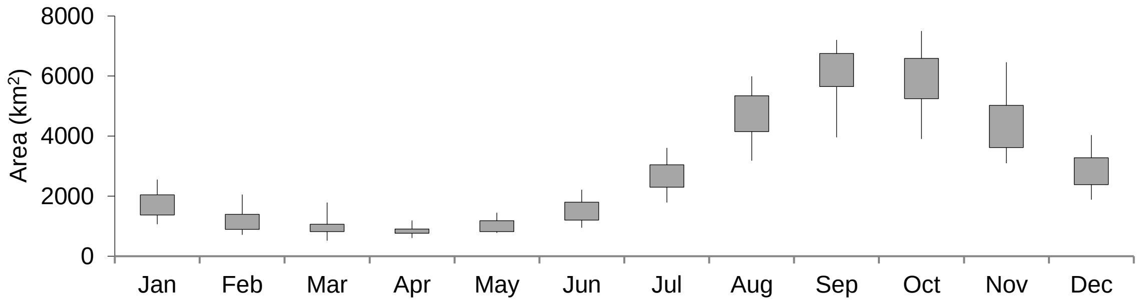

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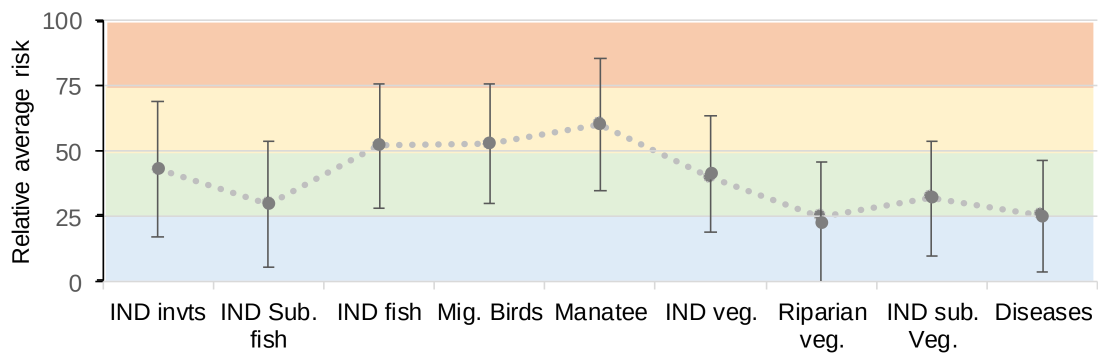
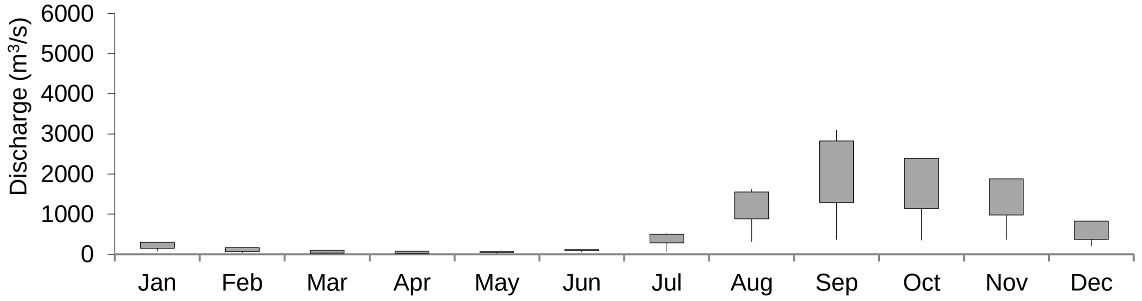


Supplementary Figure S2: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the 1950-2005 Historical flows scenario. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S4: Flow duration table of monthly average flows representing Environmental Flows (EFA) scenario.

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	299.2	164.7	100.3	74.8	71.8	119.3	524.5	1628.4	3100.6	2395.9	1880.5	828.8
1	299.2	164.7	100.3	74.8	71.8	119.3	524.5	1628.4	3100.6	2395.9	1880.5	828.8
5	299.2	164.7	100.3	74.8	71.8	119.3	524.5	1628.4	3100.6	2395.9	1880.5	828.8
10	299.2	164.7	100.3	74.8	71.8	119.3	521.9	1601.5	3002.7	2395.9	1880.5	828.8
15	299.2	164.7	100.3	74.8	71.8	119.3	513.3	1575.7	2932.5	2395.0	1880.5	828.8
20	298.4	164.4	100.1	74.7	71.5	119.3	500.5	1550.9	2825.0	2387.2	1877.3	826.5
30	295.2	162.9	99.3	72.4	70.8	118.7	478.9	1480.5	2664.5	2359.1	1853.8	787.5
40	289.4	148.6	91.0	56.4	68.5	117.6	463.9	1404.7	2509.4	2314.6	1831.7	712.2
50	249.0	123.5	67.8	46.5	66.9	115.9	432.8	1347.6	2274.5	2162.8	1688.7	630.8
60	227.5	109.2	57.2	39.5	62.2	112.0	401.5	1186.2	1981.1	1949.4	1560.2	584.7
70	187.2	96.8	42.8	31.8	50.5	105.9	351.2	1039.9	1714.5	1686.2	1283.6	537.4
80	150.4	70.9	28.5	24.8	41.4	94.9	285.3	881.6	1292.3	1135.5	974.4	375.4
85	117.8	61.6	26.0	21.1	31.9	86.7	218.9	713.3	1097.8	897.5	780.0	302.3
90	97.6	50.0	22.4	16.2	24.5	71.3	159.7	584.2	776.2	672.3	579.8	250.2
95	85.2	41.9	18.1	14.4	18.4	60.0	107.7	421.9	579.8	463.8	447.9	213.1
99	80.4	38.4	15.6	12.9	15.8	54.2	76.5	333.4	399.1	386.8	391.4	199.8
99.9	78.9	37.8	15.0	12.7	15.5	52.4	64.4	309.1	361.1	348.0	361.7	194.9

A.



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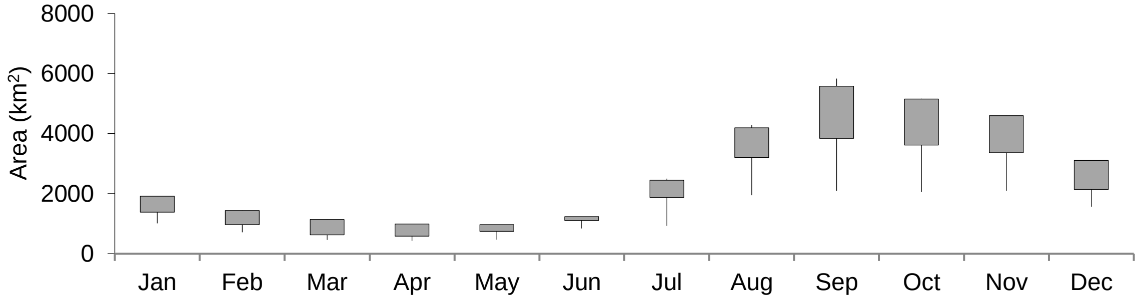

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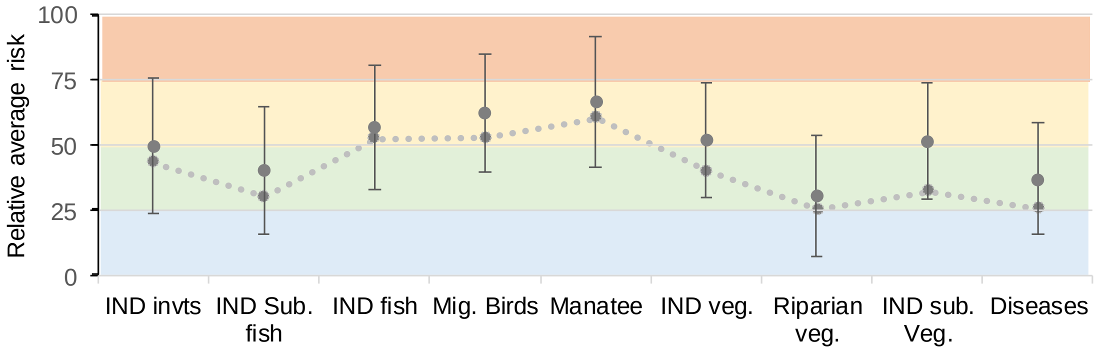
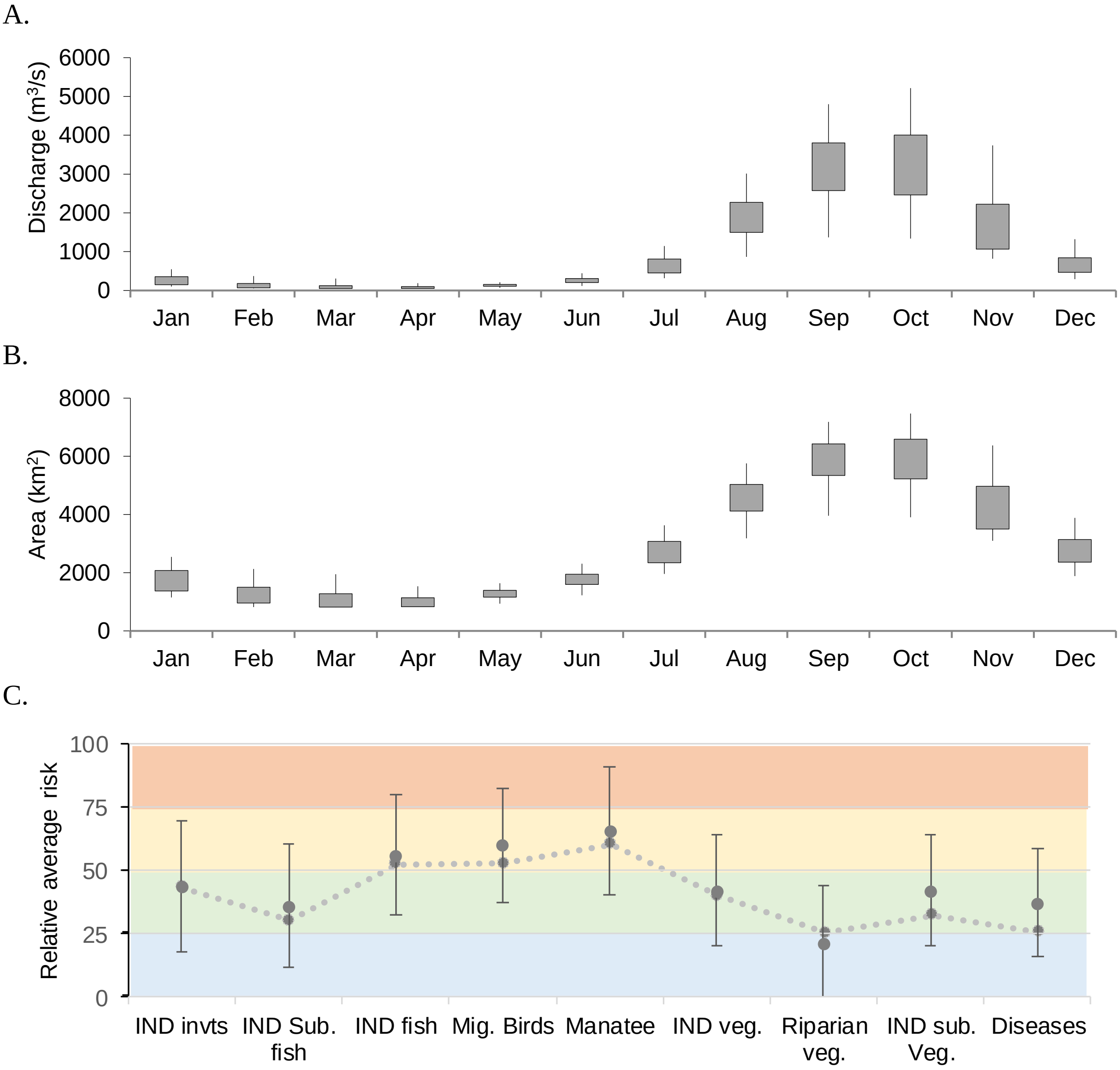


Supplementary Figure S3: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the Environmental Flows (EFA) scenario. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S5: Flow duration table of monthly average flows representing 1950-2005 Present day flows scenario.

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	544.6	373.3	310.7	188.1	216.1	441.9	1144.9	3016.4	4801.8	5216.3	3738.5	1320.0
1	530.0	326.7	282.7	182.0	209.0	435.3	1090.3	2972.3	4666.8	5061.6	3581.7	1316.6
5	442.7	234.6	215.1	146.3	194.4	416.5	976.4	2717.2	4314.1	4514.1	3141.0	1305.3
10	419.7	212.9	157.9	131.5	177.1	395.3	952.6	2480.9	4133.7	4230.0	2821.6	1080.3
15	385.3	190.6	145.6	115.4	163.8	340.0	898.6	2337.6	3982.5	4173.9	2311.1	970.7
20	352.7	179.4	128.3	101.0	154.3	308.5	811.0	2272.0	3805.7	4005.7	2219.5	844.0
30	317.7	166.3	112.7	89.8	142.4	283.1	736.7	2124.6	3677.7	3497.8	1887.8	714.7
40	256.8	127.4	94.1	74.1	138.0	253.5	676.4	2056.9	3587.1	3076.4	1643.2	666.1
50	238.5	110.1	78.6	67.7	129.0	245.7	627.8	1909.0	3274.8	2838.0	1467.6	602.1
60	214.6	100.0	74.7	60.8	122.4	226.1	563.6	1785.1	2986.3	2575.2	1336.1	554.4
70	195.3	94.6	57.3	57.7	108.5	214.0	498.9	1593.8	2817.1	2487.1	1170.8	485.3
80	148.4	70.0	50.2	52.3	104.7	205.1	455.1	1494.2	2576.0	2465.4	1063.4	464.1
85	142.4	64.8	50.0	50.8	87.2	197.3	439.3	1428.0	2548.4	2403.6	1053.6	438.7
90	128.4	58.3	50.0	50.3	84.0	184.8	377.6	1327.1	2498.1	2247.3	1010.2	420.6
95	124.4	53.6	50.0	50.3	76.6	145.6	315.2	1259.5	2376.2	2037.7	972.2	371.2
99	107.4	50.7	50.0	50.2	70.1	119.7	313.5	924.9	1681.3	1541.7	869.2	309.2
99.9	101.5	50.3	50.0	50.2	66.7	116.3	312.7	868.7	1370.6	1339.0	818.6	289.9

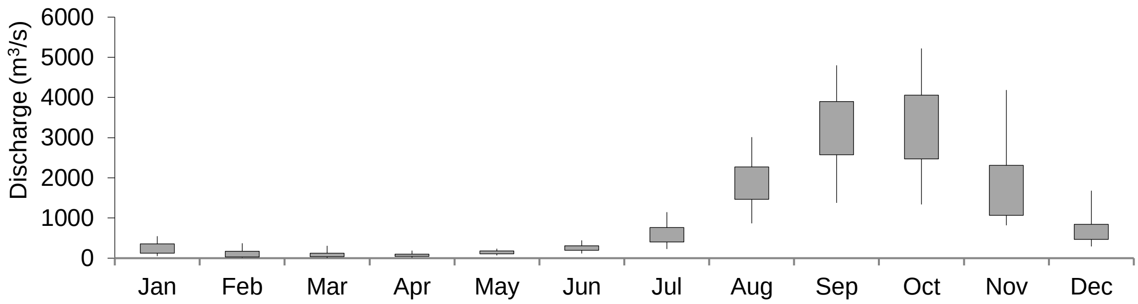


Supplementary Figure S4: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the 1950-2005 Present day flows (PRS1) scenario. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S6: Flow duration table of monthly average flows representing 1950-2005 Present day flows (PRS2).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	544.6	373.1	310.7	188.1	237.3	441.9	1144.9	3016.4	4801.8	5221.1	4186.9	1679.2
1	530.0	325.0	282.7	182.0	230.2	435.3	1090.3	2972.3	4666.8	5109.2	4037.9	1555.1
5	469.4	228.4	215.1	146.3	209.9	416.5	976.4	2810.3	4314.1	4886.7	3211.6	1306.8
10	421.9	196.7	151.8	132.3	197.5	385.9	952.6	2629.9	4182.6	4559.0	2821.6	1080.3
15	385.3	184.0	142.2	125.7	193.8	340.0	834.6	2353.9	4059.0	4270.1	2538.0	970.7
20	352.7	172.6	128.3	101.0	182.5	308.5	766.0	2272.0	3900.1	4058.1	2313.5	844.0
30	313.0	132.5	110.5	88.9	160.9	283.2	682.3	2117.7	3677.1	3497.8	1887.8	754.7
40	245.5	114.3	81.3	73.0	152.5	254.7	664.2	1963.2	3344.1	3153.7	1662.9	656.2
50	205.8	99.7	73.4	68.2	141.1	243.5	562.3	1834.5	3172.6	2838.0	1460.7	578.7
60	180.1	75.9	47.5	59.0	126.7	227.4	494.6	1682.8	2963.5	2584.7	1326.2	544.1
70	129.9	54.1	41.4	52.5	119.5	212.6	468.6	1531.4	2704.3	2530.3	1198.9	485.3
80	121.3	29.6	33.8	45.6	105.4	199.4	407.3	1468.3	2576.0	2474.2	1063.4	464.1
85	107.2	21.5	27.2	42.2	96.7	190.2	327.8	1324.0	2548.4	2437.5	1055.7	457.7
90	74.5	17.7	17.2	37.3	84.1	158.9	314.4	1283.0	2498.1	2356.6	1039.8	427.3
95	69.0	13.1	10.7	28.6	76.6	133.2	297.5	1054.9	2388.4	2023.5	972.2	371.2
99	57.5	9.7	7.7	11.5	70.1	119.7	232.3	924.9	1711.4	1506.7	869.2	309.2
99.9	52.9	9.2	7.3	11.0	66.7	116.3	229.0	868.7	1373.6	1335.5	818.6	289.9

A.



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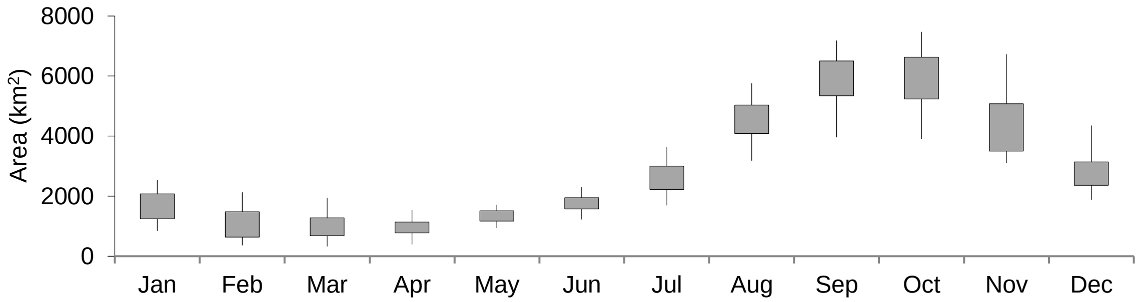

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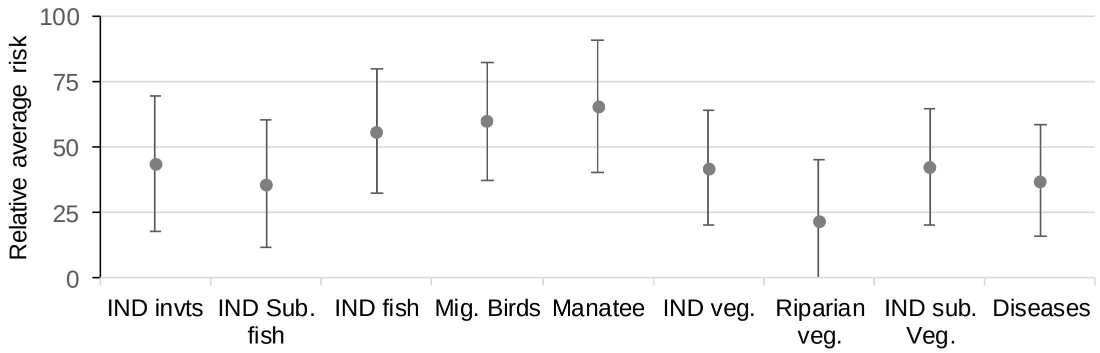

Supplementary Figure S5: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the 1950-2005 Present day flows (PRS2) scenario. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S7: Flow duration table of monthly average flows representing Future flows scenario 1 (FUT1).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	277.0	157.6	234.0	181.3	264.0	400.8	759.6	2569.2	4114.9	4408.3	3425.3	999.2
1	246.0	111.1	202.1	175.2	253.2	396.2	751.4	2542.5	3955.2	4234.9	3307.0	998.0
5	172.1	22.7	114.9	144.9	232.4	380.2	728.4	2210.7	3514.1	3813.3	2931.1	943.1
10	146.6	11.1	89.4	130.2	230.5	326.9	676.4	2042.8	3302.9	3539.0	2475.5	822.2
15	114.5	3.4	80.0	116.6	225.9	297.9	634.2	1939.7	3141.6	3385.4	1931.4	736.2
20	95.6	2.7	60.5	102.0	215.7	293.2	604.7	1768.4	3042.6	3297.3	1814.7	608.6
30	40.2	1.8	40.9	91.4	205.1	264.2	511.0	1739.2	2904.0	2589.6	1512.6	516.9
40	31.3	1.1	19.4	68.5	198.1	244.0	454.5	1635.2	2751.6	2224.5	1242.1	452.9
50	17.9	0.4	9.0	61.0	194.6	230.4	403.1	1442.9	2570.6	2023.9	1065.3	441.7
60	6.3	0.0	1.2	54.3	179.0	217.9	353.8	1359.8	2207.8	1799.8	883.4	397.3
70	1.1	0.0	0.8	37.3	165.1	195.4	306.5	1260.2	2106.2	1688.0	846.9	349.6
80	0.0	0.0	0.4	29.5	141.2	177.2	246.3	1151.0	1862.0	1613.7	723.1	318.5
85	0.0	0.0	0.1	25.6	134.0	145.3	235.6	1049.3	1780.7	1582.3	682.7	304.0
90	0.0	0.0	0.0	17.0	117.3	120.2	176.7	977.1	1734.5	1338.4	637.9	273.3
95	0.0	0.0	0.0	5.8	88.6	101.0	156.6	911.7	1701.9	1305.2	606.2	251.6
99	0.0	0.0	0.0	2.5	74.1	54.7	135.5	617.7	1026.5	896.9	493.2	197.0
99.9	0.0	0.0	0.0	1.7	69.9	34.6	129.5	574.2	746.2	735.3	449.4	186.8

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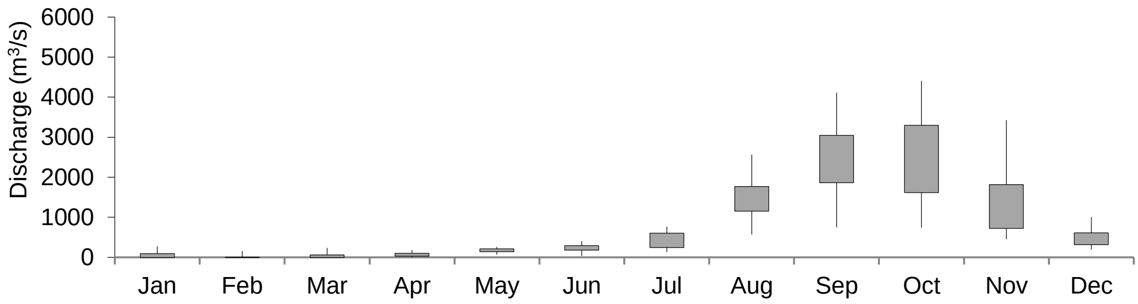

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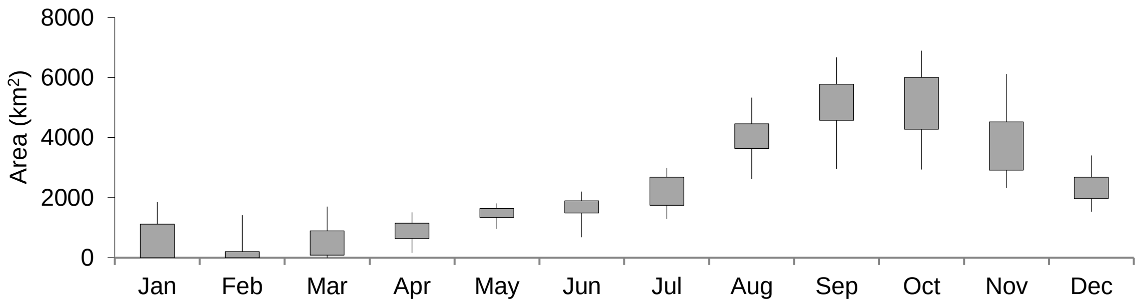

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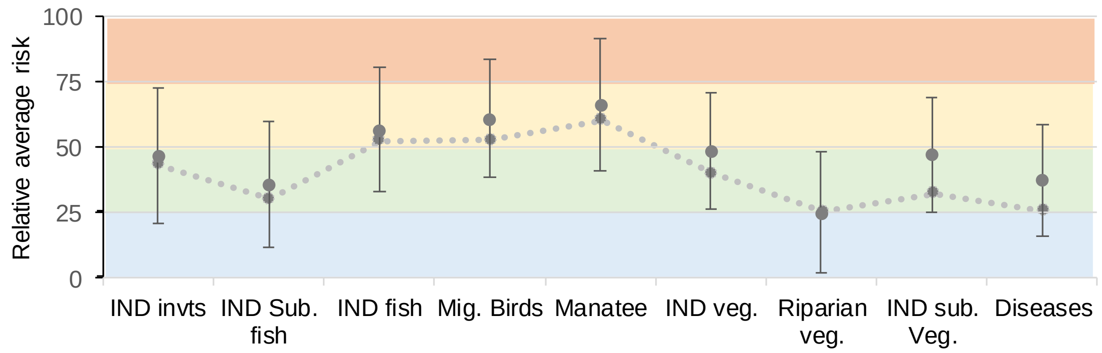
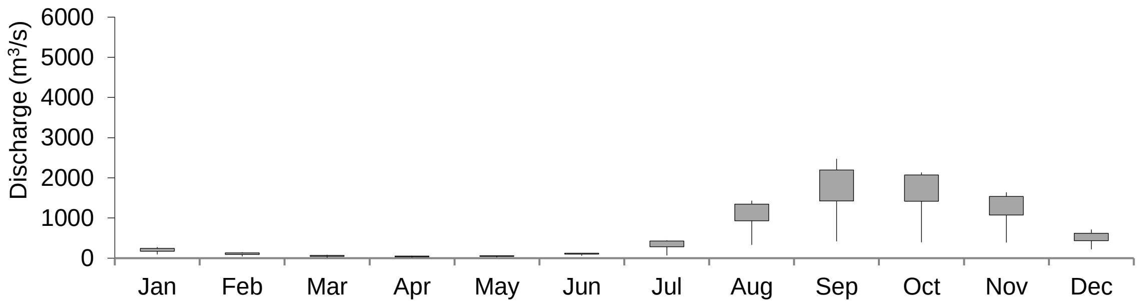


Supplementary Figure S6: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the <u>Future flows scenario 1 (FUT1)</u>. Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S8: Flow duration table of monthly average flows representing Future flows scenario 2 (FUT2).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	273.31	146.40	86.30	62.77	69.64	123.70	443.57	1432.02	2474.92	2135.51	1639.65	712.77
1	267.19	142.93	83.45	60.49	68.43	123.78	440.01	1414.54	2418.98	2123.05	1619.62	694.07
5	261.06	139.46	80.60	58.21	67.23	123.86	436.45	1397.05	2363.03	2110.59	1599.58	675.36
10	254.93	135.98	77.75	55.93	66.02	123.94	432.89	1379.57	2307.08	2098.13	1579.55	656.66
15	248.81	132.51	74.90	53.65	64.82	124.02	429.33	1362.09	2251.14	2085.66	1559.51	637.95
20	242.68	129.04	72.05	51.36	63.61	124.10	425.78	1344.60	2195.19	2073.20	1539.47	619.25
30	236.55	125.57	69.20	49.08	62.41	124.18	422.22	1327.12	2139.24	2060.74	1519.44	600.54
40	230.43	122.10	66.36	46.80	61.20	124.26	418.66	1309.64	2083.30	2048.28	1499.40	581.84
50	224.30	118.63	63.51	44.52	60.00	124.34	415.10	1292.15	2027.35	2035.81	1479.37	563.14
60	207.98	109.06	57.62	40.84	54.73	116.01	372.11	1172.43	1826.34	1830.55	1343.35	520.06
70	191.66	99.50	51.74	37.15	49.46	107.68	329.13	1052.70	1625.33	1625.28	1207.34	476.99
80	175.34	89.93	45.85	33.47	44.20	99.36	286.14	932.98	1424.32	1420.02	1071.33	433.91
85	159.02	80.37	39.97	29.78	38.93	91.03	243.16	813.25	1223.31	1214.75	935.31	390.83
90	142.70	70.80	34.08	26.10	33.66	82.70	200.17	693.53	1022.30	1009.49	799.30	347.76
95	126.38	61.24	28.20	22.42	28.39	74.38	157.19	573.81	821.29	804.22	663.29	304.68
99	110.06	51.67	22.31	18.73	23.12	66.05	114.20	454.08	620.29	598.95	527.27	261.61
99.9	93.74	42.11	16.43	15.05	17.86	57.72	71.22	334.36	419.28	393.69	391.26	218.53

A.



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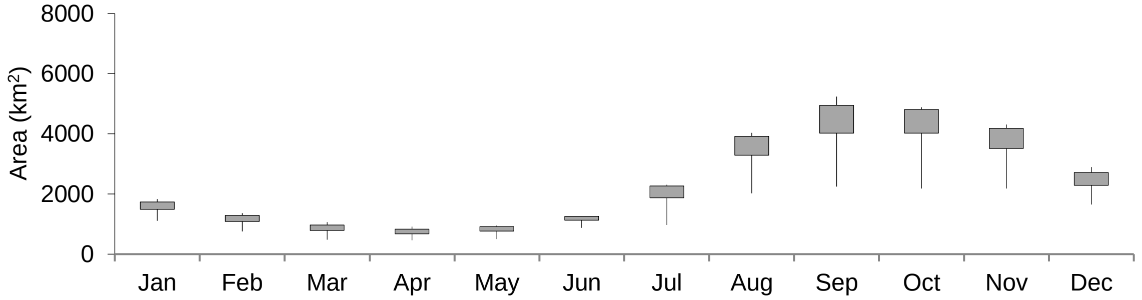

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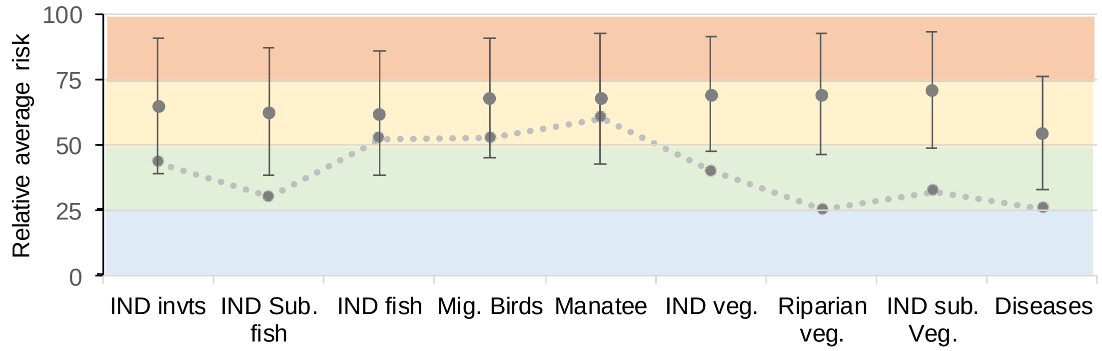
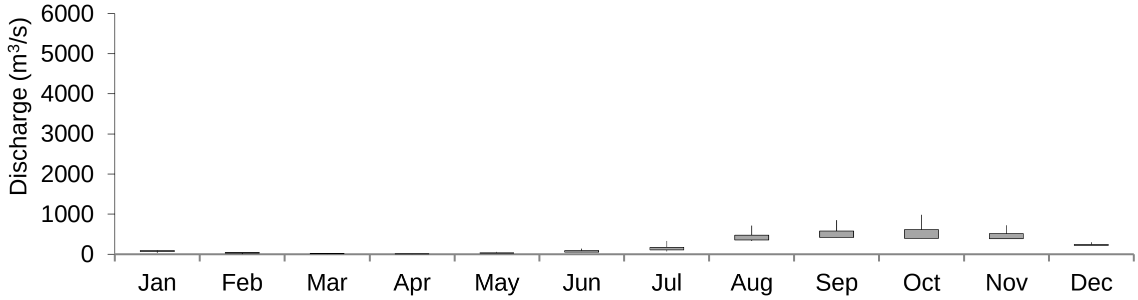


Supplementary Figure S7: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the Future flows scenario 2 (FUT2). Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S9: Flow duration table of monthly average flows representing Future flows scenario 3 (FUT3).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
1	97.01	46.26	21.34	15.05	50.91	130.14	302.02	376.32	419.28	393.69	391.26	218.53
5	96.54	45.67	20.63	15.05	46.19	119.80	269.05	370.33	419.28	393.69	391.26	218.53
10	96.08	45.07	19.93	15.05	41.47	109.45	236.07	364.33	419.28	393.69	391.26	218.53
15	95.61	44.48	19.23	15.05	36.74	99.11	203.10	358.34	419.28	393.69	391.26	218.53
20	95.14	43.89	18.53	15.05	32.02	88.76	170.13	352.34	419.28	393.69	391.26	218.53
30	94.68	43.29	17.83	15.05	27.30	78.41	137.16	346.35	419.28	393.69	391.26	218.53
40	94.21	42.70	17.13	15.05	22.58	68.07	104.19	340.35	419.28	393.69	391.26	218.53
50	93.74	42.11	16.43	15.05	17.86	57.72	71.22	334.36	419.28	393.69	391.26	218.53
60	86.52	37.38	14.58	13.34	23.52	56.40	83.68	381.60	473.14	467.49	432.52	228.27
70	79.30	32.66	12.73	11.64	29.19	55.07	96.14	428.84	527.00	541.28	473.77	238.00
80	72.09	27.93	10.87	9.94	34.86	53.74	108.61	476.08	580.87	615.08	515.03	247.74
85	64.87	23.21	9.02	8.23	40.52	52.42	121.07	523.32	634.73	688.88	556.29	257.47
90	57.65	18.48	7.17	6.53	46.19	51.09	133.54	570.56	688.60	762.68	597.54	267.21
95	50.43	13.76	5.32	4.83	51.86	49.76	146.00	617.81	742.46	836.47	638.80	276.94
99	43.21	9.03	3.47	3.12	57.52	48.44	158.47	665.05	796.33	910.27	680.05	286.68
99.9	35.99	4.31	1.62	1.42	63.19	47.11	170.93	712.29	850.19	984.07	721.31	296.41

A.



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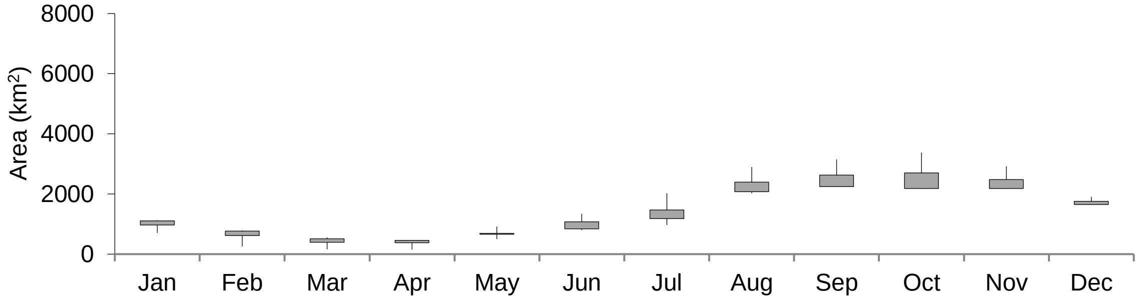

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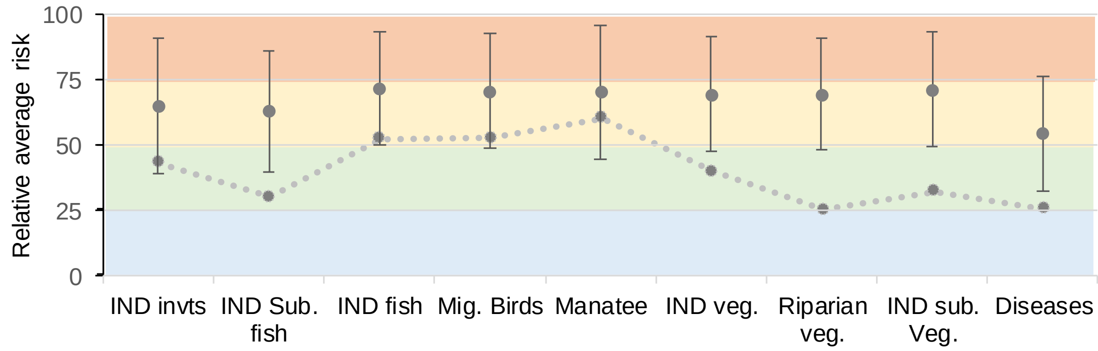

Supplementary Figure S8: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the Future flows scenario 3 (FUT3). Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S10: Flow duration table of monthly average flows representing Future flows scenario 4 (FUT4).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
1	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
5	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
10	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
15	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
20	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
30	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
40	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
50	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
60	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
70	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
80	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
85	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
90	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
95	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
99	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53
99.9	97.48	46.85	22.04	15.05	55.63	140.49	334.99	382.32	419.28	393.69	391.26	218.53

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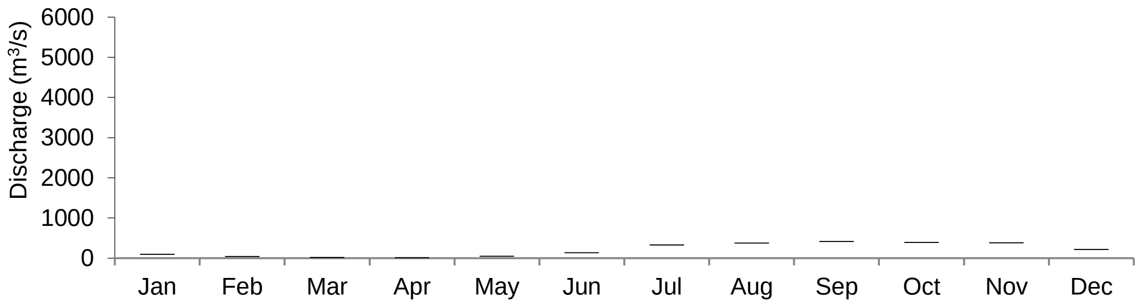

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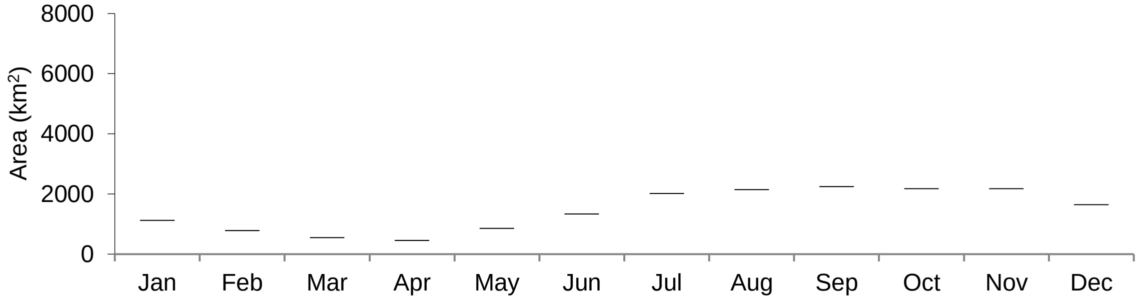

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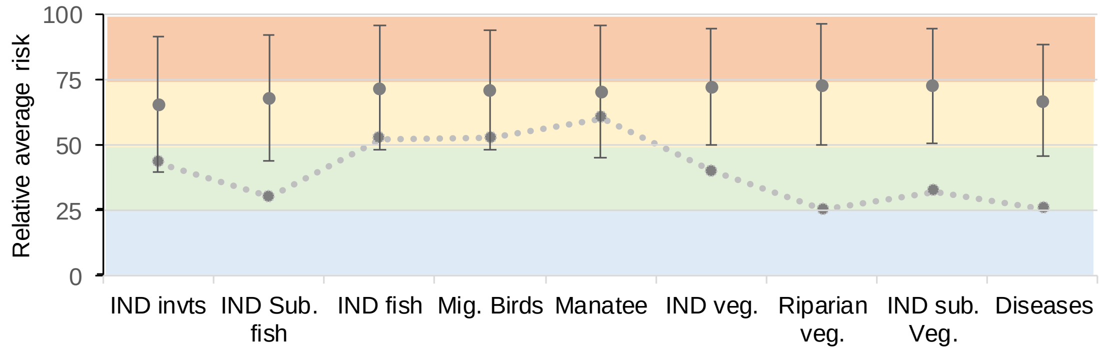
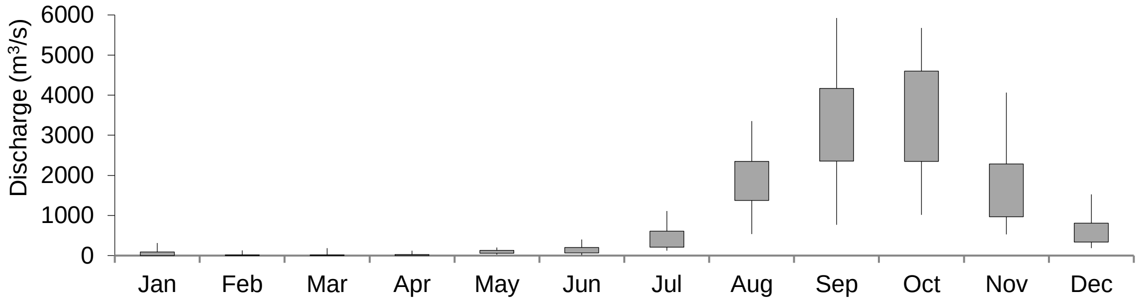


Supplementary Figure S9: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the Future flows scenario 4 (FUT4). Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S11: Flow duration table of monthly average flows representing 1950 Future flows scenario 5 (FUT5).

Percentiles	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	310.5	128.2	188.2	120.0	197.6	397.7	1114.8	3357.7	5924.3	5676.8	4065.2	1525.2
1	282.1	103.7	145.0	101.4	189.5	378.9	1071.2	3283.5	5614.3	5473.6	3934.9	1514.3
5	225.0	32.3	55.2	65.6	155.1	326.5	875.1	3111.7	4771.7	5077.1	3385.2	1368.6
10	182.5	23.6	28.1	46.8	149.8	241.6	805.6	2979.0	4427.8	4806.6	3020.1	1086.7
15	163.0	15.5	20.7	43.0	138.9	224.5	677.0	2690.4	4377.3	4751.0	2702.1	992.2
20	90.9	14.5	19.2	29.2	131.5	199.3	605.2	2345.7	4166.6	4599.6	2287.6	810.0
30	64.3	4.1	6.4	19.5	124.2	182.7	508.7	2159.5	3781.9	4050.8	2009.7	726.5
40	36.2	1.0	0.0	8.5	112.1	139.8	479.0	1918.9	3561.7	3266.8	1728.4	562.3
50	13.2	0.0	0.0	4.5	95.9	126.0	429.6	1847.4	3286.4	2927.3	1356.0	498.1
60	4.0	0.0	0.0	2.9	88.2	116.3	348.2	1594.1	2916.2	2618.8	1182.2	431.0
70	1.1	0.0	0.0	1.6	77.5	94.2	312.0	1436.3	2646.3	2509.1	1132.6	372.8
80	0.2	0.0	0.0	1.5	60.3	69.3	206.4	1373.9	2355.1	2346.4	968.3	340.8
85	0.0	0.0	0.0	1.1	52.2	59.6	164.3	1095.9	2215.6	2214.9	891.0	321.6
90	0.0	0.0	0.0	1.0	48.7	55.3	141.9	992.9	2166.9	1913.1	859.6	304.2
95	0.0	0.0	0.0	0.9	36.6	38.6	129.5	946.3	1949.5	1793.1	767.8	229.8
99	0.0	0.0	0.0	0.6	31.7	11.5	120.8	560.6	1168.4	1253.7	588.0	196.4
99.9	0.0	0.0	0.0	0.6	29.8	8.2	118.7	535.4	765.5	1016.2	527.2	184.3

A.



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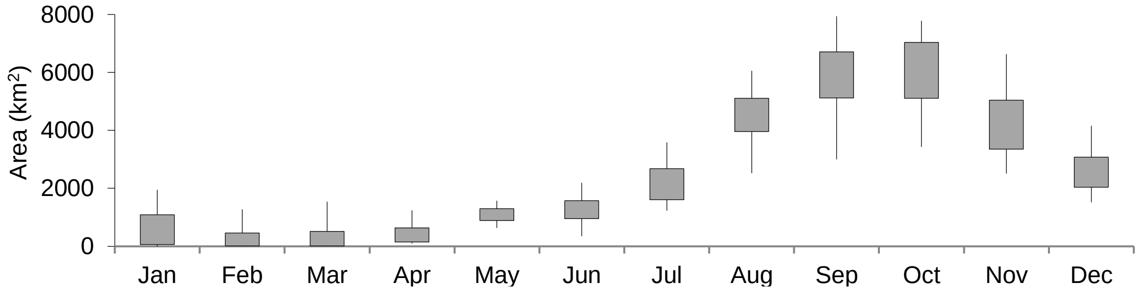

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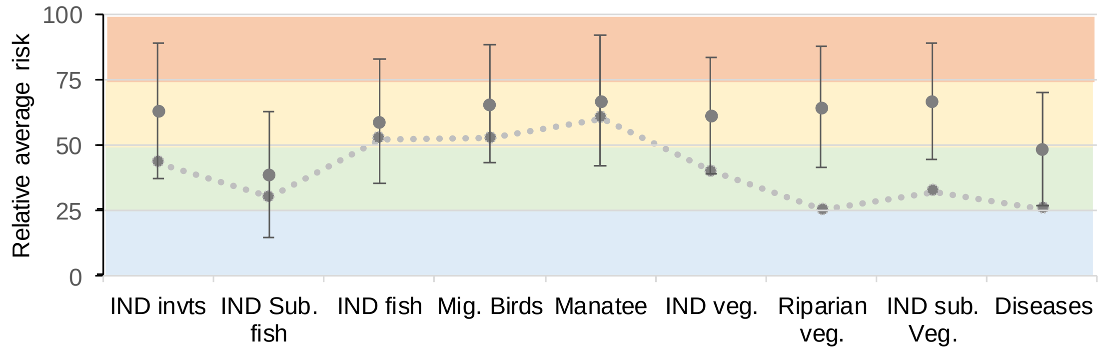

Supplementary Figure S10: Graphs of the range of monthly averaged hydrology (m^3/s, A) and inundation area (km^2, B) of the Inner Niger Delta for the Future flows scenario 5 (FUT5). Box represents 20-80 percentiles and whiskers represent range from 0.01 to 99.9 percentiles. Relative risk score (C) overlaid on zero (blue), low (green), moderate (yellow) and high (orange) risk ranks for endpoints (REF flows overlaid dotted line). Endpoints include invertebrates (IND invts), subsistence fish (IND Sub. Fish), floodplain fish (IND fish), migrating birds (Mig. Birds), manatee populations (Manatee), aquatic vegetation (IND veg.), riparian vegetation (Riparian veg.) subsistence vegetation (IND sub Veg.) and water disease (Diseases).

Supplementary Table S11: Sensitivity analyses outcomes of the Bayesian Network application in the study to evaluate the socio-ecological consequences of altered flows in the Upper Niger River and Inner Niger Delta including variance reduction, cumulative percentile, mutual info and percent variance of beliefs in the network.

Node	Variance Reduction	Percent	Mutual info	Percent	Variance of Beliefs
Vegetation social endpoint sensitivity analysis					
Vegsoc_WB	431.9	100	1.28661	100	0.2939541
Veg_Pot_Social	203.5	47.1	0.51704	40.2	0.0743588
Veg_Suit_Soc_Veg	14.02	3.25	0.06535	5.08	0.0046489
Veg_Suit_Rip	4.493	1.04	0.01692	1.31	0.0007524
Vegetation ecological endpoint sensitivity analysis					
Veg_WB	509.2	100	1.78006	100	0.473403
Veg_WB_FloodVeg	134.1	26.3	0.33222	18.7	0.0429471
Veg_Pot	91.16	17.9	0.20996	11.8	0.0473819
Veg_Pot_Floodplain	45.2	8.88	0.09719	5.46	0.0150354
Veg_Suit_Floodplain	27.41	5.38	0.07042	3.96	0.0049532
Veg_WB_Ripveg	26.65	5.23	0.0588	3.3	0.0061727
Veg_Suit_Rice	7.906	1.55	0.01861	1.05	0.0011368
Veg_Suit_Vetiver	7.279	1.43	0.01684	0.946	0.0009378
Veg_Suit_Rip	7.054	1.39	0.01238	0.696	0.0007816
Veg_Suit_Soc_Veg	4.103	0.806	0.00655	0.368	0.0003757
Subsistence fishery endpoint sensitivity analysis					
SubF_Endpoint	590.3	100	1.82909	100	0.4997603
SubF_Potential	306.8	52	0.67446	36.9	0.1323985
SubF_Env_Suit	55.77	9.45	0.17525	9.58	0.0178112
SubF_DTW	10.17	1.72	0.02466	1.35	0.0019998
SubF_Productivity	8.944	1.52	0.0221	1.21	0.0018322
SubF_PhyHab_Suit	6.767	1.15	0.01715	0.938	0.0012555
SubF_QSedmov	3.104	0.526	0.00756	0.413	0.0006497
Floodplain invertebrate community endpoint sensitivity analysis					
FPInvert_Endpoint	524.6	100	1.80842	100	0.4831315
FPInvert_Potential	189.9	36.2	0.4119	22.8	0.078933
FPInvert_Env_Suit	106.7	20.3	0.29471	16.3	0.0362422
Manatee_Food	20.82	3.97	0.04822	2.67	0.0038717
Invert_WQ_Suit	19.67	3.75	0.04267	2.36	0.0039457
FPInvert_InundArea	18.75	3.57	0.04175	2.31	0.0032078
FPInvert_Seasonality	18.04	3.44	0.03871	2.14	0.0032712
FPInvert_QTiming	5.329	1.02	0.01106	0.612	0.0009306
FPInvert_QDuration	5.125	0.977	0.01043	0.577	0.0009188
River fish community endpoint sensitivity analysis					
RFish_Endpoint	593.2	100	1.52126	100	0.3699238
RFish_potential	336.6	56.8	0.57203	37.6	0.0570814
Fish_DTW	10.82	1.82	0.0595	3.91	0.0013811
RFish_Env_Suit	5.001	0.843	0.03017	1.98	0.0009657
Floodplain fish community endpoint sensitivity analysis					

FPFish_Endpoint	569.4	100	1.86328	100	0.5057324
FPFish_Potential	152.7	26.8	0.31491	16.9	0.0558187
Fish_DTW	99.22	17.4	0.23561	12.6	0.0245115
FPFish_PhyHab	53.95	9.47	0.13853	7.43	0.0196816
FPFish_QFPConnect	21.79	3.83	0.04524	2.43	0.0043427
FPFish_QHabDepth	10.77	1.89	0.02263	1.21	0.0023239
RFish_Endpoint	8.521	1.5	0.01824	0.979	0.0017657
Human health endpoint sensitivity analysis					
WD_Endpoint	429.6	100	1.66983	100	0.4307894
WD_Potential	114.2	26.6	0.32942	19.7	0.058047
WD_Parasites	43.31	10.1	0.12712	7.61	0.0133497
WD_Pathogens	35.34	8.23	0.10818	6.48	0.0157214
WD_BilhRecruit	9.186	2.14	0.02552	1.53	0.0031076
Bilharzia_Threat	8.92	2.08	0.02545	1.52	0.0026321
WD_AbnHumComm	8.767	2.04	0.02428	1.45	0.0030773
WD_Culicid_Control	5.384	1.25	0.01589	0.951	0.0014196
WD_WQAmel	4.5	1.05	0.01235	0.74	0.0017002
WD_Sanitation	3.373	0.785	0.00919	0.55	0.0011545
Manatee endpoint sensitivity analysis					
Mtee_Endpoint	635.5	100	1.61885	100	0.4141958
Mtee_potential	361.8	56.9	0.4796	29.6	0.0856362
Mtee_Env_Suit	48.9	7.69	0.19205	11.9	0.0317051
Manatee_DTW	22.51	3.54	0.08008	4.95	0.0132996
Mtee_Hab_Suit	3.072	0.483	0.01085	0.67	0.0019386
Mtee_PhysHab	0.739	0.116	0.00259	0.16	0.0004793
Mtee_QHabConnect	0.4263	0.0671	0.00148	0.0916	0.0002657
Manatee_Food	0.3462	0.0545	0.00121	0.0748	0.0002191
Resident birds endpoint sensitivity analysis					
Resbirds_Endpoint	597.1	100	1.87847	100	0.5128057
Resbirds_Potential	191.8	32.1	0.34545	18.4	0.056903
Resbirds_Breeding	72.59	12.2	0.19676	10.5	0.0291227
Birds_Hunting	71.98	12.1	0.18992	10.1	0.0271704
Migrbirds_Endpoint	40.49	6.78	0.09583	5.1	0.0103058
Resbirds_Roost_Suit	34.37	5.76	0.08027	4.27	0.0089562
Birds_Fitness	16.11	2.7	0.03692	1.97	0.0040277
Birds_HabMod	12.75	2.13	0.02801	1.49	0.0027414
Resbirds_Roosts	10.29	1.72	0.02244	1.19	0.0021143
Birds_Mudflats	1.861	0.312	0.00404	0.215	0.0003727
Veg_Suit_Floodplain	0.9709	0.163	0.00212	0.113	0.0002024
Migratory birds endpoint sensitivity analysis					
Migrbirds_Endpoint	564.5	100	1.85608	100	0.5031549
Migrbirds_Potential	173.6	30.8	0.34363	18.5	0.0570835
Birds_Hunting	83.59	14.8	0.22486	12.1	0.0296028
Birds_Fitness	51.35	9.1	0.14713	7.93	0.0227363
Resbirds_Endpoint	38.54	6.83	0.09583	5.16	0.009744
Resbirds_Breeding	11.94	2.12	0.02837	1.53	0.0032512

Birds_Mudflats	10.24	1.81	0.02367	1.28	0.0023372
Birds_HabMod	9.052	1.6	0.02118	1.14	0.0021281
Veg_Suit_Floodplain	5.623	0.996	0.01318	0.71	0.0013232
Resbirds_Roost_Suit	2.079	0.368	0.00472	0.254	0.0005208
Birds_Mudf_Sed	2.063	0.365	0.00457	0.246	0.0004079
Veg_WB_FloodVeg	1.935	0.343	0.00445	0.24	0.0004417
Veg_Suit_Rice	1.626	0.288	0.00373	0.201	0.0003666
Veg_Suit_Vetiver	1.611	0.285	0.00371	0.2	0.0003923
Birds_Mudf_Flush	1.592	0.282	0.00352	0.19	0.0003166
Birds_Mudf_Dep	1.14	0.202	0.00251	0.135	0.0002551