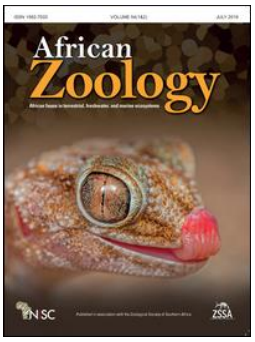

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Systematic review

A review of some aspects of the ecology, population trends, threats and conservation strategies for the common hippopotamus, *Hippopotamus amphibius* L, in Zimbabwe

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This review explores some ecological aspects of the common hippopotamus (hippo), *Hippopotamus amphibius* L, threats to its population and contextual peculiarities affecting its conservation in selected water systems in Zimbabwe. Scoping surveys of literature and thematisation of common issues related to hippo ecology, human-hippo conflict and conservation were used for data collection. Hippos play integral ecological roles, such as habitat engineering through track creation in water systems, nutrient recycling by swirl spread of highly organic faeces, harbouring commensal water birds, parasites and leeches. Regardless, the hippo population is not well documented for the country with indications of sharp declines in freshwater systems during the period 1982 to 1992 and gradual recovery thereafter. Habitat degradation, water pollution, climate change, drought-induced extreme water level fluctuation, poaching and deliberate culling, as part of problem-hippo control (PHC), are key drivers of hippo population declines. However, it appears much of the attention is on human-hippo conflict and its consequences, resulting in negative perceptions among human communities. Commercial breeding of hippos for non-consumptive tourism, and export-orientated meat, and ethnomedical mimics of hippo sweat and milk products are new, potentially viable, but unexplored options for conserving and increasing the population of the species in Zimbabwe. Currently, it appears more anti-hippo poaching patrols and awareness campaigns especially in water systems outside protected areas may be key to sustaining the current hippo population. For the future, it is essential to increase the scope for hippo census data to include water systems inside and outside protected areas for sustainable conservation of the species in the country.

Keywords: ethnomedicine, freshwater conservation, human-hippo conflict, sustainability

Introduction

Global conservation concerns on hippo population

The common hippopotamus*, Hippopotamus amphibius* L, (hereafter referred to as hippo) is found throughout sub-Saharan Africa (Kingdon 2015). Hippos are widely denoted as an ecosystem engineer, bioengineer and iconic species in many freshwater systems because their activities profoundly affect and modify the landscape (Lock 1972; Subalusky et al. 2015). Rangewide, hippo populations have been declining in developing sub-Saharan African countries, such as Zimbabwe, South Africa, Zambia, Democratic Republic of Congo and Namibia (Eksteen et al. 2016; Linchant et al. 2018). A number of factors (e.g. habitat fragmentation, climate change, droughts and poaching) have been cited as key drivers of hippo population declines worldwide (Eksteen et al. 2016; IUCN 2016). In relatively more developed African nations (e.g. South Africa), long-term and consistent hippo censuses, that have produced accurate hippo population estimates, have contributed to the conservation of the species (IUCN 2016). For resource challenged African and South American countries (e. g. Colombia, which has an entirely non-native population), there are no accurate and reliable hippo population estimates, a situation that has resulted in confusion over the conservation status of hippos in the respective countries (IUCN 2016). The missing key is a comprehensive review, re-examination and analysis of the few available and fragmented hippo population data in each country and then consolidation of the data on a global scale, as indicated by Eksteen et al. (2016) and IUCN (2016) to develop accurate hippo population estimates. Accurate hippo population estimation allows the formulation of pragmatic conservation initiatives best suited for the unique contextual reality on the ground for each country (Eltringham 1999; Linchant et al. 2018).

Eksteen et al. (2016) indicated that despite being an iconic African species, relatively little is published on aspects of the social behaviour and ecology of hippos in general, even on a global scale. This reflects that a metapopulation approach may be required to understand the threats and opportunities for hippo conservation in developing countries, such as South Africa, Mozambique, Zambia and Zimbabwe (Eksteen et al. 2016; IUCN 2016). Accordingly this review paper seeks to explore some ecological aspects of the common

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hippo, *Hippopotamus amphibius L*, threats to its population and contextual peculiarities affecting its conservation with recommendations for future sustainability of the species in water systems of Zimbabwe. Firstly, the paper explores some pertinent ecological aspects of hippos that tend to affect their population dynamics, such as feeding ecology, its role as a terrestrial/aquatic ecosystem engineer species, social behaviour, and then briefly reviews issues around the conservation status of hippo globally, before contextualising the situation for Zimbabwe and then concludes with a segmented discussion of the threats, conservation strategies and opportunities for sustainable commercial utilisation of hippos for the benefit of humans. The basic idea is that for effective hippo conservation and reduction in human-hippo conflict there is a requirement to first accurately estimate the entire hippo metapopulation and its distribution. Secondly, it is imperative to identify and examine threats to hippo populations in wetlands located inside and outside protected areas. Afterwards, formulation of practical hippo conservation strategies for sustainable utilisation and implementation in Zimbabwe and sub-Saharan African countries will be possible (Eksteen et al. 2016).

Hippos as aquatic ecosystem engineers

Hippos spend the nights grazing in the savanna and during daytime wallowing in shallow pools to keep cool and escape the sun (Lewison 2011). Hippos defaecate in water and their excreted waste enriches the nutrients in water resulting in favourable conditions for diatoms, macroinvertebrates and large fish populations (Olivier and Laurie 1974; Onyeanusi 1999; McCauley et al. 2015). Some fish populations, including *Labeo* spp. were observed to feed on microorganisms and algae that grow on hippo skin especially around the hooves (Onyeanusi 1999). The African mud catfish, *Clarias gariepinus,* thrive on the mineral rich detritus, macroinvertebrates and macrophytes that grow in hippo tracks (Onyeanusi 1999; Dawson et al. 2016). As hippos wallow, they excrete waste, which in some cases deplete oxygen from the water as it decomposes (Olivier and Laurie 1974). Microbial activity in hippo dung and tracks also produce chemicals like ammonium and sulphide, known to be toxic to fish (Bengis et al. 2016; Dutton et al. 2018; Stears et al. 2018). This has resulted in several fish kills in hippo-infested water systems (Mosepele et al. 2009; Wolanski and Gereta 1999; Dawson et al. 2016; Dutton et al. 2018).

In hippo pools, hippo wallowing activity tends to positively correlate with the depth and area of the pool, and partially determines the changes in the distribution of oxygen levels in such pools (Dutton et al. 2018). Hippo dung, which tends to be dropped at the littoral shoreline edges, has been shown to increase fish predation by terrestrial consumers and birds, because the fish will be exposed when they are feeding on the nutritious dung (Stears and McCauley 2018). Moreover, hippo dung influences the distribution of oxygen in the water column, with highest oxygen levels being found at the water surface. Fish alter their behaviour and move to the water surface to access the oxygen. In doing so, this exposes them to terrestrial predators. As a result, hippos directly move nutrients from terrestrial to aquatic systems, but also indirectly move nutrients back to terrestrial consumers (Stears and McCauley 2018).

Hippos as terrestrial ecosystem engineers

Hippos play pivotal roles in the terrestrial ecosystem, primarily, as megaherbivores preferring short palatable grasses normally in the drawdown zones adjacent to rivers and reservoirs (Utete et al. 2017). Kingdon (1979), Cerling et al. (2008) and Timbuka (2012) indicate that despite their biological requirements for an aquatic habitat, hippos hardly graze on macrophytes and hydrophytes, rather they feed mostly on terrestrial vegetation. Hippos feed on short sweet grasses (Eltringham 1999) although contemporary stable isotope studies indicate that they may also feed on dicotyledonous shrubs, forbs and small trees (Cerling et al. 2008). In the process, hippos play a critical role in determining vegetation composition, and by also defaecating on land they aid nutrient cycling for instance by adding silicon, phosphorus, and nitrogen (Schoelynck et al. 2019), especially in the drawdown zone and peripheral areas (Utete et al. 2017). Terrestrial hippo tracks also act as small ephemeral pans in the wet season with a succession of plant communities and associated microflora and microfauna, such as invertebrates (Eksteen et al. 2016). O'Connor and Campbell (1986) indicate that hippos and competing herbivores, such as impala, exert grazing pressure on drawdown zone vegetation, resulting in the degradation of the river banks through the formation of gulleys and channels. Some of the gulleys formed by hippos serve as habitats for small mammals, such as squirrels and hedgehogs (O'Connor and Campbell 1986).

Hippo feeding ecology

In terms of feeding ecology, a hippo is categorised as an obligate herbivore favouring short grass and plants (Owen-Smith 1988; Eltringham 1999; Grey and Harper 2002; Kanga et al. 2013). Other research on water systems in east, western and southern Africa indicates that in times of drought and dire herbage shortages (Mugangu and Hunter 1992), hippos can also eat flesh and are cannibalistic (Dudley 1996, 1998; Dorward 2015; Dudley et al. 2016). Some studies have indicated that hippos are facultative carnivores that can feed on intestinal tissues from the carcasses of other animals (Lewison 1998; Dutton and Subalusky 2011; Dudley et al. 2016). Regardless, there is extensive research showing that hippos are grazers that supplement with shrubs and other vegetation, and on odd occasions have been observed 'feeding' on carcasses (Field 1970; Lock 1972; Scotcher 1974; Scotcher et al. 1978; Lewison and Carter 2004; Zoeller and Bond 2013; Subalusky et al. 2014). This is a crucial element in that it defines the way hippos use ecosystems, which tend to also determine their population dynamics in terms of recruitment and dispersal (Lock 1972; Lewison and Carter 2004; Clauss et al. 2013).

Social and reproductive behaviour of hippos

The social and reproductive behavioural systems of hippos are complex comprising solitary individuals, typically bulls, who forage alone especially at night (Laws 1968; Lock 1972; Klingel 1991). During the day and in aquatic habitats, hippos are highly gregarious and territorial moving in pods (Owen-Smith 1988; Klingel 1991; Eltringham 1999; Linchant et al. 2018). A typical hippo pod comprises calves, juveniles, subadults and adults of both sexes (Linchant et al. 2018). The number of hippos in a pod normally depends on the size of the wetland (Kingdon 2015). Both female and male hippos are highly aggressive, a trait linked to abnormal testosterone levels (Kingdon 1979; 2015). Fights for mates and territory are common among hippos, resulting in severe injuries and fatalities and disaggregation of the pod in some instances (Lewison 1998). The social behaviour of hippos largely determines the population growth of the species, because it allows for mating, reproduction, dispersal and reconfiguration of hippo pods in response to forage availability and habitat suitability in the wetlands (Owen-Smith 1988; Eksteen et al. 2016). More so, hippos are K-selected in their reproduction strategy, which implies that there must be suitable and conducive environmental and social conditions for courtship and mating (Owen-Smith 1992). The fact that hippos are K-selected is important in aiding understanding of how quickly their populations can bounce back from droughts and or serious declines (see Pienaar 1966; Smuts and Whyte 1981; Owen-Smith 1992, Clauss et al. 2004, 2013).

Conservation status of hippos

Worldwide, hippos are valued for tourism (game viewing and sport hunting), or cropping (bush meat), and also for ecosystem services provision, such as fertilizing the aquatic habitat (IUCN 2016). However, the global hippo population, which is estimated to be between 125 000 and 150 000, is declining at a rate of 6–8% per annum resulting in current efforts to reclassify the species as threatened from vulnerable on the IUCN red list (IUCN 2016). With the lack of adequate population data, because of the absence of long-term hippo censuses in Zimbabwe, and most African countries, the wildlife authorities have a tendency of following the IUCN classification system on hippos with little regard to the actual situation in aquatic systems (Erb et al. 2001; Linchant et al. 2018). Accordingly, there is a requirement for a review of hippo conservation status in most African countries.

Habitat degradation (Lewison and Oliver 2008b), drought (Cole 1992), water pollution (IUCN 2016), water level fluctuation (Viljoen 1995; Viljoen and Biggs 1998; Stommel et al. 2016), climate change, poaching and retributive killings by humans (Linchant et al. 2018) comprise some key factors affecting the global hippo population. Changing land-use patterns in developing countries highlighted by water system modification and destruction, deforestation and settlement encroachment towards lakes and rivers, account for loss of hippo habitats and grazing lands (Nchanji and Fotso 2006; Eltringham 2010; Chansa et al. 2011; Kanga et al. 2011, 2013). Regardless, the conservation status of hippos is largely unknown for most developing countries, such as Zimbabwe, because of logistical challenges and poor management, resulting in misinformed classification of the species as least threatened or vulnerable on the red list of threatened species (IUCN 2004, 2016; Lewison and Pluháček 2017).

The contextual situation for Zimbabwe

Zimbabwe, is a developing country and has a human population close to 14 million, with agriculture-, mining- and wildlife-based tourism as the mainstay of the economy (ZIMSTAT 2012). The Gross Domestic Product (GDP) of the country has been constantly changing from 13% in 2009 to 4.5% in 2018, because of the constant change in national currency, which normally consists of simultaneous circulation of bond notes and a basket of international currencies. Majority of the population (approximately 86% of the people) are unemployed and live on less than one American dollar per day (ZIMSTATS 2012). The country waged a protracted liberation struggle, which intensified from 1972 to 1979. In addition, there were intermittent severe drought periods in 1984 and 1992 to 1994. The combined effects have threatened hippo habitats, reduced hippo recruitment, exacerbated human-hippo conflict, and increased human fatalities (Marshall 2011). However, the threats tend to differ in magnitude and intensity, consequently there is a requirement for a comprehensive review of the risks facing the hippos in a Zimbabwean context.

This review paper explores the ecology, population trends, threats, human-hippo conflict and the opportunities for conservation of hippos in Zimbabwean dams and rivers. The aim was to highlight some aspects of hippo ecology and establish factors affecting its population and conservation with recommendations for future sustainability of the species.

Materials and methods

A dataset of research articles on hippos was compiled from all available databases in the commonly used ISI Web of Knowledge (ISI WoK), with no historical cut off dates. This study explicitly searched for studies focusing on hippos in all subgroups of limnology, water resource conservation and fisheries research, including fishers and the fishing sector with reports on human-wildlife conflicts in Zimbabwe. The terminal search terms used were as follows: (hippopotamuses AND ("human-wildlife conflicts in Zimbabwe*")). The articles were ordered by relevance under ISI Wok search criteria. From an initial list of 213 articles, the abstracts were screened for relevant items that could be classified into four thematic areas; population status of hippos, threats to hippos, human-hippo conflict and conservation options for hippos in Zimbabwe. The rationale was to screen the dataset to manageable and relevant sizes. After thorough screening, a total of 106 items were used to reflect the breadth of the context. An article was included if it met the following criteria: (a) It was published in a reputable journal with a known impact factor and a globally recognised International Standard Serial Number (ISSN number), international organisation technical report or a book; (b) Relevant conference proceedings on Zimbabwean water systems; and, (c) Credible human-wildlife conflict report in the national newspapers or from the National Parks author sanctioned surveys. Finally, recommendations were made from a local to global context.

Results and discussion

Population and country status of hippos

According to the IUCN Red List (2016), there are an estimated 7 000 hippos in Zimbabwean water systems. For

Zimbabwe, hippo population status is categorised as having a restricted distribution and considered as locally abundant (RD-LA) using the IUCN (2016) country data facts. In effect, the trend in hippo population for the country is regarded as stable (IUCN 2012, 2016). However, there is concern about the hippo conservation status in Zimbabwe (Zisadza et al. 2010; IUCN 2016; Utete et al. 2017). This concern arises from the partial protection offered to hippos, because of their highly migratory nature, which implies that they are also found in suitable habitats outside protected reserves (Mackie 1976; Sharp 1984; Marshall 2011). There is partial legal protection of hippos in the country, though the level of legal enforcement is regarded as excellent (IUCN 2016).

On close analysis, such assertions (above) by the IUCN (2016) may be far off the mark, because there has been accelerated human encroachment into riparian ecosystems with loss of palatable grasses and suitable pools (Zisadza et al. 2010). In reality, in the major rivers (e.g. Runde and Save) siltation and altered flow regimes, because of damming and increased water abstraction through irrigation, have resulted in the migration of hippos into the only available reservoirs that are located in national protected areas. National protected areas are mainly premised on reservoirs, and offer some respite for hippos. However, from the onset of the chaotic land reform in 2000, there was human encroachment into protected areas and misuse of reservoirs through pollution and poorly regulated abstraction (Marshall 2011). Combined with climatic factors, such as drought (Cole 1992), this resulted in the loss of water and suitable hippo habitats even in the supposedly protected national parks and dams in Zimbabwe.

Another topical issue relates to the lack of detailed information on hippo conservation status and population trends in water systems outside the reserves or protected areas. Outside the reserves or protected areas, hippos are prone to persecution and poaching and are a key species in human-wildlife conflict in riparian systems in Zimbabwe (Muboko et al. 2016). It is relatively simple to institute traceable conservation and protection measures for hippos in protected areas, but it is a different issue to create and implement effective conservation measures for hippos outside protected areas. The key question then should interrogate the kind of conservation strategies to be crafted and implemented for conserving hippos outside protected reserves. Moreover, to what extent should closely located communities be involved in the conservation of hippos? How hippo conservation awareness programmes may be packaged and transmitted to the communities outside the protected reserves in an effective manner, is a new paradigm that requires a different perspective from traditional hippo conservation strategies that are mainly implemented in protected reserves.

Analysis of available hippo population studies in Zimbabwe

The hippo population in Zimbabwe is stable, whereas the conservation status is categorised as vulnerable (IUCN 2016). However, this IUCN (2016) categorisation of hippo population for Zimbabwe appears to be primarily based on at least twenty seven recorded and available, but fragmented studies on hippo abundance, distribution and population structure that have been undertaken mainly in national protected areas or parks (e. g. Gonarezhou, Hwange, Victoria Falls, Mana Pools, Matusadonha, Victoria Falls and Zambezi Valley in Zimbabwe) (Dunham 2004; IUCN 2016). What this means is that the conservation status of hippos in Zimbabwe is based on a few incoherent records from fragmented populations in a few protected parks and therefore may be limited in its scope. As such, it exposes a requirement for the country and interested wildlife conservation agencies to conduct a coordinated, countrywide, and thorough population estimation of hippos in all water systems in Zimbabwe. The following discussion examines hippo population trends where available in Zimbabwe.

Hippo populations in the Gonarezhou National Park

The distribution of hippo studies in Zimbabwe is shown in Figure 1. It must be pointed out that hippos are present in large water bodies (i. e. rivers and lakes in Zimbabwe) in and outside protected areas though their habitats are dwindling, as a result of a number of factors (Zisadza et al. 2010). In-depth analysis of literature indicated that at least twenty-two hippo population surveys have been conducted for the protected areas, such as Gonarezhou National Park (GNP), focussing on the main rivers, Runde (formerly Lundi), Save and Mwenezi (see Mackie 1973, 1976; Sharp 1984; Zisadza et al. 2010; Chinho et al. 2015). Studies by Mackie (1976) recorded an estimated total of >750 hippos in the Lundi River in the Lowveld region of Zimbabwe. Mackie's (1976) data from the Lundi River (now Runde River) indicated a density of 4.5 hippos km^{-2} in GNP. Considering that the Runde River has a total length of 418 km and only approximately 171 km of the river passes through GNP, an estimated 769 hippos live in the stretch of river covering the protected national park. However, intermediate disturbances, such as siltation and human induced destruction of suitable hippo habitats is rife in the sections of the river inside and outside the protected GNP (see Mackie 1973; Zisadza et al. 2010; Chinho et al. 2015). A simple insight that suggests that protecting suitable habitats is a plausible conservation strategy to maintain a stable hippo population

O'Connor and Campbell (1986) indicated that the hippo population on the Lundi River in GNP increased by 330% between 1958 and 1980 to reach an estimate of >810 hippos. Follow-up studies within GNP by Zisadza et al. (2010) showed a total of 187 hippos mainly confined to the Runde River. Analysis by Zisadza et al. (2010) indicated that the highest and lowest hippo population for the period between 1965 and 2008 in GNP were recorded in 1982 and 1992, with counts of 822 and 27, respectively, although numbers have fluctuated through the period (Figure 2). Close analysis of the trends starting from the study by Mackie (1973), which recorded >750 hippos, to the study by Sharp (1984), which recorded between 810 and 850 hippos in 1980 within GNP, indicate an 8% increase in the hippo population with approximately 60–70 hippos recruited during the period 1973 to 1980.

The period 1973–1979 represents an intense phase in the armed struggle for independence with heavy casualties in human and wildlife in the Lowveld area in Zimbabwe. Accordingly, it is plausible that hippos migrated into the

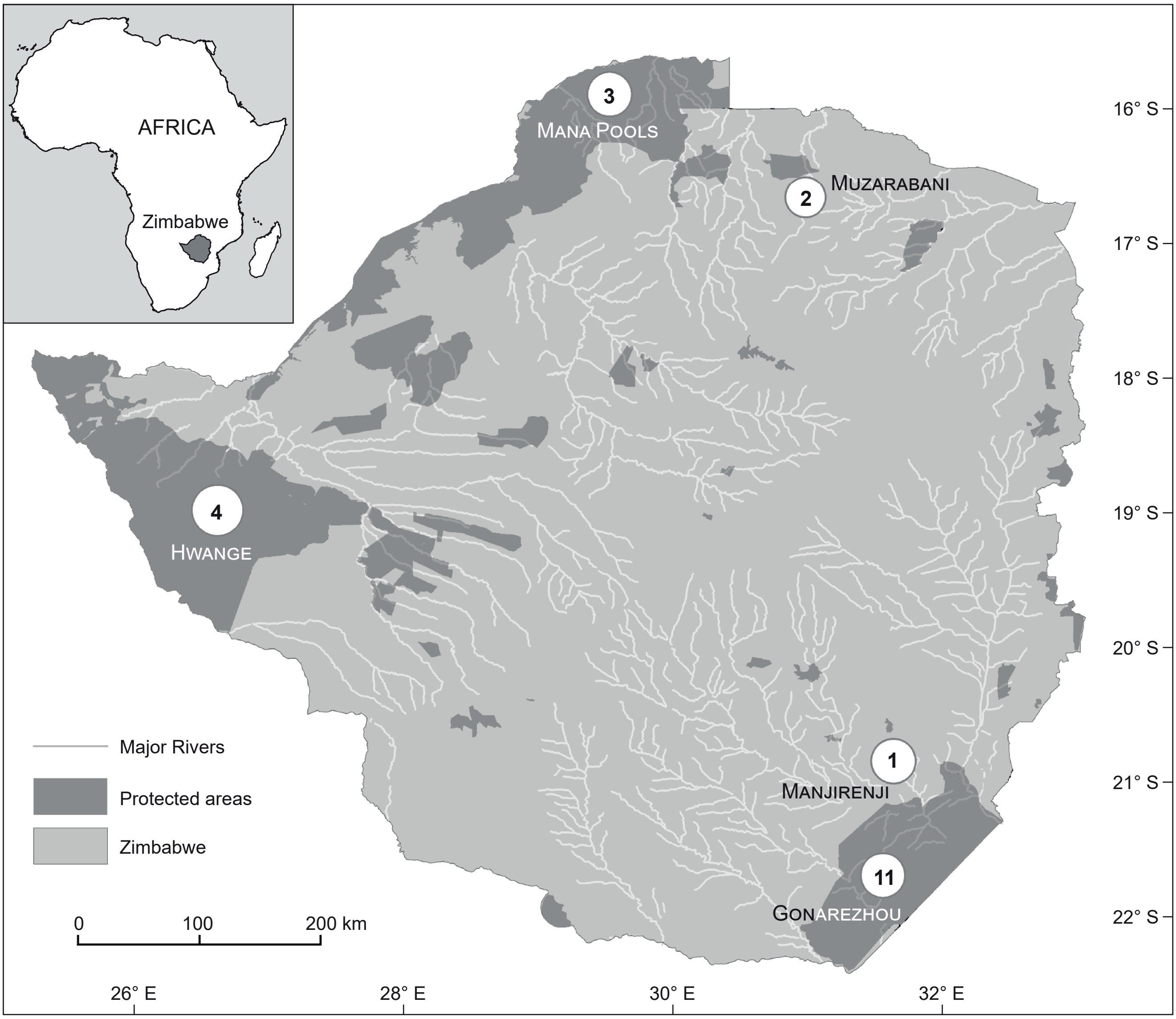

Figure 1: Map showing the numbers and distribution of documented hippo studies in Zimbabwe up to date

more protected GNP to avoid persecution hence the increase in the estimated numbers during this period 1973–1980 (Sharp 1984). However, the fact that only nine (9) hippos were added to the population may be explained by the reproductive ecology of the species. Hippos, as K-selected species, have a gestation period of close to 246 days, and normally start reproducing on average at 6–14 years of age (Erb et al. 2001); factors that may be responsible for the 8% increase in the population over a period of nearly ten years (Laws and Clough 1966; Dudley 1998). For GNP, however, there are no accurate estimates of the real extent of suitable hippo habitats for reproduction and, hence, no accurate carrying capacity estimates that indicate constant survival rates of the adults could be established for the park (Gaillard et al. 1998, 2000). Smuts and Whyte (1981) indicated that there is a positive correlation between the availability of suitable grazing matter, wading habitats, adequate mating space for hippos and recruitment rate in any given wetland disregarding human disturbance. It reflects that there is a necessity to accurately estimate suitable hippo habitats for mating and reproduction in order to accurately estimate the carrying capacity of any given wetland (Linchant et al. 2018).

From 1980 to 1982, the estimated hippo population in GNP slightly decreased from 850 to 822, a decline of 3.4% (Figure 2). In effect, it just shows that the hippo population remained stable from 1980 to 1982 in GNP; with the change in 28 hippos attributable to weather or hippos being out of water at the time of sampling or a number of other factors. Sharp (1984) indicated that human encroachment into GNP by demobilised freedom fighters resulted in a slight reduction in the hippo population mainly attributed to poaching by humans. More pertinently, the two studies by Mackie (1973) and O'Connor and Campbell (1986), used different methods of estimating hippo populations that might explain the subtle differences in the estimates.

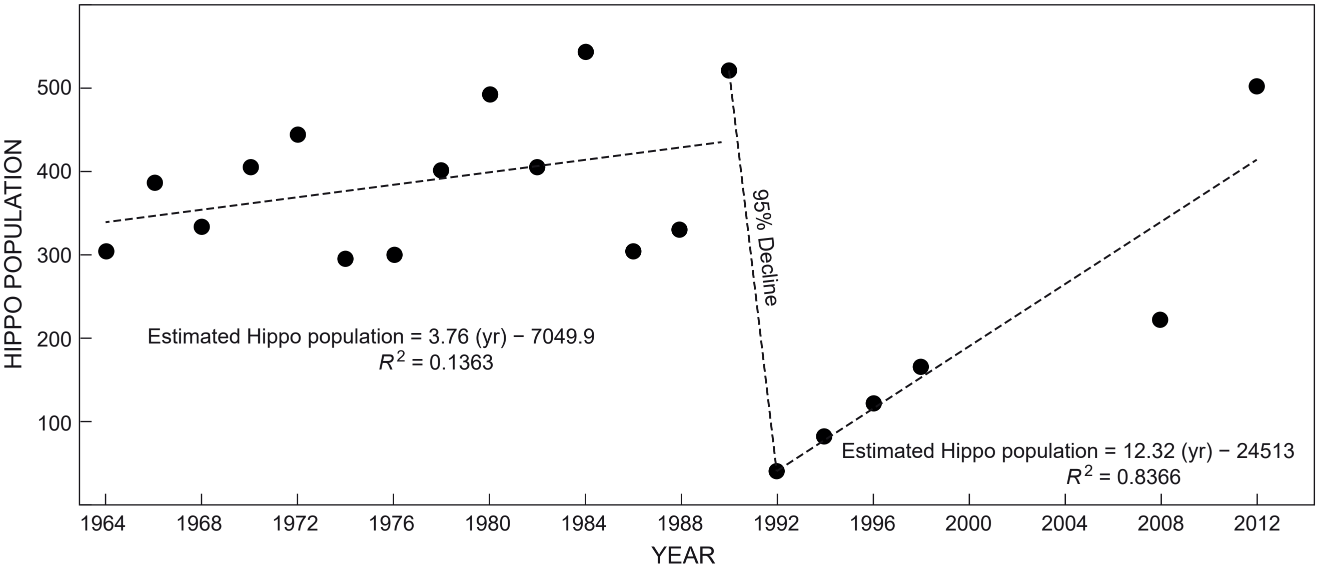

Figure 2: Estimated hippo populations in Runde and other fringe wetlands in the Gonarezhou National Park in Zimbabwe (adapted from Zisadza et al. 2010)

In the period 1982 to 1992, there was a drastic decrease/crash in the hippo population in GNP from 822 to 27 in the Runde-Save confluence, as indicated in Figure 2. The 95% decline in the hippo population within GNP may be explained by the severe drought that occurred in 1984 and 1992, in Zimbabwe (Zisadza et al. 2010). Major rivers, such as the Runde River dried up, and there were no suitable habitats, resulting in massive mortalities of hippos. The data for the period 1982–1992 is based on estimates from anecdotal aerial and land-based, foot-patrol hippo surveys carried out by the Parks Authority in the area (Sharp 1984, 1986; Zisadza et al. 2010). As such the accuracy may be limited though it generally depicts a pattern highlighting severe losses in water volume and permanence of flow in major rivers in these drought years that resulted in massive migration and deaths of hippos. Moreso, the most feasible conservation strategies, such as artificial riverbed drilling and translocation of hippos were constrained by lack of resources, which were mainly channelled towards saving human lives and livestock (Sharp 1984; Mazvimavi 2010).

Hippo estimates from the period 1992 (n = 27) to 2008 (n = 187) in GNP indicated that the hippo population recovered and is steadily growing (Zisadza et al. 2010; Chinho et al. 2015). This is expected, because the successive years from 1992 had reasonable to above normal rainfall levels, which enabled suitable hippo habitats and palatable riparian grass to reestablish and consequently hippo recruitment has been on the increase (Zisadza et al. 2010). From the estimates in 2008 (n = 187) to 2012 (n = 337), the hippo population in GNP has been increasing (see Figure 2). Using the hippo population in 1992 as the base for reestablishment, there has been a 1296% increase in hippo numbers in GNP for the period 1992–2012. The increase in the hippo population within GNP also indicates that the species is resilient enough to adapt to the prevailing conditions such that if the environment is conducive the population quickly bounces back from crashes or declines similar to those induced by droughts (Smuts and Whyte 1981; Owen-Smith 1992, Clauss et al. 2004, 2013).

The key drivers to the increase in the hippo population in the period 2008–2012 comprise intensification of anti-poaching patrols in the rivers in GNP, and normal to above normal rainfall levels in the period 2008–2012, which ensured establishment of permanent suitable hippo habitats and availability of palatable grass (Mazvimavi 2010; Zisadza et al. 2010; Gandiwa et al. 2013; 2014; Chinho et al. 2015; Mhuriro-Mashapa et al. 2018; Matseketsa et al. 2018). Of note is that the annual variation in hippo numbers for the different protected areas in Zimbabwe are as a result of the different sampling techniques, but the overall trend can still be useful. This suggests a strong case for implementing suitable sampling techniques that are reproducible in hippo censuses.

Hippo population estimates in Manjirenji Dam in Zimbabwe

Some fragmented hippo population surveys have been done in Manjirenji Dam along the Chiredzi River (Utete et al. 2017). This survey indicated at most 177 hippos over an eight months study period in the manufactured reservoir (Utete et al. 2017). The study was a once off survey and does not provide long-term temporal trends in the hippo population of the Manjirenji Dam although the estimation could be useful in calculating the national hippo population. The boat survey also indicated the suitability of protected national dams, such as Manjirenji to provide habitats and support a sizeable hippo population (Utete et al. 2017). More pertinently, the study established that hippos tend to move to the deepest parts of the reservoir during daylight and track into adjacent communities to graze, potentially clashing with humans and livestock at night (Utete et al. 2017). Additionally, hippo pods migrate into the entrance point of the tributary Chiredzi River during periods of intense drawdowns especially droughts. This implies that hippos also move out of the protected reservoir to look for suitable grass and pools, and become prone to human persecution and poaching (Matseketsa et al. 2018). It is imperative then to estimate the population and explore plausible conservation strategies for hippos when they are outside protected reservoirs.

Hippo population counts in the Zambezi Valley region in Zimbabwe

An aerial survey initiated by the African Wildlife Foundation (AWF) led by Dunham (2004) recorded a total of 825 hippos out of the estimated national figure of 4 751 hippos in the Zambezi Valley region of Zimbabwe. Dunham (2004) indicated that the Mana Pools National Park, a UNESCO Biosphere Reserve, has the largest concentration of hippos in the country with actual observed figures of 458 hippos. The same study (Dunham 2004) in the Zambezi Heartland of Zimbabwe found substantial hippo populations in Hurungwe Safari Area (234), Sapi Safari Area (95), Chewore Safari Area (4), Charara Safari Area (30) and Dande Safari Area and Guruve Communal lands (4). Trend analysis from the long-term annual surveys of hippos in Hwange National Park (HNP) indicated a sustained increase from 1972 to 2019 (Figure 3). The highest numbers of hippos (i. e. 154 and 163) were recorded in 2016 and 2019, respectively, whereas the fewest (i. e. 6) were recorded in 1986 (Figure 3). The low hippo numbers observed is expected as the area is very arid such that artificial water pumps had to be installed to provide adequate water in the pans for the animals to survive (Msiteli-Shumba et al. 2017). Naturally, this limits the availability of suitable hippo habitats (Chinho et al. 2015). Overall, the significant increase in hippo numbers over the years in the highly arid, largest, national park (HNP) in Zimbabwe is attributable to the increased installation of artificial water pumps in the pans and pools (Msiteli-Shumba et al. 2017; WEZ 2018).

The most complex issue in estimating hippo numbers and subsequent calculation of the national population in Zimbabwe has been the uncoordinated use of different methods and techniques comprising aerial-, boat- and foot-based surveying methods. In the aerial (and even boat) hippo surveys, there is an element of underestimation, because of the nature of surveying by aerocraft, which tends to disturb hippos (Linchant et al. 2018). After disturbance, hippos react by submerging and migrating underwater for longer distances before emerging at another site, resulting in either underestimation or double counting of the animals (Tembo 1987; Zisadza et al. 2010; Linchant et al. 2018). Moreso, aerial surveys do not readily provide the social structure of hippos, but merely estimates numbers (Linchant et al. 2018). Use of land patrols has limitations, which include low spatial coverage, and they are tedious, costly and expose enumerators to danger from the species especially during the calving stages (Linchant et al. 2018). This then suggests that more comprehensive hippo surveys must combine methods, such as aerial survey, foot- (land-) and boat-based surveys to get adequate information on hippo pods. Currently, unmanned aerial vehicles (UAV) or drones are used to monitor hippo pods temporally and over a large geographical range, although

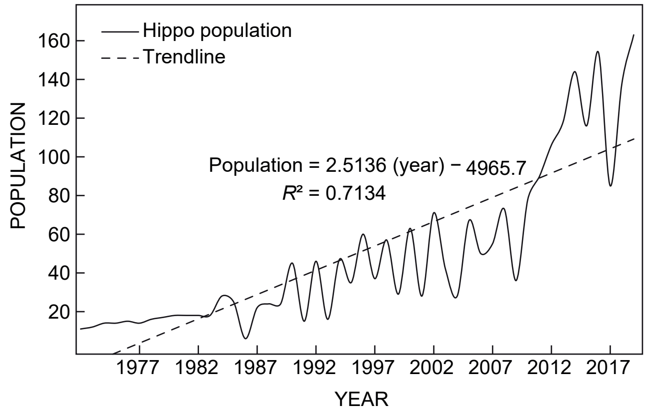

Figure 3: Estimated hippo populations in Hwange National Park in Zimbabwe (source WEZ 2018)

the expense and expertise required for this method may limit its applicability in developing countries, such as Zimbabwe (Linchant et al. 2018).

The exact figures on hippo populations for Mana Pools and other large water systems, including Lakes Kariba, Mutirikwi, the newly constructed Tokwe-Murkosi, Sebakwe, Osborne, Mazvikadei, Manyame and Manjirenji among others are not readily available from the Parks authorities (ZIMPARKS 2012). The little available data mainly from surveys in the GNP, HNP and Mana Pools National Parks and Manjirenji Dam point to a severe decline in hippo populations, with current reestablishment of hippo numbers underway in some of the parks (Zisadza et al. 2010; Utete et al. 2017).

Threats to hippos in Zimbabwe

Analysis of literature within freshwater systems of Zimbabwe indicated that hippos face ongoing multiple threats to their habitats and existence. The threats and severity have been summarised in Table 1. Before political independence in 1980, human intrusion and disturbance characterised by war of liberation, civil unrest and military exercises threatened the existence of hippos especially in remote areas like Mana Pools, GNP and HNP (Mackie 1976). At independence, the proliferation of residential and commercial development mainly in urban and peri-urban areas, resulted in massive encroachment into wetlands, lakes, rivers, ponds and national protected areas degrading, silting and polluting many freshwater systems (Wekwete 1992; Cumming 2011; Marshall 2011). In between, there were massive drought periods like 1984 and 1992 to 1994 (ZIMSTATS 2012), which reduced available hippo habitats. The land reform program of 2000–2002 also resulted in encroachment into wildlife areas (Cumming 2011).

Rapid expansion of settlements, especially urban and peri-urban encroachment, threatens the existence, quality, integrity and ecosystem services of lakes and rivers (Wekwete 1992; Munzwa and Jonga 2010; Nyandoro and Muzorewa 2017). Climate change, expressed mainly through erratic rainfall, high atmospheric temperatures and surface evapotranspiration influences water storage capacity of the freshwater systems in Zimbabwe (Jury

Table 1: Threats facing hippos ranked in order of severity with corresponding evidence in Zimbabwe

Rank	Threat	Literature evidence	Data quality	Demonstrated impact
1	Habitat degradation	Mackie (1976), O'Connor and Campbell (1986), Zisadza et al. (2010)	Qualitative	Suitable hippo habitats destroyed
2	Poaching	Sharp (1984), Gandiwa et al. (2012), Muboko et al. (2014). Matseketsa et al. (2018).	Quantitative	Hippo numbers decrease
3	Damming	Marshall (2011)	Quantitative	Suitable riverine hippo pools destroyed and converted
4	Agriculture	Mazvimavi (2010), Marshall (2011)	Quantitative	Water abstraction reduce water volume and flow regimes
5	Settlement/ encroachment	Zisadza et al. (2010), Cummins (2007), Cumming (2011), Chinho et al. (2015)	Quantitative	Habitat degradation and poaching
6	Drought	Sharp (1984), Zisadza et al. (2010)	Quantitative and qualitative	Hippo habitats reduced. Hippo mortality increased
7	Poisoning	Muboko et al. (2014)	Quantitative	Hippo mortality increased
8	Culling	Gandiwa et al. (2012). Matseketsa et al. (2018)	Quantitative	Hippos numbers decreased
9	War (Armed conflict)	Mackie (1976), Sharp (1984)	Quantitative	Hippo mortality increased
10	Aquaculture	Marshall (2011)	Qualitative	Hippos displaced by cages

2012; Masimba 2016; Nyarumbu and Magadza 2016; Marshall 2017; Utete et al. 2018). Wildlife rich areas are threatened by poaching of trophy species, such as elephants, rhinos, pangolins and lately hippos, giraffes, fish and bird eggs (Groom et al. 2013; Gandiwa et al. 2014; Muboko et al. 2014; 2016). The interactive effects of socio-economic activities, poaching and climate change threatens biodiversity in water systems of Zimbabwe (Kupika et al. 2017; Utete et al. 2018).

This has resulted in migration of hippos to suitable habitats and reduced recruitment, slowing hippo population increases (Sharp 1984; Zisadza et al. 2010). Increased dam construction in response to increased irrigation water demands caused modification of river systems reducing suitable hippo pools (Marshall 2011). In as much as the dams and lakes provide a viable habitat for hippos, competing water interests, such as abstraction for irrigation, domestic, industrial use, and recreation in lakes and dams pose a threat to hippos through erratic water level fluctuations (Utete et al. 2017, 2018). Natural modification of the freshwater and peripheral systems through climate change and severe weather patterns like drought, high evapotranspiration, wind speed and low humidity results in reduction in water levels, water quality and herbage for hippos (Mugangu and Hunter 1992; Timbuka 2012; Utete et al. 2017). High temperatures pose a threat to hippo skin, which has a very thin epidermis and lacks sweat glands and sebaceous glands, therefore allowing quick evaporation of water, which can cause severe dehydration to the animal, resulting in death (Estes 1992).

Currently, the biological resource uses, such as legal and illegal hunting, and poaching and illegal trade for hippo meat, skin and teeth, as well as deliberate culling, as part of problem hippo control (PHC) affect hippo populations in Zimbabwe (Gandiwa et al. 2012, 2013; Matseketsa et al. 2018). Agricultural activities tend to reduce forests, degrade wetlands and leach pollutants into water bodies and result in abstraction of water resources (Utete et al. 2018). These result in aquatic habitat degradation and displacement of hippos (Mackie 1976; Sharp 1984; Zisadza et al. 2010). Aquaculture involving cages, dredging, netting, and use of poison may affect the habitat integrity for hippo proliferation in some water bodies (e. g. Lakes Kariba, Chivero, Manyame and Mutirikwi) in Zimbabwe (Marshall 2011). Although it must be pointed out that no studies have shown the cause-effect relation between aquaculture and hippo habitat integrity in water bodies of Zimbabwe. Moreso, in Zimbabwe, to date, data on hippo poaching and subsequent illegal trade of hippo products to local, regional and international cartels are scarce, and in most cases tend to be too fragmented to provide insight into the threats facing the species. This hampers conservation efforts towards sustainable exploitation of hippos (Gandiwa et al. 2013; Gandiwa 2014).

Human-hippo conflicts in Zimbabwe

Hippos are facing multiple pressures in Zimbabwe, however, the species receives a lot of attention in relation to human-hippo conflicts (Zisadza et al. 2010; Gandiwa et al. 2013; Zisadza-Gandiwa et al. 2013; Chinho et al. 2015; Utete et al. 2017). In most cases, human fatalities are recorded and reported in national media outlets, whereas hippo fatalities caused by humans rarely receive attention (Gandiwa and Gandiwa 2012; Gandiwa et al. 2013). This results in a one-dimensional perspective portraying hippos as a destructive species, because it feeds on crops and harms humans (Gandiwa 2012). Accordingly, there is a requirement for a comprehensive review of the ecological significance of hippos, offset by their destructive activities in peripheral communities around lakes and rivers in Zimbabwe (Chinho et al. 2015).

Hippos differ from other grazing megaherbivores, because they have a diurnal feeding ecology and space requirement characterised by day wallowing and littoral shoreline grazing, and nocturnal far open range grazing (Eltringham 1999; Timbuka 2012). The nocturnal, far open range grazing nature of the species entails encroachment into agricultural lands, forestry, open wooded lands and grasslands (Nyirenda et al. 2011). This inevitably results in utilisation of resources in human dominated areas or settlements, and two-way confrontations or hostilities between humans and hippos, termed human-hippo conflicts, frequently occur (Kanga et al. 2011, 2012; Spinage 2012). For this reason, many researchers indicated that hippos are a conflict species, occasionally attacking people and damaging crops near aquatic habitats (Mkanda 1994; Dunham et al. 2010; Kendall 2011; Gandiwa et al. 2013). In Zimbabwe, several human–wildlife conflict reports frequently indicate crocodiles, lions, buffaloes, elephants and hippos as the main mammal protagonists of conflict (Dunham et al. 2010; Gandiwa et al. 2013; Muboko et al. 2016; Matseketsa et al. 2018).

As a result, hippos, have received negative attention (Timbuka 2012). However, like most other hippo range states in Africa (Mkanda 1994; Kanga et al. 2012), Zimbabwe has done little to evaluate the type, extent and consequences of human–hippo conflicts, even though local communities report numerous complaints on hippo damage (Gandiwa et al. 2013; Muboko et al. 2016; Matseketsa et al. 2018). The detailed reports, which are mostly highlighted in national newspapers tend to be lopsided, because they only show the extent of the damage to crop and human fatalities caused by hippos. In most cases, the same reports mostly do not indicate the fate of hippos even in peculiar circumstances where humans are attacked, while fishing, bathing or doing laundry in hippo territory or when trying to poach hippos. However, an online article on News24 (2017) reported on the deaths of hippos in Mlibizi District in Binga along the Zambezi River, a transboundary river between Zambia and Zimbabwe. It highlighted the suspected causes of hippo deaths, which included, among others, suspected mercury poisoning by poachers or nearby villagers starved of meat. The report also suspected some epizootic disease/s. Hungry villagers in the area were feeding on the carcasses. This sensational reporting provides an example of the imbalanced nature and skewedness of reports on human-hippo interaction in some popular literature in Zimbabwe.

Wildlife interactions are termed conflicts, because of the negativity associated with the wildlife-human encounters (Cumming 2011). In Zimbabwe, most human-hippo conflicts are reported in newspapers with a negative tone, and the official data are not readily available from parks authorities. This has resulted in persecution of hippos, which poses a threat to the population status of the species (Dunham et al. 2010; Zisadza et al. 2010; Gandiwa 2013; Chinho et al. 2015). Examination of human–hippo conflict literature indicates that there is no explicit definition of human-hippo interaction, the impact of the interaction and the different interests of the humans and hippos (Cumming 2011). What this suggests is that the antagonists in human-hippo conflict have to be specifically identified and their interests and roles defined in order to deliver long-term solutions for the benefit of hippo populations and human communities (Matseketsa et al. 2018). This additionally implies that conservation of aquatic resources, such as hippos and suitable habitats, should not only seek technical solutions to deal with the impacts, but consider hippo ecology, habitat dynamics in the water and adjacent terrestrial ecosystems for both protected and unprotected areas, as well as establish the perceptions and attitudes of surrounding communities towards hippos (Cumming 2011; Gandiwa et al. 2012; Matseketsa et al. 2018). Consequently, the different livelihood strategies, such as fishing, irrigation, tourism and water-based recreation, which interact and interfere with hippos, have to be integrated as part of long-term conservation efforts (Zisadza et al. 2010; Chinho et al. 2015).

Conservation and sustainable options for hippos in Zimbabwe

Conservation of hippos, a charismatic member of the continent's megafauna, is a major goal of local and international conservation groups (IUCN 2016). In that respect, several conservation organisations have initiated numerous hippo surveys especially in areas where the populations are under severe threat (Lewison 1998, 2007, 2011). The key idea for hippo conservation as an ecosystem engineer, is based on the concept of holistic conservation, which not only involves hippo ecology, but its environment, as well as its interaction with humans (Lewison 2011, Kanga et al. 2012; Timbuka 2012). Figure 4 represents a schematic framework summarising the interlinked conservation measures that have been and can also be applied in future to sustain hippo populations in Zimbabwe. So far a combined approach has been implemented to understand the ecological and socio-economic factors, as well as cultural factors affecting the distribution, population and hippo ecology in freshwater systems of Zimbabwe (Mackie 1976; Gandiwa et al. 2013). In as much as concerted efforts to protect hippos have included ring fencing national parks, and increasing law enforcement patrols in protected dams and lakes, the highly migratory nature of the species renders it vulnerable to poaching, hunting and persecution in Zimbabwe (Mackie 1973; Dunham 2004; Zisadza et al. 2010; Utete et al. 2017).

Poaching is rife in Zimbabwean water systems especially outside protected reserves (Matseketsa et al. 2018). In a majority of cases, the poachers use poison, such as cyanide to kill hippos and target the tusks for sale (Gandiwa et al. 2012; Muboko et al. 2016). This has the net effect of reducing hippo populations and degrading hippo habitats and killing other hydrobionts in the affected area, as a result of the residual toxicity of the cyanide (Muboko et al. 2016). Conversely, trophy hunting of hippos, which is the shooting of carefully selected hippos under official government licence, for pleasure, results in regulated or carefully monitored hippo population decreases in water systems of Zimbabwe (Matseketsa et al. 2018). Subsistence hunting where humans hunt strictly to provide food for themselves and their families has been limited for hippos in Zimbabwe, because of the strict restrictions and regulations on wildlife hunting (Gandiwa et al. 2012). Legal hunting, which is the regularised or authorised hunting of hippos is done as part of culling, as a problem-hippo control measure or for the provision of meat rations for the well-being of the Parks officials (Matseketsa et al. 2018). These conservation measures, particularly trophy, legal

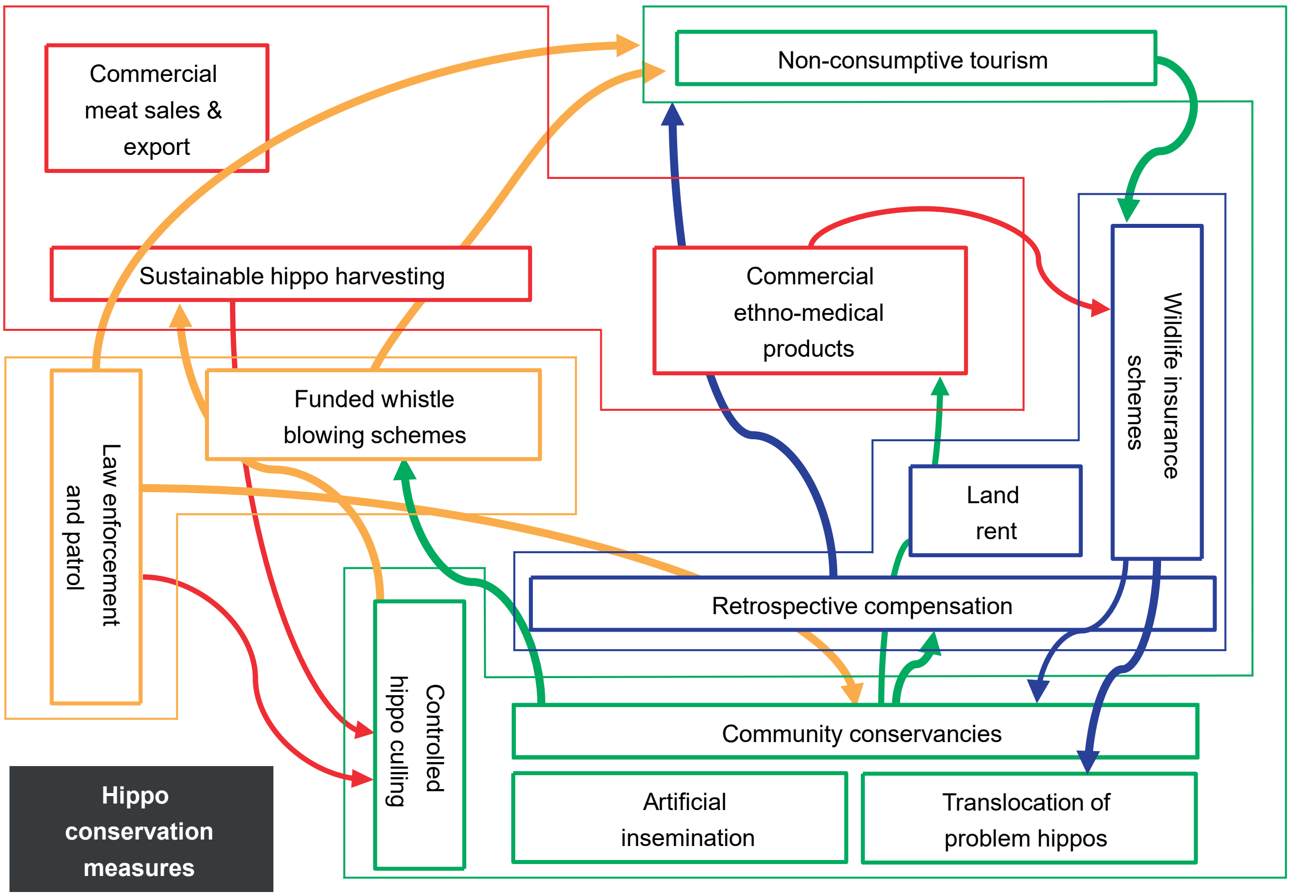

Figure 4: Conservation measures applicable for hippos in Zimbabwe, Africa and the global entirety

and regulated hunting, have the net effect of reducing hippo populations in water systems of Zimbabwe, in as much as the intention is to control hippo populations in aquatic systems. The gradual increases in hippo numbers observed in certain protected areas, such as HNP and GNP, from 1992 onwards in this study suggest limiting hunting, until suitable population estimates have been obtained for areas where hunting occurs and no population data exist, as a viable management option in Zimbabwe.

Additional efforts the authorities could adopt to enhance hippo conservation in Zimbabwe include integration of indigenous knowledge traditions of the freshwater systems and hippo and human coexistence with modern technologies, such as real time GIS and remote sensing of habitat suitability and monitoring of the hippo populations in the water systems (Utete et al. 2017). A viable option would be to undertake a simultaneous hippo and hippo habitat conservation and education awareness of adjacent communities (Cumming 2011; Matseketsa et al. 2018). Moreso, as advocated by Zisadza et al. (2010) and Chinho et al. (2015) there is a requirement for regular, cyclic and well-coordinated national hippo surveys for updating the database and establishing the true population and conservation status of the species. This must be supported by astute recording and archiving of balanced and detailed reports on human-hippo conflicts in the nation. Globally and locally, there is a genuine requirement for formal compensation and benefit-sharing schemes from hippo related products especially for peripheral communities who are the most vulnerable to hippo attacks (Timbuka 2012; Muboko et al. 2014).

Affordable wildlife insurance schemes and provision of land rents for residents and farmers living close to wildlife rich areas may be initiated to fund retrospective and prospective compensation in the event of hippo and other wildlife attacks in Zimbabwe (Cumming 2011). Translocation of problem hippo is another viable option to minimise conflicts with adjacent communities although it is expensive (Kanga et al. 2012; Muboko et al. 2014). Community conservancy schemes are an initiative that have been tried in Zimbabwe, but have yielded no tangible benefits to adjacent communities and appear to work more favourably for large terrestrial mammals, such as elephants, but not hippos (Gandiwa et al. 2013).

Innovative utilisation of hippo products, such as meat for biltong, and milk mimics for medicinal purposes (Saikawa et al. 2004; Hashimoto et al. 2007) can be beneficial to the country. Large-scale commercial breeding using artificial insemination in protected areas can be a functional solution to increase hippo population and enhance non-consumptive tourism, which generates foreign currency (Saikawa et al. 2004). It is noteworthy that breeding can only work if the threats or activities, such as water abstraction, pollution, poisoning, and poaching that degrade, and destroy suitable hippo habitats and reduce hippo populations, are addressed. Breeding programs can be viable only if there are concerted efforts to track the population trends of hippos, a task that demands resources, is limited to mostly protected areas, and would not be effective outside protected water systems. In areas where hippo population declines have been seen, it might not be necessary to encourage hippo breeding, because this exercise is costly and risky. However, for dams located in private conservancies, breeding programs may be an alternative method to increase hippo populations, as long as the capital input is offset by consumptive and non-consumptive benefits.

Research priorities for hippos in Zimbabwe

This review identified some pertinent, but not exhaustive, research priorities for hippo conservation. Firstly, it is a prerequisite to establish, qualitatively and quantitatively, the impact of illegal hunting or poaching on hippo population stability and trends in rivers and lakes in Zimbabwe. Secondly, research has to be intensified into the accurate estimation of the rates of land-use and land cover pattern changes near hippo subpopulations in and outside protected reserves in the country, in order to formulate effective and long-term hippo conservation strategies. Currently, there is an urgent requirement for understanding the effect of climate change on hippo populations, distribution and loss of suitable hippo areas of occupancy. With a shift in human demography and settlement encroachment, a research priority entails exploring the effects of siltation and sedimentation of hippo pools and declining water quality on the dynamics and distribution of this bioengineering species. In summary this literature review prioritises the main areas for additional research, which include the necessity to:

1. Gain an understanding and development of a functional model for the prediction of hippo population dynamics.
2. Understand the social structure and interactions between hippos and other hydrobionts.
3. Describe the impacts of hippos on the environment in their role as bioengineers.
4. Determine the carrying capacity for the population, and what the consequences will be if this is exceeded in protected (and even for unprotected) water systems.
5. Gain an understanding of human-hippo interactions, both from the aspect of crop-damage, human injuries and fatality, hippo mortality and injuries, and for ecotourism.

The hippo population in Zimbabwe is no doubt under severe threat from a plethora of interactive factors, and accordingly concerted and astute conservation measures are required to guarantee the sustainability of the species (Zisadza-Gandiwa et al. 2013; Utete et al. 2017). Broadly, human-hippo conflicts in Zimbabwe cannot be entirely eliminated, but can be mitigated by prohibiting agricultural and industrial, as well as mining activities in protected areas, wildlife migration corridors, riparian and littoral shoreline zones of freshwater systems (Cumming 2011). Urban and peri-urban encroachment on lands bordering riparian habitats must be avoided at all costs, because the areas serve as grazing pastures for hippos and spawning habitats for other aquatic species like fish and wetland birds (Marshall 2011). It is essential to promote sustainable use of water systems, including through wildlife conservation, and maximising the ecosystem and economic value obtained from hippos with the overall goal of enhancing human wellbeing. Besides the deleterious human-hippo conflicts, creative and innovative utilisation of the hippo and its products in the freshwater ecosystem has the potential to make it a keystone, charismatic and iconic species.

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