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AQUACULTURE IMPACT ON POPULATION DYNAMICS OF KOLLERU WILDLIFE SANCTUARY, ANDHRA PRADESH, INDIA

Kakani Nageswara Rao
G. Demudu
B. Hema Malini

Abstract

Kolleru Lake, the largest coastal freshwater wetland in India and a wildlife sanctuary is severely degraded in recent decades due to burgeoning commercial aquaculture. Time series satellite imageries revealed spread of aquaculture encroachments from 10.73 per cent of the total area in 1990 to 47.08 per cent by 2004 in the Kolleru Wildlife Sanctuary (KWS). The demolition of fishponds in KWS by the government in 2005 reduced the aquaculture activity to 28.85 per cent area in its periphery by 2006, but revived to cover 49.77 per cent area by 2017. The temporal changes in aquaculture are correlated with population trends in KWS. The Census data indicated that KWS population increased by 37.40 per cent during 1981-2001 as the aquaculture increased, but during the following decade of 2001–2011 the population decreased (-1.18 per cent) with the decline in aquaculture. However, the scheduled caste (SC) and scheduled tribe (ST) population in KWS increased by 14.53 per cent during 2001-2011, while the population of other categories decreased (-6.68 per cent) perhaps due to increased numbers of farm labourers (mainly SC and ST), while the small farmers (mainly other categories) emigrated as their landholdings were amalgamated into large corporate-scale fishponds.

Introduction

Coastal wetlands are shallow water bodies and muddy expanses such as tidal mudflats, mangrove swamps, salt marshes, peat bogs, lagoons and lakes in the low-lying coastal zones. Coastal wetlands sustain large population engaged in conservative, self-sustaining, subsistence economic activities of capture fishery, cattle grazing, and firewood, honey and shell collection (Pan and Wang, 2009; Msusa, 2011; Turyahabwe et al., 2013; Jankowski et al., 2017). Most of the coastal wetlands are either salt or brackish water bodies as they are located close to the seashore in the intertidal zones under the influence of regular tides. However, some of the coastal wetlands that occupy local topographic depressions, especially along the prograding (advancing seaward) coasts experience diminishing influence of tides with time and hence turn into freshwater bodies with inputs from inland streams. Kolleru Lake, the largest freshwater body along the east coast of India is one of such freshwater wetlands. Considering its ecosystem services as a flood-balancing reservoir, a haven for a variety of migratory and resident birds, and a source of livelihood for thousands of traditional fishermen and farming

communities, Kolleru Lake covering an area of 910 km^2 has been designated as a wetland of international significance under Ramsar Convention (Nageswara Rao et al., 2004; Bhattacharya et al., 2013). A number of geomorphological studies have been done on the evolution and environmental degradation of Kolleru Lake. Mapping of landforms such as series of relict sandy beach ridges (each representing a former shoreline position) in the 30-km-wide coastal belt between the Kolleru Lake and the present shoreline, and pollen analysis, which revealed an abundant mangrove pollen in the lakebed sediments supported by radiocarbon dating, indicated that the Kolleru Lake was originated around 6000 years ago as a coastal lagoon and was occupying about 1050 km^2 area in the intertidal zone (Nageswara Rao, 1985; Sadakata et al., 1998; Bhattacharya et al., 2013; Naga Kumar et al., 2016). However, the lake has turned into a freshwater body with time as the tidal influence diminished due to the seaward advancement of the shoreline by 30 km, and continued freshwater inputs through several rivulets and drains discharging into the lake. In spite of silting up over the past six millennia, the lake continues to exist and remain capacious although its area has shrunk to about 245 km^2 as measured from the topographic maps from 1930s (Nageswara Rao et al., 2004). However, the human activities in just a few recent decades have almost completely defaced the Kolleru Lake. Several studies were also conducted on the extant conditions of the lake which showed that large-scale encroachments for aquaculture, degraded the lake ecosystem during the past four decades, as the 2-3 m high embankments around hundreds of fishponds have compartmentalised almost half of the lake area (Nageswara Rao et al., 2004; 2010; Naga Kumar et al., 2016). Moreover, the urban sewage, and industrial and agricultural effluents are polluting the lake leading to weed infestation (Nageswara Rao et al., 2004; Adhikari et al., 2009) and increased concentration of toxic metals in the lake waters and sediments as well as the fish grown in it (Chandra Sekhar et al., 2004; Das Sharma and Sujatha, 2016). Traditionally, the main occupation of the people is capture fishery and duck-rearing in the Kolleru lakebed villages, whereas paddy cultivation is practised in the border villages. Besides, significant alternations of the lake's physical environment, the burgeoning growth of corporate-scale culture fishery in the Kolleru Lake and pollution of water and soil resources have impacted the socio-economic and livelihood conditions of the indigenous population. However, no studies are available on the demographic and socio-economic ramifications of the changing face of the Kolleru Lake ecosystem. This study therefore is an attempt in this direction.

Objectives of the study

Major objectives of the present study are:

- to analyse the temporal trends in aquaculture and population in the Kolleru Lake region; and
- to understand the impact of commercial aquaculture on the population dynamics.

Study Area

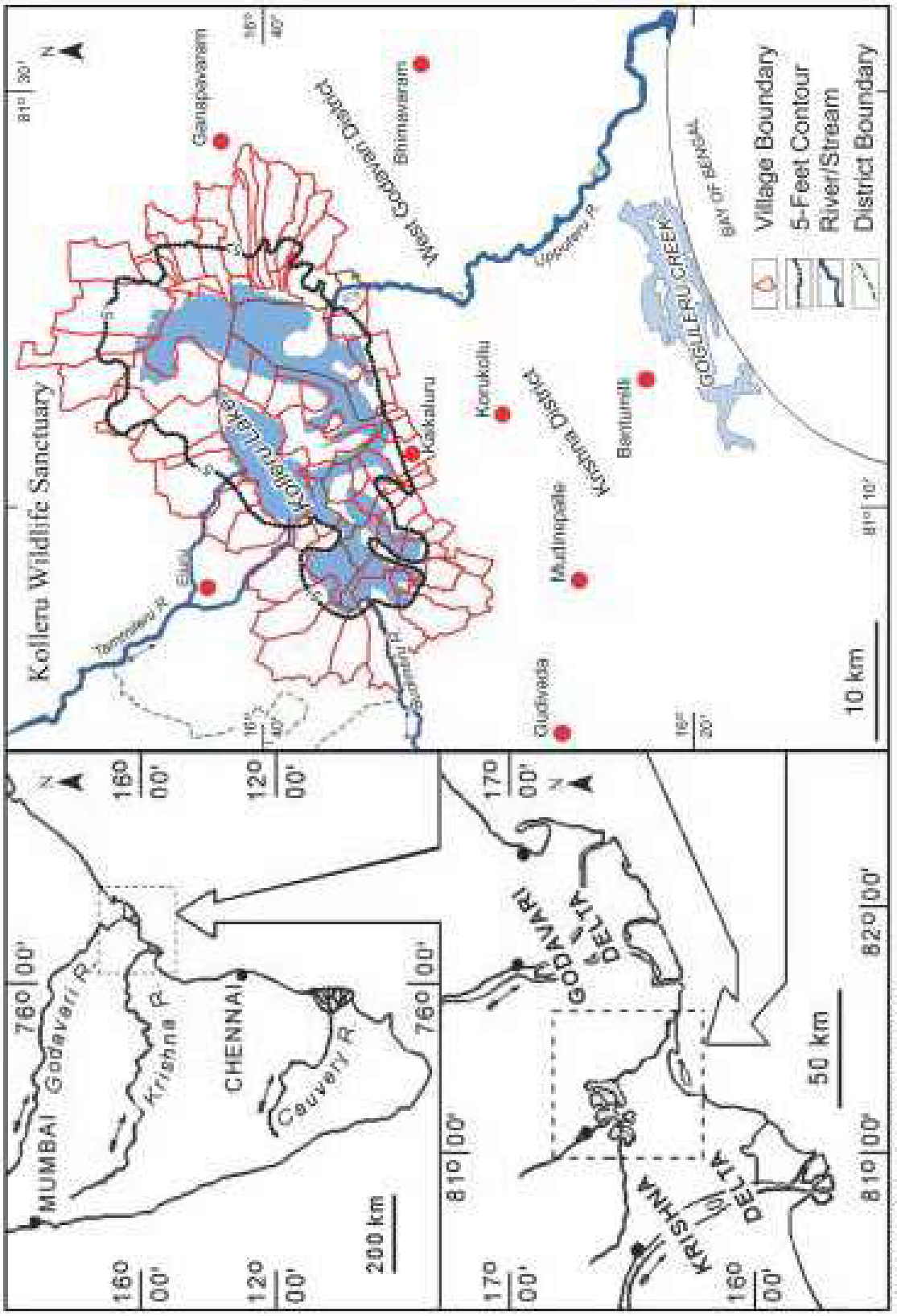
The Kolleru Lake is situated in a low-lying coastal setting between the Krishna and Godavari deltas along the east coast of India in Andhra Pradesh (AP). The lake being a shallow water body, with its depth ranging from 0.5 m to about 2.0 m, appears more like a muddy wetland with many inhabited islands in between. The Lake's water-spread area fluctuates seasonally. It occupies more than 300

km^2 during monsoon but, in summer, most of it dries out leaving only a few patches of weed-infested shallow water pools. Although the lake is located at about 30 km inland from the sea, it is connected to the Bay of Bengal through a 60-km-long intricately meandering tidal channel, which is locally called Upputeru River (Fig. 1). Several ephemeral streams including Tammileru and Budimeru rivers draining a combined catchment of about 6100 km^2 decant freshwater into the Lake. However, during high tide, seawater enters the lake through Upputeru River since some parts of the lake bed are below the sea level. In 1999, the AP government designated this important coastal wetland as Kolleru Wildlife Sanctuary (KWS) up to the 5-feet (~1.5 m) contour (black dotted line in Fig. 1), covering an area of about 493 km^2.

There are about 70 villages in the KWS area of which one is uninhabited and two are exclusively water bodies. The population of the 67 inhabited villages in the area is 2,60,945 persons (Census of India, 2011). The entire area of the 70 revenue villages (including the one uninhabited and two water bodies) is spreading in two districts- Krishna district to the west and West Godavari district to the east. The boundary between these two districts (green dashed line in Fig. 1) runs almost along the Upputeru River and across the Kolleru Lake. It may be noted that the boundaries of many of the 70 villages (red solid lines in Fig. 1) are partly within the 5-feet contour (i.e., within KWS) and partly beyond (Fig. 1). As the present investigation involves a comparison of temporal trends in aquaculture and population, the entire 915 km^2 area covered by the 70 villages is considered in this study for mapping of the aquaculture extent as well as the analysis of population. This area is approximately similar to the Ramsar designated Kolleru wetland area (910 km^2). In the present study, the entire 915 km^2 area encompassing 70 villages is referred to as KWS for brevity.

Database and Methodology

Time series satellite imageries were used to map the temporal trends in aquaculture spread in the KWS. For this purpose, Landsat MSS (1977); Landsat TM (1990); Indian Remote Sensing Satellite (IRS) LISS III (2004); IRS AWiFS (2006); IRS LISS IV (2012) and Landsat OLI TIRS (2017) images were analysed. All the FCC (false colour composite) images were geo-referenced by co-registering the selected ground control points that were prominently identified from the images as well as the Survey of India topographic maps of the area and brought them to a common geographic coordinate system, which helped in comparing them with one another for estimating the areas and temporal changes in the land use/land cover including the aquaculture encroachments. The map showing the various contours around the Kolleru Lake region generated in 1966 by the AP Irrigation Department was also geo-referenced and the 5-feet (~1.5 m) contour was extracted from this map using the onscreen digitisation process and then overlaid on all the satellite images. Similarly, the village boundary maps available in geo-referenced format from the AP Space Applications Centre were also overlaid on the satellite images. Thus, the area covered by all the 70 villages in the KWS was subset from each of the satellite images. These sub-images showing the study area were then computer-processed using the digital image processing software (ERDAS Imagine) to sharpen the visibility of features in the study area. For this purpose, automatic log residuals (ALR), an image enhancement technique in the image processing software was used. ALR is a combination of three digital processing algorithms, namely normalization, log residuals, and three-dimensional rescaling of



Source: Compiled by Authors

Fig. 1

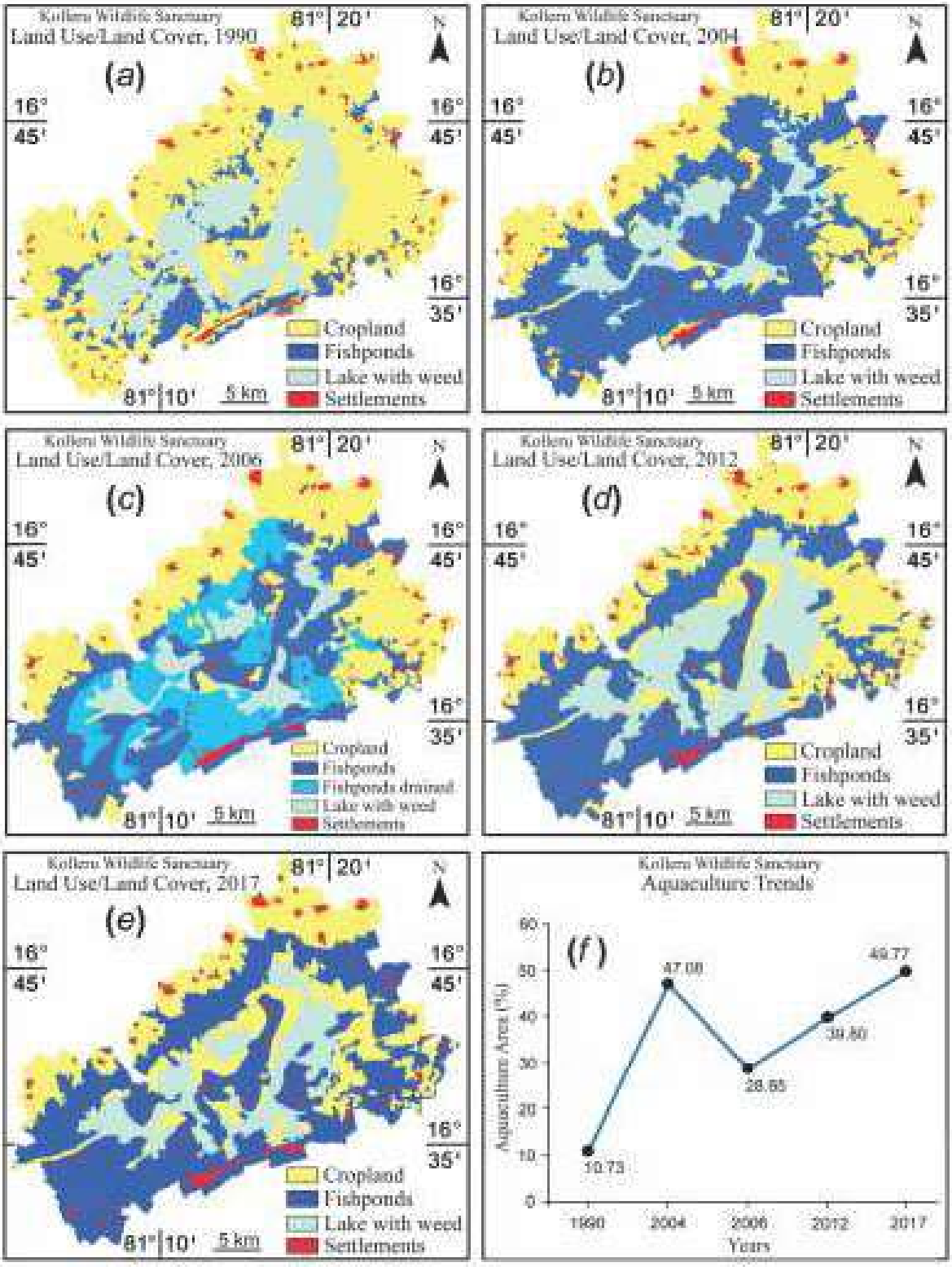
an image (Nageswara Rao et al., 2004; Naga Kumar et al., 2016). This technique differentiates various land cover classes by grouping and normalizing the like pixels of same DN (digital number) values from different spectral bands. The output image highlighted the visual discrimination between different feature classes for easy image interpretation. The image enhanced through ALR technique has aided mapping of various land use/land cover features such as the fishponds, the weed-infested lake areas, cropland, and built-up land (settlements) through onscreen digitisation (Fig. 2). Thus, the area statistics of all the land use/land cover features including that of the fishponds were extracted from the digitally enhanced time series satellite images of 1990, 2004, 2006, 2012 and 2017.

Results and Discussion

Trends in Aquaculture and Allied Land use/Land cover

The data on the land use/land cover features of the KWS area extracted from the satellite images have shown changes through time (Fig. 2; Table 1). The fishponds representing the commercial aquaculture activity occupied 98.22 km^2 (10.73 per cent) of the total 915 km^2 extent of the study area in 1990 (Fig. 2 a and f) and increased to 430.73 km^2 (47.08 per cent) area by 2004 (Fig. 2 b and f). However, AP government has demolished the fishponds in the region in 2005 under the Supreme Court orders to clear all encroachments in KWS, as the large-scale commercial aquaculture activity has become a serious threat to the environment in several ways: (i) the high-rise embankments around the fishponds were hindering the floodwaters from entering into the lake system, and, as a result, water remained stagnated for days together in the houses and farmlands of the adjoining villages, (ii) the removal of vegetation and digging of fishponds were preventing the seasonal migratory birds from roosting in the region, for which the Kolleru Lake was famously known, and (iii) the chemical wastes released from the fishponds were polluting the soil and water in the region. The demolition of the embankments of the fishponds and draining the water contained in the fishponds was conducted over an extent of 197.70 km^2, i.e., 21.61 per cent of the total area, whereas the fishponds remained intact in about 264 km^2, i.e., 28.85 per cent of the total area (Table 1), especially beyond the 5-feet (~1.5 m) contour in the KWS periphery as inferred from the 2006 satellite images that represents the immediate post-demolition period (Fig. 2 c and f). That means between 2004 and just before the removal of fishponds by the government in 2005, the total area under the fishponds increased to 461.7 km^2, an addition of ~31 km^2 area from its 2004 level. However, the perfunctory action on the part of the AP government has not only failed to completely remove the fishponds from the Sanctuary, but also could not prevent the subsequent revival and even spread of fishponds into other areas of KWS. It can be noticed from the satellite images, that the area under fishponds has increased to 364.13 km^2, i.e., 39.80 per cent area) by 2012 (Fig. 2 d and f) and further increased to cover about a half of the study area (455.34 km^2, i.e., 49.77 per cent area) including in the zone enclosed by the 5-feet (~1.5 m) contour by April 2017 (Fig. 2 e and f).

Of the other land use/land cover features, the cropland, where only one crop of paddy is possible in this seasonally flood-prone region, has shown a consistently decreasing trend during 1990-2017 from 562.73 km^2 area (61.50 per cent of the total area) in 1990 to less than half of it to 245.80 km^2 (26.86 per cent) by 2017 (Table 1). The water spread area of the



Source: Satellite imageries

Fig. 2

Table 1
Kolleru Wildlife Sanctuary: Land use/Land Cover, 1990-2017

Land use/land cover Type	Area (km^2)				
	1990	2004	2006	2012	2017
Cropland (paddy)	562.73 (61.50)	340.02 (37.16)	336.23 (36.75)	331.64 (36.25)	245.80 (26.86)
Lake (weed-infested)	226.33 (24.74)	114.40 (12.50)	86.92 (9.50)	188.99 (20.65)	181.62 (19.85)
Fishponds	98.22 (10.73)	430.73 (47.08)	264.00 (28.85)	364.13 (39.80)	455.34 (49.77)
Fishponds drained	-	-	197.70 (21.61)	-	-
Built-up land (settlements)	27.72 (3.03)	29.85 (3.26)	30.15 (3.29)	30.24 (3.30)	32.24 (3.52)
Total	915.00	915.00	915.00	915.00	915.00

(Figures in parentheses are percentage of area)
Source: Satellite Imageries.

lake, which is covered by dense weed has also undergone changes from 226.33 km^2 (24.74 per cent of the total KWS area) in 1990 to as low as 86.92 km^2 (9.50 per cent area) by 2006 and again increased to 188.99 km^2 (20.65 per cent) by 2012 from where it has marginally decreased to 181.62 km^2 (19.85 per cent) by 2017 (Table 1). Apparently, the spread of aquatic weed into the abandoned fishponds after they were drained in 2005 has accounted for the increase in the area of the weed-infested lake in the subsequent years. The fluctuations in the water spread area of the lake reflected the aquaculture spread since the fishponds have encroached the lake area also. The built-up area, i.e., the area occupied by human settlements showed a marginal increase throughout during 1990-2017 from 27.72 km^2 (3.03 per cent of the total KWS area) in 1990 to about 32.24 km^2 (3.52 per cent) by 2017 (Table 1).

Trends in Population

The total population of the 67 inhabited villages in KWS was 1,92,185 persons in 1981, which increased to 2,37,770 persons by 1991 and further increased to 2,64,065 persons by 2001. But, significantly, the population has decreased to 2,60,945 persons by 2011, a clear reduction of 3,120 persons from their 2001 number. However, the combined population of scheduled caste and scheduled tribe (SC and ST) categories in the region has consistently increased during the study period from 20,110 persons in 1981 to 29,955 persons by 1991, further to 38,067 persons by 2001 and 50,056 persons by 2011 (Table 2). Therefore, the decline of the total population was due to the decrease of the population of other categories. Initially, the population of other categories has increased from 1,72,075 persons in 1981 to 2,07,815 persons by 1991, further to 2,25,998 persons between 1991 and 2001. But, their number has declined by 15,109 persons during the subsequent decade from 2,25,998 persons in 2001 to 2,10,889 persons by 2011.

Aquaculture Impact on Population Dynamics

Apparently, the study highlights that the trends in the growth of commercial aquaculture and population in the KWS are strongly correlated. The growth of aquaculture in the region is distinctly discernible from the time

Table 2
Kolleru Wildlife Sanctuary: Population Trends in KWS and the Krishna and West Godavari Districts, 1981-2011

Census Year	Decadal Population					
	Kolleru Wildlife Sanctuary (KWS)			Krishna and West Godavari Districts Combined		
	SC and ST Categories Combined	Other Categories	Total	SC and ST Categories Combined	Other Categories	Total
1981	20,110 (10.46)	1,72,075 (89.54)	1,92,185	10,23,147 (17.58)	47,98,397 (82.42)	58,21,544
1991	29,955 (12.60)	2,07,815 (87.40)	2,37,770	14,19,062 (19.66)	57,97,339 (80.34)	72,16,401
2001	38,067 (14.42)	2,25,998 (85.58)	2,64,065	16,80,065 (21.02)	63,11,293 (78.98)	79,92,458
2011	50,056 (19.18)	2,10,889 (80.82)	2,60,945	19,24,297 (22.76)	65,30,067 (77.24)	84,54,364

(Figures in parentheses are percentage of area)
Source: District Census Handbooks.

series satellite images. The satellite image from 1977 (not shown here) indicated that there was no commercial aquaculture activity in the region at that time. A more than four-fold increase in the area under aquaculture between 1990 and 2004, followed by a sharp decline by 2006 (as a consequence of draining of fishponds by the government) and its subsequent revival thereafter by 2012 and 2017 has impacted the population dynamics in the region. This is evident from the Census data of 1981-2011, which indicated that KWS population increased by 37.40 per cent during 1981-2001 as the aquaculture increased, but decreased (-1.18 per cent) during the following decade, 2001-2011 with the decline in aquaculture. Notably, the SC and ST population showed a significant rise with respect to the other categories during this period (Table 2).

The per cent share of the combined SC and ST population in the total population of the KWS region showed an increasing trend from 10.46 per cent in 1981 to 12.60 per cent by 1991, followed by 14.42 per cent in 2001 and 19.18 per cent in 2011 (Table 2). Needless to mention, the population of the other categories declined during 2001 to 2011 (Table 2). Although the per cent share of the combined SC and ST population in the Krishna and West Godavari districts as a whole has also increased during 1981-2011, the trend was comparatively higher in the KWS than in the two districts. The increase of SC and ST population between 1981 and 1991 was 2.14 per cent in KWS against 2.08 per cent increase in the districts. Similarly, during 1991-2001, the increase in the share of SC and ST population in KWS was 1.82 per cent, which is relatively higher than 1.36 per cent increase in the two districts put together. Significantly, however, the share of the combined SC and ST population in KWS recorded a more than two and a half times rise by 4.76 per cent during 2001-2011 than in the previous decade against an increase of 1.74 per cent only in the district. The study clearly reveals varying trends in population growth among different social groups. While the per cent share of the other category population has steadily decreased during the period and even declined in absolute numbers from 2,25,998 persons in 2001 to 2,10,889 persons by 2011, i.e., a distinct decrease by 15,109 persons. The combined SC and ST population has largely increased throughout the study period at a higher rate even when compared with that of the districts as a whole.

Conclusions

A first order inference on the steady increase in the per cent share of the combined

SC and ST population in KWS during 1981-2011 reflected the impact of burgeoning aquaculture in the region. At the same time, the decrease in the share of the population of other categories mostly comprising small and marginal farmers, and even a decline in their absolute numbers, especially during 2001-2011 is perhaps due to the demolition of their fishponds in 2005 in KWS and the continuous process of amalgamation of small landholdings into the big corporate fish farms in the region. In such a situation, the small farmers belonging to the other categories of population are rendered jobless, which might have resulted in their outmigration. At the same time, the labour-intensive aquaculture activity in large-size fishponds (each extending over 50-100 ha) run by the corporate bodies attracted the workforce, mainly belonging to SC and ST categories into the region leading to a substantial increase in the share of their population. However, this phenomenon needs a detailed investigation through the household surveys in the region to ascertain the population dynamics as a result of the changing aquaculture scenario in the Kolleru Lake region.

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Dr. Kakani Nageswara Rao, Professor,
ICSSR Senior Fellow,
Department of Geo-Engineering
Andhra University, Visakhapatnam

Dr. G. Demudu, UGC Post-Doctoral Fellow

Dr. B. Hema Malini, Professor,
UGC Emeritus Fellow
Email: bhmalini@yahoo.com
(Author for Correspondence)
Department of Geography
Andhra University, Visakhapatnam