CMPA Technical Report Series

32

Floral Biodiversity Monitoring to Support the Management Planning at Khijadiya Wildlife Sanctuary and Gosabara Wetland Complex in Gujarat

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Indo-German Biodiversity Programme
Conservation and Sustainable Management of Coastal and Marine Protected Areas

CMPA Technical Report Series No. 32
Floral Biodiversity Monitoring to Support the Management Planning at Khijadiya Wildlife Sanctuary and Gosabara Wetland Complex in Gujarat

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Though, this appears to be an exhaustive list, we feel it to be much deficient. Therefore, we thank all those whose names might not have appeared here but of course, their cooperation and contributions made this work possible.

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1. INTRODUCTION

Wetlands are the area where saturation with water is dominant factor determining the nature of soil and the types of plants and animal communities living upon it. They are amongst the most productive ecosystems on the Earth (Ghermandi *et al.*, 2008) and provide many important services to human society (ten Brink *et al.*, 2012). However, they are also ecologically sensitive and adaptive systems (Turner *et al.*, 2000). Wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant species, soil and sediment characteristics (Space Applications Centre, 2011). They cover diverse and heterogeneous assemblage of habitats such as lakes, ponds, rivers, river flood plains, inter-tidal areas, estuaries, mangroves, coral reefs and other related ecosystems. The prolonged presence of water creates conditions that favours the growth of specially adapted plants and promote the development of characteristic wetland (hydric) soils.

Wetlands were categorised into marine (coastal wetlands), estuarine (including deltas, tidal marshes, and mangrove swamps), lacustarine (lakes), riverine (along rivers and streams), and palustarine ('marshy' – marshes, swamps and bogs) based on their hydrological, ecological and geological characteristics (Cowardin *et al.*, 1979). However, According to Ramsar InternationalConvention treaty on Wetlands (signed in 1971 for the conservation and wise use of wetlands and their resources), (Article 1.1) the wetlands are defined as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which atlow tide does not exceed six metres". Overall, 1052 sites in Europe; 289 sites in Asia; 359 sites in Africa; 175 sites in South America; 211 sites in North America; and 79 sites in Oceania region have been identified as Ramsar sites or wetlands of International importance (Ramsar Secretariat, 2013).

As per the Ramsar Convention, most of the natural water bodies (such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefs) and man made wetlands (such as ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms and canals) in India constitute the wetland ecosystem. Only 26 of these numerous wetlands have been designated as Ramsar Sites (Ramsar, 2013). However, many other wetlands which perform potentially valuable functions are continued to be ignored in the policy process. As a result many freshwater wetlands ecosystems are threatened and many are already degraded and lost due to urbanization, population growth, and increased economic activities (Central Pollution Control Board, 2008).

In the similar context, Khijadiya and Gosabara wetlands are facing threat owing to urbanisation, flow of polluted waterand invasive species. Some of the questions pertaining to the management of the two aquatic wetlands basically deal with algal blooms in Gosabara (Especially in transit zone of fresh and sea water), rapid proliferation and invasion of *Prosopis*, massive growth of *Parthenium* in loose soil resulted from eradication of *Prosopis*.Agriculture ingress in wetland zone resulting in excessive use of fresh water, underground electric wiring and ethical use of organic manure/papers for keeping the water potable and healthy for the safety of migratory birds and localites.

1.1. STUDY AREA

1.1.1 Gosabara wetland complex

Gosabara Wetland Complex is located in the Porbandar district of Gujarat state of India. It is a group of wetlands including Medha creek, Kuchhadi, Subhashnagar, Zavar, Kurly I, Karly II, Vanana, Dharampur, Gosabara, Bhadarbara, Mokarsagar, Bardasagar and Amipur of Porbandar district of Gujarat (Nagar *et al*, 2015) as shown in Figure 1. The huge area of more than 200 sq. km., is a source of fresh water for many farmers and villagers.The wetland is formed by Karli Recharge Reservoir and Karli Tidal Regulator. There is a combination of Estuary and fresh water habitat. The wetland is dominated by sedges and other hydrophytic vegetation (Nagar *et al*, 2015). It is a lifeline for the community as well as the wetland dependent biodiversity including both the flora (mangrove, macroalgae, macrophytes) and fauna (birds, reptiles, insects and mammals).

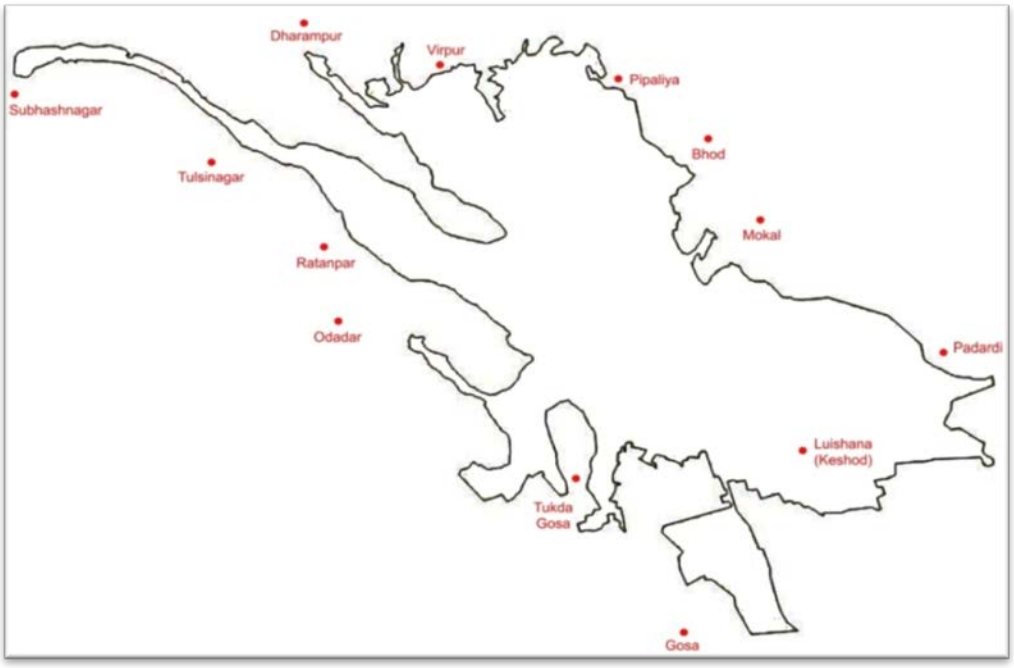


Figure 1: Gosabara wetland complex map

1.1.2. Khijadiya Bird Sanctuary

Khijadiya bird sanctuary is located 10 km away from the Jamnagar district of Gujarat, India. It is having a unique habitat with fresh water on one side and salt pans on other side. Large creek flowing from Gulf of Kutch is located besides the habitat. This supports Mangroves and Marine diversity.

Khijadiya bird sanctuary is divided into 2 parts: Part 1 and Part 2. Vegetation like *Accacia nilotica*, *Salvodora persica* and *Prosopis juliflora* are in abundance. The sanctuary is located at the watershed of Ruparel and Kalindri River at the North East coastal region of Jamnagar district in the Gulf of Kutch as shown in the Figure 2.

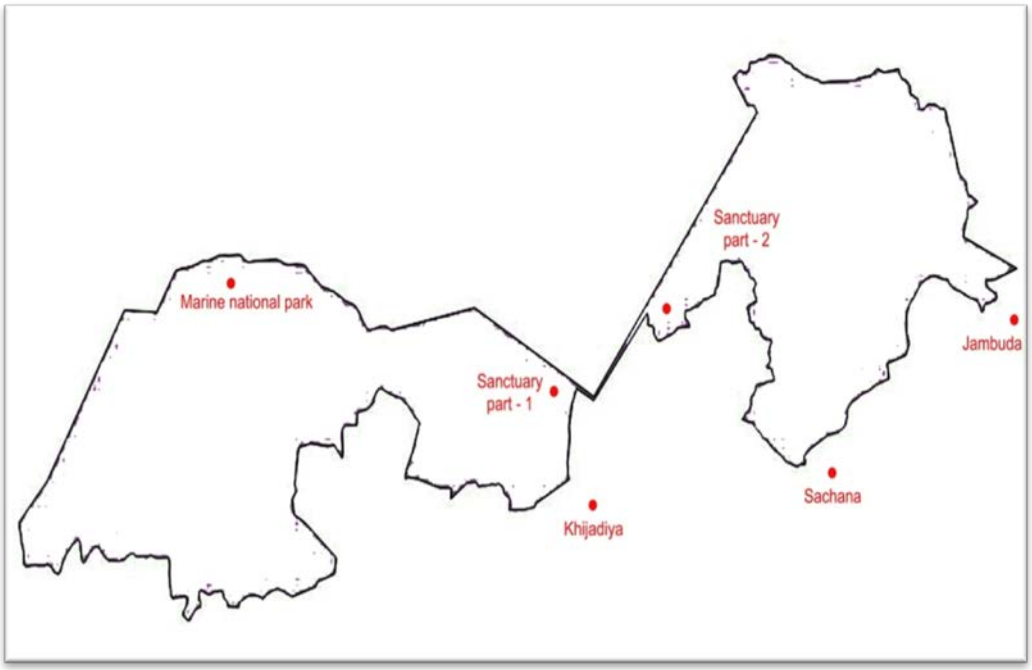


Figure 2: Khijadiya Bird Sanctuary map

1.1.3. Desk Study for *Prosopis* and *Parthenium* Managment

Exotic plant species have economic, environmental or aesthetic values due to which they have been purposely and/or accidentally introduced globally. The possiblility of invasiveness of the species result into either positive or negative or both impact on environment, social as well as economical. These kind of negative intrusion of invasive species results into reduction of crop yield, genetic erosion of biodiversity, disruption of water flow, poisoning of livestock, formation of impenetrable thickets etc.

On the same account *Prosopis juliflora* is one of the invasive species at the respective site whose uncontrolled growth is becoming havoc. The prosopis is a prominent woody species in agro ecosystems, arid and semi-arid regions of India. The species growth expanding rapidly in village common lands, grazing lands, along railway tracks and roads, canal and village pond banks and degraded forest lands. Moreover natural regeneration is profuse through out the entire arid and semi-arid regions of the nation.

The tree is used by most of the rural communities to its full potential in arid and semi-arid tracts of India. In particular there is necessity to increase awareness programs regarding different applications of the species and the level of information related to plantation management among rural communities and developmental agencies such as state forest departments, agriculture departments and non government organizations.

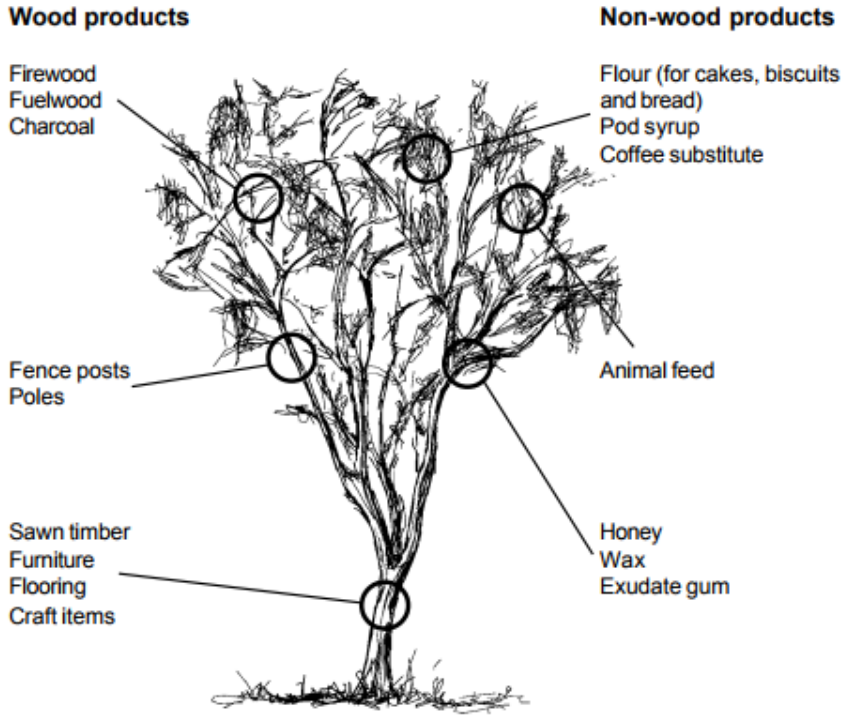


Figure 3: Successfully marketed products of *Prosopis juliflora*

Traditional methods of the weed control for *Prosopis* are insignificant such as soil solarisation and mechanical methods. This study was carried out to manage this weed with the available herbicides on cultivated land at the Main Agricultural Research Station, University of Agricultural Sciences Campus, Raichur in Karnataka State in southern India during 2009 to 2011.

Several easily available herbicides were used including Mera – 71 (Glyphosate), Paraquat, 2, 4-D amine and ester, Diuron, Keroscene and Coaltar as individual chemicals with different concentrations and combination of chemicals were also tried. The study reveals that all treatments except diuron / keroscene / coaltar combinations reduced growth and development of *Prosopis*. Mera-71, 2,4-D amine and ester followed by paraquat were the best in affecting weed recovery. The control of regrowth of *Prosopis juliflora* is effectively achieved by two times applications of systemic translocated herbicides such as Mera-71 (Glyphosate) and 2,4-D amine and ester found better as compared to paraquat, diuron and other farmer practices (Shanwad *et al*., 2015).

Naturalized and/or weedy *Prosopis* are reported in 112 countries. Currently 23 countries with weedy or invasive *Prosopis* (21 %) implement some form of formal management. No countries rely exclusively on biological control, 6 use only mechanical or chemical control, 5 use control through utilization and 11 use an integrated approach (Shackleton et al., 2014). Countries that have used chemical and mechanical control are mainly from Middle East and are usually wealthier nations. Control through utilization is applied in poorer countries such as Kenya and Ethiopia. Biological control is driven by Australia and South Africa; however, there are also areas where 'biological control agents' are present but were not deliberately introduced, for example, Egypt (seed-feeding beetles— Coleoptera and Burchidae), Sudan and Yemen (Algarobis prosopis) (Delobel and Fediere 2002; Al-Shurai and Labrada 2006; Babiker 2006).

Many efforts have been done to eradicate and control prosopis. Geesing *et al*., 2004 categorized the eradication methods into three broad types:

• Mechanical; In this plants are removed by hand pulling, cutting, hand digging or mechanical uprooting. This is severely done in Gash, Sudan and Afar, Ethiopia but it didn't give the expected result, due to lack of maintenance. In Australia several mechanical methods have been used. This is **stick racking** (best results are achieved when soil moisture is sufficient to allow machinery to work with minimum strain, but soil is dry enough so the root system desiccates), **chain pulling** (may kill up to 90% of trees in a mesquite infestation), bulldozer pushing and blade ploughing.
• Chemical; Larger trees and shrubs are killed by cutting the stem at ground level and spraying or painting the freshly cut stumps with suitable herbicide. Herbicides like Round up, 2-4, D, Glenside Kerosene and diesel oil are used in Queensland, Australia.
• Biological; predators or pathogens are used to control the reproduction. Sudanese researchers found some predator insects that attack the leaves that lead to deterioration of the tree canopy. In Australia four species of insects have been introduced as biological control agents against mesquite: The Algarobius bottimeri and Algarobius prosopis (The larvae of these beetles destroy mesquite seeds in mature pods both in the trees and on the ground), the Prosopidopsylla flava (a sap-sucking psyllid that causes dieback) and Evippe spp. (a leaf-tying moth that causes defoliation). Nevertheless, this is a very slow operation to eradicate the tree. (DAFF Queensland 2013).

1.1.3.1 Negative impacts/costs

Prosopis invasions have a variety of negative social, ecological and economic impacts (Figs 1 and 2). They alter ecosystem services such as water supply, hydro- logical functioning, grazing potential and soil quality (DeLoach 1984; Bedunah and Sosebee 1986; Archer1989; Le Maitre et al. 2000; van Klinken et al. 2006; Ndhlovu et al. 2011; Nie et al. 2012; Dzikiti et al. 2013). Native biodiversity in many parts of the world has also been negatively impacted by invasive Prosopis species (Steenkamp and Chown 1996; Dean et al. 2002; El-Keblawyand Al-Rawai 2007; Belton 2008; Kaur et al. 2012).
Local communities in Kenya, Sudan, Eritrea, Malawi and Pakistan noted a range of negative consequences arising from invasive Prosopis (Choge et al. 2002; Chikuni et al. 2004; Mwangi and Swallow 2005; Laxe´n 2007; Bokrezion 2008; Kazmi et al. 2009). These included effects on livestock health, Prosopis thorns causing tyre punctu- res and flesh wounds, dense thickets reducing access to water points, roads, infrastructure and agricultural and range lands, drying up of water sources, reducing natural forest cover and the services from these forests, as well as providing refuge for thieves.
In many parts of Africa Prosopis invasions are a leading cause of detrimental impacts on local community struc- ture and functioning, leading to an increase in their vulnerability. This includes the potential loss of land rights for local livestock herders in Mali and violent conflict over limited natural resources between neighbouring commu- nities in Ethiopia and Kenya (Centre for Sustainable Development Initiatives 2009; Djoudi et al. 2011; Starket al. 2011). One Kenyan community has even taken the Food and Agricultural Organization (FAO) and the Kenyan government to court over the harm created by the introduction of Prosopis (Pasiecznik et al. 2006a).
Native weedy Prosopis taxa are also estimated to cause a loss of US$200 – 500 million per annum to the livestock industry in the USA (DeLoach 1984). In South Africa costs of managing Prosopis invasions are substantial, averaging $35.5 million per annum (van Wilgen et al. 2012).

1.1.3.2 Benefits vs. costs and the dimensions of contentious issues

Perceptions on the benefits and costs of invasive alien species are strongly influenced by invasion abundance (Binggeli 2001; Shackleton et al. 2007). As abundance in- creases, associated costs rise and benefits fall due to is- sues such as resource accessibility (Wise et al. 2012). In India, Prosopis was initially seen as beneficial, but over time the negative consequences became more apparent, leading to increasingly negative perceptions of the plant from some quarters (Pasiecznik et al. 2001). A similar situ- ation arose in Kenya where, as Prosopis became invasive, it was described as a 'bad omen' by some local people (Choge and Chikamai 2004) and more than 65 % of peo- ple in three villages mentioned that their lives would have been better off if Prosopis was never introduced (Maunduet al. 2009). In Sudan, over 90 % of livestock farmers viewed Prosopis as a problem as it became more wide- spread (Elsidig et al. 1998).
In many areas, invasive Prosopis trees do not sustain their full use potential due to intraspecific competition in dense stands which, generally, form over time. In such cases relatively few pods are produced for fodder and human consumption and dense invasive stands be- come impenetrable for humans and livestock making utilization of resources difficult (Chikuni et al. 2004; Mwangi and Swallow 2005). Wise et al. (2012)show that net economic benefits decrease as invasion densities increase in South Africa. They predict that the net cost of having Prosopis in the country will become negative in 4 – 20 years depending on future rates of spread.

A framework by Shackleton et al. (2007) also shows that useful invasive aliens initially have high benefits, but as invasion densities increase, costs rise which lead to an in- crease in human vulnerability. This raises questions about the introduction of 'miracle' species in the past such as Acacia, Leucaena and Prosopis because the adverse im- pacts tend to exceed the benefits as the invasions pro- gress, if left unmanaged (de Wit et al. 2001; Pasiecznik 2004; Wise et al. 2012; Low 2012), as well as the contin- ued promotion of invasive alien species like Prosopis for biofuels today (Witt 2010; Naseeruddin et al. 2013).
The fact that the detrimental effects emerge only after invasions have reached unmanageable levels exacer- bates contentious issues surrounding invasive species and may delay management decisions, in many cases re- stricting the implementation of effective management. There have also been conflicts of interest regarding which form of management to implement—how best to preserve, exploit and even enhance benefits while reducing negative impacts of Prosopis invasions (Zimmermann 1991).

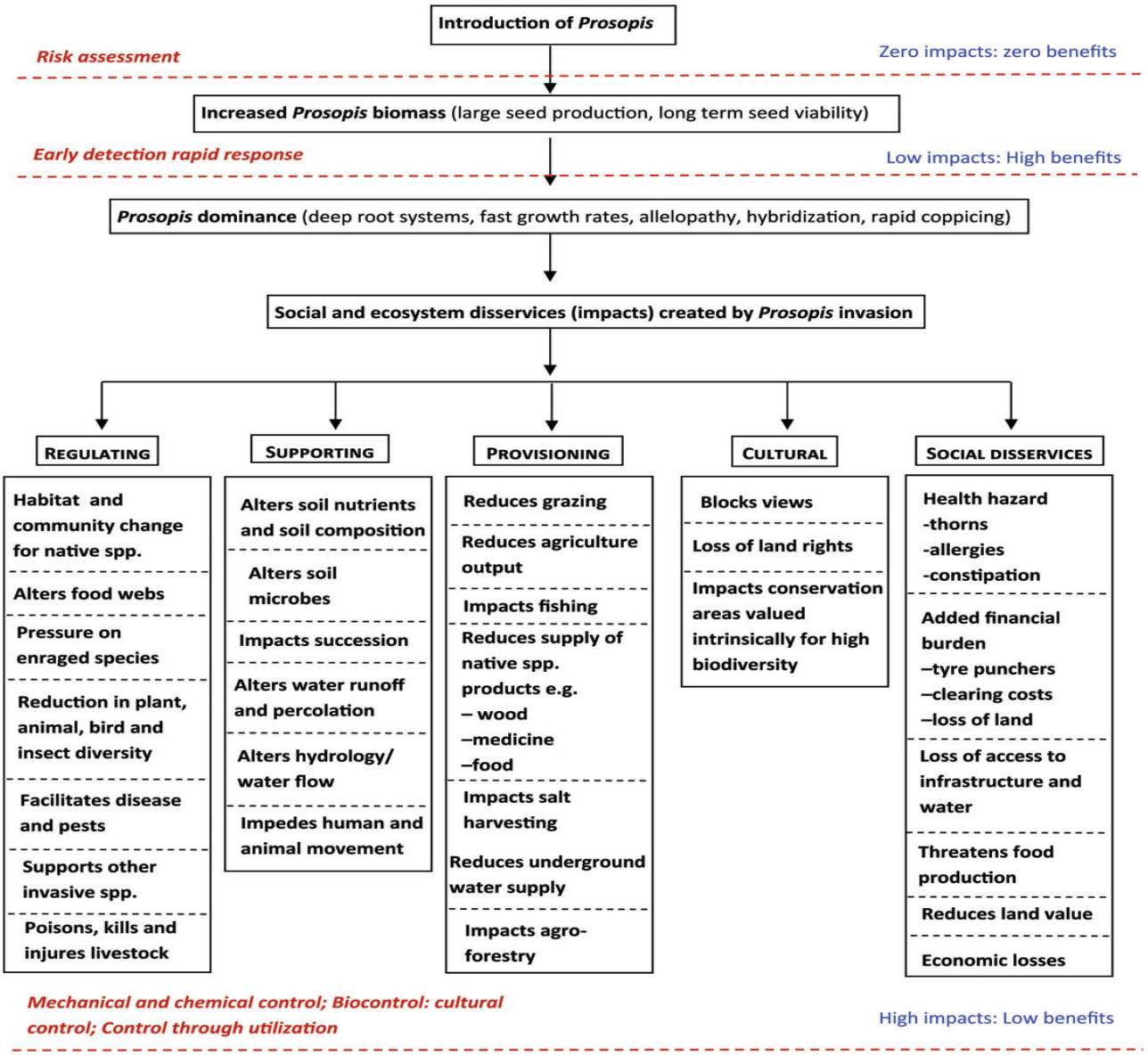


Figure 4. Cause-and-effect network diagram showing the negative effects of *Prosopis* invasions and management options that can be used to target each stage of invasion

1.1.3.3 Management of Prosopis

Naturalized and/or invasive Prosopis has been reported from 112 countries. Currently 23 countries invasive Prosopis (21%) implement some form of formal management. No countries rely exclusively on biological control, 6 (26%) use only mechanical or chemical control, 5 (22 %) use control through utilization and 11 (48%) apply an integrated approach (three or more methods, including biological control, mechanical control, chemical control, control through utilization and cultural control).

Table 1. Comparison of techniques for managing *Prosopis* and their advantages and disadvantages.

Controltype	Advantages	Disadvantages
Biological control implemented	Relatively inexpensive once, Works over large areas, including areas that are inaccessible for mechanical control, Minimal associated costs after biocontrol agent is released (monitoring is required)	Biocontrol agents have not yet had substantial impacts on reducing stand density or extent of invasions and rates of spread in some areas such as South Africa but have been more successful in places like Australia
Mechanicalcontrol	Efficient at removing *Prosopis* overlarge areas	Labour and capitalintensive
Chemical control	Efficient at removing *Prosopis* overlarge areas	Labour and capitalintensive, Encouraging utilization may create dependency on the species, thereby exacerbating conflicts of interest
Utilization	Maximizes on benefits to be had from biological invasions, Promotes rural social–economical development, Reduces overexploitation of native spp., Profits counteract management costs	Some areas have lower-value Prosopis spp. (more thorny, bitter pods, shrubby forms) making utilization more difficult, Many Prosopis invasions are in remote areas making large-scale utilization difficult
Cultural control/other control (e.g. fire, grazing and livestock transport management)	Low costs Can also prevent other typesof degradation	Requires people to change perceptions, Large-scale education programmers are needed, Does not always work for all Prosopis spp.—e.g. fire-tolerant hybrids Not applicable in all areas, e.g. places with low biomass and fire-tolerant hybrid

Countries that are using only chemical and mechanical control are mainly found in the Middle East and have small isolated invasions and are usually wealthier nations, whereas control through utilization is applied in poorer countries such as Kenya and Ethiopia. Biological control is driven by Australia and South Africa; however, there are also areas where 'biological control agents' are present but were not deliberately introduced, for example, Egypt (seed-feeding beetles—Coleoptera and Burchidae), Sudan and Yemen (*Algarobis Prosopis*) (Delobel and Fediere 2002; Al-Shurai and Labrada 2006; Babiker 2006). In Yemen there is no evidence that the non-native *A. Prosopis* feeds on the native *Prosopis cineraria* (Al-Shurai and Labrada 2006). There are concerns, however, that introduced insects could affect less invasive *P. pallid* populations in these areas that are utilized by local communities (Pasiecznik *et al*. 2006 *a, b*). Another view is that any effect of

such insects could improve the usefulness of less invasive taxa by reducing seed production and therefore potential invasiveness and could lead to less dense stands with larger trees and greater pod production (Zachariades *et al*. 2011).

Logistic regressions were run to determine which factors underpin whether a country has formal management of *Prosopis* taking place or not. The degree of understanding of *Prosopis* invasion impacts and ecology (besides residence time—the time since introduction) is a better determinant of whether or not a country will manage *Prosopis* than the socioeconomic conditions of the country (Table 1). The stepwise regression reveals that the level of impacts and overall knowledge on *Prosopis* invasions are key determinants of the presence of management within a country or not. Having knowledge on invasion potential/risk allows countries either to act timeously or to develop protocols to guide management based on an overall understanding of impacts, ecology, uses and special scales. Having a good understanding surrounding *Prosopis* invasions also helps to highlight the need for management, and subsequent management also stimulates the accumulation of further knowledge on invasions. Residence time might not be a significant predictor, because in wetter areas invasions tend to establish much faster than in drier areas (Table 1). Also, all countries have had *Prosopis* long enough to have naturalized and invasive populations (Zimmermann *et al*. 2006).

Simple socioeconomic variables are poor predictors of the existence of management strategies as there is evidence of management in countries at all levels of development (Table 1). Many of the poorer countries receive foreign aid to implement and run management programmes, at least at the outset.

The findings of this review contradict previous publications that have argued that less developed countries have conducted less research and management of invasive alien species (McNeely *et al*. 2005; Pyšek *et al*. 2008; Nuñez and Pauchard 2009; McGeoch *et al*. 2010). Some developing countries are at the forefront of *Prosopis* research and management such as Kenya (control through utilization, social impacts) and South Africa (biological control), along with developed countries such as Australia and the USA. Witt (2010) noted that the prominence and severity of the impacts of *Prosopis* in developing countries has motivated this investment in research and understanding. However, there may be a lack of research for less prominent invasive alien species in poorer regions of the world.

Table 2. Logistic regression highlighting the importance of different ecological, economical and social factors in determining management of *Prosopis* with in a country.

Explanatory variable	Nagelkerke R^2	Predictions—% correct	Waldstatue	*P*val
No. of introduced *Prosopis* spp.	0.540	84.3	13.04	0.000
Source of introduction known	0.234	70.0	4.815	0.999
Time since introduction	0.009	47.1	0.275	0.626
Use level	0.103	67.1	4.19	0.242
Distribution and extent of *Prosopis* cover known	0.616	81.4	7.087	0.069
Level of *Prosopis* impacts	0.685	87.1	19.638	0.000
No. of publications relating to *Prosopis*	0.960	88.6	20.765	0.000
Overall knowledge of *Prosopis* invasions	0.686	92.9	16.993	0.005
GDP per capita	0.013	65.7	0.680	0.410
Human development index	0.041	68.6	0.324	0.569

The classification and regression model highlights the factors that underpin which management approaches counties are likely to adopt (Fig. 5). Similar to the regression output, the overall level of knowledge of *Prosopis* is an important factor when predicting which management approach or technique a country will adopt (Fig. 5). Countries with a good understanding of *Prosopis* based on the number of publications and the diversity of published materials have a higher chance of having some form of management, and in general this takes the form of integrated management. The level of development of a county, indicated by gross domestic product per capita, also influences the type of management approach a country is likely to adopt. Wealthier countries are more likely to implement mechanical and chemical control methods, which are the most costly but also currently the most effective options. Middle-income countries most commonly implement integrated management, whereas poor countries predominantly adopt control through utilization for managing *Prosopis*.

The advantages and disadvantages of these approaches differ (Table 2), and are closely linked to the costs of the control method. For example, countries with limited invasions are more likely to use mechanical and chemical control, whereas those with large-scale invasions are more likely to adopt an integrated approach, as purely mechanical and chemical control becomes too costly (van Klinken *et al*. 2006). Control through utilization aims to aid local development while simultaneously controlling *Prosopis* impacts and is therefore promoted in poorer parts of the world.

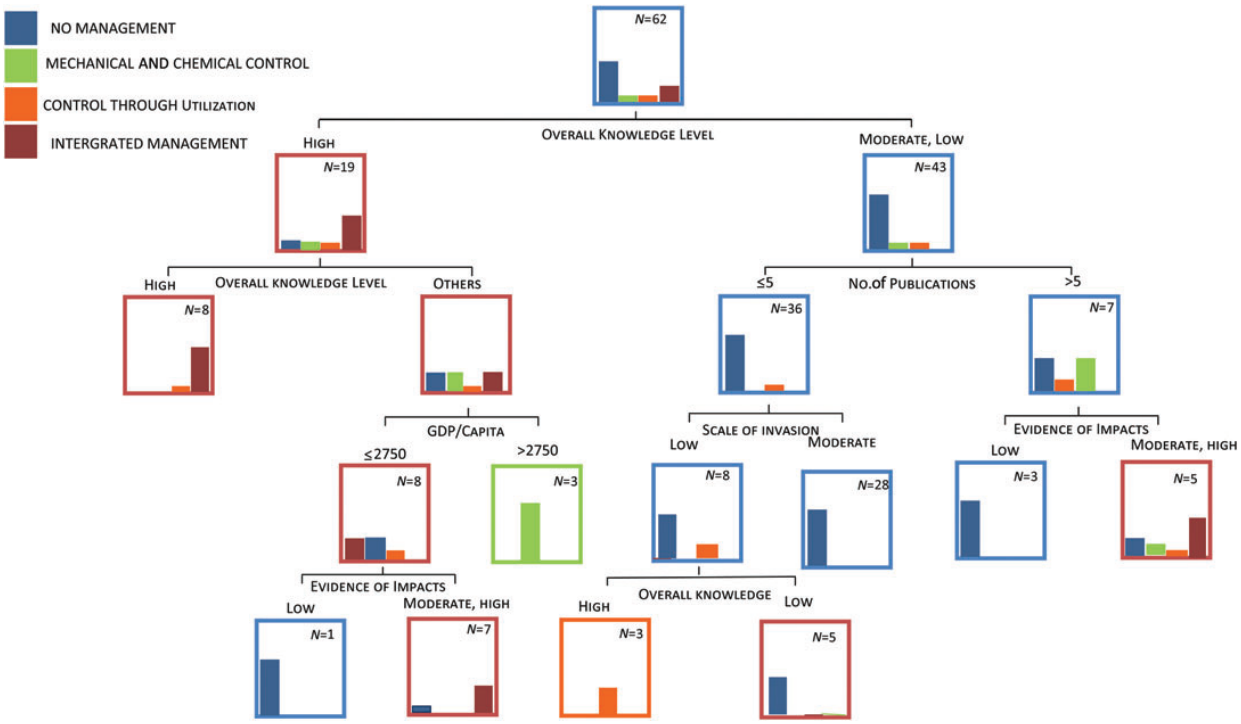


Figure 5. A classification and regression tree model using social, ecological and economic variables to explore the drivers of different types of *Prosopis* management globally

1.1.3.4 Contentious issues surrounding invasive *Prosopis* taxa and their management

The benefits and impacts and choice of different management approaches of *Prosopis* have led to contentious issues regarding management. Control through utilization is advocated by some as a management technique that enables benefit of invasive *Prosopis* to be utilized while simultaneously reducing the negative impacts of invasions and promoting local development (Choge and Chikamai 2004). However, many believe that this approach is inefficient at reducing invasions and leads to other problems such as dependencies (Table 2) (van Wilgen *et al*. 2011) and that other approaches such as chemical and mechanical clearing should be prioritized, although they are costly (Witt 2010). To date, there is no evidence of the success of control through utilization as a management technique (Table 2). The control through utilization approach is motivated around local development (which is needed) more so than managing invasions at large spatial and temporal scales.

There are conflicting views on best management approaches (eradication vs. control through utilization) in different villages in Kenya (Mwangi and Swallow 2005; Njoroge *et al*. 2012). Similar cases of contentious issues and conflicts of interest have been seen for other management approaches such as biological control. In South Africa only seed-feeding beetles were introduced so that neither the *Prosopis* trees themselves nor the production of pods would be harmed (Richardson 1998*a*) - even though better biological control agents have been identified that would harm trees and be more effective in reducing invasions (Zachariades *et al*. 2011).

1.1.3.5 Case studies comparing different management approaches

Despite the growing body of research on management options for invasive *Prosopis* stands (van Klinken *et al*. 2006), there is an ongoing debate on how to effectively manage large-scale invasions. Different approaches are currently being used to manage *Prosopis*, each with their own set of advantages and disadvantages (Table 2). The following case studies were selected as being representative of different management strategies and also encompass the approaches most commonly employed in countries with different levels of socioeconomic development (developed—Australia; emerging economies—South Africa; developing—Kenya). The case studies are also characteristic of management strategies driven and implemented by different stakeholders, e.g. government driven with mainly private implementation (Australia), mainly government driven and implemented (South Africa) and government driven with some non-government organization (NGO) and international support (Kenya).

Australia

Prosopis has invaded over one million hectares and could potentially spread over 70 % of Australia's land area (Osmond 2003). *Prosopis* taxa are considered as one of the 20 worst invasive in Australia, and in accordance with the *Weeds Management Act* 2001, a strategic plan has been developed to guide management (Australian Weeds Committee 2012). *Prosopis* is a declared weed in all the mainland states and one territory in Australia and has been categorized in accordance with the threats it poses and the corresponding management responses that need to be implemented (van Klinken and Campbell 2009). This includes preventing introductions, trade, sale or movements of *Prosopis* taxa and the eradication of small populations and control of large populations (Australian Weeds Committee 2012). In general, most landowners use mechanical and chemical control measures to manage *Prosopis*. Although control and eradication programmes are primarily funded by the state, many private landowners also fund management operations. For example, in Queensland $A4 million was allocated for *Prosopis* management by the government, which was supplemented further by over $A600 000 by landholders between 1995 and 1999 and over $A2 million was spent on clearing between 2001 and 2005 (Martin and van Klinken 2006).

Control of *Prosopis* first started in 1954 at Mardie Station, Western Australia, and by 1962 a major reduction in *Prosopis* density had been achieved. Populations increased again when funding diminished, but in the mid-1970s the allocation of government funding led to substantial progress with clearing (van Klinken and Campbell 2009). In other areas of Western Australia control was improving, but after funding lapsed many infestations returned in the 1990s with the exception of some areas such as Yeeda Station where control had been successful due to annual monitoring and clearing (van Klinken and Campbell 2009). In Queensland substantial funding was invested for clearing in the area around Comongin Station, and by 2005 over 4000 ha of dense *Prosopis* stands had been removed (van Klinken and Campbell 2009). In northern Queensland research concluded that eradication was feasible in the region and significant steps have been made towards this goal (van Klinken and Campbell 2009). New South Wales and South Australia have similar examples of good control efforts and others that have had limited success due to a lapse in control and monitoring (van Klinken and Campbell 2009).

Four biological control agents have been released in Australia: Algarobius bottimeri and A. *Prosopis* (seed-feeding bruchids), Evippe species (a leaf-tying moth) and Prosopidopsylla

flava (a sap sucker) (van Klinken et al. 2003; van Klinken 2012). Two have established widely (A. *Prosopis*, Evippe species), and the latter has had noticeable impacts on *Prosopis* populations through reducing long-term growth rates (van Klinken 2012). Biological control in Australia has been more successful than in other places like South Africa and the benefit-to-cost ratios are positive (0.5), with expectations to increase in the future (Page and Lacey 2006). The release of more agents is recommended to further improve control (van Klinken et al. 2003; van Klinken 2012).

Experiments have shown that some species are highly fire tolerant (especially the hybrids), which reduces the potential for using fire as a control method in many areas (van Klinken et al. 2006). Grazing control has also been advised to help prevent establishment and further spread of *Prosopis* (Csurhes 1996), although this approach has had limited success in Argentina and the USA (Dussart et al. 1998; Brown and Archer 1989). There are also regulations on the transport of livestock in areas infested with *Prosopis* to prevent its spread and accidental introduction elsewhere in Australia (Australian Weeds Committee 2012). Management policy is backed up by good legislation; Australia is one of two countries with a national management strategy. The government has also published many easily accessible documents on *Prosopis*management methods to inform landowners on control measures, and the *Prosopis* strategic plan places a lot of emphasis on educating and making stakeholders aware of *Prosopis* invasions and how to manage them (Australian Weeds Committee 2012). There have been rewarding examples of control success (van Klinken and Campbell 2009); however, *Prosopis* populations continue to spread in many areas and further management is needed.

South Africa

Prosopis invasions in South Africa cover an estimated 1.8 million hectares, and are increasing at 8 % per annum (Versfeld et al. 1998; Van den Berg 2010). They have the potential to invade between 5 and 32 million hectares of South Africa based on climatic suitability—about a third of the area of the country (Rouget et al. 2004). *Prosopis* is declared as a category 2 invasive alien species because it provides benefits and causes harm; this status means that it is legal to grow *Prosopis* in demarcated areas once a permit has been issued. A combination of mechanical, chemical and biological control methods is used to control *Prosopis*, mainly by the government-managed Working for Water programme. Three seed-feeding beetles (*Prosopis*, *A. bottimeri* and *Neltumius arizonensis*) were introduced as biological control agents to try and reduce spread while maintaining its benefits (Zimmermann 1991; Coetzer and Hoffmann 1997). Neltumius arizonensis failed to establish (Zachariades et al. 2011). Although biological control is considered the most cost-effective way of managing large-scale invasions of many species, there are many cases where the agents fail to make a significant impact and *Prosopis* is one of them (van Wilgen et al. 2012). The overall return on investment is low compared with biological control programmes for Opuntiaspecies and Australian Acacia species in South Africa (van Wilgen et al. 2012). There is potential to release more agents, such as the Evippe species which is already successful in Australia (see above), should the contentious issues surrounding the benefits and costs of *Prosopis*be resolved (Zachariades et al. 2011). *Prosopis* cover increased by ~35 % between 1996 and 2008, despite the expenditure of R435.5 million (US$42.7 million) on control over this period. Only 15 100 ha were cleared using mechanical and chemical control with this substantial budget (van Wilgen et al. 2012), which makes the cost/ha very expensive (US$2828). The limited success to date may be due to lack of a management strategy and of prioritization of management projects (Forsyth et al. 2012). There is a need for researchers,

managers and policy-makers to agree on new strategies for prioritizing areas for interventions to curb the spread of *Prosopis* and to ensure that the limited resources are used effectively (Forsyth et al. 2012). There have been some attempts at controlling *Prosopis* through utilization, but they had no noticeable impacts on invasions, and these initiatives failed as input and transport costs were too high and financial returns were low (Zimmermann et al. 2006). South Africa also has many particularly aggressive hybrids that form dense shrub-dominated stands, which make the utilization approach difficult (Zimmermann et al. 2006).

Kenya

Prosopis is estimated to have invaded one million hectares and has the potential to invade nearly half of Kenya's surface (Maundu et al. 2009; Witt 2010). It was declared a noxious weed in 2008 (Low 2012). Biological and mechanical control was initially proposed as the management approach to combat *Prosopis* invasions, but the government later opted for a control-by-utilization approach (FAO 2006; Pasiecznik and Felker 2006). The FAO, with support from several NGOs, initiated programmes to manage *Prosopis* through utilization. These efforts were continued by the government's forestry department and forestry research organization (KEFRI) following the end of these projects. Considerable time and effort was taken to build capacity, formulate good policies and educate communities to utilize the goods and services from *Prosopis* (Pasiecznik et al. 2006a). For example, small-scale utilization projects were established and a cookbook using *Prosopis* flour was created and supplied to communities to promote its use (Choge et al. 2006; Pasiecznik et al. 2006a). Although initial costs for training and purchasing appropriate small-scale processing machinery are high, they are considered to be lower than other control approaches (Pasiecznik et al. 2006a). In 2002, trade in *Prosopis* goods and services was worth US$2122 per household per year in some villages (Choge et al. 2002). Ten years later, trade in *Prosopis* products in four selected areas was estimated to exceed US$1.5 million (Choge et al. 2012). Each tonne of pods that are collected and milled into flour is estimated to remove approximately two million viable seeds (Pasiecznik et al. 2006a). Changes in legislation, and the promotion of *Prosopis* use, helped drive the substantial rise in use and led to 100 % of the locals in one village supporting control through utilization as the most preferred management method to adopt in Kenya (Njoroge et al. 2012). However, in other villages 85–90 % of people surveyed considered complete eradication of *Prosopis* to be the best option (Mwangi and Swallow 2005). There are still, however, contentious issues surrounding the benefits and costs of the species and management approaches in Kenya (Pasiecznik et al. 2006a). There are many publications on the profits that are being made through utilization, but there is no evidence that these utilization programmes have contained or reduced the extent of *Prosopis* invasions. There is, therefore, a need for further investigation of the successes and failure of control through utilization programmes (Geesing et al. 2004). A common problem with trying to promote *Prosopis* utilization is that it is seen as an inferior resource in many communities, with people preferring to use native species (Geesing et al. 2004). Recently, a new utilization approach to increase invasive *Prosopis* use has been adopted in Kenya—a power station (based on technology from India) is currently being built in the Kenyan Rift Valley which aims to produce electricity for the local area from burning *Prosopis* biomass (S. Choge, pers. comm.).

1.1.3.6 Research and management needs

The topic highlights key management and research issues that need to be addressed to improve *Prosopis* control and the factors that currently constrain progress in these areas (Fig.6). There is a great need for countries to develop national and even regional strategies, to provide guidelines for research and management in a targeted way, as each country has unique requirements and needs. Australia and Ascension Island are the only counties/territories to have strategic plans for *Prosopis* management and countries with long-standing *Prosopis* control programmes such as South Africa and Kenya still do not.Some broad-scale factors that need to be considered are suggested below.

Requirements for research and management needs regarding *Prosopis* and factors limiting success.

1.1.3.7 Policy and management

National strategies and management/action plans need to be created and adopted to guide the coordinated control of *Prosopis* (Fig.6). Such national strategies and plans are important to set up frameworks on how to guide *Prosopis* management and research. Numerous organizations and national governments globally have undertaken projects to control *Prosopis*, and planning and prioritization from the outset would ensure greater success. Country-specific strategic plans need to be created as there are large differences in invasion rates and scales and socio-economic situations within different areas of the world.

Introductions of known invasive *Prosopis* species to climatically suitable countries where it does not already exist should be undertaken such as in China, European countries along the Mediterranean and North East Asia, and spread of *Prosopis* into new areas within countries where it is invasive should be prevented. Risk assessments for purposeful introductions need to be conducted in the future. Pathways of accidental introductions between neighbouring countries and into new areas in countries with invasive *Prosopis* need to be managed. This could include regulations on livestock and fodder transport which is currently implemented in Australia (Australian Weeds Committee 2012). This is done by holding livestock in feed lots for a week before they are transported to ensure that all *Prosopis* seeds have excreted.

Countries need to eradicate small naturalized populations before they become invasive. Early detection and rapid response is a cost-effective way of preventing invasive species from getting out of hand and causing devastating, irreversible impacts in the future. For example, in Spain, *Prosopis* has started to show signs of naturalization at a single location where it was planted for experiments and eradication attempts now would be most cost effective in the long run (N. Pasiecznik and E. Peñalvo López, unpubl. res.).There is also an urgent need for managers and researchers to monitor the effectiveness of control measures. Adaptive management needs to be promoted and applied for controlling *Prosopis* invasions where operational success is so far limited, so that the causes of the failures can be identified and addressed to improve overall control. Managers and researchers need to collaborate in research to design from the outset successful adaptive management strategies to be implemented.

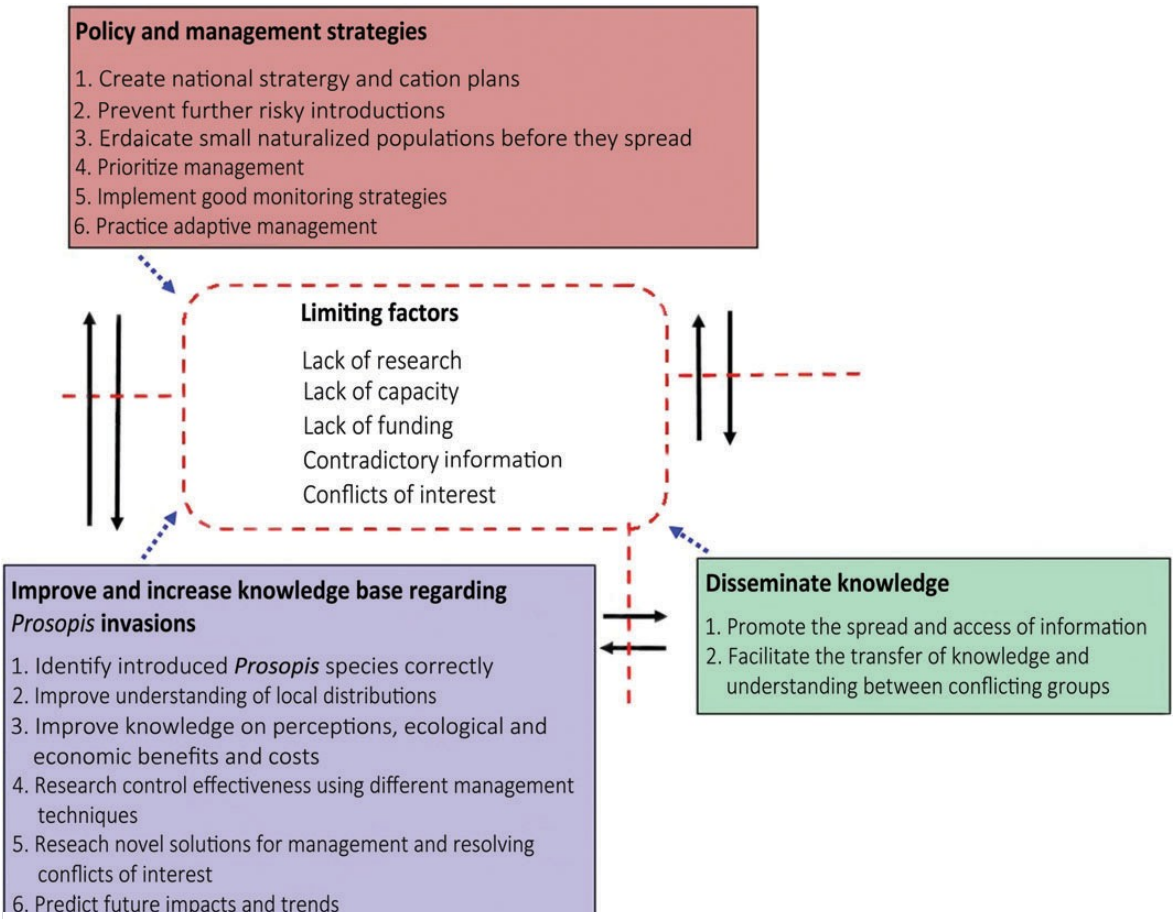


Figure 6. Requirements for research and management needs regarding *Prosopis*and factors limiting success.

Improve knowledge

There are many research questions regarding *Prosopis* invasions in many parts of the world that need to be answered to improve management (Fig. 6).

These include correctly identifying *Prosopis* species present and gaining consensus on the status introduced and weedy species (e.g. following the criteria proposed by Pyšek et al. 2013). There have been numerous misidentifications of introduced *Prosopis* species,

especially in Africa. This has caused much taxonomic confusion and contradictions between different sources of information that are only starting to be clarified. There are also hybridized populations in many areas where *Prosopis* has been introduced, further hindering identification (Zimmermann 1991. It was recently recognized that *P. pallida*, which was seen as not being as invasive as other species, is more widespread than originally thought as it was misidentified as P. juliflora in Africa (Pasiecznik et al. 2006b). Most species introduced to Africa were described as P. chilensis, but this is not the case, and accurate species lists are not available for many African countries such as Angola. Molecular methods are useful for clarifying taxonomic issues, especially in areas where hybridization has taken place. It is important to know which taxa are present for management, e.g. when looking for biological control agents and understanding ecology and rates of spread (Pyšek et al. 2013).

There is a need to improve the understanding of *Prosopis* distribution and population sizes in introduced ranges to guide management planning (Wilson et al. 2014). As indicated earlier, only 13 % of countries with naturalized and invasive *Prosopis* have maps or detailed records of occurrence and scale of invasion. No information is available on the scale of *Prosopis* invasions on any of the Pacific (besides Hawaii), Indian Ocean or Caribbean Islands. Only a few African countries have a good understanding of the scale of invasions and, in Asia, information on the distribution of invasive *Prosopis* is only available for India and Pakistan. Such knowledge is essential for planning and implementing management. Bioclimatic mapping at board local scales is useful for understanding potential spread and occurrence of invasive species. However, bioclimatic models can be of limited value at very local scales as other biotic and abiotic factors come into play (Robinson et al. 2011). On a global scale, bioclimatic modelling is useful for highlighting which countries and species need risk assessments for purposeful introductions, and where introduction pathways need to be monitored to prevent unintentional introductions, e.g. between India and China or Iran and Turkmenistan.

Further knowledge on the ecology, local perceptions, and the ecological, economic and social benefits and impacts of *Prosopis* is needed to guide management (Wilson et al. 2014). Our study has highlighted that knowledge on *Prosopis* invasions is essential for management (Table 1; Fig. 6). Most of the literature comes from a handful of countries (Australia, India, Kenya, South Africa, USA), and research in other areas is needed since each region has its own set of factors that drive invasions and complicate management. There is also a need for research to better predict trends such as future densities, extent and impacts which is particularly important when it comes down to developing strategic responses. Drivers of weediness in areas where it is native such as Argentina, Mexico, Middle East and the USA require further study to improve understanding of what drives native plants to become invasive and provide insight into how to manage them.

The issue of the lack of knowledge is also present for research on the effectiveness of controlling populations using different methods. Utilization as a control method is becoming popular in many areas such as Djibouti, Ethiopia and Kenya. However, despite many reports showing how much monetary benefit *Prosopis* has provided, there is no information on how successful this approach is for controlling *Prosopis*invasions. There are also conflicting ideas on the role and success of biological control in Australia and South Africa and further work is needed (Zachariades et al. 2011). There is scope for identifying and potentially releasing additional biological control agents to improve control success in areas where this has been limited until now, such as in South Africa (Zachariades et al. 2011). Research is needed to identify novel solutions to aid the dilemma of management and contentious issues regarding

invasive *Prosopis*globally. These include methods that retain the benefits, but reduce the impacts substantially.

Risk assessments need to be run for *Prosopis* species that have not been introduced yet to determine whether they might be better candidates for introduction, by providing benefits with fewer costs associated with invasiveness.

1.1.3.8 Dissemination of knowledge

Organizations should involve in addressing land degradation and invasions should promote the dissemination of knowledge and awareness of both the impacts and benefits of *Prosopis* to prevent unwise introductions and promote management (Fig. 6). Some people still advocate the introduction of *Prosopis* species long after the severe impacts caused by invasions of these species were widely publicized; this has been described as ‘dangerous aid’ (Low 2012). Having regular multidisciplinary international meetings or workshops on *Prosopis* invasions may help to spread knowledge and create dialogue between parties, which could help to reduce contentious issues surrounding many invasive *Prosopis* species. The creation of management strategies using transdisciplinary approaches would also help to provide solutions acceptable to all stakeholders in situations where conflicting goals exist.

2. OBJECTIVES

1. **Floral biodiversity monitoring over space and time-at two wetland.**
   - Conduct detailed floral biodiversity monitoring surveys on the two wetlands, over key seasons, for key plant communities as identified in the baseline studies conducted on these wetlands under the project during 2015-16.
   - Identify and mark permanent monitoring plots (linear/ area) that can be used by the wetland managers in the future for regular monitoring of floristic biodiversity. The permanent monitoring plots should be selected in agreement with the forest official incharge of the wetland, and after finalization, plots should be recorded on the wetland maps, using GPS.

2. **Observation on habitat dependence of faunal species plant communities.**
   - Key floral species/ assemblages/ spatial communities that are the primary food sourceof the key bird species at the two wetlands.
   - Water dependence of critical species/ vegetation communities.

3. **Assessment of existing plant invasive species and possible management option atthe two wetlands.**
   - Conduct a detailed population and density study of *Prosopisjuliflora* and Parthenium in the two wetlands, including their regeneration potential.
   - Conduct a desk study on the available management options for *Prosopis* and *Parthenium* in similar climatic and bio-physical conditions.

4. **Documentation and reporting.**
   - Photo document different plants parts of the important floral species of the two wetlands, and submit a CD/ external hard disk with all the photos of species with their scientific names as captions.
   - The consultant will be required to submit draft reports as per the timelines in section 6 of this document, and participate in project meeting to present the key results as per the agreed timelines, revise the report based on feedback, and submit the final report and along with an executive summary, and all raw data.

3. METHODOLOGY

3.1. Floral biodiversity monitoring over space and time at two wetlands.

3.1.1.Floral Biodiversity Monitoring

The Diversity study has been carried out from December 2016 to July 2017 to observe the change in the vegetation cover over key seasons.For floristic study the wetlands were divided into various sub-habitats and micro-habitats based on the changes occurred over a key seasons.

3.1.1.1. Sub-habitats of Gosabara Wetland Complex

The Gosabara wetland is divided into six sub-habitats to observe the change in the vegetation pattern in different habitats over a period of time. The six sub-habitats were further divided into various microhabitats. The details of sub-habitats with their micro-habitats are given in Figure 7.

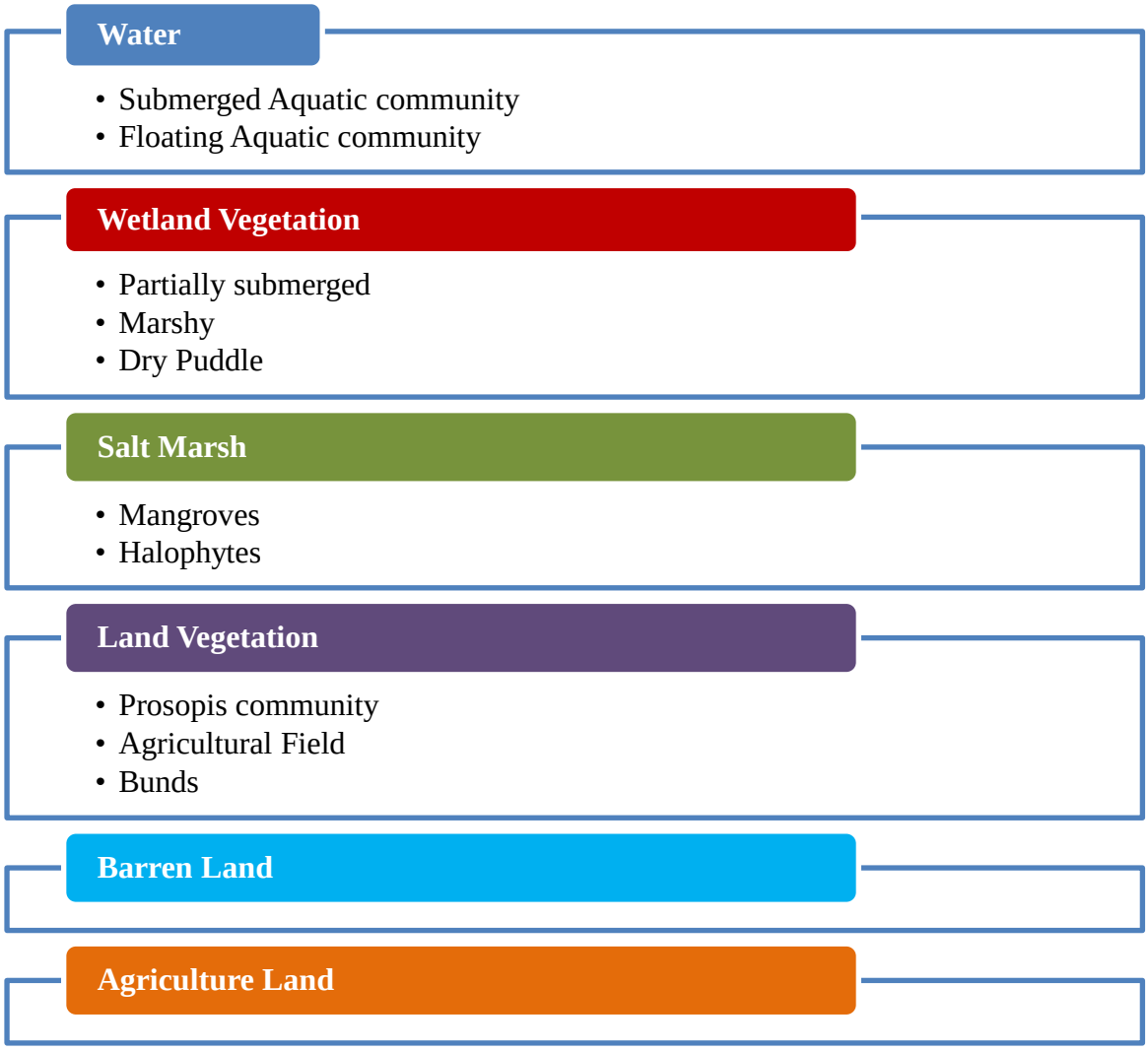


Figure 7: Habitat classification of Gosabara Wetland

3.1.1.2. Sub-habitats of Khijadiya Bird Sanctuary

The Khijadiya Bird Sanctuary was divided into four sub-habitats. The four sub-habitats were further divided into various microhabitats. The details of sub-habitats with their micro-habitats are given in Figure 8.

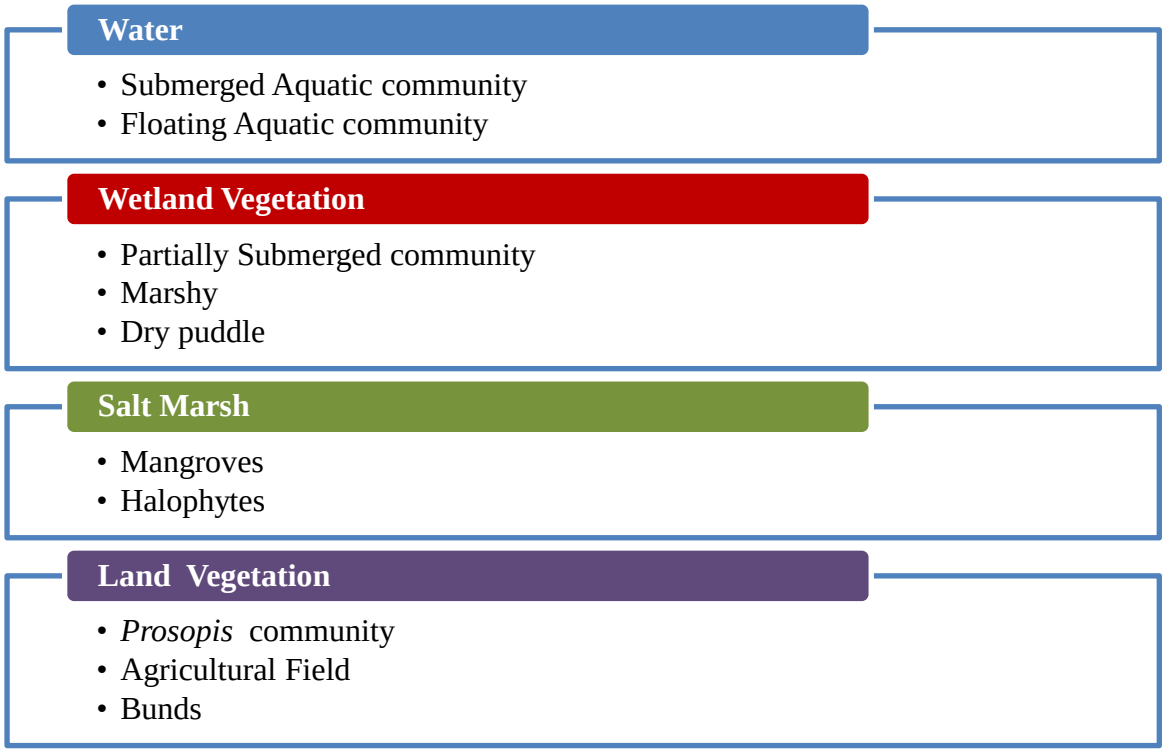


Figure 8: Habitat classification of Khijadiya

The plants were collected from the various sub habitats wereand identified in the lab with the help of relevant literature.The checklist of collected plantwas preparedfor both the wetlands according to their habitat and the information on their family and origin.

3.2. Observations on Habitat dependence of faunal species on plant communities

3.2.1. Key floral species/ assemblages/ spatial community analysis

The study of plant Communities were carried out for dominating and invasive species. For tree species representative quadrate of 10 × 10 m^2 were taken in their respective zones (Vegetation type) and for regeneration (*Prosopis*) 5 × 5 m^2 sample plots were prepared. For Shrubs 5 × 5 m^2 and for herbs random sample plots of 1 × 1 m^2 were taken in each vegetation type or composition as shown in Figure 9.

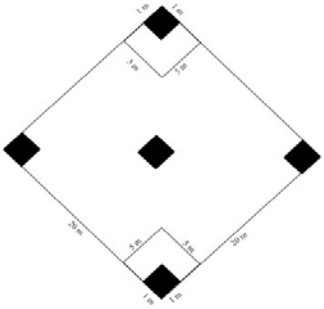


Figure 9: Position of samples in a nested quadrat approach

Based on the quadrate studies Frequency, Abundance, Density, Relative frequency, Relative Density and Relative dominance and Importance value Index (IVI) has been calculated (Misra, 2013)

$$\textbf{Frequency} = \frac{\text{No.of Quadates in which species occured}}{\text{Total Number of quadrates studied}} \times 100$$

$$\textbf{Abundance} = \frac{\text{Total no.of Individuals of the species in which species occured}}{\text{No.of quadrates in which species occured}}$$

$$\textbf{Density} = \frac{\text{Total No.of individuals of a species in all quadrates}}{\text{Total no.of quadrates studied}}$$

$$\textbf{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all the species}} \times 100$$

$$\textbf{Relative Density} = \frac{\text{No.of individuals of a species in all quadrates}}{\text{No.of individual of all species in all quadrates}} \times 100$$

$$\textbf{Relative Dominance} = \frac{\text{Total stand basal cover of the species}}{\text{Total stand basal cover of all the species}} \times 100$$

Importance Value Index = Relative frequency + Relative density + Relative dominance

3.2.2. Water dependence of critical species/ vegetation communities

3.2.2.1. Plankton Analysis

Phytoplankton's and Zooplankton's were collected using appropriate method (Goswami *et al.* 2004). The sample collection involves primarily the filtration of water through net. The sampling success will largely depends on the selection of a suitable gear, mesh size of netting material, time of collection, water depth of the study area and sampling strategy. The standard nylon net with 20 microns pore diameter was used for phytoplankton collection while, the pore size of the net for zooplankton was 50 microns.The nets with finer mesh captured smaller organisms, larval stages and eggs of planktonic forms and fish eggs while those with coarse netting material are used for collecting bigger plankton and fish larvae.The plankton collections were made by horizontal hauls because the water depth was 50-60 cm only. In the horizontal sampling the net is towed at a slow speed usually for 5 to 10 minutes. The towing speed of the net recommended for horizontal samples is 1.5 to 2.0 knots. The collected samples were immediately preserved in either Lugol's solution or 4% formalin made in freshwater or saline water as per the collected samples. The samples were brought to the laboratory for further analysis. The plankton was identified through microscopic observations using appropriate keys (Goswami *et al.*, 2004).

Sampling Site Selection:

Following criteria were considered for determining sampling sites:

1) **Observation of wetland for bird's diversity status**– Observation of behavioural pattern of birds, their habitat and their activity at particular location. Whether they feed, rest or breed.
2) **Study of water depth** – Some birdsnorish themself from certain water depth or resting water body. Ducks and herons are few examples.
3) **Which water body is used as only as a resting ground** – Some water bodies are utilised as a resting area of Birds. Why the birds are using that particular area only as a resting ground? There is no plankton? Or there is low temperature?
4) **Where the threatened birds are feeding** – To conserve threatened bird, their identificationare necessary. Are they feeding on some specific kind of planktons which are available in that particular water body?
5) **Where the Human disturbance and interruption is low**– usually birds are feed, breed, rest and nest at particular area. Upto what extent human activity influence the population of fauna?

3.3. Assessment of existing plant invasive species and possible management options at the two wetlands

3.3.1. Population and Density study of *Prosopis juliflora* and *Parthenium hysterophorus*

The field survey was carried out from December 2016 to May 2017 to collect the vegetation data depending upon the ecology of *P. hysterophorus*. Where massive growth of the weed occurs, road transect survey method was employed (Wittenberg *et al*., 2004) in 50 m distance to lay a quadrat. Since the study area is well known in its agroforestry system other than grazing land, 140 quadrats (10 from each pocket) around roadsides, open area/bunds and the surrounding farmlands weresampled. For herbaceous vegetation 1 × 1 m^2quadrae were laid in order to collect data and assess impact of *Parthenium* on aboveground vegetation cover. GPS readings were recorded for each sampling unit. In order to investigate the relative abundance and composition of the herbaceous vegetation as impacted by *Parthenium*, the proportion of individual species (cover and abundance of the plant species) encountered in each of the quadrats was recorded using the procedure documented by Wittenberg et al. (2004). This method involves a total estimate based on abundance and cover of the species where invasion is spatially patchy. The total estimate scale (abundance plus coverage) will be assessed as a plant species covers a very small area (+), cover small area (1), less or equal to 5% area coverage (2), 6 to 25% area coverage (3), 26 to 50% area coverage (4), 51 to 75% area coverage (5) and 76 to 100% area coverage (6). Following the methods suggested by Chellamuthu et al. (2005), the sample sites will be categorized into different groups based on parthenium invasion levels: None, very low (< 10%), low (11 to 25%), moderate (26 to 50%) and high (> 50%) of the total percent area coverage of parthenium weeds.
Based on the survey, suitable techniques to eradicate the invasive species was recognised and experimented.
For understanding the impact of Prosopis quadrat of 10 X 10 m (100m^2) across different sub-habitats was studied with special reference to ingress of *prosopis* in aquatic zones. Based on the experimental method, management assessment was done on how *Prosopis*can be eradicated from the region.

4. RESULTS

4.1. Floral biodiversity monitoring over space and time at two wetlands:

4.1.1. Floral biodiversity monitoring

4.1.1.1. Diversity monitoring at Gosabara Wetland Complex

The Gosabara wetland complexcomprises of 141 taxa, among them two are Pteridophyte and the remaining are angiosperms (139) (Annexure 1). Within 139 species of Angiosperm; 107 are Dicots belonging to 91 genus and 32 are monocots from 31 genus. Fabaceae and Asteraceae are the two dominant families among all dicotyledons. The comparison of angiosperm diversity was done during the current year survey 2016 – 2017 with that of previous year 2015 – 2016 report as shown in Figure 10. The diversity is less probably owing to poor rain fall in 2016-17.

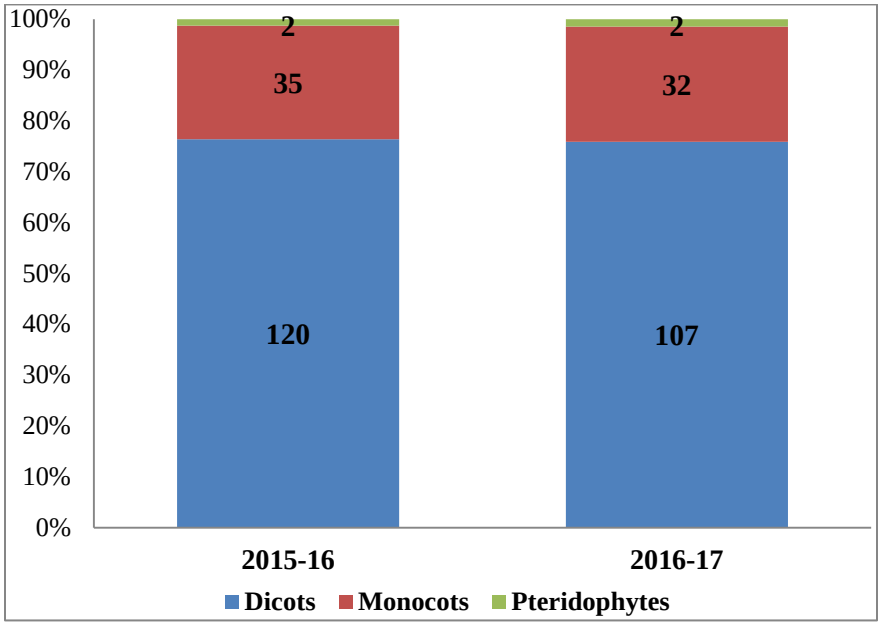


Figure 10: Comparative Account of Floral Diversity at Gosabara Wetland Complex

During current field survey (2016–2017), 141 plant taxa were identified from Gosabara wetland which were further classified into six different classes on the basis of their habitats namely Water (aquatic) vegetation, Wetland vegetation (incl. aquatic vegetation), Salt marshy vegetation, Barren land vegetation, Land vegetation and Agriculture land vegetation.**Water (aquatic) vegetation** comprises of 11 species which were further classified into two micro habitats. Five species were having sub-merged habitat with Hydrocharitaceae as a dominant family and six species belongs to floating habitat. **Wetland Vegetation** comprised of 31 species, of which four were partially submerged, 12 were of wetland or marshy habitat, 15 from dry puddle habitat and a species of mangrove *Avicennia marina* (Forssk.) Vierh. from Avicenniaceae family. The **salt marsh vegetation** was represented by seven salt tolerant species and the area under the influence of tides was dominated by Chenopodiaceae family on saline ground. **Land vegetation** consists of 84 species representing seven species from *Prosopis* occupied area (*Prosopis* is an invasive plant which is the main dominant species), 40 species from Bunds and 35 species from open land area of wetland. **Barren land vegetation** comprised of six species from sandy beach habitat. **Agriculture land vegetation** enlisted only *Cadaba fruticosa*plant which is used as hedge on the

agricultural fields to the surrounding and adjacent wetland. So the overall obtained result from the survey acquaint with 141 species classified on the basis of their habit.96 were herbs, seven climbing herbs, three twining herbs, one creeping herb, 15 shrubs, two twining shrubs, four climbing shrubs, five under shrubs and eight trees as shown in **Annexure 1**.

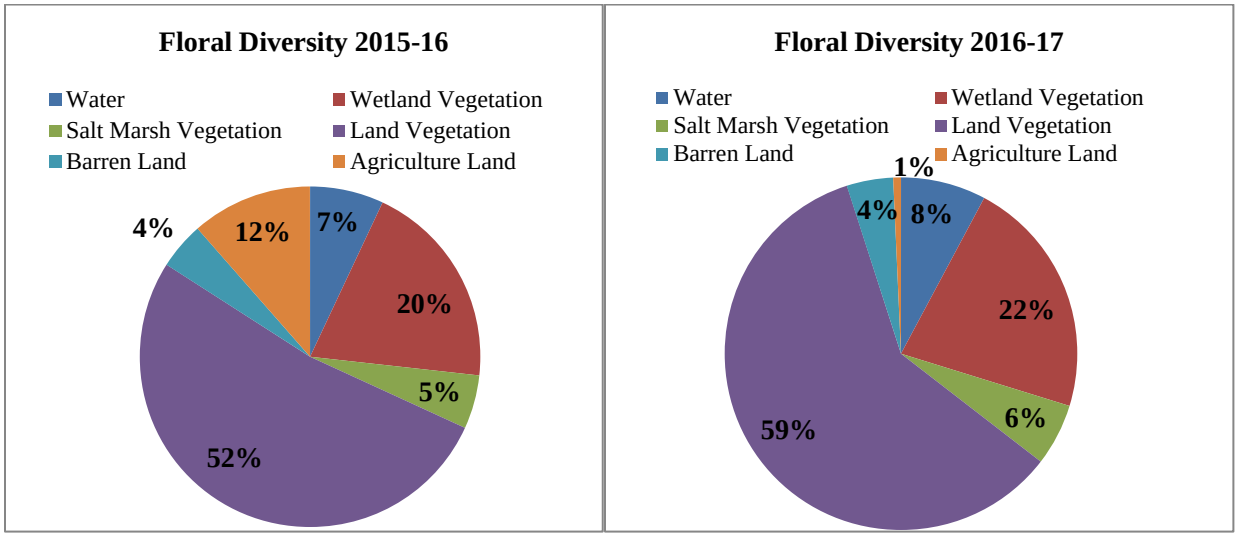


Figure 11: Comparative account of floral diversity at various sub habitats of Gosabara

The comparison of floral diversity from various microhabitats in 2015-16 and 2016-17 are shown in the Figure 11. Water vegetation, barren land vegetation, wetland vegetation and salt marsh vegetation show no significant change in the flora. 8% increase in the population diversity of the land vegetation was observed compared to last year survey. The major diversity change was observed in the case of Agriculture vegetation. In 2015-16 Agriculture vegetation comprised of 12% of the total diversity while in 2016-17 it was reduced down to 1% which is a serious concern regarding the point of conservation of flora diversity of the Gosabara region.

4.1.1.2. Diversity Monitoring at Khijadiya Bird Sanctuary

The Khijadiya Bird Sanctuary comprises of 88 taxa, among them one is Pteridophyte and remainining are angiosperms (87) (Annexure 2). Within 87 species of Angiosperm; 70 are Dicots belonging to 64 genus and 17 are monocots from 17 genus. Out of the 70 dicots, 63 are of indigenous origin and 7 are exotic with Chenopodiaceae and Asteraceae as dominant family. Similarly out of 17 species ofmonocots, 15 are ofindigenous origin and 2 are exotic with Poaceae as domiant family. The comparison of angiosperm diversity was done during the current year survey 2016-2017 with that of previous year 2015-2016 report as shown in Figure 12.

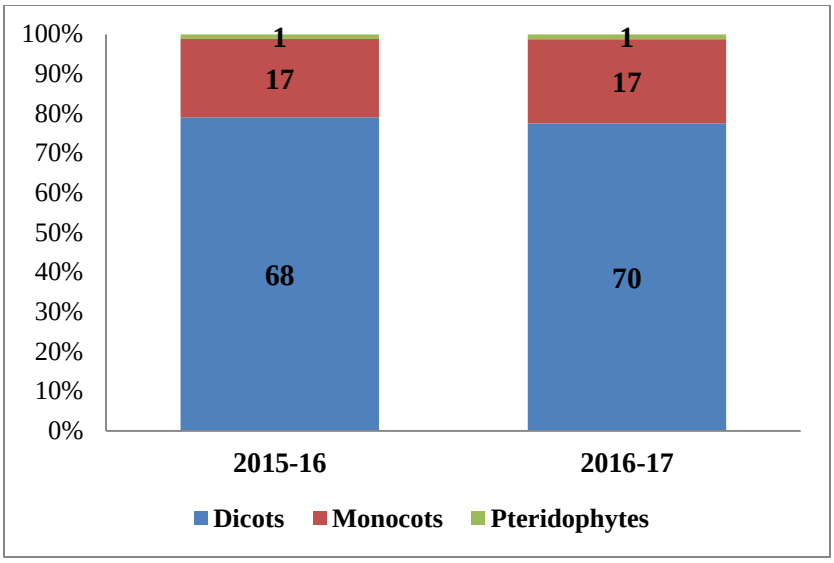


Figure 12: Comparative Account of Floral Diversity at Khijadiya Bird Sanctuary

In the current field survey of 88 species of plants were explored from various sub-habitats namely Water, Drying Wetland (wetland vegetation), Salt marsh vegetation and Land vegetation of Khijadiya Bird Sanctuary. **Water (aquatic) vegetation** comprises of eight species which were further classified into two micro habitats. Five species were having sub-merged habitat with Hydrocharitaceae as a dominant family and three species belongs to floating habitat. **Drying wetland vegetation** comprises of 21 species which were further classified on the basis of their micro habitats. Three species were having partially sub-merged; six species are of wetland or marshy plants and 12 species are of dried wetland (Dry puddle).The **salt marsh vegetation** was represented by 14 salt tolerant species and 3 species of mangroves. **Land vegetation** includes plants on the open land area of wetland which represents 44 species where *Prosopis* is the main invasive species in whole sanctuary. On the basis of habit, out of 88 species 56 were herbs, three climbing herbs, one creeping herb, two twining herb, two climbing shrub, three under shrub, elevenshrubs and eleven trees (Annexure 2).

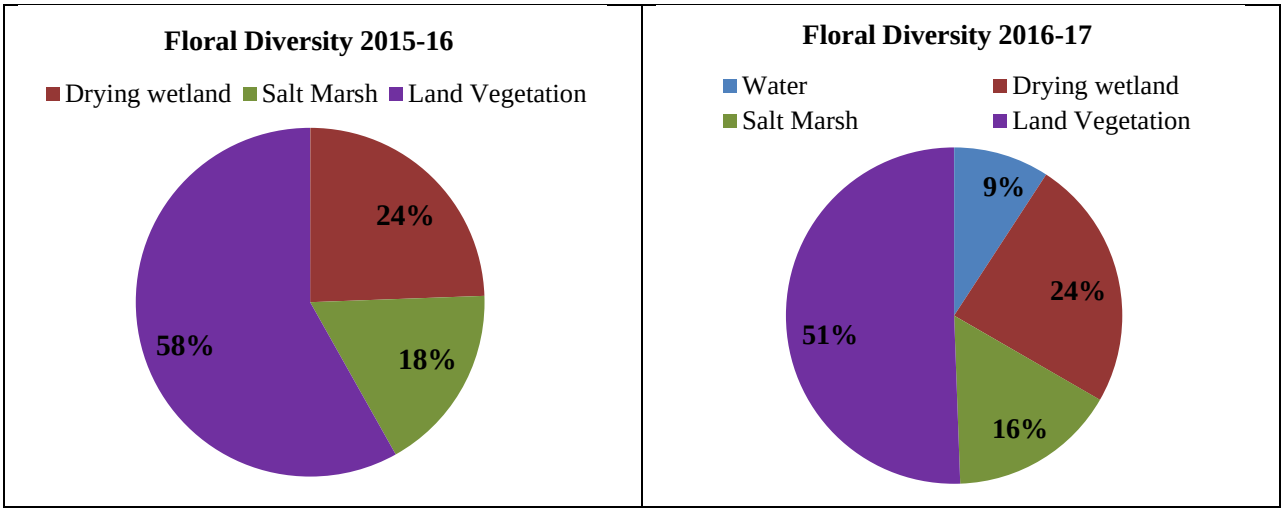


Figure 13: Comparative account of floral diversity at various sub habitats of Khijadiya

Floral diversity comparison embodies various microhabitats in 2015-16 and 2016-17 (Figure 9). It shows during 2015-16 due to scarcity of rain no water bodies were formed leading to lack of aquatic plant diversity but during 2016-17 good amount of water is harvested by the forest department leading to the growth of some aquatic plant species. There is no significant change in the floral diversity of other sub-habitats. Slight change was observed in Drying wetland and Land vegetation. In 2015-16 drying wetland and Land Vegetation comprised of 58% and 24% of the total diversity while in 2016-17 it was reduced down to 2% which is a serious concern regarding the point of conservation of flora diversity.

4.1.2. Permanent Monitoring Plot

4.1.2.1. Permanent Monitoring Plot at Gosabara

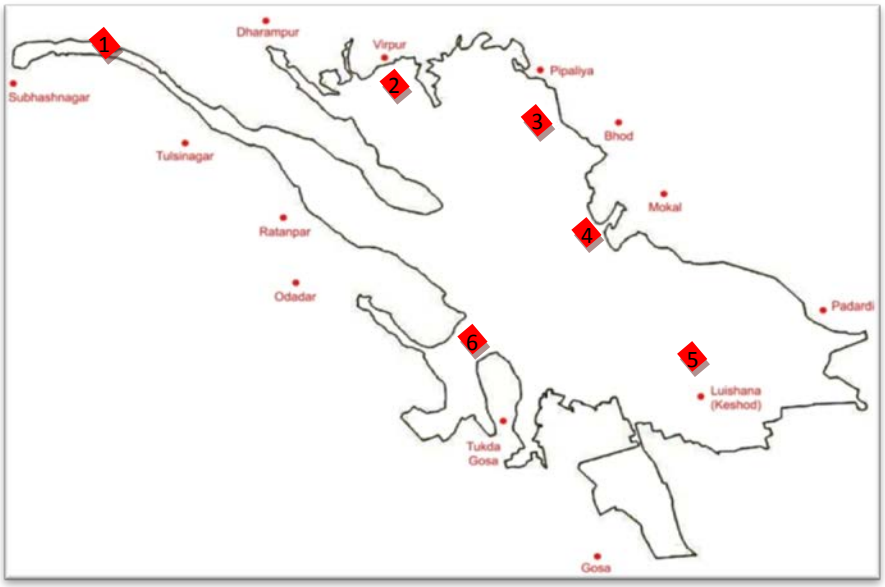


Figure 14: Permanent Monitoring Plot at Gosabara

GPS Points of Permenent Monitoring Plot at Gosabara

1.21°38’58.83”N, 69°37’30.72”E

2.21°38’17.84”N, 69°42’18.04”E

3.21°38’14.44”N, 69°44’36.79”E

4.21°35’44.94”N, 69°45’31.19”E

5.21°33’59.21”N, 69°46’58.89”E

6.21°32’27.09”N, 69°43’07.45”E

4.1.2.2: Permanent Monitoring Plot at Khijadiya

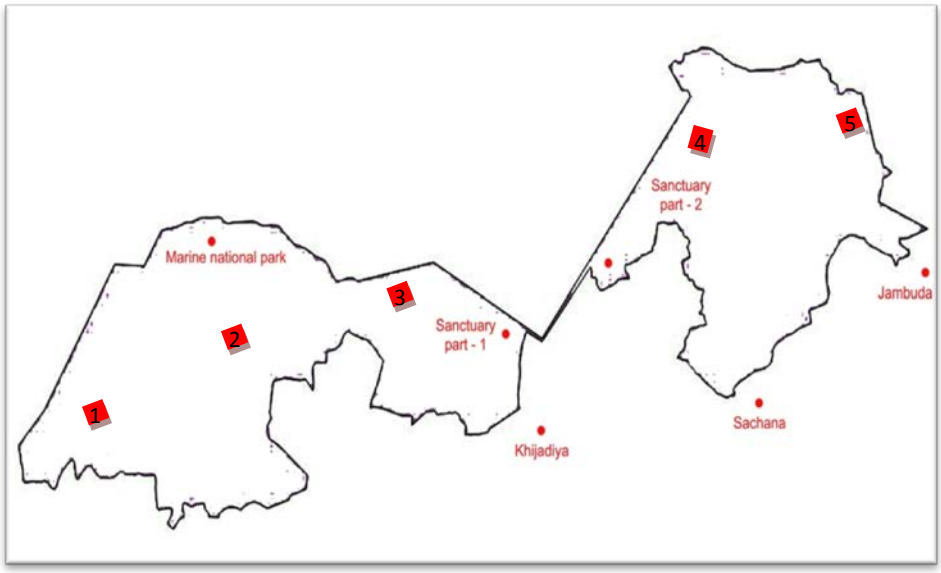


Figure 15: Permanent Monitoring Plot at Khijadia

GPS Points of Permenent Monitoring Plot at Khijadiya

1.22°30’36.73”N, 070°06’10.98”E

2.22°30’52.72”N, 070°07’11.48”E

3.22°31’15.35”N, 070°08’16.89”E

4.22°32’11.63”N, 070°10’26.88”E

5.22°32’17.45”N, 070°11’23.62”E

4.2. Observations on habitat dependence of faunal species plant communities

4.2.1. Key floral species/assemblages/spatial communities that are primary food source of Key bird species at two wetlands

Phytosociologial analysis was carried out for understanding the Key Floral species/assemblages/spatial communities that are primary food source of Key bird species at the two wetlands.Different Parameters namely frequency, density, abundance, relative frequency, relative density, relative dominance and IVI were taken into consideration for the analysis.

4.2.1.1. Key floral species/assemblages at Gosabara Wetland Complex

In Gosabara, eight dominant species were taken into consideration for phytosociologial analysis which includes two trees and five species of herbs. Two dominant tree species considered for analysis are *Prosopis juliflora* and *Acacia nilotica. A. nilotica* was having IVI value 9.75 which is lowest among all considered species (Table 1). The five dominant species of herbs considered

for IVI analysis are *Cressa cretica*, *Suaeda nudiflora*, *Bolboschoenus maritimus*, *Aeluropus lagopoides* and *Salicornia brachiata*.

S. nudiflora is the dominant species in Gosabara wetland with maximum IVI value 55.08 and highest frequency value that shows its even distribution in all the sites of wetland followed by *B. maritimus, C. cretica, S. brachiata* and *A. lagopoides* with IVI 55.08, 48.62, 29.87 and 10.09 respectively. The distribution patterns of individuals of different species indicate their reproductive capacity and adaptability to the environment. *S. nudiflora* is found to be most frequent and adjustable species for wetland area. The IVI value of *A. lagopoides* compared to the other species is less, indicating its restricted distribution.

4.2.1.2. Spatial Community Analysis at Gosabara Wetland

The community of *Prosopis* is though occurring invasively to the resting site for the terrestrial and aquatic birds. However the *Prosopis* can be gradually removed and replaced by indigenous *Acacia nilotica* and *Salvadora persica* on (Bunds). The fruits (drupe) of *Salvadora* are an important food resource for the migratory and terrestrial birds.

Similarly the community of *Schoenoplectus* and *Bolboschoenus* are the source of starchy tubers which are eaten by many aquatic birds especially blue moorhen. The community of *Cressa cretica, Salicornia, Suaeda, Aeluropus* is potentially a good feeding ground for many birds during winter and summer period.

The Gosabara wetland complex is spread over an area of 129 square km. A total of 10 communities were studied during the period of 2016-17 and the area covered by various communities is calculated in sq. km. Among 10 communities five are pure and the remaining are mixed communities. Amongst pure communities; the community formed by *Prosopis juliflora* has covered maximum area (1.06% of the total area) of the wetland, followed by *Cressa cretica* (0.22%) and *Bolboschoenus maritimus* (0.12%). The community of *Salicornia brachiata* has covered minimum area (0.05%) of the wetland compared to the other communities.Amongst the mixed communities; the community formed by *Suaeda nudiflora + B. maritimus + C. cretica* (The appearance of *S. nudiflora* is an indicative of conjunction between the fresh waterand sea water) has covered the maximum area of the wetland (4.85%) followed by *B.maritimus*+ *C.cretica* and *B.maritimus + S.nudiflora* covering area 2.59% and 0.88% respectively of the total area of wetland respectively. The community formed by *Sporobolus virginicus + C. cretica* has covered minimum area of the wetland (Fig.16).

Table 3: Key floral species/assemblages of Gosabara Wetland Complex

S.No.	Species	Frequency %	Abundance	Density	Relative frequency %	Relative Density %	Relative Dominance %	IVI
Herbs (m^{-1})								
1.	*C.cretica*	23.07	25.57	31.06	23.07	24.48	-	48.62
2.	*S. nudiflora*	41.02	21.19	23.86	43.58	21.17	-	64.76
3.	*B.maritimus*	16.67	30.01	25	16.67	16.67	-	55.08
4.	*A.lagopoides*	5.12	4.97	3.78	5.12	4.96	-	10.09
5.	*S.brachiata*	11.53	18.35	16.67	11.53	18.33	-	29.87
Tree (ha^{-1})								
6.	*A.nilotica*	13.14	2.53	3.57	13.15	2.53	-	9.75

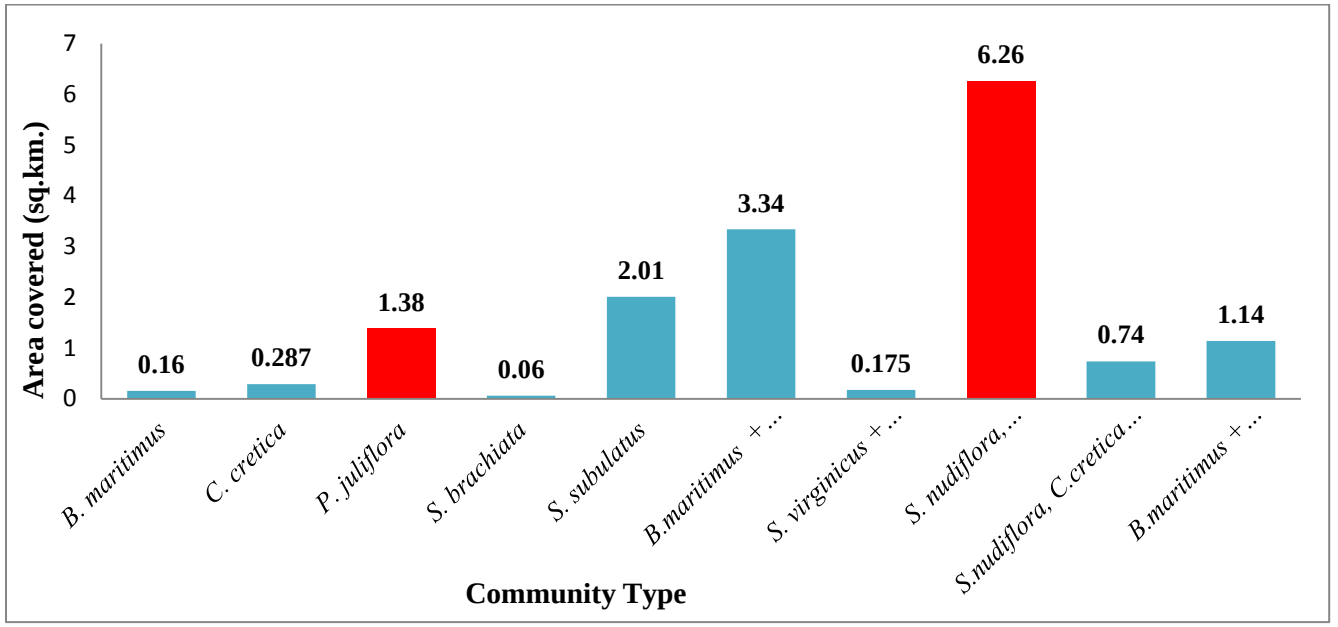


Figure 16: Plant Communities in Gosabara Wetland Complex

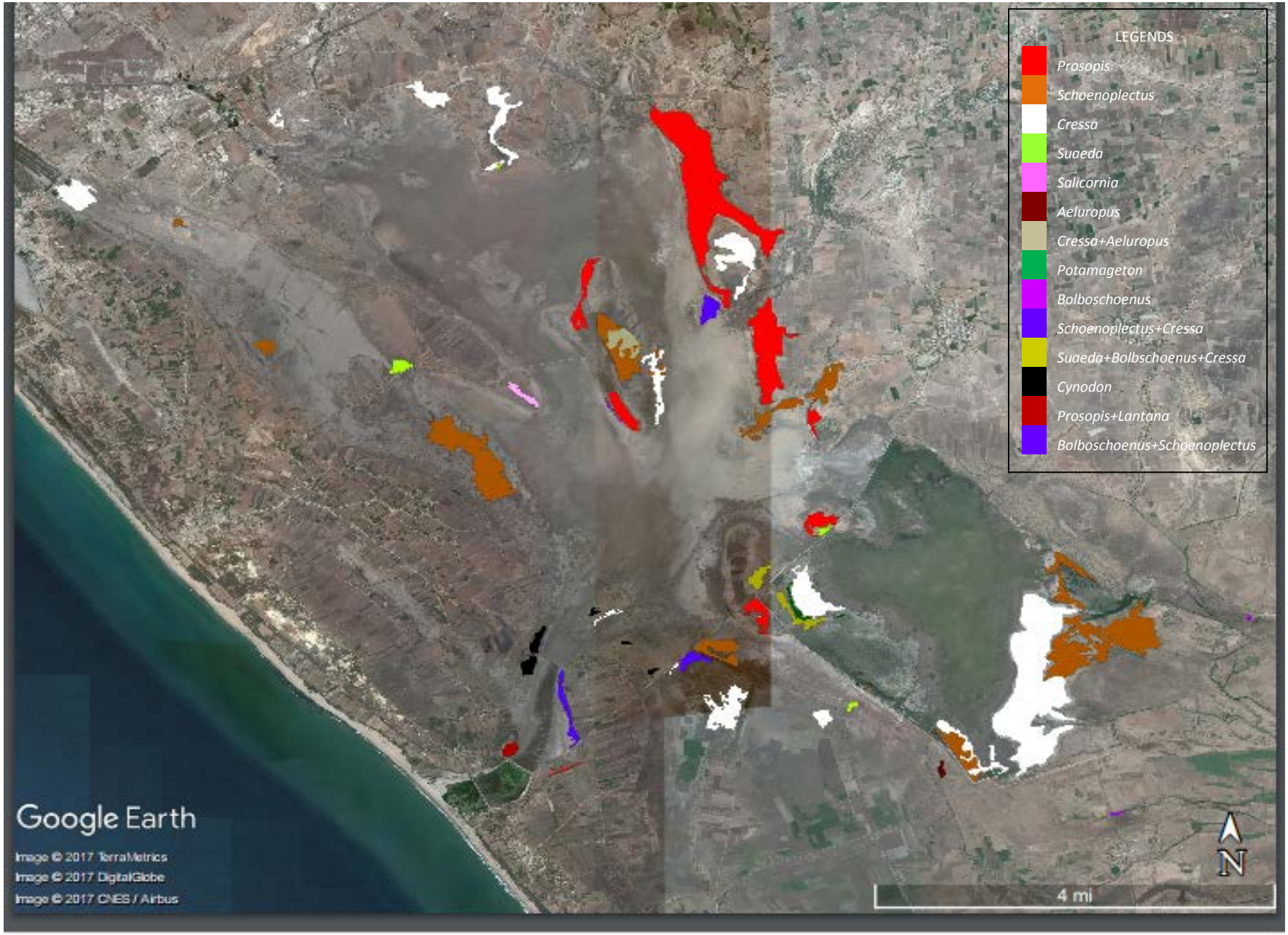


Figure17: Different plant Communities in Gosabara in Feb 2017

4.2.1.3. Key floral species/assemblagesatKhijadiya Bird Sanctuary

From Khijadiya Sanctuary, 11 tree species were recorded. Among them twoare dominant species *i.e. Prosopis juliflora* and *Salvadora persica* which were considered for phytosociologial studies. *S. persica* has scanty distribution; found on the bunds and scattered on some site with IVI value 61.8 and highest abundance. The detail about population analysis of *P. juliflora* is given in invasive species analysis of Table 4.

56 species of herbs were recorded of which three dominant species were taken into considerationfor the analysis. *Cressa cretica* is the most dominant species with IVI value 146.49 followed by *Aeluropus lagopoides* and *Suaeda nudiflora* with IVI values 19.6, 3.62 respectively. *A. lagopoides* has IVI value is less compared to *C. cretica* but shows highest frequency value indicating its even distribution in all the parts of the sanctuary. As *C. cretica* is dry puddle species and found on the saline grounds. As soon as water gets evaporated from the shoreline, *C. cretica* spreads all over the area and become dominant herb.

Table 4: Key floral species/assemblages of Khijadiya Bird Sanctuary

S.N.	Species	Frequency %	Abundance	Density	Relative frequency %	Relative Density %	Relative Dominance %	IVI
Herbs (m^{-1})								
1.	*A. lagopoides*	11.86	8.01	14.4	8.01	13.58	-	19.86
2.	*C.cretica*	6.25	84.6	90.93	76.27	74.57	-	146.49
3.	*S.nudiflora*	3.39	0.23	0.1	3.38	0.23	-	3.62
Regeneration (ha^{-1})								
4.	*S.persica*	77078	97.67	16.45	24.67	59.07	-	61.82

4.2.1.4. Spatial Community Analysis at Khijadiya Bird Sanctuary

The Khijadiya Bird Sanctuary is spread over an area of 19 square km. A total of six communities were studiedand the area covered by various communities is calculated in sq. km. Among six communities three are pure and three are mixed communities. Amongst the pure communities; the community formed by *Prosopis juliflora* has covered 13.47% area of the sanctuary followed by *Cressa cretica* (0.68%) and *Phragmites karka* (0.005%). Among mixed communities the area covered by *Tamarix indica* + *C.cretica* is relatively more (0.16%) compared to the others (Figure 18).

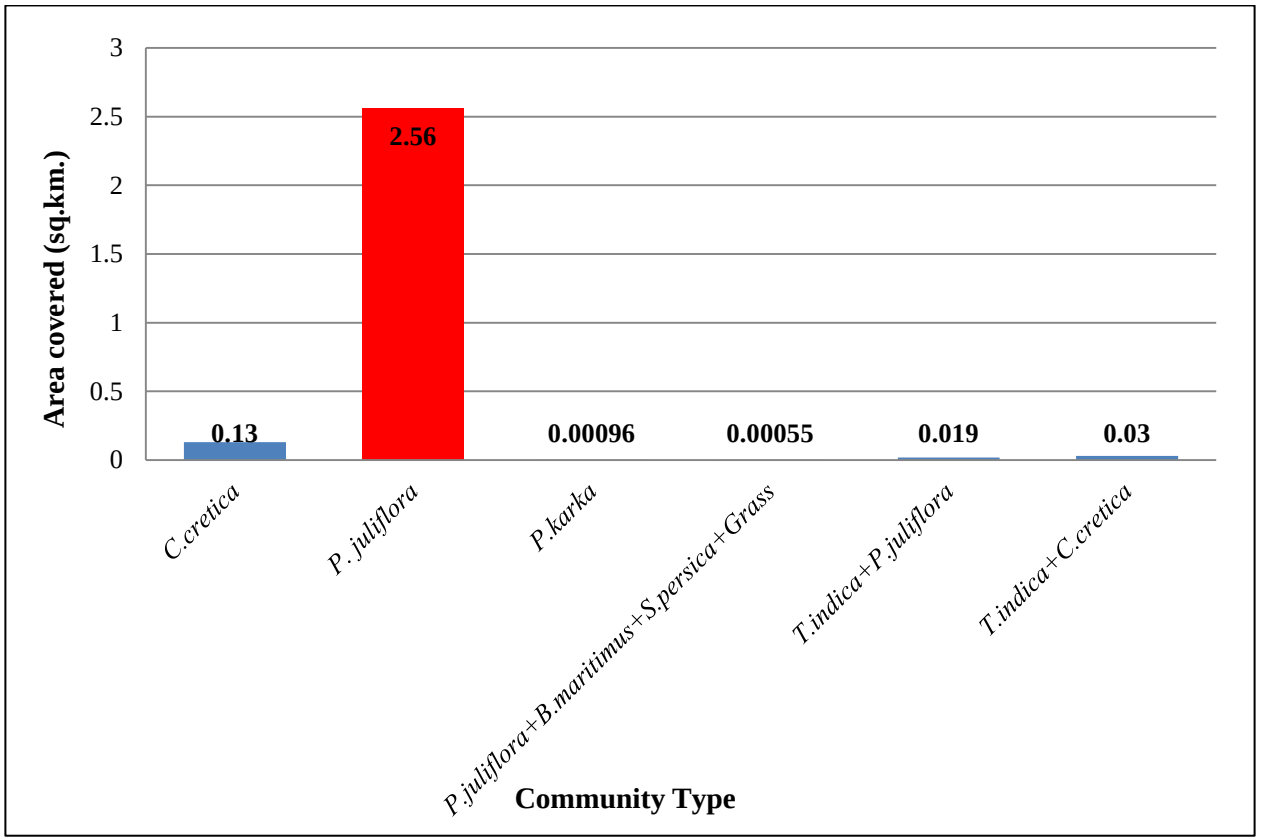


Figure 18: Plant Communities in Khijadiya Bird Sanctuary Feb 2017

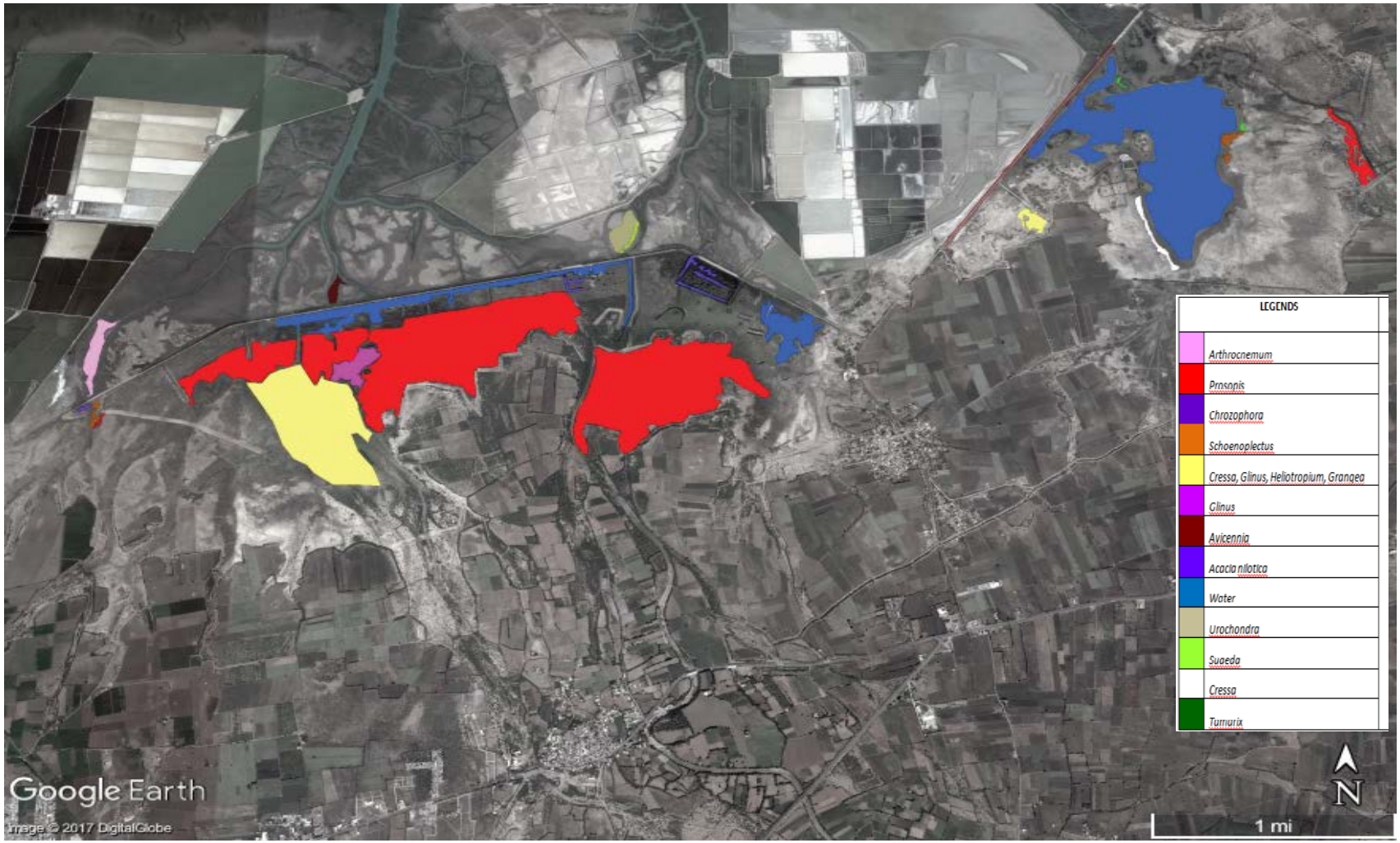


Figure 19: Different Plant Communities in Khijadiya Bird Sanctuary

4.2.1.5. Water Dependence of Critical Species/Vegetation Communities.

4.2.1.5.1. Niche for Bird habitat across different plant communities

Table 5 represents the data of bird habitat across different plant communities of both the wetlands.Mainly birds in Gosabara and Khijadiya bird sanctuary.

Table 5: Niche of Birds across different plant communities at both the wetlands

S.No.	Common Name	Scientific Name	Plant Species	Resting	Hiding	Perching
1	Asian Koel	*Eudynamys scolopacea*	*Prosopis juliflora*	-	+	+
2	Bank Myna	*Acridotheres ginginianus*	*P.juliflora, Salvadora persica*	+	-	+
3	Black Drongo	*Dicrurus macrocercus*	*P.juliflora, Acacia nilotica*	-	-	+
4	Black naked stork	*Ephippiorhynchus asiaticus*	*Bolboschoenous maritimus*	-	-	-
5	Black-headed Bunting	*Emberiza melanocephala*	*P. juliflora*	-	+	+
6	Blyth's Reed Warbler	*Acrocephalus dumetorum*	*B.maritimus*	-	+	+
7	Brahminy Starling	*Sturnus pagodarum*	*P.juliflora , S. persica, A.nilotica*	-	-	+
8	Common Kingfisher	*Alcedo atthis*	*P. juliflora*	-	-	+
9	Common Myna	*Acridotheres tristis*	*P.juliflora, S.persica*	+	-	+
10	Common Stonechat	*Saxicola torquatus*	*B. maritimus*	-	+	+
11	Drongo	*Dicrurusma crocercus*	*P. juliflora*	-	+	-
12	Eurasian Collared Dove	*Streptopelia decaocto*	*P.juliflora,A.nilotica*	-	-	+
13	Eurasian Wryneck	*Jynx torquilla*	*P.juliflora*	-	+	+
14	Great Egret	*Casmerodius albus*	*Lantana camara*	-	-	+
15	Greater Coucal	*Centropus sinensis*	*P.juliflora, A.nilotica*	-	+	+
16	Grey Heron	*Ardea cinerea*	*P.juliflora*	-	-	+
17	House Sparrow	*Passer domesticus*	*P.juliflora, S.persica*	+	+	+
18	Indian Silver bill	*Lonchura malabarica*	*P.juliflora, B.maritimus*	+	+	+
19	Isabelline Shrike	*Lanius isabellinus*	*P.juliflora*	-	-	+
20	Laughing Dove	*Streptopelia senegalensis*	*P.juliflora, A.nilotica*	-	+	+
21	Little Egret	*Egretta garzetta*	*Lantana camara*	-	-	+

S.No.	Common Name	Scientific Name	Plant Species	Resting	Hiding	Perching
22	Long-Tailed Shrike	*Lanius schach*	*P.juliflora, A.nilotica*	-	-	+
23	Oriental Magpie Robin	*Copsychus saularis*	*P.juliflora*	-	+	+
24	Oriental white eye	*Zosterops ceylonensis*	*S.persica*	-	+	-
25	Oriental white eye	*Z.palpebrosus*	*Avicennia marina*	-	+	-
26	Oriental White-eye	*Z.palpebrosus*	*S.persica*	+	+	+
27	Pied Bush Chat	*Saxicolacaprata*	*P.juliflora*	-	+	+
28	Plain Prinia	*Prinia inornata*	*S.persica*	-	+	+
29	Pond Heron	*Ardeola grayii*	*L. camara*	-	-	+
30	Purple swamphen	*Porphyrio porphyrio*	*B.maritimus*	-	+	-
31	Radde's warbler	*Phylloscopussu baffinis*	*B.maritimus*	-	+	-
32	Red Headed Bunting	*Emberiza bruniceps*	*P.juliflora*	-	+	+
33	Red- headed bunting	*Emberizame lanocephala*	*P.juliflora*	+	-	-
34	Red-Vented Bulbul	*Pycnonotus cafer*	*P.juliflora, S.persica, A.nilotica*	+	+	+
35	Rock Pigeon	*Columba livia*	*A. nilotica*	-	-	+
36	Rosy Starling	*Sturnus roseus*	*P.juliflora , S.persica, A.nilotica*	+	+	+
37	Spotted Dove	*Streptopelia chinensis*	*P.juliflora, A.nilotica*	-	+	+
38	Yellow-crowned Woodpecker	*Leiopicus mahrattensis*	*A.nilotica*	-	+	+

"+" =used;"-" =notused

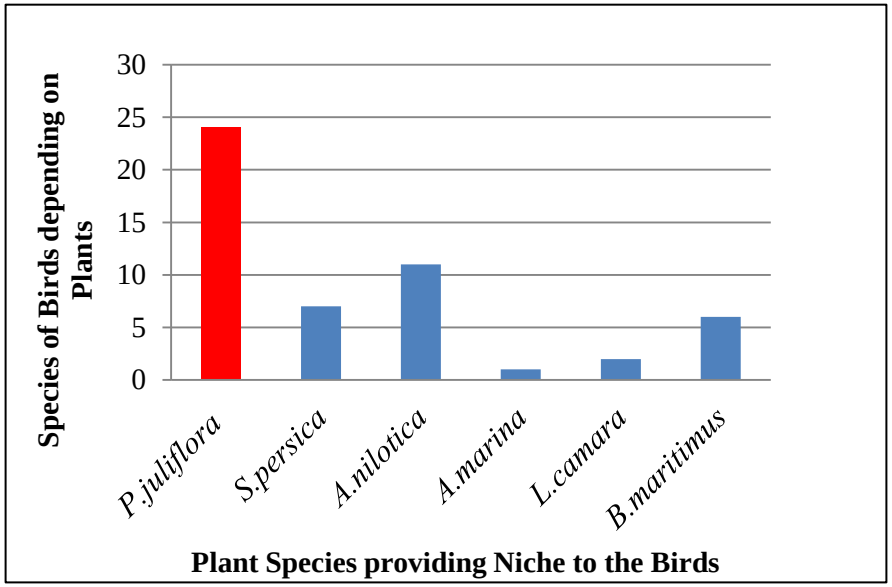


Figure 20: Key species of plants providing Niche

Figure 20 show that *P. juliflora* is the Key species.It is the main source of resting, hiding and perching for number of bird species (24 species) followed by the community of *A. nilotica* (11 species), *S. persica* (7 species) and *B. maritimus* (6 species). Oriental white eye exclusively depends on *A. marina* community for hiding purpose. Pond heron and little egrot chiefly rely on *L. camara* for perching.

4.2.1.5.2. Food Preference of Bird in Wetland

Table 6 represents the list of frugivore bird species primarily depends on plant parts mainly fruits. The fruit of *Salvadora persica* are the main diet for 12 species of birds. The other species of plants used by the birds for feeding purpose are *Bolboschoenus maritimus*, *Prosopis juliflora*, *Stuckenia pectinata* and *Avicennia marina* (Table 6). Eurasian Coot was observed on many occasions eating the fruits of *Nymphaeae* and *Ottelia*. Northern shoveler was observed to eat fruits of *S. pectinata* and that of algal species. Bulboschnecous and Schenoplectous tubers and seeds were eaten by many aquatic birds specially, *Purple swamphen.*

Table 6: Feeding habitat of birds in both the wetland

S.N.	Bird Name		Plant species	Part of plant used				
	Common name	Scientific name		Stem	Blub	Fruit	Seed	Nectar
1.	Bank Myna	*Acridotheres ginginianus*	*S.persica*	-	-	+	-	-
2.	Black naked stork	*Ephippiorhynchus asiaticus*	*B.maritimus*	-	+	-	-	-
3.	Brahminy Starling	*Sturnus pagodarum*	*S.persica*	-	-	+	-	-
4.	Common crane	*Grusgrus*	*B.maritimus*	-	+	-	-	-
5.	Common Myna	*Acridotheres tristis*	*S. persica*	-	-	+	-	-
6.	Common Tailorbird	*Orthotomus sutorius*	*S.persica*	-	-	+	-	-
7.	Common White-throat	*Sylvia communis*	*S.persica*	-	-	+	-	-
8.	Drongo	*Dicrurusma crocercus*	*P.juliflora*	-	-	-	-	-
9.	Eurasian Coot	*Fulicaatra*	*S.pectinata, Nymphaea pubescence, Ottelia*	+	+	+	-	-
10.	House crow	*Corvuss plendens*	*S.persica*	-	-	+	-	-
11.	Northern shoveler	*Anasclypeata*	Algal material, *S.pectinata*	-	-	-	-	-
12.	Oriental white eye	*Zosterops ceylonensis*	*S.persica*	-	-	+	-	-
13.	Oriental white eye	*Zosteropspalpebrosus*	*A.marina*	-	-	-	-	-
14.	Purple Sunbird	*Cinnyris asiaticus*	*S.persica*	-	-	-	-	+
15.	Purple swamphen	*Porphyrio porphyrio*	*B.maritimus*	+	+	-	-	-
16.	Radde's warbler	*Phylloscopussu Baffinis*	*B.maritimus*	-	-	-	-	-
17.	Red- headed bunting	*Emberizame lanocephala*	*P.juliflora*	-	-	-	-	-
18.	Red vented bulbul	*Pycnonotus cafer*	*S.persica*	-	-	+	-	-
19.	Rosy starlings	*Pastor roseus*	*S.persica*	-	-	+	-	-
20.	Scaly breasted munia	*Lonchura punctulata*	*S.persica*	-	-	+	-	-
21.	White eared bulbul	*P.leucotis*	*S.persica*	-	-	+	-	-
22.	White eared bulbul	*P.leucotis*	*A.marina*	-	-	-	+	-

"+" = used/eaten;"-" = not used

4.2.1.5.3. Gosabara Wetland Dependence - Plankton Diversity

Gosabara wetland is a complex wetland with a conjuction of Sea and fresh water. It is connected with Karli recharge reservoir to Arabian seas. The detail of plankton diversity with GPS location is given in Table 7, Figure

Table 7: Plankton diversity at Gosabara Wetland

S.N.	Location & time	Phytoplankton	Zooplankton	Birds
1	N $21^0$37'39.80" E $69^0$37'44.66" 7-8 AM 21st Jan 2017	*Spirulina* sp.	*Acrocalanus gracilis, Brachionus plicatilis,Copepod naupli, Tigriopus californis, Acartia tonsa, Keratella hiemalis,Oncaea venusta, Temora stylifera, Oithona nana, O.revicornis, Euterpina acutifrons, Globigerina rubescense*	Ducks, Waders, Lesser flamingos (feeding, resting)
2	N $21^0$32'33.91" E $69^0$43'36.34" 6-7 PM 21st Jan 2017	-	*Bivalve larvae,Brachionus plicatilis,*fish egg	Sea gulls (resting), Waders (feeding)
3	N $21^0$33'27.91" E $69^0$43'39.74" 5:30 PM 21st Jan 2017	*Synedra* sp., *Volvox*	Egg juvenile of copepod,*Gastropod veliger,Oncaea venusta, Parasagitta elegans*	Waders, Lesserflamingoes, Cranes, Swamphen, Duck, Coots, Dalmatian pelicans, Black wing stilt
4	N $21^0$32'80.55" E $69^0$43'20.05" 6-7 PM 21st Jan 2017	*Ballerochea malleus* *Nitchia* sp.		Dalmatian pelicans,Herons
5	N $21^0$32'24.85" E $69^0$43'20.71" 7:30 AM 22nd Jan2017	*Coscinodiscus centralis*	*Acartia tonsa,Acrocalanus gibber, A.gracilis, Clytemnestra scutellata, Euterpina acutifrons,Paracalanus parvus, Pseudodiaptomus aurivilli*	Egrets, Penta stork,Coots, Dalmatian pelicans, Lesser flamingoes,Duck, Pintails
6	N $21^0$34'08.23" E $69^0$45'32.63" 7-8 AM 22nd Jan 2017		*Acartia tonsa, Acrocalanus gracilis, A.longicornis, Calanopia minor, Euterpina acutifrons, Oncaea venusta, Pseudodiaptomus aurivilli,Clytemnestra Scutellata*	Common sand piper, Common Heron

S.N.	Location & time	Phytoplankton	Zooplankton	Birds
7	N $21^0$34’58.28” E $69^0$46’40.92” 8-9 AM 22nd Jan 2017	*Spirulina sp.*	*Eggedized cypris shell, Euterpina acutifrons,Oncaea venusta*bivalve larvae	Black wing stilt, Waders, Dalmatian pelicans, Black tailed godwit,Ruff,Red tailed hawk, Mark sandpiper, Moorhen, Barbler
8	N $21^0$34’58.32” E $69^0$46’21.85”	*Coscinodiscus centralis, Volvox, Surirella, Trichodesmiumerythraeum, Bacillaria paxillifer*	*Euterpina acutifrons*	Birds Common Sandpiper, Mark sandpiper

4.2.1.1.4. Plankton Diversity at Khijadiya Bird Sanctuary

A. Freshwater Ponds

Fresh water ponds are result of the water body of Part-A, where water comes from the Ruparel and Kalindri River during Monsoon. Due to good amount of fresh water and vegetationthe migratory birds comes during winter. The increase intemperature during summer leads to evaporation of water so many of the migratory birds leave the Sanctuary. Salinity of this water body are 0-5 ppt. Diversity invegetation attracts the Bird’s, such as Coot which feeds on seed of *Hydrilla verticillata.*Copepods are also diverse and in huge number which is very good indicator of health of birds and fishes (Cao *et al.*, 2001). The detail of plankton diversity with GPS location is given in Table 8 & 9 with their sampling sites Figure 21 & 22.

Table 8: Plankton diversity at Fresh Water pond of Khijadiya Bird Sanctuary

S.N.	Location & Time	Phytoplankton	Zooplankton	Birds
1	$22^0$31’11.69”N to $22^0$31’15.32”N $70^0$08’44.63”E to $70^0$08’20.30”E	*Microcystis*	*Copepod naupli, Oithona tonsa*	darter, wader, black necked stork, duck,black wing stilt, coots
2	$22^0$31’15.32”N to $22^0$31’19.87”N $70^0$08’20.30” to $70^0$08’09.48” E	*Ceratium azoricum, Coscinodiscus centralis, Melosira* sp., *Naviculla*	*Acrocalanus gracilis,Brachionus plicatilis, B.calcyflororus Copepod nauplius, Keratellahiemalis,Polyarthravulgaris,Cephalodella gibba,Scaridium longicaudam*	Darter, Coots,Ducks
3	N $22^0$31’15.32” E $070^0$08’09.48”	*Ceratium azoricum Coscinodiscus centralis*	*Acrocalanus gracilis, Paracalanus parvus, Copepod nauplius*	Ducks,Coots, Pelicans, Darter, Heron

Table 9: Plankton diversity at Salt Water bodies of Khijadiya Bird Sanctuary

S.N.	Location & time	Phytoplankton	Zooplankton	Birds
1	N $22^0$32'80.40" E $070^0$08'45.52" 6:30 AM-12th Feb 2017	*Cocconeis, Prorocentratium minimum*		Greater Flamingoes
2	N $22^0$32'14.23" E $070^0$08'40.50" 6-7 AM-12th Feb 2017	*Coscinodiscus centralis,Triceratium reticulatum, Achnanthes inflata*	fish egg	Greater Flamingoes
3	N $22^0$32'25.28" E $070^0$08'45.84" 6-7 AM-12th Feb 2017	*Trichodesmium erythraeum*		no single Bird were recorded
4	N $22^0$32'11.08" E $070^0$08'35.86" 6-7 AM-12th Feb 2017	*Coscinodiscus centralis*	*Euterpina acutifrons*	Greater Flamingoes
6	N $22^0$31'46.57" E $070^0$08'56.62" 6-7 AM-12th Feb 2017	*Bacillaria paxilifer* *Surirella sp*	*Caridean larvae* *Artemia salina*	Greater Flamingoes, Waders,Terns, Pied avocet
7	N $22^0$31'23.02" E $070^0$09'03.45" 6-7 AM-12th Feb 2017		*Acartia clausi, Calanus helgolandicus, Nematode cypris shell*	Sea Gulls,Greater flamingoes, Waders, Terns, Pied avocet

Table 10: Numerical strength Plankton Diversity at both the Wetlands

S.N.	Area/Wetland	Number of Species		Total
		Phytoplankton	Zooplankton	
1	**Gosabara wetland complex**	10	22	32
2	**Khijadiya wetland**			
	a. Fresh water bodies	7	11	18
	b. Salt water bodies	6	4	10

Table 11: Details of Phytoplankton

S.N.	Class	Genus	Species	Description
1	Bacillariophyceae	*Pleurosigma* (Fig 17, 1.1)	*Pleurosigma sp.*	Valves sigmoid, presence of chloroplasts
		Coscinodiscus (Fig 17, 1.2)	*C. centralis*	Cells disc shaped, valve areolated with a clean rosette at the centre,valve edfge narrow and striated, marginal spines clear, numerous small plate like chloroplasts
		Navicula (Fig 17, 1.3)	*Navicula* sp.	Valves lanceolate with slightly produced ends, transapical striae lineate, cell broad at center with fairly pointed ends.
		Melosira (Fig 17, 1.4)	*Melosira* sp.	Filaments are cylindrical, the cells longer than they are wide, gelatinous cushions on each end of the valve pairs join the cells together, the two valves are circular in vertical view,ornamentation is concentric in the two parts.
		Synedra (Fig 17, 1.8)	*Synedra* sp.	Elongated apical axis, rodlike, girdle band narrow, bilaterally symmetrical.
		Bellerochea (Fig 17, 1.9)	*B. malleus*	Cells flat and form ribbon-like chains, apertures slit-like but closed in middle due to rounded valves, chromatophores many and disc-shaped.
		Nitzschia (Fig 17, 11.10)	*Nitzchia* sp.	Occurs in freshwater, brackish and marine habitats, forming stellate or chain-like colonies, cells and valves seen in valve or girdle view, usually highly elongate, rounded, rostrate or 43rustules poles.
		Surirella (Fig 17, 1.11)	*Surirella* sp.	Surirella cells have rounded to slightly pointed ends that may be iso or heteropolar, the raphe runs around the margin of the cell on a wing supported by ribs which give the characteristic markings on the 43rustules surface.
		Bacillaria	*B. paxillifer*	Cells rectangular, cells in colonies sliding along

S.N.	Class	Genus	Species	Description
		(Fig 17, 1.12)		one another to form a linear array to retract into a tabular array.
		Cocconeis (Fig 17, 1.5)	***C.** placentula*	Valves elliptical to linear elliptical in outline and less strongly arched, the raphe valve has a narrow, linear axial area with a small oval to circular central area, almost parallel at the centre becoming radiate towards the poles
		Achnanthes (Fig 17, 1.6)	*Achnanthes inflata*	Frustules are heterovalvar with a raphe valve and a rapheless valve, the valves are triundulate with the central valve margin wider than the apices, which are broadly rounded and capitate.
		Triceratium (Fig 17, 1.7)	*T. reticulatum*	Cells possess three cornered valvar plane with corners rounded, areolae of different sizes are found rounded and scattered, a side of valve measures 24-128µm
2	Chlorophyceae	*Microspora* (Fig 17, 3.1)	*M. pachyderma*	Green algae, Autotrophic fungus like protists that are often characterized by their many segments.
		Ankinodesmus (Fig 17, 3.3)	*Ankinodesmus* sp.	Green algae, Specifically of the selenastraceae.
		Volvox (Fig 17, 3.2)	*Volvox carteri*	Colonial green algae in the order Volvocales, forms large spherical colonies, colonies contain mostly somatic cells plus a smaller number of gametes
3	Cyanophyceae	*Microcystis* (Fig 17, 2.1)	*Microcystis* sp.	Colonial in nature, unicellular fast growing culture in the absence of flagellate, ciliate, and zooplankton predators.
		Spirulina (Fig 17, 2.3)	*Spirulina* sp.	Simple one-celled microscopic blue-green algae, cultivated worldwide; used as a dietary supplement as well as a whole food and is also available in tablet, flake and powder form
		Trichodesmium (Fig 17, 2.2)	*T. erythraeum*	Cells are filamentous, they have photosynthetic pigments, and these cells are capable of fixing

S.N.	Class	Genus	Species	Description
				atom. Nitrogen.
4	Dinophyceae	*Ceratium* (Fig 17, 4.1)	*C. azoricum*	Small body, epithica equal to hypotheca.
		Prorocentrum(Fig 17, 4.2)	*Prorocentrum minimum*	Bivalvate species, cells are small

Table 12: Details of Zooplankton

S.N.	Class	Genus	Species	Description
1	Maxillopoda	*Acrocalanus* (Fig 18, 5.1)	*A.gracilis*	Urosome 4 segmented, the 5th legs are absent, the cephalosome is more rounded, the 1st antennae reach beyond the caudal rami, the cephalosome is not humped in lateral view.
		Tigriopus (Fig 18, 5.3)	*T. californis*	Handle extreme high temperatures varies among populations, urosomal segment varies between 0.90mm to 1.2mm, typical cyclopoid habitus, shorter antennules.
		Acartia (Fig 18, 5.4)	*A.tonsa*	Female 1.3-1.5 mm; male 1.0-1.1 mm, long first antennae, biramous (branched) second antennae, joint between their fifth and sixth body segments
		Oncaea (Fig 18, 5.5)	*O.venusta*	Females are 1.1–1.3 mm long, males are only 0.8–1.0 mm long, the front of the head is unusually wide and the body is brightly colored, usually yellow–orange but sometimes red, feeds on a variety of zooplankton and phytoplankton
		Temora (Fig 18, 5.7)	*Temora stylifera*	Females symmetrical, males inner appendix on left Narrow, bend in right terminal hook does not extend to distal border of right segment.

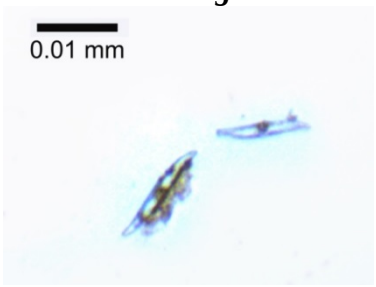
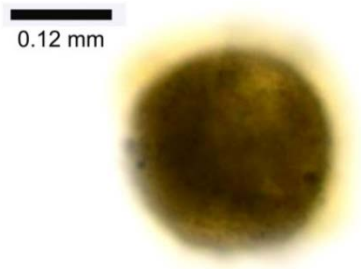
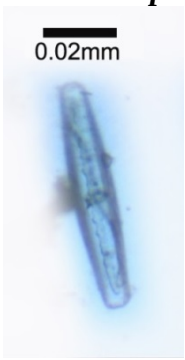
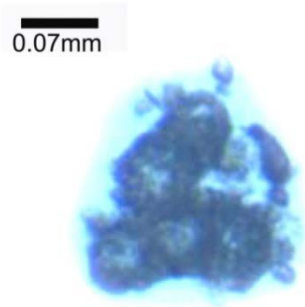
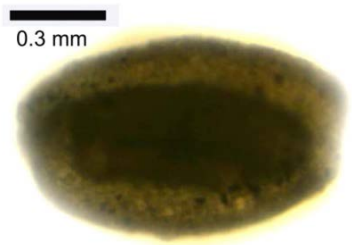
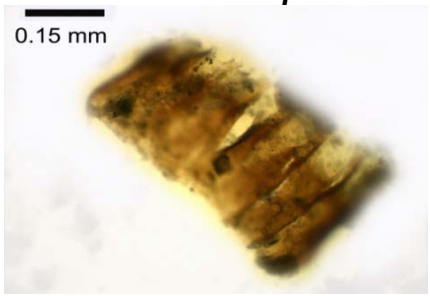
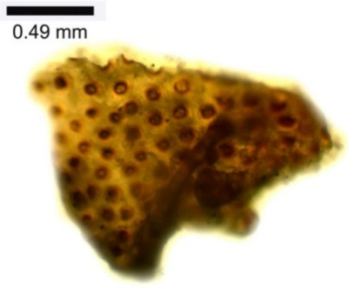
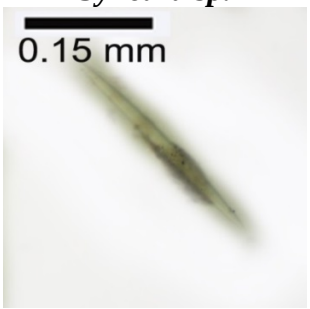
S.N.	Class	Genus	Species	Description
		Oithona (Fig 18, 5.6)	*Oithona nana*	In the female the 1st antennae reach to the end of the 3rd prosome segment, the genital segment is nearly the same length as the next two segments combined; in the male the 1st antennae are modified to form grasping structures.
		Euterpina (Fig 18, 5.2)	*E. acutifrons*	The rostrum is stout, the anterior of cephalosome is sharply pointed, body widens to the posterior of the cephalosome then narrows posteriorly; Body articulation is distinct.
		Oithona (Fig 18, 5.8)	*Oithona brevicornis*	Females forehead rounded in dorsal view, gradually tapering towards tip, armed with 4 setae, Males: represented by 1 setae; with 1 thick, curved blunt spine and 1 pointed spinals spine on distal tip
		Paracalanus (Fig 18, 5.9)	*Paracalanus parvus*	Female 0.6-1.3 mm; male 0.8-1.4 mm, 1st antennae are longer than the prosome; prosome of female with 4 segments and urosome with 4 segments.
		Acrocalanus (Fig 18, 5.10)	*A.gibber*	Urosome 5 segmented, cephalosome having a humped outline, body compact, first antenna does not reach beyond caudal rami.
		Clytemnestra (Fig 18, 5.11)	*C.scutellata*	Body considerably flattened, cephalosome and first three metasome segments with prominent angular projections at the posterior corners, urosome 5 segmented, anal segment as long as the penultimate segment.
		Pseudodiaptomus (Fig 18, 5.12)	*P. aurivilli*	Urosome 4 segmented, 1st antennae alike on the two sides.
		Acrocalanus (Fig 18, 5.13)	*A.longucornis*	Cephalosome rounded, armature of the distal portion of the terminal exopodite segment of the 4th legs consists of a few fine teeth whereas the teeth on the proximal portion are comparatively coarser and more numerous.

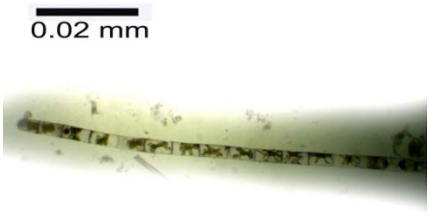
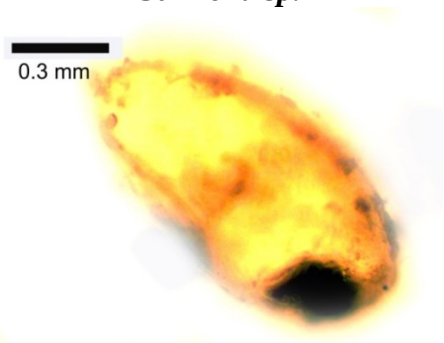
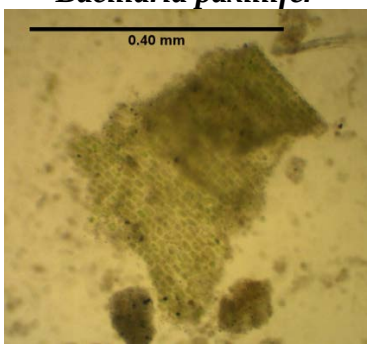
S.N.	Class	Genus	Species	Description
		Calanopia (Fig 18, 5.14)	*C.minor*	The last metasome segments produced on each side into an acute spine, the rostrum pointed, urosome 2 segmented, the second segment distinctly longer than the genital segment.
2	Monogonta	*Brachionus* (Fig 18, 7.1)	*b. plicatilis*	Euryhaline rotifer and is possibly the only commercially important rotifer, broad distribution in salt lakes around the world, food of fishes.
		Keratella (Fig 18, 7.4)	*Keratella hiemalis*	Postero-lateral facets on the dorsal surface of the lorica closed, pustules present on lorica surface, the anterior horizontal ridge of anteromedial facet is short relative to the other sides of the facet, giving a distinctly triangular shape
		Scaridium (Fig 18, 7.2)	*Scaridium longicaudum*	Periphytic in weedy stagnant and slow running freshwaters of varying trophy, also in peat bogs, inundation areas, paddy fields, and athalassic saline waters; among macrophytes, filamentous algae, reed, detritus, and on mud, occasionally tychoplanktonic
		Polyarthra (Fig 18, 7.3)	*Polyarthra vulgaris*	Comes under Rotifer
3	Crustacea	*Nauplius* (Fig 18, 6.1)	*Copepod naupli*	Body shield shaped with 3 pairs of jointed appendages, not ciliated , distinct eye on the front side, first pair of limb is uniramous and others biramor
		Caridean (Fig 18, 6.2)	*Caridean larvae*	Carapace and abdomen usually without large numbers of spines, posterolateral margins of carapace smooth,antennal exopod unsegmented, telson dorsoventrally flattened.
4	Polythalamea	*Globigerina* (Fig 18, 10.7)	*G.rubescense*	Spinose, with 4 globular chambers in last whorl, shell margin rounded, subquadrate, shell surface smooth.

S.N.	Class	Genus	Species	Description
5	Gastropoda	*Gastropod* (Fig 18, 12.1)	Gastropod veliger	The shell is either inflated or coiled, the body is asymmetrical.
6	sagittodea	*Parasagitta* (Fig 18, 13.1)	*P. elegans*	Body narrow, firm and opaque, head relatively small, eyes with a small, round pigment spot.
7	Ostracod	*Cypris* (Fig 18, 14.1)	Cypris shell	Size : 0.5 – 3 mm, including the head, is enclosed by a bean-shaped shell, just the antennae and limbs appear out of the gap between the two halves of the shell as they move amongst vegetation and mud, some of the smaller rounded water fleas
8	Branchiopoda	*Artemia* (Fig 18, 8.3)	*A.salina*	Artemia salina have three eyes and 11 pairs of legs and can grow to about 15 millimetres (0.6 in) in size, their blood contains the pigment hemoglobin, which is also found in vertebrates, larval size less than 1 mm.
		Penilia (Fig 18, 8.1)	*P. avirostris*	Bivalve carapace which covers the body and appandages, the antennules are as long as the carapace, the eye is comparatively small, the trunk limbs number 4 to 6 pairs.
		Pseudevadne (Fig 18, 8.2)	*Pseudevadne tergestina*	Nearly transparent with a prominent compound eye, body is oval shaped without a terminal carapace spine, body stout and oval, posterior end of carapace rounded & lacking spine, varying is shape from elongate oval to hemisphere.
9	Eurotatoria	*Cephalodella* (Fig 18, 9.1)	*Cephalodella gibba*	Rotifers in the family Notommatidae.

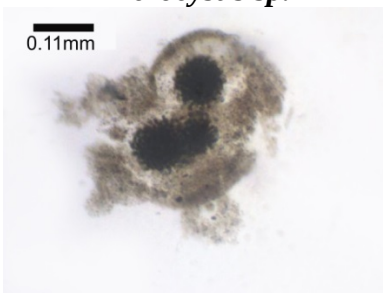
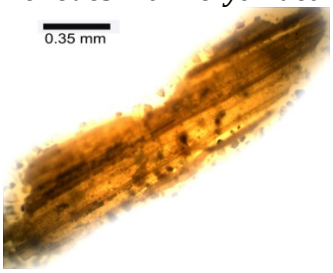
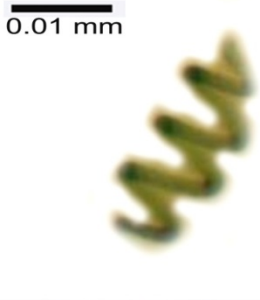
Figure 21: PHYTOPLANKTON (Figure 1.1 to 4.2)

Bacillariophyceae

Pleurosigma  . 1.1	***Coscinodiscus centralis***  . 1.2
Navicula sp.  . 1.3	***Melosira sp.***  . 1.4
Cocconeis sp  . 1.5	***Achnanthes inflata***  . 1.6
Triceratium reticulatum  . 1.7	***Synedra sp.***  . 1.8

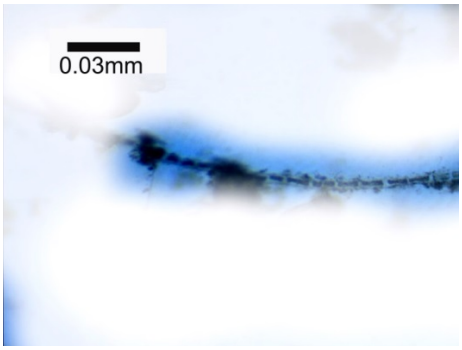
Bellerochea malleus  . 1.9	***Nitschia sp***  . 1.10
Surirella sp.  . 1.11	***Bacillaria paxillifer***  . 1.12

Cyanophyceae

Microcystis sp.  . 2.1	***Trichodesmium erythraeum***  . 2.2
Spirulina sp.  . 2.3	

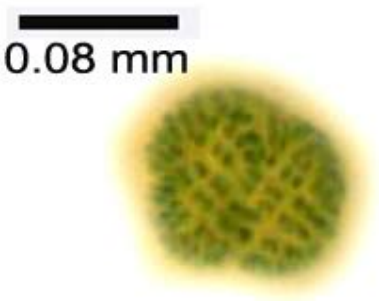
Chlorophyceae

Microspora sp.



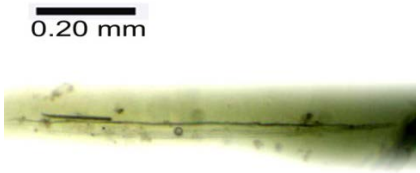
. 3.1

Volvox sp.



. 3.2

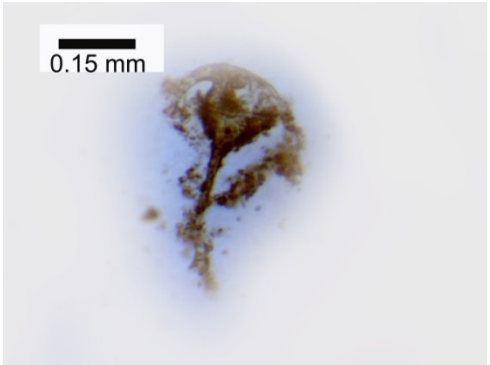
Ankinodesmus sp



. 3.3

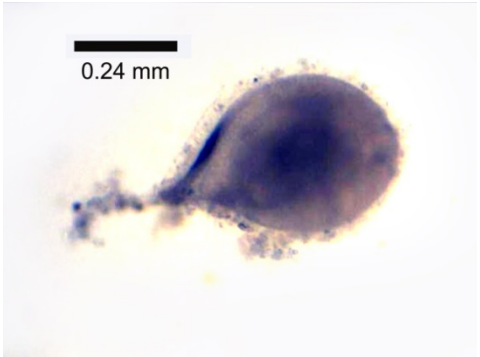
Dynophyceae

Ceratium azoricum



. 4.1

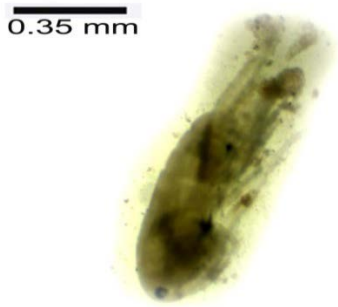
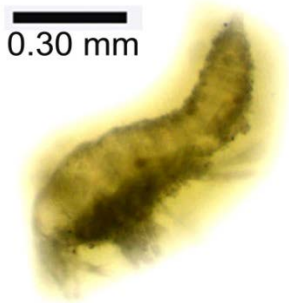
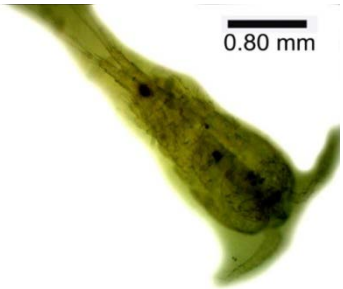
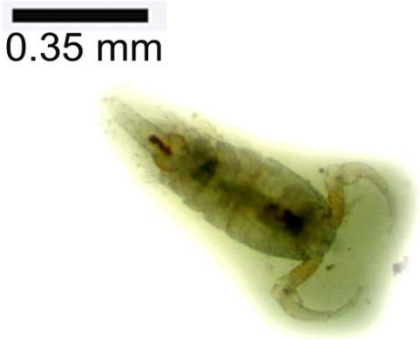
Prorocentrum minimum

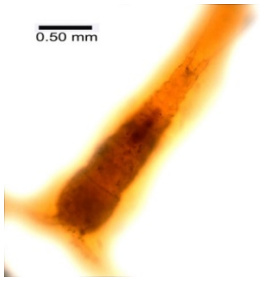
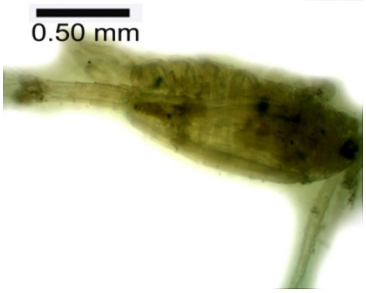
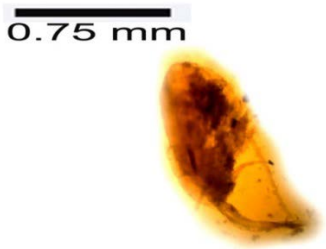
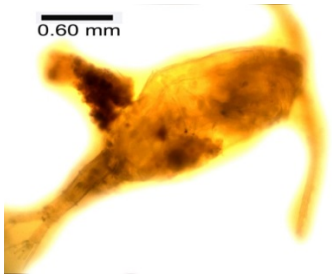


. 4.2

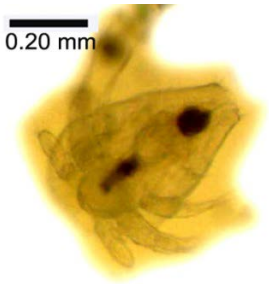
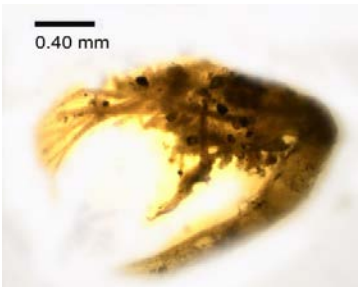
Figure 22: ZOOPLANKTON (Figure 5.1 to 14.1)

Maxillopoda

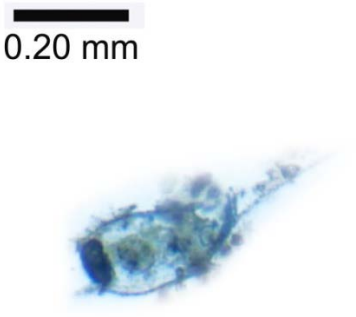
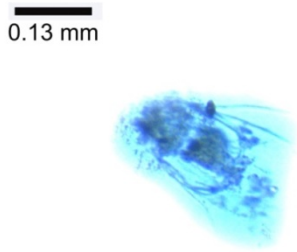
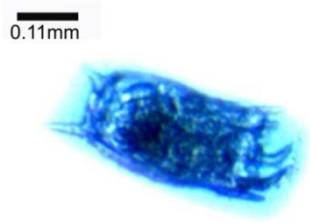
A.gracilis  . 5.1	***E. acutifrons***  . 5.2
T. californis  . 5.3	***Acartia tonsa***  . 5.4
O.venusta  . 5.5	***Oithona nana***  . 5.6
Temora stylifera  . 5.7	***Oithona brevicornis***  . 5.8

Paracalanus parvus  . 5.9	***A.gibber***  . 5.10
C.scutellata  . 5.11	***P. aurivilli***  . 5.12
A.longicornis  . 5.13	***C.minor***  . 5.14

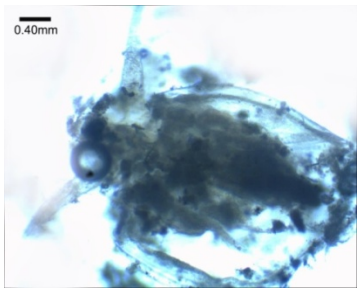
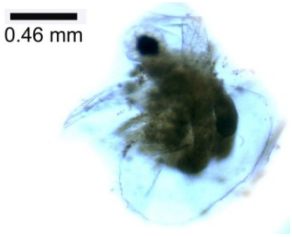
Crustaceae

Copepod naupli  . 6.1	***Caridean larvae***  . 6.2

Monogonta

B. plicatilis  . 7.1	***Scaridium longicaudum***  . 7.2
Polyarthra vulgaris  . 7.3	***Keratella hiemalis***  . 7.4

Branchiopoda

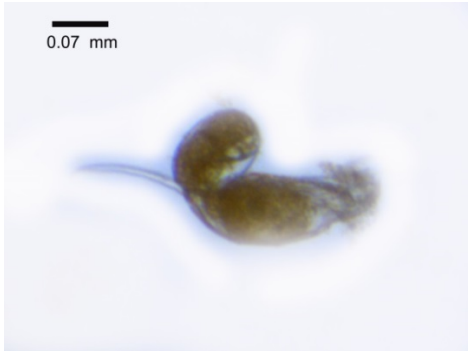
P. avirostris  . 8.1	***Pseudevadne tergestina***  . 8.2

A.salina

. 8.3

Eurotatoria

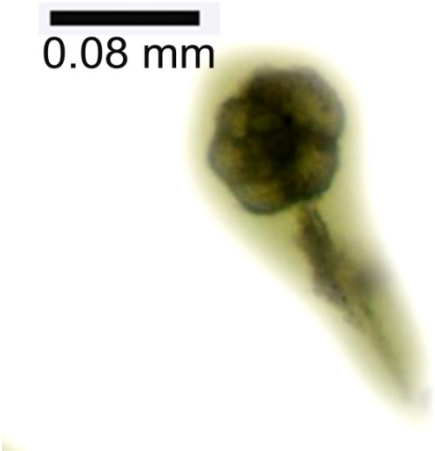
Cephalodella gibba



. 9.1

Polythalamea

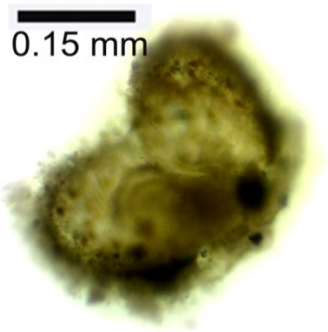
G.rubescense



. 10.1

Gastropoda

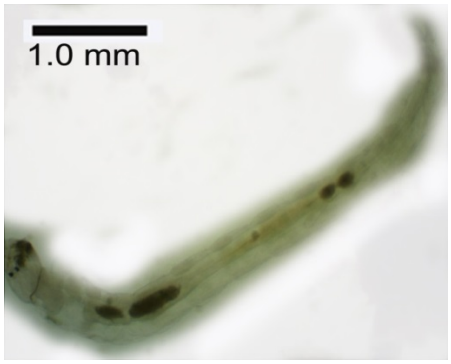
Gastropod veliger



. 12.1

Sagittodea

P. elegans



. 13.1

Ostracod

Eggedized cypris shell

. 14.1

4.3. Assessment of existing plant invasive species and possible management options at the two wetlands:

4.3.1. Population and Density study of *Prosopis juliflora* and *Parthenium hysterophorus*

The field study was supposed to be done between December 2016 and April 2017 to collect the vegetation data depending up on the ecology of *P. hysterophorus*. However, before we could start the survey the species was manually eradicated from Khijadiya Bird Sanctuary. Though we could not do any quantitative survey of the species in Khiadiya bird sanctuary however, based on visual observation it was found on the newly formed bunds in anarea less than equal to 5% area coverage. In addition, the parthenium invasion levels was very low (< 10%) in Oct – November 2016 (Based on our visual interpretation).There was no massive invasion of *Parthenium* in Gosabara wetland with few sporidiac individuals near agriculture fields.
P. juliflora is the dominant tree species in Gosabara with maximum IVI value *i.e.* 184.3. *Prosopis* is invaded in the open land area of wetland and it may be increase due to grazing of pods by the cattles. The other parameters like frequency, density and abundance also shows highest value indicating its even distribution in almost all the sites of the Gosabara wetland. The area highlighted in Figure 20 shows the invasion of *Prosopis* in Gosabara. There was no change in the *P. juliflora* expansion in Gosabara.It is the most dominant invasive species of the Khijadiya bird sanctuary having fast regeneration capacity showing maximum IVI value of 150.86.

The change in the pattern of *P. juliflora* was significantly observed in Khijadiya bird sanctuary as the species was manually eradicated (Figure 19) from wetland and Bunds in 2015-2016. The Prosopis was spread in 288 hactere in 2015-2016 which was reduced to 183 hectares in 2016-2017. This data is based on spatial analysis (Figure 23).

Figure 23: Eradication of *Prosopis* from Khijadiya Bird Sancturay

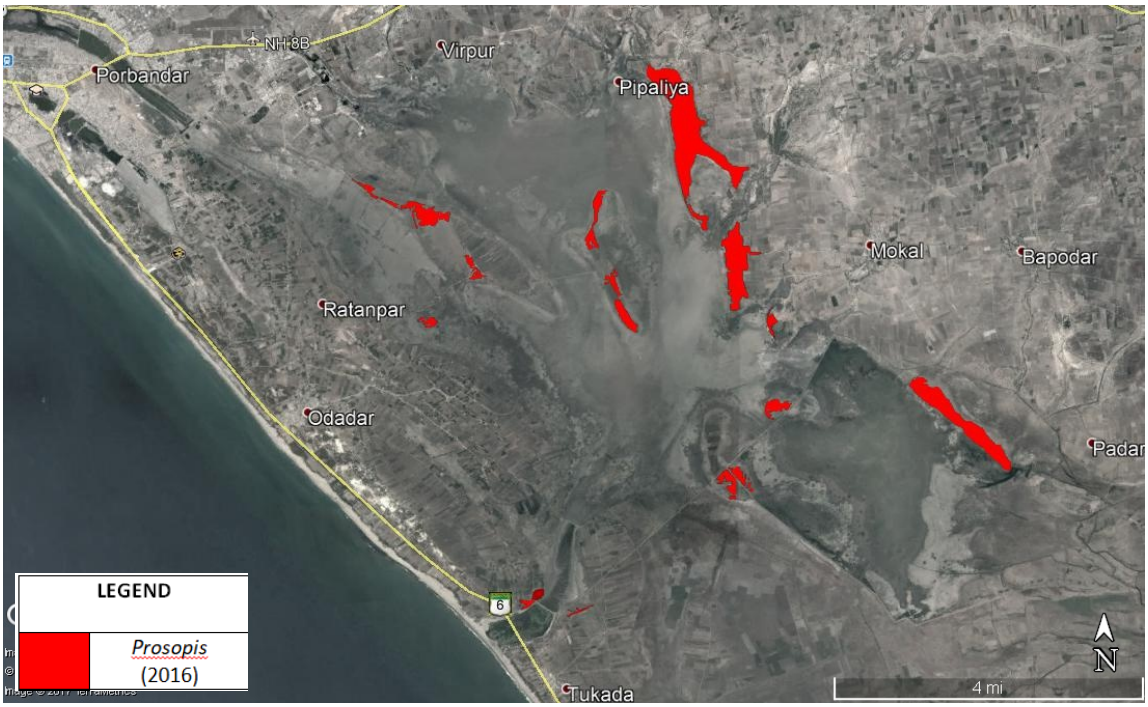


Figure 24: *Prosopis* invasion in Gosabara Wetland

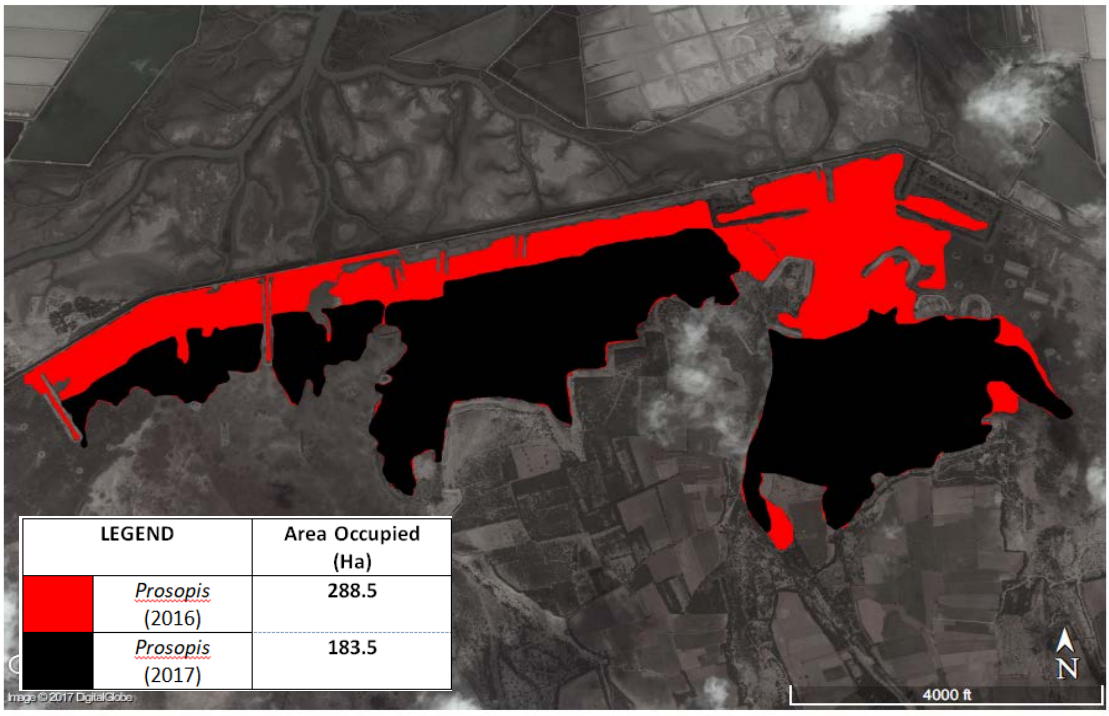


Figure 25: Impact of *Prosopis* on Khijadiya Bird Sanctuary

Summary

The surveys of both the wetlands were conducted during December 2016 to July 2017. The wetlands were studied based on the microhabitats classified in 2015-2016. Thus Gosabara and Khijadiya wetland were surveyed in six and four sub-habitats respectively.

The Gosabara wetland complex showed presence of 141 taxa which includes two Pteridophyte and 139 angiosperms. Of the 139 Angiosperm; 107 are Dicots and 32 are monocots with Fabaceae and Asteraceae being the two dominant families among dicotyledons. The plant diversity in 2016 – 2017 was comparatively less probably owing to poor rain fall. The poor rainfall affected the proper regeneration and establishment of *Schenoplectous, Bulboschnecous, Nymphae* and other related aquatic species. This also led to longer dry period in Gosabara and sprouting of prosopis saplings in many pockets. The tubers and seeds of *Schenoplectus* and Bulboschnecous were primary foods especially for blue moorhen. *Potamageton pectinatus* sago pondweed is a dense, bushy perennial growing from matted rhizomes. Sago pondweed has been cited as one of the most important waterfowl foods. It produces numerous seeds, and its starchy tubers (tender, underground growing tips) and abundant leaves are important waterfowl diets.
Coontail, Ceratophyllum sp., is a perennial of often deeper, clear waters. The leaves and stems provide food for waterfowl, and the plant is important in the food chain.

The Khijadiya Bird Sanctuary showed presence of 88 taxa, of which 87 species are angiosperm and one is Pteridophyte. Of the later; 70 are Dicots and 17 are monocots with Chenopodiaceae and Asteraceae as the dominant family. There was no significant change in the floral diversity in comparision to last year study. However, the aquatic plant diversity recoreded in 2016-2017 was not prevailing in 2015-2016. The change wasowing to the renovation of dam and appropriate digging of water pockets in Khizadiya bird sanctuary by the forest department.The proper water harvesting lead to the growth of some aquatic plant species(*Ottelia*sp., *Potamageton*sp.*Nymphae* and *Ottelia*) which were not observed in 2015-2016, the fruits these plants were primary food source for many of the ducks and aquatic birds observed during post-monsoon period.

Phytosociological analysis states that *P.julifloral*is the dominant tree species in Gosabara with maximum IVI value. It has invaded the drying wetland owing to irregular rain pattern in the region. During odd years (poor rainfall), the saplings of *Prosopis* gets established to aheight of of 3-4 feet.However, the plants does not get totally submerged in the water and the shoots coming out from the water assist the plant thrive along one and half month of submergence. In addition the *Prosopis*hard seed coat gets soften owing to the pods eaten by the ruminanats (Cows and Buffaloes), Goats and Sheep and the ungulates such as Nilgay. The cow/buffalo dung and Goat/Sheep droopings is seed bank for *Prosopis* establishment. With the first rain, mushroming growth of *Prosopis* sprouts from the dungs and drropings are observed and within no time the roots penetrates the aquatic pockets and establishes all across the weland. If the rains are irregular the saplings are able to establish in efficient way. In these wetlands the eradication of *prosopis*is main factor or we will lose the open aquatic pockets wherein the migratory birds search for there food. If the prosopis saplings are removed every year manually probably we will be able to mitigate the mushrooming growth of *Prosopis*.

With regard to herbaceous community, *Sueda nudiflora* is the dominant species in Gosabara wetland with maximum IVI value and frequency.*S. nudiflora* a halophyte is able

survive across both the season owing to its ability to survive under saline conditions. Most of the ecological suvey where made in post monsoonal period and by then the ephemerals and annuals have already vanished.Similarly in Khijadiya *P. julifora* is the most dominant invasive species having fast regeneration capacity showing maximum IVI value. *Cressa cretica* was the dominant herbs followed by *Aeluropus lagopoides* and *Suaeda nudiflora.* IVI value of *A. lagopoides* was less than *C. cretica* owing to vast distribution of *Cressa cretica* all the dried fresh water zones and the saline zones while the *Aeluropus* was restricted to saline zones only.

Community study shows that in Gosabara, *S. nudiflora*, *B. maritimus* and *C. cretica* covers the maximum area of the wetland while in Khijadiya the pure community of *Prosopis* covers the maximum area of the sanctuary. Eradication of *Prosopis* was a good initiative at Khizadiya Bird sanctuary.

Though *Prosopis*is the key species for birds for resting, hiding and perching on which maximum birds were observed but this plant should be gradually replaced by *Acacia nilotica* and *Salvadora persica*. The fruit of *Salvadora persica* was the main source of food for the terrestrial birds.

Plankton analysis in Gosabara wetland complex showed there were 10 species of phytoplankton and 22 species of Zooplanktons. In Khijadiya Bird Sanctuary, Fresh water body comprised of 7 and 11 species of Phytoplanktons and Zooplanktons respectively. Salt water bodies of Khijadiya comprised of 6 species of Phytoplanktons and 4 species of Zooplanktons. Flamingo in Khizadiya and Gosabara were predominantly found in the area where *Spirulina* (Phytoplankton) was more. More extensive study in Zooplanktons and phytoplanktons would bring the real basis for the change in the migratory bird diversity and population. Ducks were seen around the algal bloom during early morning hours and in late evenings. Though Algal blooms are considered harmful. Many ducks were observed around algal blooms.

Generally the ideal wetlands have all forms of vegetation depending on the depth of the water body. It is composed of marshy, swampy, floating anchored, free floating and submerged plants as the depth progresses. The food plants in the present case also represented all these classes of vegetation which catered for different types of birds like waders, dabblers and divers indicating the suit-ability of the habitat for avian flora. Further, the phenology of the food plants species i.e., production of soft vegetative tissue, flowering, fruiting and seeding period matched with the rise and fall of winter. Maximum spe-cies produced food during peak winter months and this number started declining with departure of winter or ris-ing temperature.

This was very well synchronized with the arrival and departure of large number of migratory and resident birds in the wetland. High diversity and abundance of avian flora indicated intensive use of the wetland which was due to structural diversity of vegeta-tion provided by broadleaved species and tall grasses (Mitsch and Gosselink,1986). Rahmani *et al.,* (2010) had also observed that this Sanctuary retains all the essential characteristics of an ideal water bird habitat and attracts more than fifty thousand aquatic birds in the winter. More than two and a half dozen of plant species were preferred by around a dozen of aquatic birds nar-rated in the previous section appears to be a reasonable database since intensive but not extensive survey of lit-erature suggested that previous report on the subject is scanty. *Vallisneria* sp. and *Hydrilla verticillata* were be-ing used by 5-7 waterfowl species (Folker, 1987 in Perry and Deller, 1996). Greylag Goose and Bar-headed Goose were reported to eat 14 and 7 species, respectively (Middleton, 1992). Some of the species common to the study site were

Ceratophyllum demersum, Eleocharis palustris, Ipomoea aquatica, Hydrilla verticillata, Bulboschnecous and *Schenoplectous*.

The Study reflects that the Wetland is not only significant as wetland but as a dried wetland/puddle also. While many birds harbor in this esturine land. Each habitat with in wetland i.e. open land, fresh water Edges, costal edges every aspect of the habitat is important. As all these sites provides a niche for different types of birds. An interesting example is that of intermediate zone of fresh water and saline zone has good abundance of spirulina which is a main source of food for flamigoes. The open zone where in the *Nymphaea* is observed in food for Ducks and Saras crane. The bunds wherein Salvadora is growing, the fruits of the plant are food for a number of birds. Though *prosopis* is giving resting site for birds, over all if we observe there invasive nature is gradually eating the wetlands. One of the important communities of Schenoplectous and Bulboschnecous where the tubers are food of Blue more hens is gradually getting reduced owing to the invasion of Prosopis. Phytoplanktons and Zooplanktons which are found at different site have their own importance. These planktons are food for various birds which are not seen but get affected by the rise and decrease in the water level.

Maintaining a diverse plant community is beneficial to migrating and wintering water birds (Benedict and Hepp, 2000). Vegetation and open water ratio play an important role in marsh utilization (Duffield, 1986). Fifty percent vegetation cover and **fifty percent open water** is the ideal condition for supporting maximum bird richness and abundance (Smith et al., 2004). However, without taking these findings in account there is a general practice of removing aquatic plants/weeds from the Bird Sanctuaries for habitat management and other wetlands for commercial or domestic use. This practice leads to reduction in food availability for the aquatic birds and hence possible reduction in avian diversity. It is suggested that food plants removal must be done judiciously keeping in view the bird load in particular wetland; otherwise for want of optimum carrying capacity of the wetland birds may get diverted to the neighboring agriculture field affecting the pro-ductivity of the crop adversely or they might stop landing in the wetland in future. Perry and Deller (1996) also reviewed that decline in areal cover of submerged vegetation shifted the distribution of swan and geese from shallow water areas to upland agricultural areas.

The designation of Khijadiya and Gosabara Wetlands as Ramsar site is very promising. Data for all relevant criteria were collected and the features of the ecosystem are compiled in an adequate way. The minimum requirements to establish the protection of bird diversity are the following:

- keep the fishing activities on a low subsistence level
- prohibit or restrict and control the bird hunting activities during wintering season
- limit the grazing activities in the shore region of the lake, to maintain the natural cover of semi-desert vegetation.
- Aquatic Habitat should be retained in its natural form with no anthropogenic interference or introduction of new species without proper judgement and research.
- Keeping a control over the excessive growth of *Prosopis* and *Parthenium* in the region

By this enlargement, habitat species diversity could be enhanced and consequently a representative ecosystem complex of the Gosabara and Khizadiya would be protected. Especially the highly endangered and completely unprotected zones of the wetlands.

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Annexure 1: Floral Diversity of Gosabara Wetland Complex

S. N.	Botanical name	Family	Habit	Phenology	Origin
Aquatic Vegetation					
Submerged aquatic plants					
1.	*Hydrilla verticillata* (L. f.) Royle	Hydrocharitaceae	Aquatic herb	Oct-Jan	Indigenous
2.	*Najas marina* L.	Hydrocharitaceae	Aquatic herb	Jan-Apr	Indigenous
3.	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae	Aquatic herb	Oct-Mar	Indigenous
4.	*Stuckenia pectinata* (L.) Boerner	Potamogetonaceae	Aquatic herb	Aug-Oct	Indigenous
5.	*Vallisneria natans* (Lour.) H. Hara	Hydrocharitaceae	Aquatic herb	Oct-Feb	Indigenous
Floating aquatic plants					
6.	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Aquatic herb	Oct-Dec	Exotic
7.	*Ipomoea aquatica* Forssk.	Convolvulaceae	Twining herb	Oct-Dec	Indigenous
8.	*Lemna gibba* L.	Lemnaceae	Aquatic herb	Sep-Dec	Indigenous
9.	*Limnophyton obtusifolium* (L.) Miq.	Alismataceae	Aquatic herb	Sep-Feb	Indigenous
10.	*Nymphaea pubescens* Willd.	Nymphaeaceae	Aquatic herb	Oct-Dec	Indigenous
11.	*Nymphaea rubra* Roxb. ex Andrews	Nymphaeaceae	Aquatic herb	Oct-Dec	Indigenous
Wetland vegetation (incl. aquatic vegetation)					
Partially submerged aquatic plants					
12.	*Bolboschoenus maritimus*sp. *affinis* (Roth.) T. Koyama	Cyperaceae	Annual	Sep-Dec	Indigenous
13.	*Fimbristylis ferruginea* (L.) Vahl.	Cyperaceae	Perennial	Sep-Nov	Indigenous
14.	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Perennial	Oct-Feb	Indigenous
15.	*Schoenoplectus subulatus* (Vahl) Lye	Cyperaceae	Perennial	Sep-Jan	Indigenous
Wetland or marshy plants					
16.	*Ammannia baccifera* L. var. *baccifera*	Lythraceae	Marshy herb	Dec-Feb	Indigenous
17.	*Bacopa monnieri* (L.) Pennell	Plantaginaceae	Herb	Jan-Mar	Indigenous
18.	*Ceratopteris thalictroides* (L.) Brongn.	Pteridaceae	Herb	-	Indigenous
19.	*Eclipta prostrata* (L.) L. var.*Prostrate*	Asteraceae	Herb	Aug-Jan	Indigenous

S. N.	Botanical name	Family	Habit	Phenology	Origin
20.	*Echinochloa colona* (L.) Link	Poaceae	Annual	Aug-Feb	Indigenous
21.	*Eleocharis geniculata* (L.) Roem. & Schult.	Cyperaceae	Annual	Aug-Feb	Indigenous
22.	*Hygrophila schulli* (Buch.-Ham.) M. R. Almeida & S. M. Almeida	Acanthaceae	Herb	Sep-Mar	Indigenous
23.	*Marsilea quadrifolia* L.	Marsileaceae	Herb	-	Indigenous
24.	*Paspalidium geminatum* (Forssk.) Stapf	Poaceae	Perennial	Aug-Nov	Indigenous
25.	*Paspalum vaginatum* Sw.	Poaceae	Annual	Jul-Nov	Indigenous
26.	*Oxystelma esculentum* (L. f.) Sm.	Asclepiadaceae	Twining herb	Aug-Oct	Indigenous
27.	*Typha angustifolia* L.	Typhaceae	Herb	Throughout	Indigenous
Dry puddle vegetation					
28.	*Chrozophora plicata* (Vahl) A. Juss. ex Spreng.	Euphorbiaceae	Herb	July-Oct	Indigenous
29.	*Chrozophora rottleri* (Geiseler) A. Juss. ex Spreng.	Euphorbiaceae	Herb	July-Apr	Indigenous
30.	*Coldenia procumbens* L.	Boraginaceae	Herb	Throughout	Indigenous
31.	*Commelina benghalensis* L.	Commelinaceae	Herb	Aug-Jan	Indigenous
32.	*Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth.	Scrophulariaceae	Herb	Aug-Dec	Indigenous
33.	*Euphorbia prostrata* Aiton	Euphorbiaceae	Herb	Throughout	Exotic
34.	*Glinus lotoides* L.	Aizoaceae	Herb	Throughout	Indigenous
35.	*Grangea maderaspatana* (L.) Poir.	Asteraceae	Herb	Dec-Apr	Indigenous
36.	*Heliotropium curassavicum* L.	Boraginaceae	Herb	Throughout	Exotic
37.	*Heliotropium supinum* L.	Boraginaceae	Herb	Aug-Apr	Indigenous
38.	*Phyla nodiflora* (L.) Greene	Verbenaceae	Herb	Throughout	Indigenous
39.	*Polygonum plebeium* R. Br. var.*plebeium*	Polygonaceae	Herb	Sep-May	Indigenous
40.	*Portulaca quadrifida* L.	Portulacaceae	Herb	Throughout	Indigenous
41.	*Merremia emarginata* (Burm. f.) Hallier f.	Convolvulaceae	Creeping herb	Aug-Feb	Indigenous
42.	*Mollugo pentaphylla* L.	Aizoaceae	Herb	Jul-Dec	Indigenous

S. N.	Botanical name	Family	Habit	Phenology	Origin
Mangroves					
43.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	Tree	Feb-Jun	Indigenous
Salt marsh vegetation					
44.	*Aeluropus lagopoides* (L.) Trin. ex Thwaites	Poaceae	Perennial	Oct-Dec	Indigenous
45.	*Arthrocnemum indicum* (Willd.) Moq.	Chenopodiaceae	Herb	Oct-Dec	Indigenous
46.	*Atriplex stocksii* (Wight) Boiss.	Chenopodiaceae	Under shrub	Sep-Apr	Indigenous
47.	*Cressa cretica* L.	Convolvulaceae	Herb	Throughout	Indigenous
48.	*Salicornia brachiata* Roxb.	Chenopodiaceae	Herb	Nov-Feb	Indigenous
49.	*Suaeda fruticosa* Forssk. ex J. F. Gmelin	Chenopodiaceae	Under Shrub	Apr-Sep	Indigenous
50.	*Suaeda nudiflora* Moq.	Chenopodiaceae	Herb	Apr-Sep	Indigenous
Barren land vegetation					
51.	*Convolvulus microphyllus* Seiber ex Spreng.	Convolvulaceae	Herb	Aug-Oct	Indigenous
52.	*Cyperus arenarius* Retz.	Cyperaceae	Perennial	Jun-Dec	Indigenous
53.	*Halopyrum mucronatum* (L.) Stapf.	Poaceae	Perennial	Oct-Dec	Indigenous
54.	*Heliotropium bacciferum* Forssk.	Boraginaceae	Herb	Dec-Apr	Indigenous
55.	*Lotus garcinii* DC.	Fabaceae	Herb	Apr-Aug	Indigenous
56.	*Polycarpaea spicata* Wight & Arn.	Caryophyllaceae	Herb	Oct-Nov	Indigenous
Land vegetation					
***Prosopis* occupied area**					
57.	*Acacia nilotica* ssp. *indica* (Benth.) Brenan	Mimosaceae	Tree	Jul-Oct	Indigenous
58.	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Tree	Aug-May	Exotic
59.	*Leucaena leucocephala* (Lam.) de Wit.	Mimosaceae	Tree	May-Feb	Exotic
60.	*Wattakaka volubilis* (L. f.) Stapf	Asclepiadaceae	Twining shrub	Apr-Feb	Indigenous
61.	*Tinospora cordifolia* (Willd.) Miers ex Hook. f. & Thomson	Menispermaceae	Climbing shrub	Jan-Aug	Indigenous
62.	*Senna auriculata* (L.) Roxb.	Caesalpiniaceae	Under Shrub	Jan-Jul	Indigenous
63.	*Salvadora persica* var. *indica* (Wight) T.	Salvadorace	Tree	Nov-	Indige

S. N.	Botanical name	Family	Habit	Phenology	Origin
	A. Rao & Chakraborti	ae		Feb	nous
Bunds					
64.	*Abutilon indicum* (L.) Sweet ssp. *indicum*	Malvaceae	Shrub	Throughout	Indigenous
65.	*Abutilon ramosum* (Cav.) Guill. & Perr.	Malvaceae	Shrub	Sep-Oct	Indigenous
66.	*Achyranthes aspera* L. var. *Aspera*	Amaranthaceae	Herb	Throughout	Indigenous
67.	*Aristolochia bracteolata* Lam.	Aristolochiaceae	Herb	Jul-Dec	Indigenous
68.	*Azadirachta indica* A. Juss.	Meliaceae	Tree	Dec-May	Indigenous
69.	*Barleria prionitis* L. ssp. *Prionitis*	Acanthaceae	Herb	Sep-Mar	Indigenous
70.	*Bergia suffruticosa* (Delile) Fenzl	Elatinaceae	Under shrub	Throughout	Indigenous
71.	*Blepharis integrifolia* (L. f.) E. Mey. & Drege ex Schinz	Acanthaceae	Herb	Oct-Mar	Indigenous
72.	*Boerhavia chinensis* (L.) Rottb.	Nyctaginaceae	Herb	Feb-Dec	Indigenous
73.	*Calotropis gigantea* (L.) R. Br.	Asclepiadaceae	Shrub	Throughout	Indigenous
74.	*Calotropis procera* (Aiton) R. Br.	Asclepiadaceae	Shrub	Throughout	Indigenous
75.	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	Shrub	Feb-Sep	Indigenous
76.	*Cardiospermum halicacabum* L.	Sapindaceae	Climbing herb	Jul-Feb	Indigenous
77.	*Clerodendron serratum* (L.) Moon	Verbenaceae	Shrub	Jun-Dec	Indigenous
78.	*Clitoria ternetea* var. *ternetea* f.*Albiflora*	Fabaceae	Climbing herb	Throughout	Exotic
79.	*Clitoria ternetea* var. *ternetea* f.*Ternetea*	Fabaceae	Climbing herb	Throughout	Exotic
80.	*Cocculus hirsutus* (L.) W. Theob.	Menispermaceae	Climbing shrub	Nov-Apr	Indigenous
81.	*Corchorus aestuans* L.	Tiliaceae	Herb	Aug-Dec	Exotic
82.	*Corchorus olitorius* L.	Tiliaceae	Herb	Aug-Dec	Indigenous
83.	*Corchorus tridens* L.	Tiliaceae	Herb	Aug-Dec	Indigenous
84.	*Corchorus trilocularis* L.	Tiliaceae	Herb	Jul-Mar	Indigenous
85.	*Ctenolepis cerasiformis* (Stocks) Hook. f.	Cucurbitaceae	Climbing herb	Aug-Oct	Indigenous
86.	*Cucumis maderaspatanus* L.	Cucurbitace	Climbing	Jul-Nov	Indige

S. N.	Botanical name	Family	Habit	Phenology	Origin
		ae	herb		nous
87.	*Cucumis prophetarum* L.	Cucurbitaceae	Climbing herb	Jul-Oct	Indigenous
88.	*Cynodon dactylon* (L.) Pers.	Poaceae	Perennial	Throughout	Indigenous
89.	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	Annual	Throughout	Indigenous
90.	*Datura metel* L.	Solanaceae	Shrub	Throughout	Indigenous
91.	*Dinebra retroflexa* (Vahl) Panz.	Poaceae	Annual	Aug-Feb	Indigenous
92.	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Asteraceae	Herb	Throughout	Indigenous
93.	*Maerua oblongifolia* (Forssk.) A. Rich.	Capparaceae	Climbing shrub	Oct-Feb	Indigenous
94.	*Passiflora foetida* L. var. *foetida*	Passifloraceae	Climbing shrub	Aug-Dec	Exotic
95.	*Pavonia ceratocarpa* Masters	Malvaceae	Herb	Aug-Oct	Indigenous
96.	*Pentatropis spiralis*(Forssk.)Decne.	Asclepiadaceae	Twining herb	Aug-Dec	Indigenous
97.	*Pergularia daemia* (Forssk.) Chiov.	Asclepiadaceae	Twining shrub	Oct-Mar	Indigenous
98.	*Peristrophe bicalyculata* (Retz.) Nees	Acanthaceae	Herb	Oct-Apr	Indigenous
99.	*Physalis minima* L.	Solanaceae	Herb	Jul-Jan	Indigenous
100	*Rungia elegans* Dalzell & A. Gibson	Acanthaceae	Herb	Sep-Mar	Endemic
101	*Rungia repens* (L.) Nees	Acanthaceae	Herb	Aug-Jan	Indigenous
102	*Senna occidentalis* (L.) Link.	Caesalpiniaceae	Under Shrub	Throughout	Exotic
103	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	Annual	Jul-Nov	Indigenous
104	*Sida mysorensis* Wight & Arn.	Malvaceae	Herb	Aug-Dec	Exotic
Open lands					
105	*Nothosaerva brachiata* (L.) Wight	Amaranthaceae	Herb	Sep-May	Indigenous
106	*Ocimum americanum* L.	Lamiaceae	Herb	Throughout	Indigenous
107	*Parthenium hysterophorus* L.	Asteraceae	Herb	Sep-Mar	Exotic
108	*Dyerophytum indicum* (Gibson ex Wight) Kuntze	Plumbaginaceae	Shrub	Oct-Feb	Indigenous
109	*Echinops echinatus* Roxb.	Asteraceae	Herb	Sep-Jan	Indige

S. N.	Botanical name	Family	Habit	Phenology	Origin
					nous
110	*Elytraria acaulis* (L. f.) Lindau	Acanthaceae	Herb	Jul-Dec	Indigenous
111	*Enicostema axillare* (Lam.) A. Raynal ssp. *axillare*	Gentianaceae	Herb	Jul-Nov	Indigenous
112	*Eragrostis ciliaris* (L.) R. Br.	Poaceae	Annual	Oct-Jan	Indigenous
113	*Euphorbia neriifolia* L.	Euphorbiaceae	Shrub	Nov-Apr	Indigenous
114	*Gossypium stocksii* Mast.	Malvaceae	Shrub	Oct-Dec	Exotic
115	*Grewia tenax* (Forssk.) Fiori	Tiliaceae	Shrub	Apr-Sep	Indigenous
116	*Justicia procumbens* L.	Acanthaceae	Herb	Jun-Dec	Indigenous
117	*Tridax procumbens* L.	Asteraceae	Herb	Throughout	Exotic
118	*Verbascum chinense* (L.) Santapau	Scrophulariaceae	Herb	Throughout	Indigenous
119	*Vernonia cinerea* (L.) Less.	Asteraceae	Herb	Throughout	Indigenous
120	*Canavalia gladiata* (Jacq.) DC.	Fabaceae	Climber		
121	*Commiphora wightii* (Arn.) Bhandari	Burseraceae	Shrub	Jan-May	Indigenous
122	*Celosia argentea* L.	Amaranthaceae	Herb	Jul-Dec	Indigenous
123	*Cenchrus ciliaris* L.	Poaceae	Annual	Jul-Jan	Indigenous
124	*Chloris barbata* Sw.	Poaceae	Perennial	Jul-Apr	Indigenous
125	*Pluchea lanceolata* (DC.) C.B.Clarke	Asteraceae	Herb	Jan-Apr	Indigenous
126	*Tamarix indica* Willd.	Tamaricaceae	Tree	Aug-Mar	Indigenous
127	*Solanum virginianum* L.	Solanaceae	Herb	Throughout	Indigenous
128	*Sporobolus virginicus* (L.) Kunth	Poaceae	Perennial	Aug-Dec	Indigenous
129	*Hyphaene dichotomoma* (Wight ex Graham) Furtado	Arecaceae	Tree	Jul-Sep	Endemic
130	*Indigofera cordifolia* B. Heyne ex Roth	Fabaceae	Herb	Throughout	Indigenous
131	*Indigofera oblongifolia* Forssk.	Fabaceae	Herb	Sep-Oct	Indigenous
132	*Senna occidentalis* (L.) Link	Caesalpiniieaceae	Shrub		
133	*Stemodia viscosa* Roxb.	Scrophularia	Herb	Oct-	Indige

S. N.	Botanical name	Family	Habit	Phenology	Origin
		ceae		May	nous
134	*Ziziphus nummularia* (Burm. f.) Wight. & Arn. var. *nummularia*	Rhamnaceae	Shrub	Jul-Jan	Indigenous
135	*Alhagi maurorum* Medik.	Fabaceae	Herb	Mar-Apr	Indigenous
136	*Alternanthera sessilis* (L.) R. Br. ex DC.	Amaranthaceae	Herb	Throughout	Indigenous
137	*Alysicarpus longifolius* (Rottler ex Spreng.) Wight & Arn.	Fabaceae	Herb	Sep-Mar	Indigenous
138	*Argemone mexicana* L.	Papaveraceae	Herb	Throughout	Exotic
139	*Aristida adscensionis* L.	Poaceae	Annual	Aug-Jan	Indigenous
140	*Xanthium indicum* J. Koenig ex Roxb.	Asteraceae	Herb	Throughout	Indigenous
Agriculture land vegetation					
141	*Cadaba fruticosa* (L.) Druce	Capparaceae	Shrub	Dec-Apr	Indigenous

Annexure 2: Floral Diversity of Khijadiya Bird Sanctuary

S. N.	Botanical name	Family	Habit	Phenology	Origin
Water					
Submerged aquatic plants					
1.	*Hydrilla verticillata* (L. f.) Royle	Hydrocharitaceae	Aquatic herb	Oct-Jan	Indigenous
2.	*Najas marina* L.	Hydrocharitaceae	Aquatic herb	Jan-Apr	Indigenous
3.	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae	Aquatic herb	Oct-Mar	Indigenous
4.	*Stuckenia pectinata* (L.) Boerner	Potamogetonaceae	Aquatic herb	Aug-Oct	Indigenous
5.	*Vallisneria natans* (Lour.) H. Hara	Hydrocharitaceae	Aquatic herb	Oct-Feb	Indigenous
Floating aquatic plants					
6.	*Ipomoea aquatica* Forssk.	Convolvulaceae	Twining herb	Oct-Dec	Indigenous
7.	*Lemna gibba* L.	Lemnaceea	Aquatic herb	Sep-Dec	Indigenous
8.	*Nymphaea pubescens* Willd.	Nymphaeaceae	Aquatic herb	Oct-Dec	Indigenous
Drying wetland					

S. N.	Botanical name	Family	Habit	Phenology	Origin
Partially submerged aquatic plants					
	Bolboschoenus maritimus ssp. *affinis* (Roth.) T. Koyama	Cyperaceae	Annual	Sep-Dec	Indigenous
10.	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Perennial	Oct-Feb	Indigenous
11.	*Schoenoplectus subulatus* (Vahl) Lye	Cyperaceae	Perennial	Sep-Jan	Indigenous
Wetland or marshy plants					
12.	*Ammannia baccifera* L. var. *Baccifera*	Lythraceae	Marshy herb	Dec-Feb	Indigenous
13.	*Echinochloa colona* (L.) Link	Poaceae	Annual	Aug-Feb	Indigenous
14.	*Marsilea quadrifolia* L.	Marsileaceae	Herb	Jan-Feb	Indigenous
15.	*Paspalidium geminatum* (Forssk.) Stapf	Poaceae	Perennial	Aug-Nov	Indigenous
16.	*Phyla nodiflora* (L.) Greene	Verbenaceae	Herb	Throughout	Indigenous
17.	*Polygonum plebeium* R. Br. var. *plebeium*	Polygonaceae	Herb	Sep-May	Indigenous
Dried wetland					
18.	*Chrozophora plicata* (Vahl) A. Juss. ex Spreng.	Euphorbiaceae	Herb	July-Oct	Indigenous
19.	*Chrozophora rottleri* (Geiseler) A. Juss. ex Spreng.	Euphorbiaceae	Herb	July-Apr	Indigenous
20.	*Coldenia procumbens* L.	Boraginaceae	Herb	Throughout	Indigenous
21.	*Corchorus depressus* (L.) Vicary	Tiliaceae	Herb	Sep-Oct	Indigenous
22.	*Dopatrium junceum* (Roxb.) Buch.-Ham. ex Benth.	Scrophulariaceae	Herb	Aug-Dec	Indigenous
23.	*Eclipta prostrata* (L.) L. var.*Prostrate*	Asteraceae	Herb	Aug-Jan	Indigenous
24.	*Glinus lotoides* L.	Aizoaceae	Herb	Throughout	Indigenous
25.	*Grangea maderaspatana* (L.) Poir.	Asteraceae	Herb	Dec-Apr	Indigenous
26.	*Heliotropium curassavicum* L.	Boraginaceae	Herb	Throughout	Exotic
27.	*Heliotropium supinum* L.	Boraginaceae	Herb	Aug-Apr	Indigenous
28.	*Merremia emarginata* (Burm. f.) Hallier f.	Convolvulaceae	Creeping herb	Aug-Feb	Indigenous
29.	*Mollugo pentaphylla* L.	Aizoaceae	Herb	Jul-Dec	Indigenous
Salt Marsh Vegetation					

S. N.	Botanical name	Family	Habit	Phenology	Origin
Mangrove					
30.	*Avicennia marina* (Forssk.) Vierh.	Avicenniaceae	Shrub	Feb-Jun	Indigenous
31.	*Ceriops tagal* (Perr.) C.B. Rob.	Rhizophoraceae	Small tree	Jul-Sep	Indigenous
32.	*Rhizophora mucronata* Lam.	Rhizophoraceae	Small tree	Aug-Dec	Indigenous
Halophytes					
33.	*Aeluropus lagopoides* (L.) Trin. ex Thwaites	Poaceae	Perennial	Oct-Dec	Indigenous
34.	*Arthrocnemum indicum* (Willd.) Moq.	Chenopodiaceae	Herb	Oct-Dec	Indigenous
35.	*Atriplex stocksii* (Wight) Boiss.	Chenopodiaceae	Under shrub	Sep-Apr	Indigenous
36.	*Cressa cretica* L.	Convolvulaceae	Herb	Throughout	Indigenous
37.	*Juncus maritimus* Lam.	Juncaceae	Herb	Oct-Dec	Exotic
38.	*Polycarpaea spicata* Wight & Arn.	Caryophyllaceae	Herb	Oct-Nov	Indigenous
39.	*Salicornia brachiata* Roxb.	Chenopodiaceae	Herb	Nov-Feb	Indigenous
40.	*Salvadora persica*L.	Salvadoraceae	Tree	Nov-Feb	Indigenous
41.	*Sesuvium portulacastrum* (L.) L.	Aizoaceae	Herb	Nov-Jan	Indigenous
42.	*Suaeda fruticosa*Forssk. ex J. F. Gmelin	Chenopodiaceae	Shrub	Apr-Sep	Indigenous
43.	*Suaeda nudiflora* Moq.	Chenopodiaceae	Herb	Apr-Sep	Indigenous
44.	*Tamarix stricta* Boiss.	Tamaricaceae	Shrub	Feb-Jun`	Indigenous
45.	*Taverniera cuneifolia* (Roth) Arn.	Fabaceae	Under shrub	Aug-Nov	Indigenous
46.	*Urochondra setulosa* (Trin.) C.E.Hubb.	Poaceae	Perennial	Oct-Jan	Indigenous
Land vegetation					
***Prosopis* occupied area**					
47.	*Acacia nilotica* ssp. *indica* (Benth.) Brenan	Mimosaceae	Tree	Jul-Oct	Indigenous
48.	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Tree	Aug-May	Exotic
Bunds					
49.	*Abutilon indicum* (L.) Sweet ssp. *indicum*	Malvaceae	Shrub	Throughout	Indigenous
50.	*Achyranthes aspera*L. var. *Aspera*	Amaranthac	Herb	Throug	Indigen

S. N.	Botanical name	Family	Habit	Phenology	Origin
		eae		hout	ous
51.	*Alternanthera sessilis* (L.) R. Br. ex DC.	Amaranthaceae	Herb	Throughout	Indigenous
52.	*Azadirachta indica* A. Juss.	Meliaceae	Tree	Dec-May	Indigenous
53.	*Calotropis procera* (Aiton)R. Br.	Asclepiadaceae	Shrub	Throughout	Indigenous
54.	*Corchorus olitorius* L.	Tiliaceae	Herb	Aug-Dec	Indigenous
55.	*Corchorus trilocularis* L.	Tiliaceae	Herb	Jul-Mar	Indigenous
56.	*Leucaena leucocephala* (Lam.) de Wit.	Mimosaceae	Tree	May-Feb	Exotic
57.	*Parkinsonia aculeata* L.	Caesalpiniaceae	Shrub	Nov-Mar	Exotic
58.	*Parthenium hysterophorus* L.	Asteraceae	Herb	Sep-Mar	Exotic
59.	*Passiflora foetida* L. var. *Foetida*	Passifloraceae	Climbing shrub	Aug-Dec	Exotic
60.	*Pentatropis spirallis* (Forssk.) Decne	Asclepiadaceae	Twining herb	Aug-Dec	Indigenous
61.	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	Tree	Jan-Mar	Indigenous
62.	*Physalis minima* L.	Solanaceae	Herb	Jul-Jan	Indigenous
63.	*Pithecellobium dulce* (Roxb.) Benth.	Mimosaceae	Tree	Jan-Jul	Exotic
64.	*Senna auriculata* (L.) Roxb.	Caesalpiniaceae	Shrub	Jan-Jul	Indigenous
65.	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	Annual	Jul-Nov	Indigenous
66.	*Sporobolus virginicus* (L.) Kunth	Poaceae	Perennial	Aug-Dec	Indigenous
67.	*Tamarix indica* Willd.	Tamaricaceae	Tree	Aug-Mar	Indigenous
68.	*Vernonia cinerea* (L.) Less.	Asteraceae	Herb	Throughout	Indigenous
Open land					
69.	*Aloe vera* (L.) Burm. f.	Liliaceae	Herb	Dec-May	Exotic
70.	*Aristida adscensionis* L.	Poaceae	Annual	Aug-Jan	Indigenous
71.	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	Shrub	Feb-Sep	Indigenous
72.	*Cenchrus ciliaris* L.	Poaceae	Annual	Jul-Jan	Indigenous
73.	*Chloris barbata* Sw.	Poaceae	Perennial	Jul-Apr	Indigenous

S. N.	Botanical name	Family	Habit	Phenology	Origin
74.	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	Climbing herb	Throughout	Indigenous
75.	*Cocculus hirsutus* (L.) W. Theob.	Menispermaceae	Climbing shrub	Nov-Apr	Indigenous
76.	*Cordia dichotoma* G. Forst.	Boraginaceae	Tree	Jan-Jun	Indigenous
77.	*Ctenolepis cerasiformis* (Stocks) Hook. f.	Cucurbitaceae	Climbing herb	Aug-Oct	Indigenous
78.	*Cucumis maderaspatanus* L.	Cucurbitaceae	Climbing herb	Jul-Nov	Indigenous
79.	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	Annual	Throughout	Indigenous
80.	*Elytraria acaulis* (L. f.) Lindau	Acanthaceae	Herb	Jul-Dec	Indigenous
81.	*Enicostema axillare* (Lam.) A. Raynal ssp. *axillare*	Gentianaceae	Herb	Jul-Nov	Indigenous
82.	*Eragrostis ciliaris* (L.) R. Br.	Poaceae	Annual	Oct-Jan	Indigenous
83.	*Fagonia schweinfurthii* (Hadidi) Hadidi ex Ghafoor	Zygophyllaceae	Undershrub	Oct-Dec	Indigenous
84.	*Indigofera oblongifolia* Forssk.	Fabaceae	Shrub	Sep-Oct	Indigenous
85.	*Justicia procumbens* L.	Acanthaceae	Herb	Jun-Dec	Indigenous
86.	*Solanum virginianum* L.	Solanaceae	Herb	Throughout	Indigenous
87.	*Ziziphus mauritiana* Lam. var. *mauritiana*	Rhamnaceae	Shrub	Sep-Feb	Indigenous
88.	*Zizyphus nummularia* (Burm. f.) Wight. & Arn. var. n*ummularia*	Rhamnaceae	Shrub	Jul-Jan	Indigenous

Annexure 3: Common Name and English name of the Species

S.N.	Botanical name	Common name	Local name
1.	*Abutilon indicum*	Indian Mallow	Khapat
2.	*Abutilon ramosum*	Indian Mallow	Dholi khapat
3.	*Acacia nilotica*	Gum arabic tree, Egyptian thorn	Dataniyo Baval
4.	*Achyranthes aspera*	Prickly Chaff Flower, Devil's Horsewhip	Aghedo
5.	*Aeluropus lagopoides*	Mangroove Grass, Rabbit-Foot	Khariyu
6.	*Alhagi pseudalhagi*	Camel thorn	Javaso

S.N.	Botanical name	Common name	Local name
7.	*Aloe vera*	Aloe, Burn plant	Kuvar
8.	*Alternanthera sessilis*	Sessile Joyweed, Dwarf copperleaf	Jal jambvo
9.	*Alysicarpus longifolia*	-	Ubho samervo
10.	*Ammannia baccifera*	Blistering Ammania	Jal agiyo
11.	*Argemone mexicana*	Mexican prickly poppy	Darudi
12.	*Aristida adscensionis*	Six-weeks three-awn	Uth lampdo
13.	*Aristolochia bracteata*	Dutchman's pipe and Pipevine	Kidamari
14.	*Arthrocnemum indicum*	-	Machur, Bholdo
15.	*Asphodelus tenuifolius*	Onionweed	Dungro
16.	*Atriplex stocksii*	Saltbush	Adbau palak
17.	*Avicennia marina*	Grey mangroove, White mangroove	Tavariya, Cheriya
18.	*Azadirachta indica*	Margossa, Indian Lilac	Limdo
19.	*Bacopa monnieri*	Indian Pennywort, Water Hyssop	Bam, Jal nevri
20.	*Barleria prionitis*	Porcupine flower	Kantasheriyo
21.	*Bergia odorata*	-	Lavadiyu
22.	*Blepharis integrifolia*	-	Utingan
23.	*Boerhavia chinensis*	Spreading Hogweed	Satodi
24.	*Bolboschoenus maritimus*	Sea clubrush	Saaj
25.	*Cadaba fruticosa*	Capper Brush	Teliyo Hemkand
26.	*Calotropis gigantean*	Crown flower	Moto Aakdo
27.	*Calotropis procera*	Milkweed	Aakdo
28.	*Capparis decidua*	Caper berry	Kerdo
29.	*Cardiospermum halicacabum*	Balloon plant, Love in a puff	Kagdodiyo, Karodiyo
30.	*Cenchrus ciliaris*	African foxtail grass	-
31.	*Ceratopteris thalictroides*	Floating water fern	-
32.	*Celosia argentea*	Plumed cockscomb, Silver cock's comb	Lampdi
33.	*Ceriops tagal*	Tagal Mangroove	-
34.	*Chenopodium album*	White goosefoot, Pigweed	-
35.	*Chloris barbata*	Swollen Finger Grass, Airport grass	Mindadiyu Ghas
36.	*Chrozophora plicata*	Turnsole	Betho okhrad
37.	*Chrozophora rottleri*	Dyer's Litmus	Suryavirt, Kalo okhrad
38.	*Clerodendron serratum*	Beetle Killer	Arni
39.	*Clitoria ternetea*	Butterfly pea	Dholi Gharni
40.	*Coccinia grandis*	West Indian gherkin	Kadvi, Ghiloda
41.	*Cocculus hirsutus*	Broom Creeper, Ink berry	Vevdi

S.N.	Botanical name	Common name	Local name
42.	*Coldenia procumbens*	Creeping Coldenia	Basariyo Okhrad
43.	*Commelina benghalensis*	Benghal dayflower, tropical spiderwort	Shishmudiyu
44.	*Commiphora wightii*	Indian bdellium-tree	Gugal
45.	*Convolvulus microphyllus*	Bindweed, Brain tonic	Shankhavali
46.	*Corchorus aestuans*	East Indian Mallow	Chunch, Jiteli
47.	*Corchorus depressus*	Corchorus	Bahufali, Jhinki chunch
48.	*Corchorus ollitorius*	Wild jute, Tossa jute	Chuchdo, Moti chunch
49.	*Corchorus tridens*	Horn-fruited jute	Kadvi chunch
50.	*Corchorus trilocularis*	African jute	Lambi chunch
51.	*Cordia dichotoma*	Indian cherry, Clammy cherry, Fragrant manjack	Gunda
52.	*Cordia sinensis*	Grey leaved saucerberry	Gundi
53.	*Cressa cretica*	Littoral bind weed	Paliyo, Pariyo
54.	*Ctenolepsis cerasiformis*	-	-
55.	*Cucumis maderaspatanus*	Madras pea pumpkin, Rough bryony	Chanak chibdi
56.	*Cucumis prophetarum*	Globe cucumber	Kantada indramana
57.	*Cynodon dactylon*	Dog's toothgrass, Bahama grass, Devil's grass, Couch grass	Dhrokad, Dhro
58.	*Cyperus arenarius*	Nutsedge	-
59.	*Cyperus esculentus*	Chufa sedge, Nut grass, Yellow nutsedge, Tiger Nut sedge, Earth almond	-
60.	*Dactyloctenium aegyptium*	Egyptian crowfoot grass	-
61.	*Datura metel*	Devil's trumpet	Daturo
62.	*Dinebra retroflexa*	Viper grass	-
63.	*Dopatrium junceum*	Rushlike Dopatrium	-
64.	*Dyerophytum indicum*	-	Pavi
65.	*Echinochloa colona*	Jungle rice, Awnless barnyard grass	-
66.	*Echinops echinatus*	Indian Globe Thistle	Untkato
67.	*Eclipta prostrata*	False daisy	Kalobhangro
68.	*Eichhornia crassipes*	Water Hyacinth	-
69.	*Eleocharis geniculata*	Bentspikerush, Canada spikesedge	-
70.	*Elytraria acaulis*	Asian Scalystem	-
71.	*Enicostema axillare*	Indian Gentian	Mamejvo
72.	*Eragrostis ciliaris*	Lovegrass, Feather lovegrass	Marmar ghas
73.	*Euphorbia perfoliata*	-	-
74.	*Euphorbia prostrata*	Prostrate sandmat	-
75.	*Fagonia schweinfurthii*	Khorasan thorn, Virgin's Mantle,	Dhamaso

S.N.	Botanical name	Common name	Local name
		Virgon's Mantlem	
76.	*Fimbristylis ferruginea*	Rusty sedge, West Indian fimbry	-
77.	*Glinus lotoides*	Lotus sweet juice	Mitho Okhrad
78.	*Gossypium stocksii*	Wild Cotton tree	Kapas, Hirvani
79.	*Grangea maderaspatana*	Madras Carpet	Jhinki mundi
80.	*Grewia tenax*	White cross berry	Gangeti, Bajothiyu
81.	*Halopyrum mucronatum*	-	Dariyai Kasado
82.	*Heliotropium bacciferum*	Turnsole	-
83.	*Heliotropium curassavicum*	-	Hathisundho
84.	*Heliotropium supinum*	Dwarf Heliotrope	Ghediyo Okhrad
85.	*Hydrilla verticillata*	Esthwaite Waterweed	-
86.	*Hygrophila schulli*	Temple plant, Marsh Barbel	Sarpat
87.	*Hyphaene dichotomoma*	Doum palm, Gingerbread tree	Ravantaad, Hokataad
88.	*Indigofera cordifolia*	Heart-Leaf Indigo	Dadiyo
89.	*Indigofera oblongifolia*	Common Indigo	Jhil
90.	*Ipomoea aquatica*	Chinese spinach, Chinese Watercress	Nala ni bhaji
91.	*Juncus maritimus*	Seaside rush	-
92.	*Justicia procumbens*	Water willow, Shrimp plant	Khetrau Khadsaliyo
93.	*Lantana camara* ssp. *aculeata*	Wild-sage, Red-sage	Abhagan
94.	*Launaea procumbens*	Creeping Launaea	Bhopatri
95.	*Lemna gibba*	Swollen duckweed	-
96.	*Leucaena leucocephala*	White leadtree, Jumbay, River tamarind	Su babul
97.	*Limnophyton obtusifolium*	Blunt Arrowhead	-
98.	*Lotus garcinii*	Bird's-foot trefoil	Moto Bhakho
99.	*Maerua oblongifolia*	Desert Maerua	Dudhiyo Hemkand
100.	*Marsilea quadrifolia*	Four leaf clover	-
101.	*Medicago sativa*	Alfalfa	Gadab
102.	*Merremia emarginata*	Kidney leaf morning glory	Undarkani
103.	*Mollugo pentaphylla*	Five Leaved Carpetweed	-
104.	*Najas marina*	Spiny naiad	-
105.	*Nothosaerva brachiata*	Minute Amaranth	-
106.	*Nymphaea pubescens*	Hairy water lily	Dholo kamal
107.	*Nymphaea rubra*	Pink water-lily	Lal kamal
108.	*Ocimum americanum*	Great basil, Saint-Joseph's-wort	Ram tulsi
109.	*Ottelia alismoides*	Duck-Lettuce, Waterplantain Ottelia	-
110.	*Oxystelma esculentum*	Rosy Milkweed Vine	Narot,

S.N.	Botanical name	Common name	Local name
			Jaldudhi
111.	*Parkinsonia aculeata*	Jerusalem thorn, Jelly bean tree	Ram baval, Til baval
112.	*Parthenium hysterophorus*	Congress weed , Carrot grass	-
113.	*Paspalidium geminatum*	Egyptian panicgrass	-
114.	*Paspalum vaginatum*	Cow grass, Rice grass, Ditch millet	Jungli Kodri
115.	*Passiflora foetida*	Wild maracuja, Bush passion fruit, Stinking passionflower	Krishna kamal
116.	*Pavonia ceratocarpa*	Sour swamp mallow	Khatichaas
117.	*Pentatropis capensis*	-	Hudiyo
118.	*Pergularia daemia*	Trellis-vine	Chamardudhli
119.	*Peristrophe bicalyculata*	Panicled Foldwing	Kali Aghedi
120.	*Phoenix sylvestris*	Silver Date Palm	Khajuri
121.	*Phragmites karka*	Tall reed	Nayri, Nali
122.	*Phyla nodiflora*	Turkey tangle fogfruit	Ratvelio
123.	*Physalis minima*	Native gooseberry, Wild cape gooseberry, Pygmy groundcherry	Parpopti, Popti
124.	*Pithecellobium dulce*	Monkeypod	Goras Ambli
125.	*Pluchea lanceolata*	Rasna	Rashna
126.	*Polycarpaea spicata*	-	Vajradanti
127.	*Polygonum plebeium*	Common knotweed	Jhinko okhrad
128.	*Portulaca quadrifida*	Chickenweed	Luni
129.	*Prosopis juliflora*	Mesquite	Gando baval
130.	*Pulicaria angustifolia*	-	Shishoriya
131.	*Rhizophora mucronata*	Loop-root mangroove, Red mangroove, Asiatic mangroove	-
132.	*Rungia elegans*	-	Dungri Khadsaliyo
133.	*Rungia repens*	Creeping Rungia	Moto Khadsaliyo
134.	*Salicornia brachiata*	Slender glasswort	Machul
135.	*Salvadora persica*	Arak, Meswak,Peelu, Toothbrush tree	Jaar, Piludi
136.	*Schoenoplectus subulatus*	Common Club-rush	Tader
137.	*Senna auriculata*	Tanner's Cassia	Aavad
138.	*Senna occidentalis*	Coffee Senna, Stinking Weed	Kasundro
139.	*Sesbania bispinosa*	Prickly Sesban	Ikad
140.	*Sesbania sesban*	Common sesban, Egyptian rattlepod, Egyptian riverhemp	Jayanti
141.	*Sesuvium portulacastrum*	Shoreline seapurslane	-
142.	*Setaria pumila*	Yellow foxtail, Pigeon grass, Cattail grass	Kalot
143.	*Sida mysorensis*	Mysore fanpetals	-
144.	*Solanum virginianum*	Thorny Nightshade, Yellow Berried Nightshade	Bhoy ringani

S.N.	Botanical name	Common name	Local name
145.	*Sporobolus virginicus*	Seashore dropseed	-
146.	*Stemodia viscosa*	Sticky Blue Rod	Nukachuni
147.	*Stuckenia pectinata*	Sago pondweed	-
148.	*Suaeda fruticosa*	Shrubby Seablite	Moras
149.	*Suaeda nudiflora*	-	Lano
150.	*Tamarix indica*	Salt cedar	Prans, Jhav
151.	*Tamarix stricta*	-	-
152.	*Taverniera cuneifolia*	East-indian Moneywort	Jethimadh
153.	*Tinospora cordifolia*	Heart-leaved moonseed	Gado
154.	*Tridax procumbens*	Mexican Daisy, Coat Buttons	Pardeshi bhangro
155.	*Typha angustifolia*	Narrowleaf cattail	Gha bajariyu
156.	*Urochondra setulosa*	-	-
157.	*Vallisneria natans*	Eelgrass, Tape grass	Jal sarpoliya
158.	*Verbascum chinense*	Common mullein	Kalhar
159.	*Vernonia cinerea*	Ash colored fleabane	Sahdevi
160.	*Wattakaka volubilis*	Sneeze Wort, Cotton milk plant	Moti dodi
161.	*Xanthium indicum*	Rough cocklebur	Gaadariyu
162.	*Zizyphusmauritiana*	Chinese date, Indian plum, Regi pandu, Indian jujube	Bordi
163.	*Zizyphus nummularia*	Wild jujube	Chaniya bor, Adbau bordi

About the Study

This study is part of the scientific and technical studies in Gujarat that the CMPA project supported towards effective and sustainable management of coastal and marine protected areas. The surveys of both the wetlands - Gosabara Wetland Complex in Porbandar and Khijadiya Bird Sanctuary in Jamnagar, were conducted during December 2016 to July 2017. The wetlands were studied based on the microhabitats classified in 2015-2016. Thus Gosabara and Khijadiya wetland were surveyed in six and four sub-habitats respectively. This study provides detailed insights into the species pattern and suggestive measures for managing the wetlands from the viewpoint of floral biodiversity conservation.

The CMPA Project

The Project "Conservation and Sustainable Management of Coastal and Marine Protected Areas" (CMPA) is a project of the Indo-German technical cooperation. It is funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and implemented by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India, and the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of BMUB.*

Established to support the achievement of the Aichi targets of the Convention on Biological Diversity, the Project's overall goal is to contribute to conservation and sustainable use of biodiversity in selected areas along the coast of India. Taking into consideration the economic importance of the coastal zone for large segments of the population, the Project's approach is people-centered, thus ensuring the support for conservation by those depending on coastal ecosystems.

CMPA Technical Report Series

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Floral Biodiversity Monitoring to Support the Management Planning at Khijadiya Wildlife Sanctuary and Gosabara Wetland Complex in Gujarat

September 2017

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

Indo-German Biodiversity Programme
Conservation and Sustainable Management of Coastal and Marine Protected Areas