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NICHE MODELLING- AN APPROACH TO PREDICT HABITATS FOR CONSERVATION OF *HIPPOPHAE* SPECIES IN TRANS AND NORTH WESTERN INDIAN HIMALAYA

Manohar Lal & *Samant, S.S.
G.B. Pant National Institute of Himalayan Environment and Sustainable Development,
Himachal Unit, Mohal-Kullu- 175 126, Himachal Pradesh
*Corresponding author email: samantss2@rediffmail.com

ABSTRACT
Hippophae rhamnoides ssp. *turkestanica* and *H. salicifolia* have great potential for greening the cold desert area and changing socio-economic status of the tribal communities. In spite of the high potential of these species, identification of suitable habitats and area for *in-situ* conservation of *Hippophae* species have not been done. Therefore, present attempt has been made to predict areas highly suitable for the *in-situ* conservation in Himachal Pradesh. Total 191 primary distribution point data and various environmental and physiographic parameters have been utilized for the prediction of geographical distribution of these species. The distribution models were quite accurate with area under curve > 0.90 for *H. rhamnoides* ssp. *turkestanica* and *H. salicifolia*. The most important factor, which determined the distribution of the potential habitats of these species, was precipitation of coldest, warmest quarter and driest period. The Maxent model depicted that potential habitat of *H. rhamnoides* ssp. *turkestanica* is in the semi arid region, and *H. salicifolia* in the semi arid and temperate regions of the Himachal Pradesh. The niche specificity of species has been argued to be one of the reasons of its limited distribution. The habitat models also revealed restricted availability of potential habitats for the species. Only 531 km^2 is suitable for re-introduction of *H. rhamnoides* ssp. *turkestanica* and 915 km^2 for *H. salicifolia.* Based on the study, it is recommended that the species should be re-introduced for conservation in the predicted suitable habitats. Participation of the Tribal Communities and Forest Department may be ensured for the conservation of species.

KEYWORDS: *Hippophae rhamnoides* ssp. *turkestanica*, *Hippophae salicifolia,* Cold Desert, Habitat, Indian Himalaya.

INTRODUCTION
Changing climate, habitat fragmentation, over-exploitation, and escalating human population are the most important factors, responsible for approximately one fifth of the plant species of globe to the brink of extinction (Brummitt & Bachman, 2010; Barnosky *et al.,* 2011; Obaid, 2004). The loss of biological diversity in the world's forests has experienced a colossal depletion in the recent past. The International Union for Conservation of Nature and Natural Resources (IUCN) has estimated about 10% of the vascular plants are varying degree of threats and nearly 25% of the floral species in the world may become extinct within the next 50 years (Schemske *et al.,* 1994). In the Indian Himalayan Region (IHR), over exploitation and habitat degradation are among the major factors leading to species vulnerability (Samant *et al*., 1998, 2007; Rana & Samant 2010; Ved *et al.,* 2003). Genus *Hippophae* (family Elaeagnaceae) represents 7 species and 8 sub-species worldwide (Swenson & Bartish 2002). All these species are native to Eurasia and commonly known as 'Seabuckthorn'. In India, three species namely, *Hippophae rhamnoides* L. ssp. *turkestanica* Rousi*, H. salicifolia* D. Don and *H. tibetana* Schlecht. are found in the Himalayan Region. All the three species of *Hippophae* are mostly found in Lahaul and Spiti district of Himachal Pradesh. However*, H. salicifolia* D. Don is recorded in Kinnaur, Chamba, Kangra, Shimla and Kullu districts between 2,000 and 3,500 m amsl. It is locally called Chharma, Sutz, Tirkug, Chasterlulu and Sarla in Himachal Pradesh; Tsemarang and Chasterlulu in Ladakh; Tare and Taroobo in north-east region and Ames and Chuk in Uttarakhand (Samant & Dhar, 1997; Pangtey *et al*., 1989; Samant *et al*., 1996, 2001; Satyal *et al*., 2002; Singh *et al.,* 2006; Dhyani *et al*., 2007). Species are diocious or occasionally monocious, spinaceous and arboresent shrub varying in height from 20 cm to 8 am. It can withstand wide range of temperatures from -43º to 40ºC. This unique feature enables the species to adapt very well in harsh climatic conditions. Its ecological, agricultural, nutritional, medicinal, food, fuel, fodder and timber values are well known and fruits are most valuable being a rich source of vitamins (Singh *et al.,* 1991; Chauhan *et al*., 2001; Singh *et al*., 2003; Singh *et al*., 2006; Singh *et al*., 2008). In national and international markets, products prepared by processing the fruits are highly demanded. China planted seabuckthorn over 5,00,000 ha area to meet the demand of it raw material (Singh *et al*., 2010). However, in India, most of the supply of raw material is mainly done by harvesting the wild populations, which are sparse. Due to over-exploitation, habitat degradation and lack of plantation, these species have become threatened in some Indian Himalayan states like Himachal Pradesh and Jammu and Kashmir (Ved *et al*., 2003). Besides their economic value, their wide ecological adaptation, rapid growth and easy suckering habit have offered them as a promising species for

combating desertification and rehabilitating degraded areas (Singh *et al*., 2012).

Realizing the importance of seabuckthorn for ecological, social and economical development, a number of scientific studies have been undertaken in India (Pangtey *et al*., 1989; Anonymous 1997; Samant & Dhar 1997; Singh *et al*., 1997; Chauhan *et al*., 2001; Roy *et al*., 2001; Singh *et al*., 2003; Singh *et al*., 2006; Dhyani, *et al*., 2007; Singh 2007; Butola & Badola 2008; Singh *et al*., 2008; Dhyani *et al*., 2010; Singh *et al*., 2010; Stobdan *et al*., 2008; Samant *et al*., 2007, 2010) and abroad (Rousi, 1971; Ma, 1989; Rong-Sen, 1990, 1992; Li 1999; Zeb, 2004).

For restoration of the depleted species populations and degraded habitats and ecosystems, species re-introduction is one of the successful ecological engineering techniques (Leaper *et al*., 1999; Kuzovkina & Volk 2009; Ren *et al.* 2009; Zai *et al*., 2009; Rodriguez-Salinas *et al*., 2010; Nazeri *et al*., 2010; Polak & Saltz, 2011; Samant & Lal 2015). A detailed knowledge on the distribution of species potential habitats is essentially required for the successful re-introduction of species in the ecosystems. Habitat distribution modeling therefore, helps to identify the areas for species reserves, re-introduction, and in developing effective species conservation measures (Adhikari *et al*. 2009, 2012; Samant & Lal, 2015). It has been successfully used in restoring critical habitats and predicting the impact of environmental and climate change on species and ecosystems (Brooks *et al*., 2004; Giriraj *et al*., 2008; Franklin 2009; Adhikari *et al*., 2009, 2012; Gogol-Prokurat, 2011; Barik & Adhikari, 2011). New insights into the factors governing the distribution of species have been developed using habitat distribution modelling or ecological niche modeling (ENM) (Guisan & Zimmermann, 2000; Elith *et al*., 2006; Kozak *et al*., 2008; Masuoka *et al*., 2010). The ENM facilitates interpolation as well as extrapolation of species distributions in geographic space across different time periods based on ecological conditions. It prepares species distribution maps with high level of statistical confidence and identify areas suitable for re-introduction of threatened species (Irfan-Ullah *et al*., 2006; Martinez-Meyer *et al*., 2006; Papes 2006; Phillips *et al*., 2006; Kumar & Stohlgren, 2009; Moran-Ordonez *et al*., 2011; Ray *et al*., 2011). Due to severe climate conditions and over exploitations of these species for fuel wood, food, medicine and various other purposes, these species are facing severe threats. Therefore, Ecological Niche modeling is essentially required to identify the suitable habitats for re-introduction and *in-situ* conservation of the species. Study also will be helpful in establishing seabuckthorn orchards for socio economic upliftment of the tribal communities of Himachal Pradesh.

STUDY AREA

The present study on *Hippophae rhamnoides* ssp. *turkestanica* and *H. salicifolia* has been carried out in Himachal Pradesh (30° 22' 40" to 33° 12'40" N latitudes and 75° 47'55" to 79° 04'20" E longitudes) of Trans and North-Western Himalaya (Figure 1). It is bounded by Tibet in the East, Jammu and Kashmir in the North, Uttarakhand in the South-East, Haryana in the South and the Punjab in the West. Physiographically, it is divided in three conspicuous zones, namely Outer Himalaya or the Shiwaliks, Inner Himalaya or mid mountain and the Greater Himalaya or alpine zones. Five rivers namely, Sutlej, Beas, Ravi, Yamuna, and Chenab with a large number of their tributaries flow through the State. It is known for its salubrious climate and experiences considerable variations in the distribution of rainfall and temperature due to varying aspects and altitude. Precipitation declines from West to East and South to North (Singh 2007).

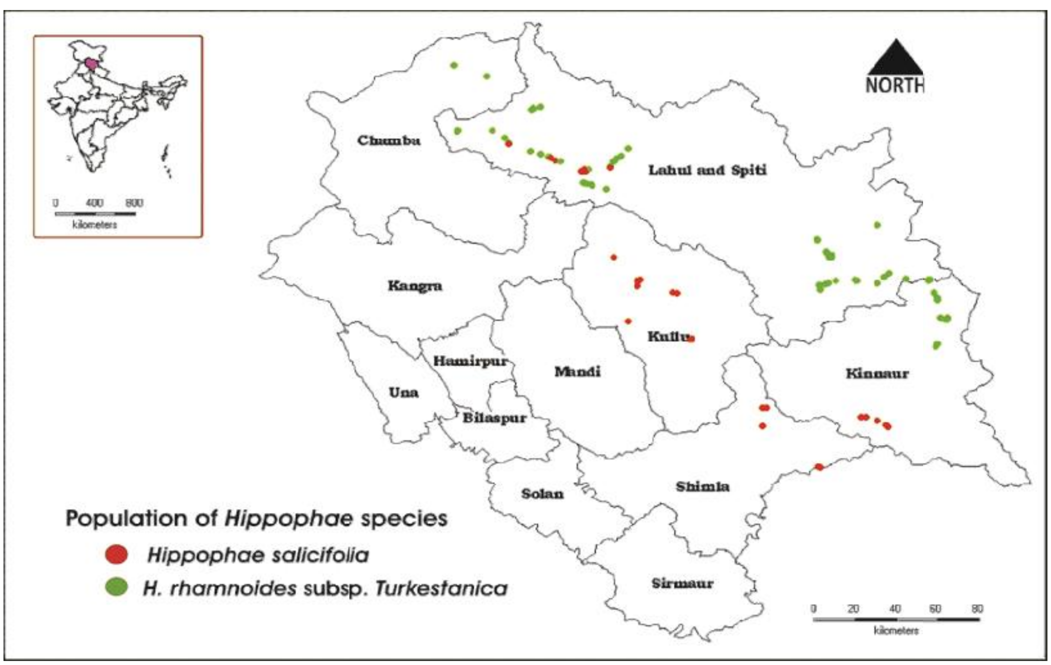

FIGURE 1. Study area and populations of *Hippophae* species

MATERIALS AND METHODS

Surveys were conducted in Himachal Pradesh during July 2013-September 2016 to identify the populations of the *Hippophae* species. One hundred ninety one (191) primary and secondary distributional records, 138 points of *Hippophae rhamnoides* ssp. *turkestanica* and 53 of *H. salicifolia* were collected through field surveys and secondary sources (Figure 1). These populations fall in different aspects *viz.*, east, west, north-east, south-west and north. The sites/populations were represented by bouldery, shady moist, riverine and rocky habitats. The coordinates of all occurrence points were recorded using a Global Positioning System (Garmin Oregon 550). Point distribution, bioclimatic, elevation, slope and aspect environmental and physiographic variables were utilized for the prediction of potential areas of species with the help of MaxEnt version 3.3.3k Ecological Niche Modelling package (Phillips et al. 2011). Predictive 20 variables selected for the habitat suitability of *Hippophae sp.* retrieved from different databases. Nineteen climatic raster data were obtained from World Clim at 30 arc-second resolution (Hijmans *et al*., 2005). Elevation was achieved from ASTER Global Digital Elevation Model (1 arc-second resolution; http://gdem.ersdac. Jspacesy stems. or.jp/). All the predictive variables rescaled to~250m pixel dimension in ArcGis 9.2. For the geographical distribution of species, MaxEnt version 3.3.3k was run using auto features, with output set to logistic, easier to interpret than raw or cumulative formats (Phillips & Dudik, 2008). To validate the robustness, 20 replicated models runs with a threshold rule of 10 percentile training presence and in the replicate cross validation technique runs. Other parameters were set to default as the program is already calibrated on a wide range of species datasets (Phillips & Dudik, 2008; Phillips *et al*., 2006). A jackknife procedure run to get an alternate measure of the importance of environmental variables by calculating several models with each variable omitted in turn, and models with variables used individually. In addition, response curve graphs were created to show how predicted probability occurrence depends on the value of each variable (Phillips et al., 2006; Phillips and Dudik, 2008). Model quality was evaluated based on Area Under Curve (AUC) value (Thuiller *et al.* (2005). The MaxEnt output in ASCII format was then exported to DIVA-GIS var.7.3 software for further analysis and map composition. Logistic threshold values were categorized into five classes for the of potential area distribution *i.e.*, very high (0.762–1), high (0.572–0.761), medium (0.381–0.571), low (0.325–0.380) and not suitable (0–0.324) (Adhikari *et al.* 2012). Assessment of actual habitat type of the species in the localities of occurrence as well as in the entire predicted potential area was done through field surveys. We also superimposed the predicted potential areas on Google Earth Ver. 6 (www.google.com/earth) imageries for habitat quality assessment. The exported KMZ files were overlaid on satellite imageries in Google Earth to ascertain the actual habitat condition prevailing in the areas of occurrence.

RESULTS

Geographical distribution and potential areas for re-introduction

Hippophae rhamnoides L. ssp. *turkestanica* Rousi

Total 138 distribution points of *Hippophae rhamnoides* ssp. *turkestanica*, were used to build the model. Maxent's model statistical demonstrated highly significant (P<0.01) performance and evaluation of model indicated that the model provided useful information.

TABLE 1. Estimates of relative contributions and permutation importance of the predictor environmental variables to the Maxent Model

Predictor variable	Name of predictor variable	*Hippophae rhamnoides* ssp. *turkestanica*		*Hippophae salicifolia*	
		Percent contribution	Permutation importance	Percent contribution	Permutation importance
bio_1	Annual Mean Temperature	0	0.1	0	0
bio_10	Mean Temperature of Warmest Quarter	0	0	0.1	3.9
bio_11	Mean Temperature of Coldest Quarter	2.1	48.5	0.1	0
bio_12	Annual Precipitation	0	0.4	0	0.3
bio_13	Precipitation of Wettest Period	0.1	0.2	1	3.5
bio_14	Precipitation of Driest Period	2.7	1	34	7.7
bio_15	Precipitation Seasonality (Coefficient of Variation)	2.3	0.5	0.2	1
bio_16	Precipitation of Wettest Quarter	0.1	0.1	0	0
bio_17	Precipitation of Driest Quarter	0	0	0.3	0.2
bio_18	Precipitation of Warmest Quarter	18.9	22.2	8.5	2.5
bio_19	Precipitation of Coldest Quarter	26.5	2.3	26.3	2.4
bio_2	Mean Diurnal Range (max temp – min temp) (monthly average)	0	0	0.1	2.5
bio_3	Isothermality (BIO1/BIO7) * 100	3.9	1.1	4.2	7.7
bio_4	Temperature Seasonality (Coefficient of Variation)	11	0.4	0.6	0.4
bio_5	Max Temperature of Warmest Period	11.6	2.2	2	0
bio_6	Min Temperature of Coldest Period	12.8	0	12.1	36.9
bio_7	Temperature Annual Range (BIO5-BIO6)	3.7	20	0.7	0.1
bio_8	Mean Temperature of Wettest Quarter	3.8	0.8	0.6	5
bio_9	Mean Temperature of Driest Quarter	0	0.1	0.3	5.2
h_dem	Elevation	0.6	0	9	20.6

The area under curve (AUC) was above 0.9 (AUC_{test} = 0.982 ± 0.025), indicating very high accuracy (Figure 4 & 7). The jackknife test showed mean temperature of coldest quarter (BIO 11) as the environmental variable with the highest training gain in the model, which indicated that it had the most predictive ability of any variable (Figure 6). The variable, which decreased the gain most when excluded from the model, was temperature annual range (BIO 7), indicating that temperature annual range had the most unique contribution to the model (Figure 6). Amongst the predictor bioclimatic variables, precipitation of coldest quarter (BIO 19), precipitation of warmest quarter (BIO 18), minimum temperature of coldest period (BIO 5) and maximum temperature of warmest period (BIO 6) were the most influential and contributed 26.5%, 18.9%, 12.8 % and 11.6%, respectively to the Maxent Model (Table 1). Considering the permutation importance, mean temperature of coldest quarter had the maximum influence on the habitat suitability model and contributed to 48.5%, while precipitation of warmest quarter (BIO 18) and temperature annual range (BIO 7(BIO5-BIO6)) contributed to 22.2% and 20.0%, respectively (Figure 2 & Table 1).

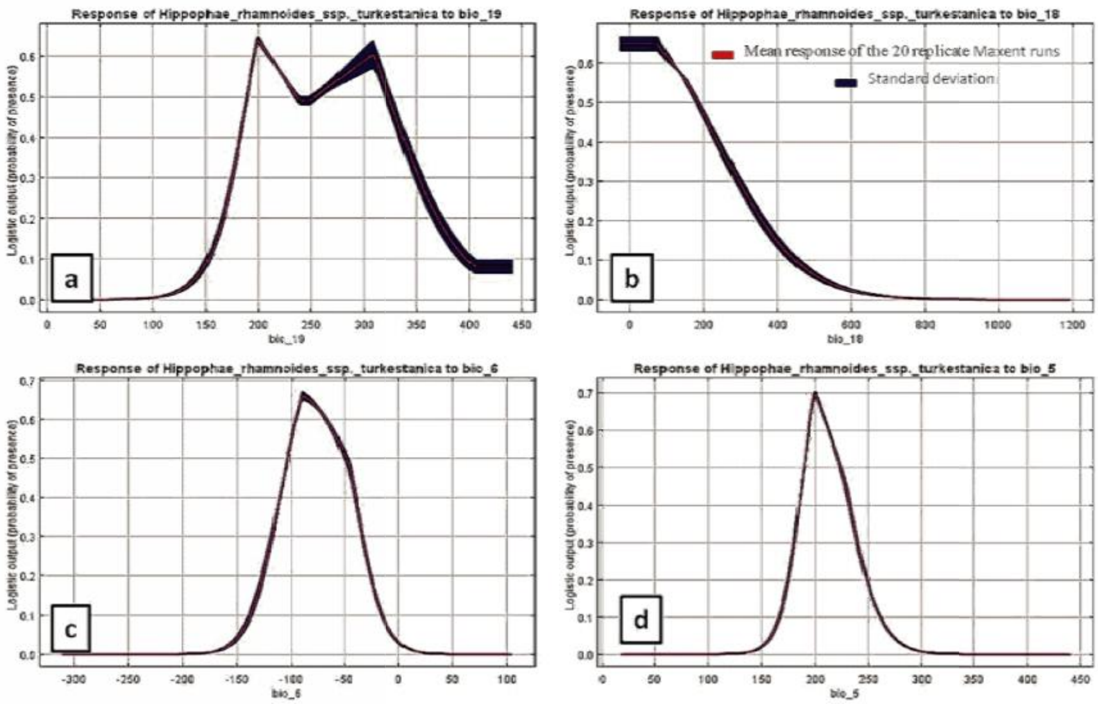

FIGURE 2. Probability of *Hippophae rhamnoides* ssp. *turkestanica* occurrence versus selected variables: (a) Precipitation of coldest quarter (BIO 19); (b) Precipitation of warmest quarter (BIO 18); (c) Maximum temperature of warmest period (BIO 6); and (d) Minimum temperature of coldest period (BIO 5).

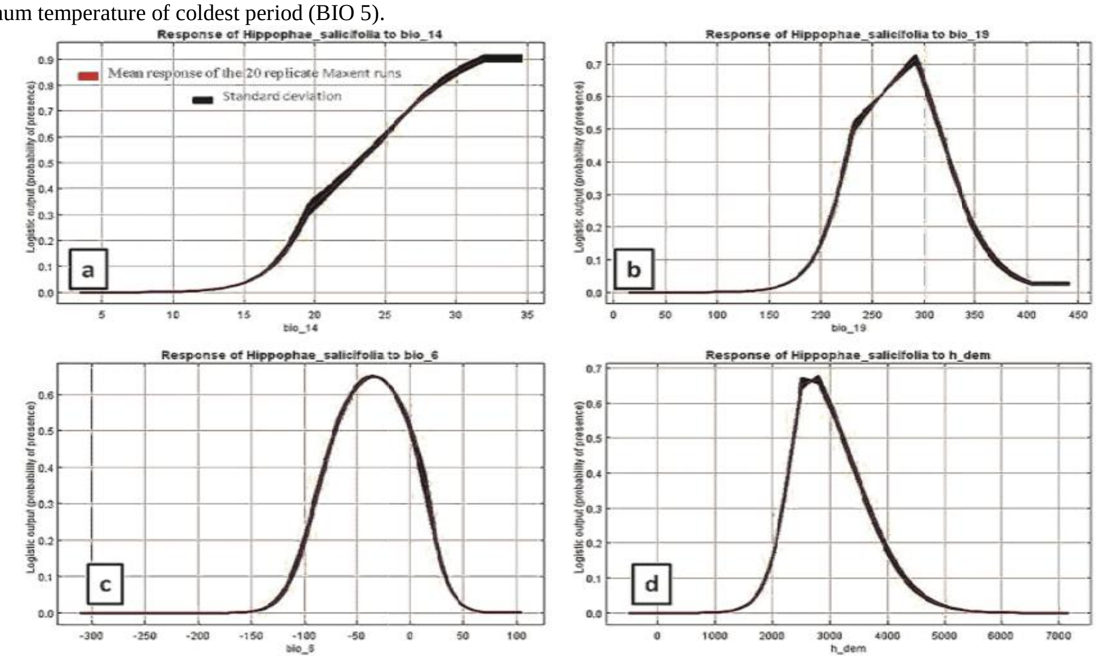

FIGURE 3. Probability of *Hippophae salicifolia* occurrence versus selected variables: (a) Precipitation of driest period (BIO 14); (b) Precipitation of coldest quarter (BIO 19); (c) Minimum temperature of coldest period (BIO 6); and (d) Elevation.

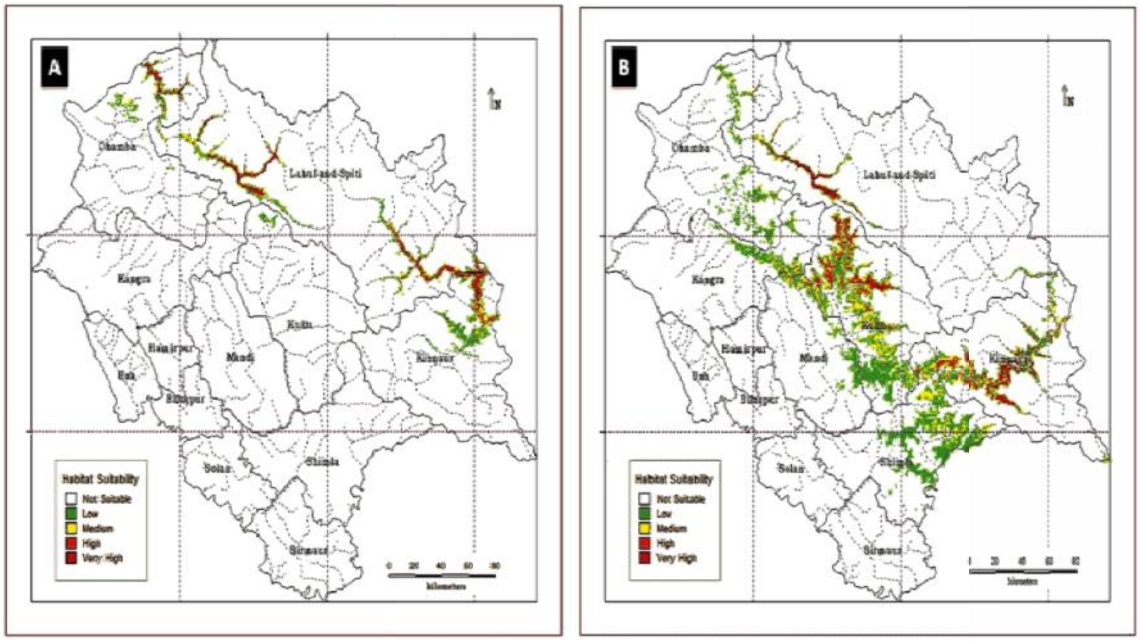

FIGURE 4. Habitat suitability and distribution of *Hippophae* species A). *Hippophae rhamnoides* ssp. *turkestanica*; and B). *Hippophae salicifolia*

Potential habitats with high suitability thresholds were distributed in the semi arid and higher elevations of the Lahaul & Spiti and Kinnaur districts of Himachal Pradesh in Trans and Northwestern biogeographic provinces of the Indian Himalaya (Figure 4 & 7). Primary field surveys revealed that the predicted potential habitats were mostly located along the water channel of Lahaul & Spiti, Chamba and Kinnaur districts of Himachal Pradesh. Areas with low to very low habitat suitability were with away from the water channels. Out of the 55,673 km^2 of Himachal Pradesh, a total potential area of ca. 531 km^2 (very high and high suitable class) in the Himachal Pradesh was predicted to be suitable for *Hippophae rhamnoides* ssp. *turkestanica* re-introduction, cultivation and conservation (Figure 7). Among the habitat suitability classes under low suitability class, an area of 705.0 km^2 was covered. Area of medium suitability was restricted only to about 435.0 km^2, and high suitability class 386.0 km^2. Area of high suitability was 146.0 km^2 (Figure 5 & 7).

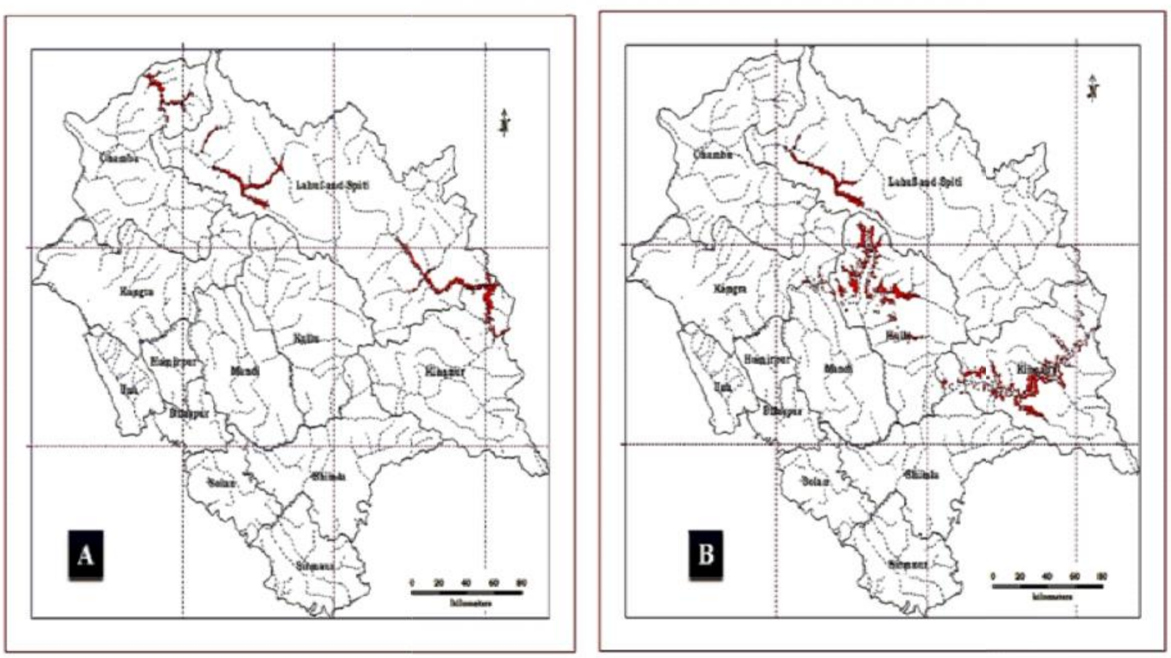

FIGURE 5. Suitable areas for re/introduction of: (A). *Hippophae rhamnoides* ssp. *turkestanica* and (B). *Hippophae salicifolia*

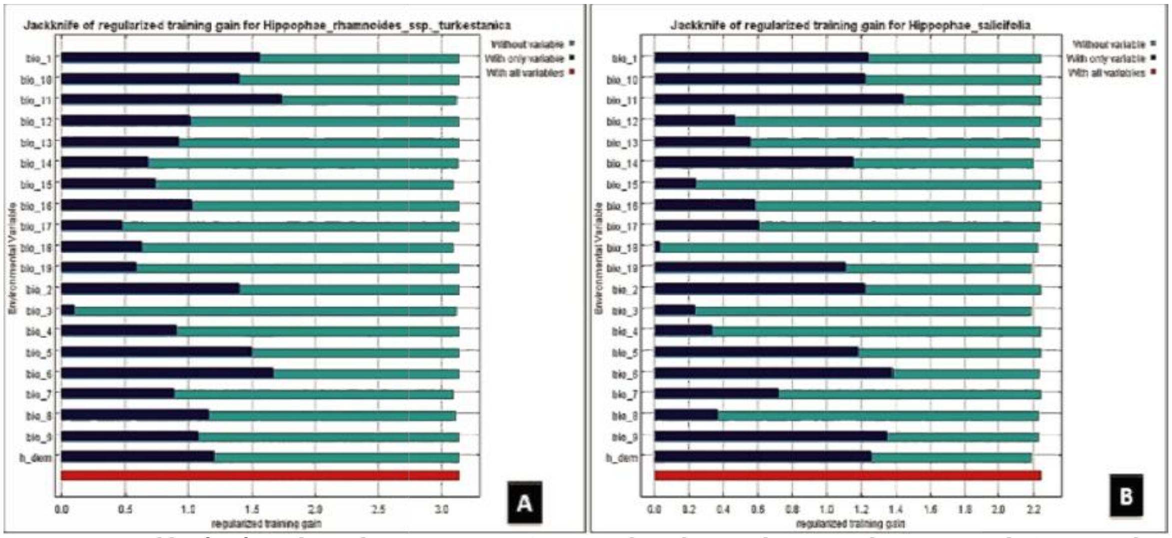

FIGURE 6. Jackknife of regularized training gain; A). *Hippophae rhamnoides* ssp. *turkestanica*; and B). *Hippophae salicifolia*

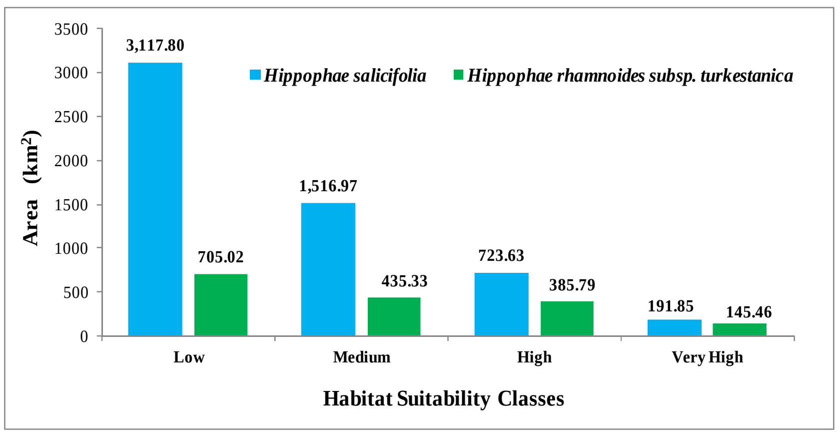

FIGURE 7. Area under different suitability classes

Field surveys for assessing the habitat types of *Hippophae rhamnoides* ssp. *turkestanica* in the predicted potential areas revealed that the species occurred in the riverine, dry slope, pasture land, rocky and scree habitats of the semi-arid and higher elevations of the Himachal Pradesh. The species was also present around human settlement areas and settled cultivation lands. Superimposing the predicted potential habitat map of the species on Google Earth satellite imageries revealed a mosaic of habitats to be suitable for the species persistence. The areas with very high to high habitat suitability for the species were continuous patches of Riverine habitat along water channels. The areas with medium habitat suitability were Pastureland, settled cultivation areas, and human settlements. The areas with very low habitat suitability were dry slope, rocky and scree. The superimposition of predicted potential habitat distribution map on Google Earth Imageries identified areas *viz*., the Lahaul and Spiti blocks of the district Lahaul & Spiti, Pangi block of Chamba district and Pooh block of the Kinnaur district. These areas would serve as highly suitable habitats for persistence of the species. These areas would act as in situ conservation areas for the species and could also be used for re-introduction/recovery and commercial cultivation of the species.

***Hippophae salicifolia* D. Don**

Total 53 distribution points of *Hippophae salicifolia* were used to build the model. Maxent's model statistical demonstrated highly significant ($P<0.01$) performance and evaluation of model indicated that the model provided useful information. The area under curve (AUC) was above 0.9 ($AUC_{test} = 0.968 \pm 0.025$), indicating very high accuracy (Figure 4). The jackknife test showed mean temperature of coldest quarter (BIO 11) as the environmental variable with the highest training gain in the model, which indicated that it had the most predictive ability of any variable (Figure 6). The variable, which decreased the gain most when excluded from the model, was precipitation of coldest quarter (BIO 19), indicating that temperature annual range had the unique contribution to the model (Figure 6). Amongst the predictor bioclimatic variables, precipitation of driest period (BIO 14); precipitation of coldest Quarter (BIO 19); and minimum temperature of coldest period (BIO 6) were the most influential and contributed 34.0%, 26.0% and 12.1%, respectively to the Maxent Model (Table 1). Considering the permutation importance, minimum temperature of coldest period (BIO 6) had the maximum influence on the habitat suitability model and contributed to 36.9%, while elevation, precipitation of driest period (BIO 14) and isothermality (BIO 3) contributed to 20.6%, 7.7% and 7.7%, respectively (Figure 7 & Table 1). Potential habitats with very high suitability thresholds were distributed in the semi-arid and moist forest of the Lahaul & Spiti and Kinnaur, Kullu, Chamba, Kangra and Shimla districts of Himachal Pradesh in Trans and Northwestern biogeographic provinces of the Indian Himalaya (Figure 4). Primary field surveys revealed that the predicted potential habitats were mostly located in the riverine and moist slope of Himachal Pradesh. Areas with low to medium habitat suitability were with dry slope and marginal land. Out of the 55,673 km^2 of Himachal Pradesh, a total potential area of ca. 915.0 km^2 (very high and high suitable class) in the Himachal Pradesh was predicted to be suitable for *Hippophae salicifolia* re-introduction, cultivation and conservations (Figure 7). Among the habitat suitability classes in the low suitability class covers an area of 3,118.0 km^2. Area of medium suitability was restricted to about 1,517.0 km^2, and high suitability class 724.0 km^2. Area of high suitability was 192.0 km^2 (Figure 5 & 7).

Field surveys for assessing the habitat types of *Hippophae salicifolia* in the predicted potential areas revealed that the species occurred in the riverine, dry slope and pasture land habitats of the semi-arid and moist forest in higher elevations of the Himachal Pradesh. The species was also present around human settlement areas and settled cultivation lands. Superimposing the predicted potential habitat map of the species on Google Earth Satellite Imageries revealed a mosaic of habitats to be suitable for the species persistence. The areas with very high to high habitat suitability for the species were continuous patches of high altitude riverine areas. The areas with medium to low habitat suitability were pasture land and settled cultivation areas. The areas with low habitat suitability were dry slope and human settlements. The superimposition of predicted potential habitat distribution map on Google Earth imageries identified areas viz., the Lahaul, Chamba, Kullu, Shimla and Kinaur districts of Himachal Pradesh which would serve as highly suitable habitats for persistence of the species. These areas would act as in situ conservation areas for the species and could be used for re-introduction/recovery of the species in the wild.

DISCUSSION

The Government Departments, Non-Government Organizations, Lahaul-Spiti Seabuckthorn Societies, Lahaul Potato Grower Society and Private Companies are working on various activities pertaining to Seabuckthorn in the study area. Co-operative Societies and Ecosphere Spiti Eco Livelihoods were collected 14 tons of berries during 2006–2007 in Spiti valley and which produced 12 tons of pulp (Singh *et al*., 2012). It clearly indicates that seabuckthorn has potential to boost up the economy of the tribal communities. Moreover, the government agencies namely Ministry of Environment, Forest and Climate Change, Defence Research and Development Organization, Indian Council of Agriculture Research, etc. have prioritized Seabuckthorn as the most potential crop for the cold desert region. Recently, the Horticulture Board of India declared the species of Seabuckthorn under horticulture crop. This initiative would definitely help in the commercial cultivation of the *Hippophae* species in the area. In view of the potential of Seabuckthorn species for the restoration of degraded land and socio-economic development of the tribal communities, the present study provided key information on natural populations of the *Hippophae* species and potential area for species re-introduction and cultivation.

The distribution of potential habitats of a species is determined by biotic and abiotic factors of the ecosystem. Field surveys and model output showed that riverine, dry slope, moist forest, agriculture land and temperate forest are the suitable natural habitats of the species distributed between higher elevations (2000-3700 m) of Himachal Pradesh. The particular geographical distribution of the highly suitable habitats of *Hippophae* species to the riverine areas indicated species habitat specificity. Herbarium records and literature also supported model output their occurrence in the riverine and dry region of the Himalaya. A predictor layer shows the role of abiotic factors, which determine the niche of the species. Geology, soil and climatic factors directly influence on vegetation of a given place at a given time. The effects of environmental condition are reflected through the spatial and temporal variation in the vegetation (Soleimani et al. 2008). Precipitation of coldest quarter bioclimatic variable played key role in defining niche of seabuckthorn. Hence, bioclimatic variables act as informative variables representing environmental condition, which determine the boundaries of the potential habitat of the species. Healthier population of the species in areas of higher model thresholds, indicated that these areas had ideal habitat conditions for persistence of the species. However, localities had low poor population status in spite of being predicted as highly suitable. The reason for this as revealed from the direct field observation that inhabitants of these localities collect species for household use and commercial purpose.

From the above observations, we can assume that healthier population status of a species in undisturbed habitats in the native range could be ascertained with reasonable level of confidence from the model output *i.e*., areas with healthier population status are predicted as models with higher threshold level and vice versa. Such assumption however, may not hold good if the populations are modified through human activities. Overall, the results of actual habitat assessment through Google Earth superimposition and field surveys were identical. Through both the methods, the prevalence of species was in similar land use and land cover types. This analysis confirms the application of Google Earth superimposition along with limited field survey as a powerful tool for habitat assessment of the species, and could be a substitute of extensive field survey (Benham *et al*., 2011). Conservation of a species and its habitat cannot be done in isolation outside the sphere of the anthropobiome (Ellis & Ramankutty, 2008).

Species re-introduction and cultivation should therefore carefully select appropriate areas under such a setting. In the present study, some areas consist of continuous and intact patches of potential habitats at higher levels of probability. Hence, such areas could serve as habitats for *in-situ* conservation, cultivation and reintroduction. To achieve this, awareness and active participation of local people, Non Government Organizations (NGOs), and Community Based Organizations are warranted. The present study demonstrated that habitat distribution modelling could be of great help in predicting the potential habitats of species for reintroduction. The areas identified in the present study for reintroduction of *Hippophae rhamnoides* ssp. *turkestanica* and *Hippophae salicifolia* would not only help in eco-restoration of species and habitats where the species had existed before but also in rehabilitating the species population and improving its conservation. Promotion of mass scale propagation through conventional and *in-vitro* methods of such species and their rehabilitation in the *in-situ* conditions or akin habitats may also help in conservation and management. Therefore, the results would be quite useful for natural resource managers in the management of these species and conserving overall biological diversity in the region.

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