Pakistan J. Zool., vol. 47(6), pp. 1545-1553, 2015.

Habitat Suitability Modeling of Great Bustard, *Otis tarda*, using ENFA and GIS

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Abstract.- During the last century, the global population of the Great Bustard (*Otis tarda*) has decreased and this species is now considered vulnerable. In Iran, the status of this species is much more critical and its distribution is limited to a few areas of Bukan county. We modeled the suitability of habitat for Great Bustards in Bukan County with the goal of determining the most important of distribution limiting factors of this valuable, rare and endangered bird in order to conservation and The map of effective factors including landform, land use, water resources and human factors was prepared using field data, previous available data, interpretation of satellite images, and their processing and analysis in GIS. To prepare the map of the variables, the circular, distance, and frequency analyses and for normalization of the maps, Box-Cox conversion were used. The model validation and the map classification of habitat suitability to desirable and undesirable classes were conducted using the Boyce index. The marginality factor (1.28) indicated that *Otis tarda* tends to live in marginal habitats. Low tolerability (0.1) and high specialization (9.2) scores also indicate that it is a special species within the county. According to our suitability map, only 6.5% (16000 ha) of the study area consists of desirable habitat.

Keywords: *Otis tarda*, habitat suitability, ENFA, GIS.

INTRODUCTION

Currently, the important animal species are facing serious threats due to activities such as illegal hunting and habitat destruction especially in developing countries. Recently, world population of *Otis tarda* (Fig. 1) has decreased and it is placed in the list of vulnerable species of IUCN (Ahmadi Sani and Ahmadi, 2013). *Otis tarda* is one of the largest herbivorous birds and is considered the heaviest bird which can fly long distances (Ahmadi Sani and Ahmadi, 2013). *Otis tarda*'s distribution starts from steppe plains and grass lands of Iberian Peninsula (Spain) and continues up to the plains of East Asia (Alonso *et al.,* 2003). The world population of *Otis tarda* in the last decade of the twentieth century was estimated at between 33,200 to 42,800 birds with more than 50% of the population found in Spain (Collar *et al.* 1994). In Iran, the status of this bird is much more critical. In the most recent reports, *Otis tarda* has been shown in danger of extinction (Ahmadi Sani and Ahmadi, 2013). Some eminent habitats of the bird in the past in Iran were seven area of West Azerbaijan, one area in East Azerbaijan, five areas of Kurdistan, seven area of Kermanshah and one area in Hamadan province (Amini, 2000). Currently, the distribution of the species is limited to the Sootav plain in Hammamian village, Ingijeh and Albelagh plains, Sekanian and Ghazlian plains in Bukan county in West Azerbaijan and based on observations the number of the birds is about 65 pieces (Abdulkarimi and Ahmadi Sani, 2012). The Sootav plain is the most important habitant in Iran where significant number (about 18 pieces) of reproducing population of *Otis tarda* is found (Abdulkarimi *et al.,* 2010).

Fig. 1. *Otis tarda* bird in Bukan county.

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0030-9923/2015/0006-1545 $ 8.00/0

Habitat destruction has been identified as the greatest threat for biodiversity worldwide and about 30% of species extinctions attributed to destruction of wildlife habitats (IUCN, 1992). According to Harris (1984), habitat fragmentation is the main cause of species extinction. Habitat is one of the most important factors in protecting the species, hence, identifying the characteristics of habitat of any species is inevitable for its protection (Karami *et al.,* 2006; Kneib *et al.,* 2011). One of the major bases for understanding ecology of species and its conservation is the knowledge of its habitat characteristics (Shao *et al.,* 2012; Naderi *et al.,* 2014). The desirable habitat has a significant effect on the survival and reproduction of species and management and protection of wildlife. The quantitative assessment of habitat is necessary to identify the effects of human activities and investigate the changes in the habitat (Karimi *et al.,* 2012). For this purpose, the habitat modeling techniques in wildlife management have been used since 1970 (Mack *et al.,* 1997; Anderson *et al.,* 1999). To determine the distribution of species and habitat suitability, the modeling techniques based on the analysis of relationships between animal species and their habitats were developed (Gibson *et al.,* 2003). These models predict the probability of species based on environmental variables (Jacqain *et al.,* 2005). Ecological niche factor analysis (ENFA) is the current method for assessment of habitat suitability that unlike many of the habitat suitability modeling approaches, only needs the data of species presence. Thus it is very efficient when access to reliable data is difficult (Omidi *et al.,* 2010). ENFA compares environmental characteristics of species presence data to environmental characteristics of the entire study area (Engler *et al.,* 2004; Rupprecht *et al.,* 2011; Yesson *et al.,* 2012; Farashi *et al.,* 2013). The habitat suitability modeling helps wildlife managers to identify threatening factors on actual and potential populations and habitats with spending less time and cost. Using the results of these studies can solve the problems facing habitat management (Bahadori *et al.* 2010). Results obtained from these models can also classify habitat to different classes of suitability in order to determine conservation priorities.

On the other hand, the development of statistical techniques and geographical information system (GIS) has led to conduct the modeling within the space. The habitat suitability models make distribution of a species related to environmental variables using GIS and statistical software (Store and Jokimaki, 2003; Jacqain *et al*., 2005). In this study, due to need to geographical data of the species presence and other ecological data as effective parameters on species distribution (such as slope, aspect, elevation, temperature, land cover/land use, water resources etc), GIS, GPS and Remote Sensing capabilities can be used like previous studies (Gibson *et al*., 2003; Store and Jokimaki, 2003; Jacqain *et al*., 2005; Omidi *et al*., 2010; Ahmadi Sani *et al*., 2011; Abdulkarimi and Ahmadi Sani, 2012; Karimi *et al*., 2012; Fattahi *et al*., 2014).

Since very few studies have been done in Iran on habitat suitability of rare birds such as *Otis tarda*. So it is necessary that habitat suitability of *Otis tarda* will be modeled using the modern methods and technologies such as ENFA, GIS and remote sensing to determine the most important effective parameters on distribution and habitat mapping of this bird as a very valuable, rare and endangered one.

MATERIALS AND METHODS

Study area

The study was conducted in Bukan County with an area of 249077 ha, located in north-western Iran (Fig.2). Bukan is a temperate, mountain foothill region with annual rainfall of more than 400 mm. According to the 2011 census, its population was 224628 people (Iranian Statistical Center, 2012).

Research methodology

To evaluate habitat suitability in a statistical GIS framework, we used ENFA, the core component of Biomapper software (Hirzel *et al.,* 2002). ENFA summarizes environmental variables into a few uncorrelated and standardized factors. Environmental characteristics of the species distribution are then compared with environmental characteristics of the entire study area (Kanaji *et al.,* 2014).

Choosing and mapping environmental variables

For this purpose, environmental factors affecting the distribution of this species were selected based on bird's behavior and review of literature (Vegvari and Kapocsi, 2005; Lopez *et al.*, 2011; Oparin *et al.*, 2013).The effective variables included landform (elevation, slope and aspect), land use (dry farming, irrigated farming, range and residential), water resources (rivers) and human factors (city, roads and villages).

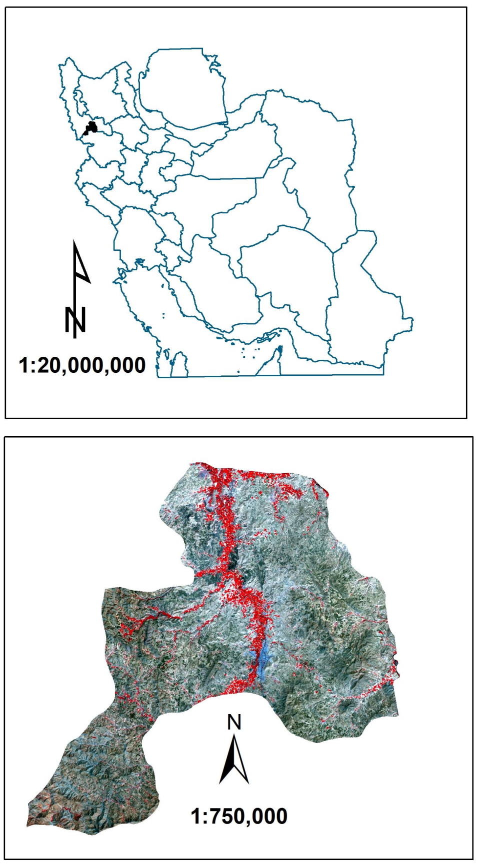

Fig. 2. Location and satellite image of study area in Iran.

Digital elevation model was prepared using a 1:50,000 topographical map. Maps of slope, elevation and aspect were extracted from DEM in the GIS environment. For classification of slope map, the provided classes for different uses in land use planning (Makhdum *et al.*, 2001) was used and slope map were categorized into three classes. For land use mapping the satellite imagery of Landsat 8 was used. To resolve geometric errors, we orthorectified the images and corrected with RMS error under one pixel. image classification was done using supervised classification and maximum likelihood algorithm. Rivers are the major water sources in this region. A 1:50000 digital map of rivers was used to create a map of distance from water source. Similarly, we created maps of distance from village and main dirt and asphalt roads 1:50000 digital maps.

Mapping of species presence

To prepare the presence map, the point coordinates of species presence (36 points) were recorded using GPS in the last three years in the habitats. The point coordinates were converted to a point map with raster format in a GIS environment.

Mapping of environmental variables

Ecological niche factor analysis requires the use of quantitative variables. According to Hirzel *et al.* (2004) for quantification, the distance calculation for variables with a threatening role (such as villages) and frequency calculation for variables with a positive source role (such as aspect) are more suitable. In this study, both types of calculation were used. Environmental variable data layers were clipped to the county border map. Box-Cox conversion was used to normalize the data maps. Correlation between variables was calculated and subsequently the correlation matrix was obtained.

Choosing the factors and suitable algorithm

Typically, a few factors can explain species marginality and specialization (Shams, 2010). Additionally, a smaller number of factors makes calculation and interpretation of results easier. In this study, the broken stick model was used for selecting the appropriate number of factors. After choosing the appropriate number of factors, proper algorithm was selected.

Model validation

To evaluate the validity of habitat suitability models based on the presence data, the frequency diagram based on area and Boyce continuous index was used.

Habitat suitability mapping

Ultimately, using the selected model and algorithm, the habitat suitability map was prepared. Then using Boyce index and the frequency diagram calculated by minimum distance algorithm, the suitable map was divided into two classes of desirable and undesirable.

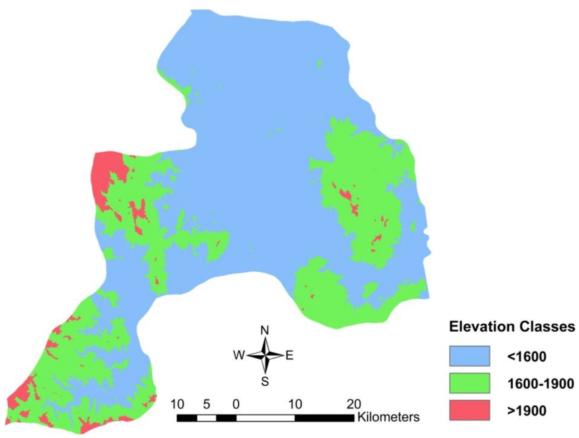

Fig. 3. The map of elevation classes.

RESULTS AND DISSCUTION

Map of environmental variables

Elevation in the study area ranged by 300 meters (Fig. 3). About 65% and 32% of the area were located in the classes of less than 1600 and 1600-1900 m, respectively. Approximately 62%, 27%, and 11% of the area were in the slope classes of less than 15%, 15-30%, and more than 30% slope, respectively. The aspect map also was categorized in four classes. Northern and eastern slopes occupied a greater area of the county as compared to western and southern slopes.

The map of main rivers, villages, roads and their position compared to presence points and the county border was prepared (Fig. 4). We found 173 villages, 570 km of roads and a city area of 1550 ha.

This study as similar studies in various fields of environmental assessment (Phua and Minowa, 2005; Wolfslehner *et al.*, 2005; Karimi *et al.*, 2006; Mendoza and Martins, 2006; Ryngnga, 2008; Ahmadi Sani *et al.*, 2011; Razaghnia, 2014), showed the ability and efficiency of GIS in mapping of ecological resources and collecting, editing, managing, interpretation, processing and analyzing large amounts of data in order to obtain evaluation and habitat suitability modeling.

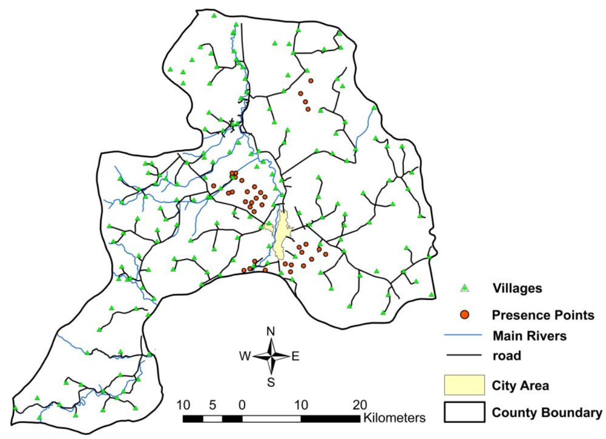

Fig. 4. The map of city, villages, main rivers and roads.

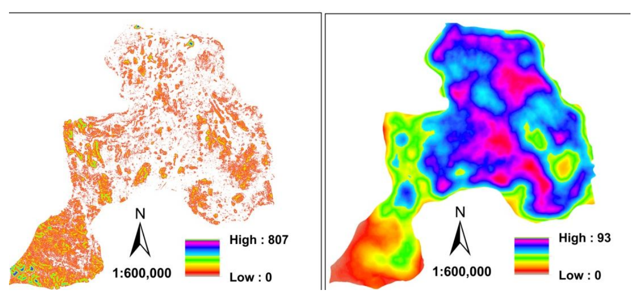

Fig. 5. The map of distance from slope 0-15% (left) and its frequency (right).

Map of habitat variables

For each of the layers, a distance map and frequency map was calculated. For example the map of distance from slope (0-15%) and frequency of slope is shown in Figure 5. In the case of the city map, and linear phenomena such as roads and rivers, just the distance map was prepared.

Results of maps normalization

For normalization of the maps, Box-Cox conversion was used. For example the normalized map of distance and frequency of 0-15% slope is shown in Figure 6.

Table I.- The scores matrix of environmental variables.

Environmental variables	M 54.47%	S1 24.05%	S2 7.56%	S3 5.06%	S4 3.5%	S5 2.7%
Frequency of eastern aspects	-0.345	-0.031	-0.013	-0.040	0.223	-0.100
Frequency of northern aspects	0.218	-0.076	0.016	-0.028	-0.453	0.024
Distance from southern aspects	0.169	0.019	-0.071	-0.014	0.080	-0.042
Frequency of southern aspects	-0.229	0.098	0.097	0.014	0.280	0.403
Distance from western aspects	-0.154	0.007	0.028	-0.022	-0.048	0.009
Frequency of western aspects	0.215	0.018	0.041	-0.119	0.323	0.122
Distance from city	-0.417	-0.159	-0.125	0.054	-0.202	0.273
Distance from 1600-1900 m	0.297	-0.450	0.480	0.031	0.057	0.501
Frequency of 1600-1900 m	-0.287	0.065	0.155	0.106	0.018	0.067
Distance from 1900-2500 m	0.130	0.805	0.420	0.137	-0.394	0.034
Frequency of dry farming	0.211	0.132	0.122	-0.151	0.552	-0.343
Distance from irrigated farming	-0.098	0.022	-0.006	0.033	0.130	0.049
Distance from roads	0.092	0.046	0.044	-0.077	-0.020	-0.111
Distance from 0-15% slope	-0.242	-0.004	-0.006	-0.002	-0.001	0.160
Frequency of 0-15% slope	0.272	-0.194	-0.618	0.731	0.139	0.129
Distance from > 30 % slope	0.214	0.202	-0.341	-0.614	-0.020	0.540
Frequency of >30 % slope	-0.258	0.053	-0.129	-0.088	0.095	-0.014
Distance from villages	0.114	-0.032	-0.065	-0.022	-0.055	-0.109

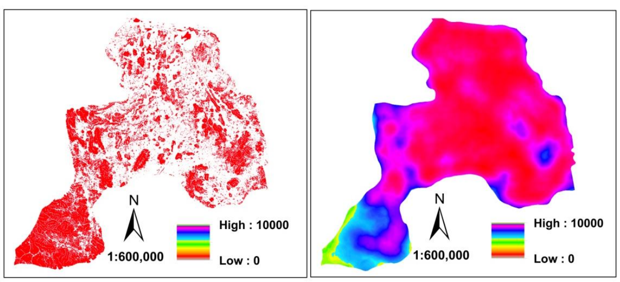

Fig. 6. The normalized map of distance (left) and frequency (right) of slope 0-15%

Correlation matrix of variables

To comply with the statistical requirements of the ENFA method, if the correlation between two variables is more than 85%, one of the variables must be omitted from analyses. Factors with correlation more than 85% included frequency and distance of some aspect, elevation and slope classes. Additionally, factors with low effectiveness scores in the matrix, such as the distance from rivers were omitted. 18 factors were used, ultimately.

Role of environmental variables

In ecological-niche factor analysis, the scores matrix has been used to determine the role of each variable (Table I). For example the coefficient of 0.272 calculated for the frequency of the variable of 0-15% slope indicated that the species tends to inhabit areas with this class of slope, more than the county on average. Conversely, a negative value indicates the tendency of species to avoid areas characterized by this variable. For example coefficient -0.229 for the frequency variable of southern aspect indicates that Great Bustards are less likely to be observed in areas with this trait. For distance variables, a positive coefficient indicates the tendency of the species to inhabit regions near to the variable, while a negative coefficient reveals the tendency of species to inhabit regions far from the variable. For example coefficient 0.417 for the variable of distance from the city indicates the species tends to the nearby city regions, whereas coefficient 0.114 for the distance variable from the village indicates tendency of species to inhabit regions far away from the villages.

Topographical variables

The coefficient obtained for the elevation indicates that *Otis tarda* does not have a tendency to use the regions with high slope and elevation. Also the species prefers the western and especially eastern aspects compared to southern and northern aspects. It is maybe due to more moderate moisture and temperature in these aspects.

Land use and water resources

Among the land use factors, dry farming frequency and the distance from irrigated farming have the most positive and negative effect on habitat suitability of *Otis tarda*, respectively. The bird prefers dry farming over rangeland area. This may be because the elevation and steep slope typical of rangeland areas is not preferred by this species. Also the remaining seeds from dry farming provide food for the species. In this study, the factor of water resources had the lowest score and effect on distribution of species. It is likely that this species is not dependent on deep water, and may use other water resources such as springs.

Human factors

The results showed that *Otis tarda* avoided sources of human activity such as villages and roads. However, the species was found near the city. This may be because the city offers greater security for this species. Hunting in these areas is much less than in remote areas.

Habitat suitability model

The total marginality score (1.28) indicated that this species tends to live in marginal habitats and choose the higher environmental conditions than the average conditions in the study area. In this study, low tolerability (0.1) and high specialization (9.2) also indicate that *Otis tarda* is a special species in the county. In other words, this species exhibits a low tolerance and inhabits a narrow ecological niche. Using the the broken stick model, we find that 5 out of 18 factors explained 97% of the species habitat preference. The first column of the matrix showed 97.32% of marginality and 54.47% of specialization and the next columns showed 24.05, 7.56, 5.06, 3.5 and 2.7% of specialization (Table II).

Validation of the model

To evaluate the validity of the model, Boyce continuous index was used. According to the Boyce index, a higher index value and lower standard deviation indicate that the selected algorithm is more appropriate (Hirzel *et al.* 2006). In this study, all algorithms performed favorably. However, the minimum distance algorithm exhibited the most favorable scores (Table II) and the habitat suitability map of species was prepared using this algorithm (Fig. 7).

Table II.- Comparison of Boyce index in different algorithms.

Algorithms	Boyce index + Standard deviation
Median	0.843 ± 0.09
Geometric Mean	0.729 ± 0.11
Harmonic Mean	0.972 ± 0.008
Minimal Distance	0.980 ± 0.003

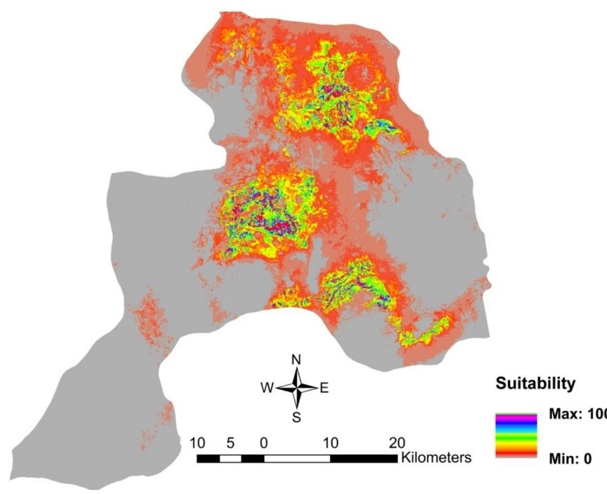

Fig. 7. The map of Habitat suitability.

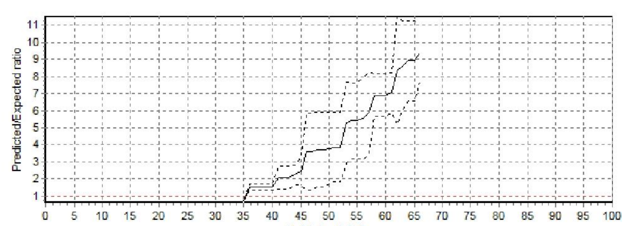

Fig. 8. The predicted/expected ratio based on minimum distance algorithm.

Habitat suitability map

The habitat suitability map created using the minimum distance algorithm shows a large percentage of Bukan County'sarea having a suitability value for Great Bustards equal to zero. For classification of habitat suitability map, we need to prepare a diagram of predicted frequency into expected one (Fig. 8). According to the diagram, the habitat suitability threshold of 35% was selected and the map was divided into desirable and undesirable classes. Using this threshold, we found that 93.5% and 6.5% of the county were undesirable and desirable, respectively

Alternatively, Hengel *et al.* (2009) suggested the use of a probability percentage higher than 50% to describe desirable areas. By combining these criteria, we created a habitat suitability map classified into three classes (undesirable <35%, partly desirable <50%, and desirable >50%). The results showed that 23000 ha (92.5%), 12800 ha (5%) and 6200 ha (2.5%) of the study area are classified respectively as undesirable, partly and quite desirable for this species (Fig. 9).

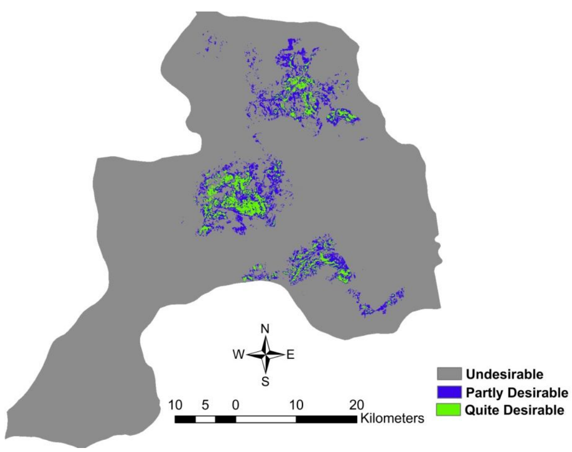

Fig. 9. The suitability classes in three-class classification.

In confirming of previous research (Gibson, 2003; Hirzel *et al.,* 2006; Karami *et al.,* 2006; Bryan and Metaxas, 2007; Braunisch *et al.,* 2008; Mostafavi *et al.,* 2010; Karimi *et al.,* 2012), it can be noted that ENFA analysis based on Biomapper software has an ability that compares the variables situation together in all presence points of species and present the best habitat for species as a map.

CONCLUSION

In this study we integrated ENFA, GIS and RS to evaluate and model habitat suitability. A major advantage of ENFA is ability to create a model with only presence data. This decreases in the time and cost of collection of field data. Also, in many cases, access to absence data is difficult to gather for animals which are secretive or highly mobile. One of the major issues for conservation of *Otis tarda* on a national and local scale in Iran is habitat destruction. We find that [these specific areas should be conserved]. Action to increase the habitat area of the species should be prioritized. We suggest that the habitat suitability be evaluated outside of the Bukan county as well. Ultimately, it is suggested that habitat suitability modeling will be used in environmental studies and conservation processes in order to protect wildlife.

ACKNOWLEGMENT

This work was supported by a research fund from Islamic Azad University, Mahabad Branch. I would like to offer my thanks to this university for providing financial support.

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(Received 24 February 2015, revised 10 July 2015)