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Habitat Suitability Analysis of *Suaeda heteroptera* in Wetlands of Laizhou West Bank Based on GIS

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Abstract

Along with the development of marine economy, west bank of Laizhou Bay, efficient and economical core area, suffered some degree of damage, and local habitats of *Suaeda heteroptera* were correspondingly affected. Using geographic information systems (GIS) technology and HIS model, analysis on habitat suitability of *S. heteroptera* in tital wetlands of Lanzhou west bank. The results show that: Although high soil salinity in the study area, and serious petroleum and heavy metal pollution, the regional environmental conditions meet the basic survival and growth requirement of *S. heteroptera*, because its strong salt tolerance, as well as petroleum and heavy metal absorption and accumulation ability, consequently, *S. heteroptera* can be relatively normally grow in this habitat. Generally, Laizhou Bay is a highly or moderate suitable area for *S. heteroptera* growth.

Keywords: *Suaeda heteroptera*, Habitat suitability assessment, Lanzhou Bay, Restoration technology

1. Introduction

Habitat, biological survival environment, is the sum of the life activities space conditions (May, 1976). With calculating habitat suitability index (HSI) and habitat area, quality quantization and evaluation are significant for habitat to management and conservation of biotic population. HSI model, originally developed by the US Fish and Wildlife Division (USFWS), proposed for the expression of the influence of major environmental factors on the distribution and abundance of species (U.S. Fish and Wildlife Service, 1980). Since HSI model helps to understand the needs of ecological niche and predict its potential distribution, therefore, it is widely used to manage the distribution of species, assess the ecological impact of environmental factors, evaluate biological invasion risk and manage endangered species (Hirzel et al., 2006). In recent years, with the 3S technology namely Geographic Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) and other technologies develop, 3S technology has become an important tool for the assessment of the habitat suitability and hence, efficiency of habitat suitability assessment has also been greatly improved. Especially GIS, a spatial information system, not only has a very powerful spatial data processing function and ultimately graphically display, combined with HSI model, makes the analysis result more comprehensive, but also a new and effective approach to habitat assessment (Rickers et al., 1995).

Suaeda heteroptera, as annual herb, belongs to the *Angiospermae*, *Dicotyledoneae*, *Centrospermae*, *Chenopodiaceae*, *Suaeda* in plant taxonomy. *S. heteroptera* grows in saline soil, usually in the river, lake, desert and coastal areas. In China, *S. heteroptera* with strong resistance is a typical and important halophyte. Absorbing soil salinity and then accumulating in the body, thereby *S. heteroptera* can significantly reduce the soil salt content (Zhao, 1998). As a result, *S. heteroptera* is a species with the developing potential ecological restoration function.

Laizhou Bay, as one of the three Bohai Bay, is an important fishery and fish and shrip spawning grounds, with abundant freshwater resources, and relatively flat seabed (Yang et al., 2014). But as overfishing and marine development projects increased, there has degradation of estuarine spawning grounds in Laizhou Bay, environmental pollution, exceeding bids of organic matter and heavy metal content, biological community structure abnormality, eutrophication and other issues (Guo and Chen, 2012; Zhang et al., 2012). Ecological environment of Laizhou Bay has been a serious pollution and destruction, and local habitats of *S. heteroptera* correspondingly affected. In this paper, taking west bank of Laizhou Bay as an example, with the support of geographic information systems (GIS) technology and local habitat suitability of *S. heteroptera* by HIS model, habitat requirement of *S. heteroptera* in Laizhou Bay can be understood and suitable habitat of *S. heteroptera* can be depicted, which can provide relevant material and scientific basis for the further exploitation of *S. heteroptera*, monitor and protect the local ecological environment.

2. Data and Method

2.1 Survey Region

The selected study area is a typical artificial coastal segment in Dongying offshoot of Laizhou Bay, about 800 meters long and about 600 meters wide, at the region (37°20'31.1496"N, 118°56'04.4292"E and 37°20'26.8788"N, 118°55'44.6136"E) extending into the sea (Figure 1). In the study area with a temperate continental monsoon climate, the average annual precipitation is about 551.6mm; rain hot during the same period. The average salinity of soil up to 17‰; the major soil type is saline soil. Zhimai River, Guangli River and

Xiaoqing River and other rivers enter into the sea here, but the mud flat is relatively flat, making deposition of pollutants, which caused serious pollution of the marine environment and destroyed critical habitats of *S. heteroptera*. (But with local economic development in Laizhou Bay, the area of mud flat gradually increasing, the water pollution further aggravating, embankment and roads making, the degradation and even the death of the local *S. heteroptera* population have been caused).

Figure 1. The map of the west of Laizhou Bay study area

2.2 Habitat Factors Determination

2.2.1 Habitat Factors of *S. heteroptera*

Determination of habitat factors is the important part of habitat suitability assessment. The study area, the mud flat in west bank of Laizhou Bay, mostly is moderate or severe salinity, meanwhile pH and salinity are much different in different locations as well. Now the pollution in the study area mainly contains petroleum pollution and heavy metal pollution. Therefore, the quality and pollution factor of soil, using in calculation HIS, are selected according to the survival demand of *S. heteroptera* for environmental conditions. Soil quality factors include soil salinity and pH; soil pollution factors include heavy metals like mercury, cadmium, copper, lead. The content of metalloid arsenic and petroleum in soil are the habitat suitability evaluation factors of *S. heteroptera.*

2.2.2 Get Data of *S. heteroptera* Habitat Factors

Setting A, B and C in the study area, as Figure 2 shown, 5 stations were set in each fracture surface, which used to investigate the content of soil salinity, PH, petroleum, copper, arsenic, cadmium, lead, and mercury(Table 1).

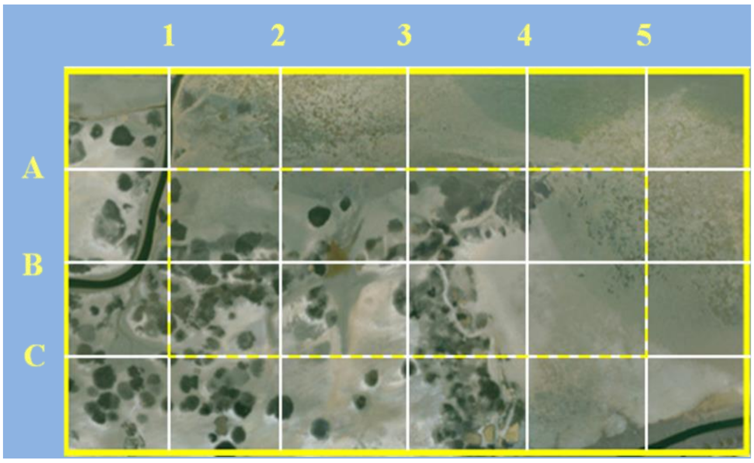

Figure 2. The survey spots of *S. heteroptera* in the west of Laizhou Bay study area

Table 1. Environment parameters of *S. heteroptera* in study area

Research Area	Soil Oil Content	Mercury Content	Cadmium Content	Copper Content	Lead Content	Arsenic Content	Salt Content	pH
A1	1.30±0.05	0.12±0.02	0.11±0.02	25.9±1.01	272.1±4.46	12.5±0.50	13.6±0.35	8.17±0.21
A2	1.75±0.04	0.16±0.03	0.13±0.04	27.3±3.01	223.3±5.80	13.7±0.26	14.2±0.37	8.24±0.33
A3	1.81±0.05	0.18±0.02	0.11±0.02	30.4±3.42	295.6±5.12	11.4±0.53	12.5±0.34	8.41±0.28
A4	1.49±0.06	0.13±0.03	0.12±0.03	34.1±3.02	324.9±5.34	15.4±0.34	15.6±0.50	8.36±0.34
A5	1.56±0.04	0.12±0.02	0.09±0.02	31.6±1.51	311.3±5.68	17.7±0.32	23.4±0.4	8.14±0.30
B1	1.34±0.04	0.29±0.02	0.28±0.02	26.9±1.32	342.8±4.48	16.9±0.52	10.3±0.28	8.32±0.39
B2	1.52±0.03	0.11±0.01	0.13±0.03	25.9±1.28	272.1±4.42	12.5±0.34	11.6±0.32	8.17±0.37
B3	1.61±0.05	0.1±0.01	0.11±0.01	27.3±1.28	347.6±5.48	10.7±0.28	13.2±0.32	8.24±0.33
B4	1.18±0.04	0.07±0.01	0.24±0.01	30.6±1.51	339.2±5.28	13.4±0.23	13.7±0.34	8.11±0.29
B5	1.57±0.05	0.27±0.03	0.18±0.02	34.7±3.01	273.6±4.32	19.4±0.34	17.1±0.41	8.26±0.30
C1	2.12±0.36	0.35±0.04	0.13±0.01	42.6±5.13	342.3±4.32	12.8±0.33	21.8±0.33	8.04±0.33
C2	2.35±0.3	0.38±0.03	0.52±0.14	36.1±3.42	346.1±4.84	13.7±0.28	13±0.38	8.22±0.27
C3	2.39±0.10	0.42±0.11	0.57±0.11	41.7±3.01	282.1±4.32	19.5±0.35	11.1±0.37	8.19±0.29
C4	2.38±0.12	0.59±0.12	0.46±0.10	37.9±3.01	248.3±4.86	10.8±0.37	10.5±0.43	8.34±0.33
C5	2.37±0.25	0.48±0.10	0.51±0.12	35.4±3.51	293.6±4.66	25.2±1.01	13.2±0.33	8.31±0.35

2.3 Classification of Habitat Suitability Degrees

Referring to the "Land Plan" produced by FAO (FAO, 1976) and the correlation analysis of the suitability and limitation of *S. heteroptera* growth, the study area is divided into four levels in accordance with the habitat suitability, the following table 2 shows.

Table 2. The habitat suitability rank of study area

	Suitability Grades	Match Condition
（1）	**Highly suitable** （Core habitat）	*S. heteroptera* can achieve wonderful growth in such habitat, where the environmental conditions are the optimum for the survival and growth .
（2）	**Moderate suitable** (Moderate suitable habitat）	*S. heteroptera* can get a better growth in such habitat, where the environmental conditions basically meet the requirement of its survival and growth.
（3）	**Marginally suitable** （Marginal habitat）	*S. heteroptera* can grow in such habitat, where the environmental conditions close to the demand of its survival and growth.
（4）	**Not suitable** （unsuitable habitat）	The growth of *S. heteroptera* will be limited in such habitat, where the environmental conditions cannot attain the basic demand of its survival and growth.

In ArcGIS 10.0, according to the growth conditions of *S. heteroptera*, the habitat stability degrees were classified: unsuitable assigned 0 points, marginally suitable assigned the 2 points, moderate suitable assigned the three points, but highly suitable assigned 4 points. The classification criteria of each degree have been shown in Table 3.

Table 3. Classification of habitat suitability for *Suaeda salsa*

Assessment Valuables	Highly suitable (SI=4)	Moderate suitable (SI=3)	Marginally suitable (SI=2)	Not suitable (SI=0)
Salt Content	11.7~17.6g/kg	17.6~29.2g/kg	29.2~35.0g/kg	>35g/kg
pH	7.9~8.2	7.0~7.9	6.0~7.0 or 8.2~9.0	>9.0 or <6.0
Soil Oil Content	<0.5mg/g	0.5~1.0mg/g	1.0~3.0mg/g	>3.0mg/g
Mercury Content	< 0.15mg/kg	0.15~1.0mg/kg	1.0~1.5mg/kg	>1.55mg/kg
Cadmium Content	<0.2mg/kg	0.2 ~1.0mg/kg	1.0~1.5mg/kg	>1.5mg/kg
Copper Content	<35mg/kg	35~100mg/kg	100 ~400mg/kg	>400mg/kg
Lead Content	<300mg/kg	300~350mg/kg	350~550mg/kg	>550mg/kg
Arsenic Content	<15mg/kg	15 ~25mg/kg	25~30mg/kg	>30mg/kg

Note: SI was the single factor habitat suitability index.

2.4 Habitat Suitability Evaluation Method in Study Area

HIS model, the widest model in assessment methods of habitat suitability, incorporates a number of issues of wildlife habitat and other resources management (Schamberger and O'Neil, 1986). In this paper, habitat analysis of *S.heteroptera* on the west bank of Laizhou Bay is demonstrated by the HIS model.

$$HSI = \left(\prod_{i=1}^{n} SI_i\right)^{\frac{1}{n}} \qquad (1)$$

The HIS value of single factor is calculated using the geometric method: n is the number of impact factors, SI_i is the suitability index of impact factor. HIS value got by geometric method strikes an average, because it considers the influence of larger or smaller SI.

The development process of HSI model are: (1) determine the habitat factors, make filed investigation, access to habitat data; (2) build a single factor suitability function of each factor; (3) construct judgment matrix, get habitat factor weight value comparing the importance of impact factors; (4) calculate the HIS value combining the different habitat suitability index; (5) produce the final results of habitat suitability (Jin et al., 2008).

3. Result and Analysis

Choose soil quality factor according to the survival requirnment of *S. heteroptera*: pH and soil salinity; soil pollution factors: mercury, cadmium, copper, and lead; the content of metalloid arsenic and petroleum in soil are the habitat suitability evaluation factors of *S. heteroptera* by HIS model and ArcGIS 10.0.

3.1 Habitat Suitability Analyis on Soil Quality Factors of S. heteroptera

In Hekou of Dongying offshoot in the west bank of Laizhou Bay, the soil of some area has high salinity and PH, but not exceeding the maximum tolerance and the survival and growth requirement. In such habitat as the moderate suitable area, *S. heteroptera* can get a better growth condition. Among other areas, especially intertidal zone, its soil quality factors both are suitable for growth of *S. heteroptera*. Additionally, the soil quality favors the survival and growth of *S. heteroptera*.

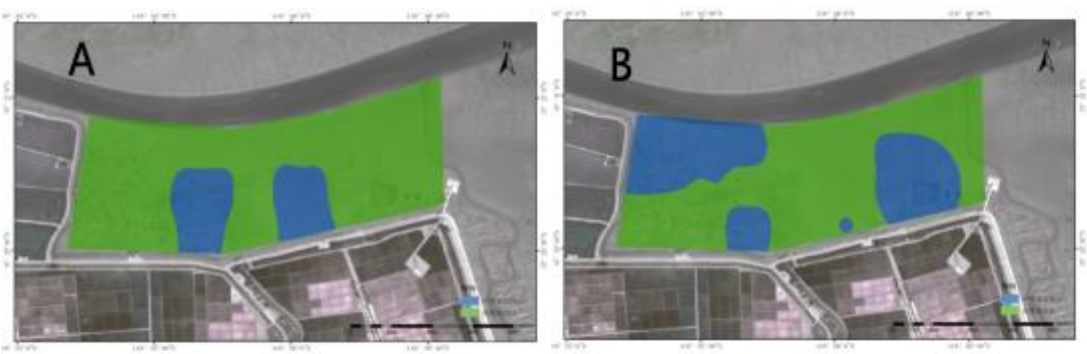

Figure 4. The habitat suitable areas of *S. heteroptera* based on single-factor of soil quality factor(A: single-factor of salt content; B: single-factor of pH)

3.2 Habitat suitability analysis on soil pollution factors of S.heteroptera

The habitat stability analysis on soil pollution factors shows although the biological environment has suffered certain of damage and the phenomenon of petroleum and heavy metal pollution, *S. heteroptera* can still be live and complete its life history, because of its strong stress resistance and adaptive capacity. In most study areas, the soil conditions favor to the survival and growth of *S. heteroptera*, which can reach the core habitat conditions. Compared to other soil pollution factor, the core habitat area of single factor index, cadmium and mercury, in the study area is relatively small; most of the soil conditions can only meet the basic requirements for survival and growth. the habitat suitability analysis on the single factor index, arsenic, of *S. heteroptera* a showed that although the most soil conditions in study area are conducive to grow, but there is a small part, reaching the edge of the Habitat level of *S. heteroptera* , only meet the basic requirements of survival and growth.

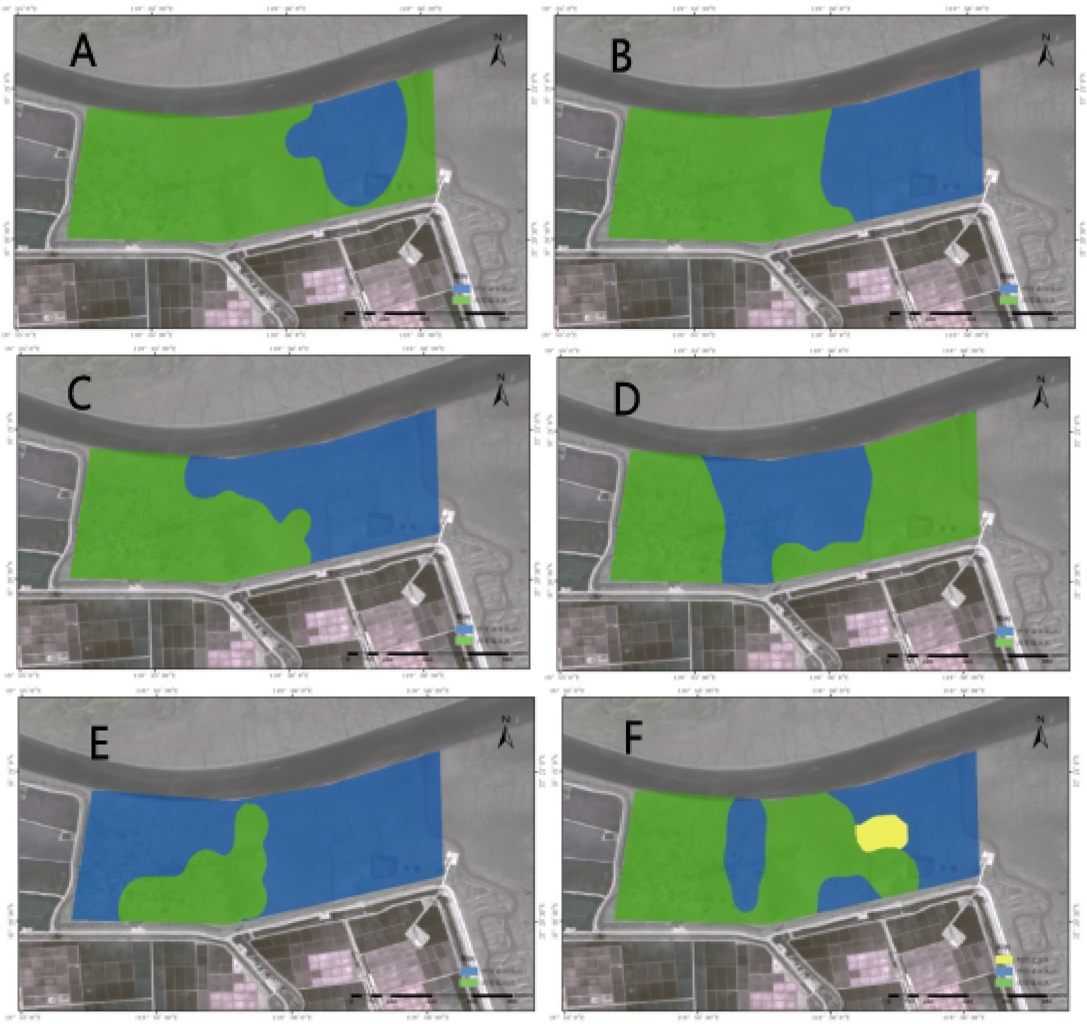

Figure 5. The habitat suitable areas of *S. heteroptera* based on single-factor of Soil pollution factor (A:single-factor of petroleum content; B: single-factor of Cu; C: single-factor of Cd; D: single-factor of Pb; E: single-factor of Hg; F: single-factor of As)

3.3 Habitat Suitability Overall Analysis of S. heteroptera in the West Bank of Laizhou Bay

From the habitat suitability analysis chart, although soil salinization in the study are is more serious, and the problem of pollution oil and various heavy metals are exist, most of region are moderate or highly suitable area because of *S. heteroptera* has strong stress tolerance and ability to assemble the petroleum and heavy metals, and can survive in a place with high salinity. Among them, the moderate suitable areas are mostly located in the river estuary, where is flat, easily deposited pollutants, and pollution of the marine environment are relatively severe. Generally, the habitat suitability analysis on *S. heteroptera* indicates that the study areas are suitable for the growth of *S. heteroptera*.

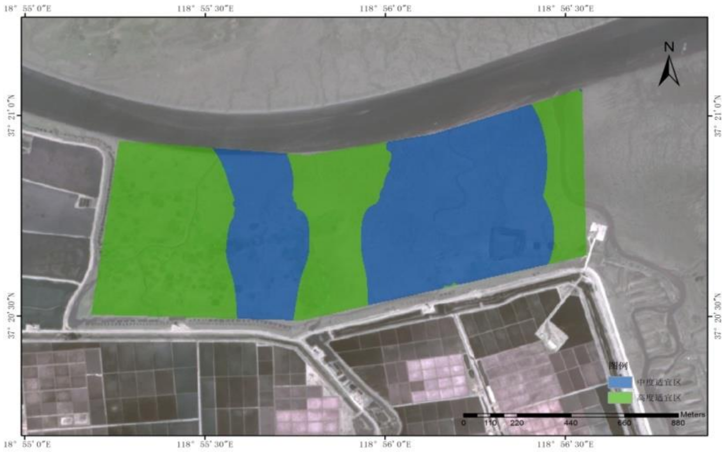

Figure 6. The habitat suitable areas of *S. heteroptera* of artificial coastal

4. Discussion

S. heteroptera, a pioneer plant in tidal wetland, is suitable for growing in areas with high moisture content, and can be able to endure the immersion in seawater for long hours (Sharma and Gupta, 1986). For *S. heteroptera*, soil salinity and PH play a major role in its growth process (Zhang et al., 2007), followed by the content of nitrogen and phosphorous (Zhao, 1991). Although some kind of soil pollutants, such as petroleum and heavy metal, can impact its growth, *S. heteroptera* can repair the pollution of petroleum, because of its stress tolerance and enrichment capacity (Liu et al., 2012; Wu et al., 2012; Glenn and Brown, 1999). The biological environment of the study area had been damaged, however, it still be the moderate or highly suitable area for *S. heteroptera* Consequently, the restoration process in tidal wetland of Laizhou Bay should give priority to the cultivation and protection of *S. heteroptera*.

Acknowledgement

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References

May, R. M. 1976. The evolution of ecology system. *Scientific American, 239*(3), 161-175.

U. S. Fish and Wildlife Service, Division of Ecological Services. 1980. Habitat Evaluation Procedure, ESM 102.

Hirzel, A. H., Le Lay, G., Helfer, V., et al. 2006. Evaluating the ability of habitat suitability models to predict species presences. *Ecological Modelling, 199*(2), 142-152. http://dx.doi.org/10.1016/j.ecolmodel.2006.05.017

Rickers, J. R., Queen, L. P., Arthad, et al. 1995. A proximity-based approach to assessing habitat. *Landscape Ecology, 10*(5), 309-321. http://dx.doi.org/10.1007/BF00128997

Zhao, K. F. 1998. *The halophytes in China*. Science Press of China, Bejing.

Yang, J. Q., Zhu, Y. G., Song, W. P., et al. 2014. The eco-environmental evaluation based on habitat quality and ecological response of Laizhou Bay. *Acta Ecologica Sinica, 34*(1), 105-114. http://dx.doi.org/10.5846/stxb201304280850

Guo, J., & Chen, Z. B. 2012. Remote sensing information extraction of the Laizhou Bay environment pollution. *Marine Science, 36*(2), 119-128.

Zhang, X., Zhang, L. J., Hou, Z. L., & Liao, W. 2012. Spatio-TemporalVariability of Principal Pollutants in Laizhou Bay from 1980 to 2008. *Periodical of Ocean University of China, 42*(11), 91-98.

FAO. 1976. A framework for land evaluation. FAO Soil Bulletin 32, Rome.

Schamberger, M. L., & O'Neil, L. J. 1986. Concepts and constraints of habitat model testing. Wildlife, 5-10.

Jin, L. R., Sun, K. P., & He, H. S. 2008. Research advances inhabitant suitability index model. *Chinese Journal of Ecology, 27*(5), 841-846.

Sharma, S. K., & Gupta, I. C. 1986. Saline Environment and plant growth. Agro Botanical Publishers, New Delhi, 172.

Zhang, L. B., Xu, H. L., & Zhao, G. X. 2007. Salt Tolerance of Suaeda Salsa and Its Soil Ameliorating Effect on Coastal Saline Soil. *Soils, 39*(2), 310-313.

Zhao, K. F. 1991. Desalinization of saline soils by Suaeda salsa. *Plant and Soil, 135*, 303-305. http://dx.doi.org/10.1007/BF00010921

Liu, S. J., Yang, C. Y., Xie, W. J., Xia, C. H., & Fan, P. 2012. The effects of cadmium on germination and seedling growth of Suaeda salsa. *Procedia Environmental Sciences, 16*, 293-298. http://dx.doi.org/10.1016/j.proenv.2012.10.041

Wu, H. F., Liu, X. L., Zhao, J. M., & Yu, J. B. 2012. Toxicological responses in halophyte Suaeda salsa to mercury under environmentally relevant salinity. *Ecotoxicology and Environmental Safety, 85*, 64-71. http://dx.doi.org/10.1016/j.ecoenv.2012.03.016

Glenn, E. P., & Brown, J. J. 1999. Salt tolerance and crop potential of halophytes. *Crit Rev Plant Sci., 18*, 227-255. http://dx.doi.org/10.1016/S0735-2689(99)00388-3

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