Pakistan J. Zool., vol. 47(1), pp. 141-146, 2015.

Effect of Saltmarsh Cordgrass, *Spartina alterniflora*, Invasion Stage on *Cerithidea cingulata* (Caenogastropoda: Potamididae) Distribution: A Case Study from a Tidal Flat of Western Pacific Ocean, China

Bao-Ming Ge,[1, 2*] Dai-Zhen Zhang,[1] Yi-Xin Bao,[2] Jun Cui,[1] Bo-Ping Tang,[1] and Zhi-Yuan Hu[2]
[1]Jiangsu Key Laboratory for Bioresources of Saline Soils, Jiangsu Synthetic Innovation Center for Coastal Bio-agriculture, Yancheng Teachers University, Kaifang Avenue 50, Yancheng, Jiangsu 224051, P. R. China
[2]Institute of Ecology, Zhejiang Normal University, Yingbin Avenue 688, Jinhua, Zhejiang 321004, P. R. China

Abstract.- The effect of saltmarsh cordgrass, *Spartina alterniflora* (Poales: Poaceae) invasion stage on *Cerithidea cingulata* (Caenogastropoda: Potamididae) distribution was studied in 2007 at the eastern tidal flat of Lingkun Island, Wenzhou Bay, China. The distribution pattern of *C. cingulata* was aggregated during each season, as shown in experiments utilizing Taylor's power regression and Iowa's patchiness regression methods ($P < 0.001$). Two-way ANOVA indicated that densities were significantly affected by *S. alterniflora* invasion stage ($P < 0.001$), however, no significant season effect was found ($P = 0.090$) and on the interaction between the seasons ($P = 0.939$). The density distribution during the invasion stage was significantly different in each season as shown in one-way ANOVA. Pearson’s correlation coefficient analysis of density data indicated that the highest densities occurred in habitats at the initial invasion stage during summer. The peak in *C. cingulata* density during spring, autumn and winter occurred in habitats where invasion was classified as initial, whereas the lowest densities occurred in the stage of invasion completed during each season. *C. cingulata* density distribution varied among different habitats, and such variation indicates the response of the species to environmental change, particularly *S. alterniflora* invasion.

Key words: Coastal wetland, distribution pattern, ecosystem engineer, gastropod, Wenzhou Bay

INTRODUCTION

Gastropods serve an important function in the habitat and ecosystem of a tidal flat; gastropods are important foragers in the benthic community and environment (Anderson and Underwood, 1997). Predatory snails can consume competitively dominant species to increase diversity in the community; such snails create sufficient space for colonisation by competitively inferior organisms such as *Nucella* spp. (Menge *et al.*, 1994). *Cerithidea cingulata* (Gmelin) (Caenogastropoda: Potamididae) is a gastropod that is distributed worldwide, particularly along the coasts of the Western Pacific Ocean, Indian Ocean, and Persian Gulf (Al-Kandari *et al.*, 2000; Zheng *et al.*, 2007; Reid *et al.*, 2008). People consume *C. cingulata* as food, but this species is also a “pest snail” competing food and space with commercially important molluscs such as *Bullacta exarata*, *Moerella iridescens*, and *Tegillarca granosa* farmed in aquaculture in coastal areas (Bagarinao and Lantin-Olaguer., 2000; Zheng *et al.*, 2007). *C. cingulata* is also widely distributed in the tidal flats of Jiangsu, Shanghai, Zhejiang, and Fujian, China.

In recent decades, salt-adapted grasses of the genus *Spartina* (cordgrass) have invaded western Pacific coasts, including those of Japan and China (Greenberg *et al.*, 2006). Many species of genus *Spartina* (cordgrass) are highly invasive (Daehler and Strong, 1996). Cordgrass is a key ecosystem engineer in a salt marsh ecosystem (Pennings and Bertness, 2001; Brusati and Grosholz, 2006), and its occurrence could significantly change the benthic community structure (Hedge and Kriwoken, 2000; Neira *et al.*, 2006). *Spartina alterniflora* Loisel. (Poales: Poaceae), commonly known as saltmarsh cordgrass, is a perennial salt marsh grass that is native to the Atlantic and Gulf coasts of North America; this species has extensively invaded the coasts of the Western Pacific Ocean and has affected native ecosystems, particularly in China (Wang *et al.*, 2006; Yuan *et al.*, 2013). In coastal wetlands, invasive plants are ecosystem engineers that can change water flow, light, and sediments and can affect benthic communities (Neira *et al.*, 2007).

---

* Corresponding author: gebaoming@gmail.com
0030-9923/2015/0001-0141 $ 8.00/0

Ecosystem engineers are species that can create, maintain, modify, or destroy the habitat of benthos, thereby strongly influencing community composition and structure (Jones *et al.*, 1994). When an invasive plant (an ecosystem engineer) colonizes a coastal wetland, the community structure and the entire ecosystem are modified because nutrient cycling, productivity, hydrology, particle flux, and habitat availability are altered (Talley and Levin, 2001; Crooks, 2002).

S. alterniflora may outcompete native plants, threaten the native ecosystem and coastal aquaculture, and reduce native species richness (Neira *et al.*, 2005; Levin *et al.*, 2006). However, the decline or increase in biodiversity in a wetland ecosystem because of *S. alterniflora* invasion is a highly controversial topic, previous studies have shown that depending on conditions, invasion can lead to either a decline or increase in biodiversity (Wang *et al.*, 2010; Alphin and Posey, 2000). A literature search has indicated that information is lacking on gastropod distribution in tidal flat patches at different stages of *S. alterniflora* invasion (Neira *et al.*, 2007). *C. cingulata* is widely distributed on the tidal flats of Jiangsu, Shanghai, Zhejiang, and Fujian, China, a region subject to ongoing colonisation by *S. alterniflora***.**

In the current study, we hypothesized that the *C. cingulata* population showed different distribution characteristics in the tidal flat at different *S. alterniflora* invasion stages, such that the plant was influencing the distribution of *C. cingulata*.

MATERIALS AND METHODS

Study area and sampling protocol

Our study was conducted at the eastern tidal flat of Lingkun Island (N 27.95°, E 120.93°), Wenzhou Bay, Zhejiang province, China. This island is located in the estuary of Oujiang River, which is characterized by a subtropical climate. The average salinity of the seawater in the tidal flat is 16 psu, and the tide type is informal semidiurnal with an average tidal range of 4.5 m (Lu *et al.*, 2005; Ge *et al.*, 2011). The soft sediment is mainly silt. In 1989, *S. alterniflora* was deliberately introduced along the eastern tidal flats of Lingkun Island to promote sediment deposition (Li *et al.*, 2009) and by 2007 had become the dominant plant in the upper and high tidal zones.

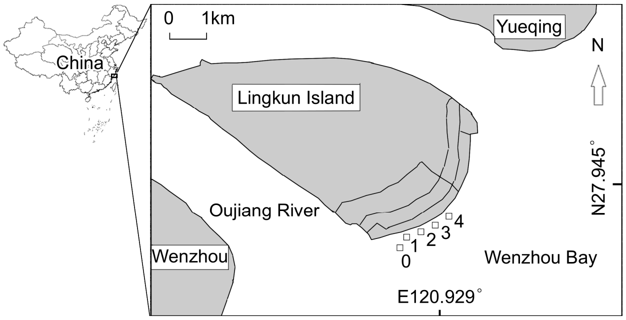

Fig. 1. Location of study area and habitat distribution. Habitat code with the invasion stage of *S. alterniflora*: 0, Naked mud flat; 1, No invasion; 2, Initial invasion; 3, Invasion underway; 4, Invasion completed.

Five habitats were selected based on similar environmental characteristics (*e.g.*, climate and salinity) (Fig. 1). In the high tidal zone, four kinds of patches of *S. alterniflora* at different invasion stages were categorised based on invasion age of *S. alterniflora*namely; (1) no invasion, (2) initial invasion (invasion age 1-2 years), (3) invasion underway (invasion age 3-4 years), and (4) invasion completed (invasion age 5-6 years) (Table I). A parallel habitat was selected as a negative control plot in the middle tidal zone and termed as (0) naked mud flat.

The site was sampled in February (winter), May (spring), August (summer), and November (autumn) of 2007. The habitats were 200-300 m apart, replicated five times with plots (1 m × 1 m) randomly sampled within each habitat and at least 2 m apart. A wooden quadrat was used to delimitate the plots and *C. cingulata* with a body length of >0.5 cm collected by hand from within each quadrat. Each season, 25 plots were sampled with a total of 100 samples collected for analysis.

Data multivariate analyses

For point pattern processes, indices were obtained mainly based on counts of individuals per unit grid (quadrat). The simplest indices were based on variance (S^2) and mean density (x) or on mean crowding (m) and mean density (x) of population

Table I.- **Sample habitats with different *S. alterniflora* invasion stages within the eastern Lingkun Island tidal zone.**

Habitat code	Tidal zone	Coverage and area	Invaded years
0	Middle	Bare	0
1	High	Bare	0
2	High	About 10% (in winter) - 30 % (in summer), about 15 m^2	1 - 2
3	High	About 40% (in winter) - 70 % (in summer), about 50 m^2	3 - 4
4	High	About 70% (in winter) - 100 % (in summer), larger than 100 m^2	5 - 6

density per quadrat. Taylor's power regression ln $S^2 = a + b\ln x$ (Taylor, 1961) and Iowa's patchiness regression $m = \alpha + \beta x$ (Iwao, 1968) facilitated the assessment of the level of aggregation by means of slope b and β. Taylor's law is an empirical law in ecology that relates the between-sample variance in density to the overall mean density of a sample of organisms in a study area. In Taylor's power regression, the slope values (b) significantly > 1 indicate clumping of the organisms. In Poisson distributed data $b = 1$. If the population follows a lognormal or gamma distribution then $b = 2$. Iowa's patchiness regression where α indicates the tendency to crowding (positive) or repulsion (negative) and β reflects the distribution of population on space and is interpreted in the same manner as b of Taylor's power. Such assessment indicated uniform [$b(\beta) < 1$], random [$b(\beta) = 1$], or aggregated [$b(\beta) > 1$] distributions of the population (Arnaldo and Torres, 2005; Vinatier *et al.*, 2011).

Two-way ANOVA (general linear model, GLM) was used to determine the mean differences in density by distance, season, and interaction between the seasons; Levene's test was used to determine equality of variance before using the GLM, and all the data sets passed this test in the current study (Ge *et al.*, 2011).

One-way ANOVA was used to determine the significance of differences in density measured in plots in each season, and Student–Newman–Keuls (SNK) method used if a significant difference occurred for multiple comparisons. Levene's test was used to determine equality of variance prior to the multiple comparison analyses. When a dataset failed to pass Levene's test, the data was transformed using ln(x + 1) (Kendrick and Walker, 1995). The data sets of mean densities in different habitats were then checked by Pearson's correlation coefficients among seasons.

SPSS 16.0 (SPSS Inc.) and Microsoft Office Excel 2003 (Microsoft Inc.) were used for statistical analysis.

RESULTS

Our results indicated that b and β was slightly greater than 1 totally (P < 0.001), and Iowa's model fitted the data better than Taylor's power law (Table II). In Iowa's model, α < 0 indicates the tendency to repulsion and indicates *C. cingulata* was aggregated in each season under the spatial scale of this study.

Two-way ANOVA revealed a significant effect of plant invasion stage ($F_{4,19}$ = 14.397, P < 0.001) on the abundance of *C. cingulata*, but no significant effect of season ($F_{3,19}$ = 2.235, P = 0.090) and interaction of season × invasion stage ($F_{12,19}$ = 0.447, P = 0. 939) was observed.

C. cingulata showed a clumped distribution in the habitats with no invasion and with initial invasion of *S. alterniflora* in the high tidal zone of Lingkun Island. Significant difference in the *C. cingulata* density across seasons were detected (SNK test, Fig. 2). The highest density occurred in habitats at the initial *S. alterniflora* invasion stage in spring, autumn, and winter and in the habitat with no invasion in summer (Fig. 2). Patches with completed invasion had the lowest density (Fig. 2).

The density in naked mud flat in the middle tidal zone showed a medium value in each season. Significantly positive correlations on abundance distribution occurred in spring vs. winter (P = 0.030), spring vs. summer (P = 0.028), autumn vs. spring (P=0.002), and autumn vs. summer (P = 0.018) according to Pearson's correlation test for density distribution among seasons (Table III). The results showed that the number composition of density distribution at different habitats varied significantly in the mentioned comparisons.

Table II.- **Estimated values of *C. cingulate* dispersion indexes based on Taylor's power law and Iowa's patchiness regression.**

Season	Taylor's power regression				Iowa's patchiness regression			
	a	***b***	**R^2**	**P**	**α**	**β**	**R^2**	**P**
Winter	-0.878	1.525	0.658	0.048	-0.330	1.077	0.965	0.001
Spring	-0307	1.355	0.805	0.019	-0.085	1.064	0.988	<0.001
Summer	-0.989	1.573	0.971	0.001	-0.430	1.080	0.998	<0.001
Autumn	-1.311	1.662	0.869	0.007	-0.595	1.084	0.993	<0.001
Total	-0.990	1.568	0.830	<0.001	-0.439	1.083	0.990	<0.001

Table III.- **Correlation test of *C. cingulate* density among seasons (two-tailed and n = 5 in each season).**

Season	Parameter	Summer	Autumn	Winter
Spring	Pearson correlation	0.919	0.986	0.914
	P	0.028	0.002	0.030
Summer	Pearson correlation		0.940	0.825
	P		0.018	0.086
Autumn	Pearson correlation			0.873
	P			0.054

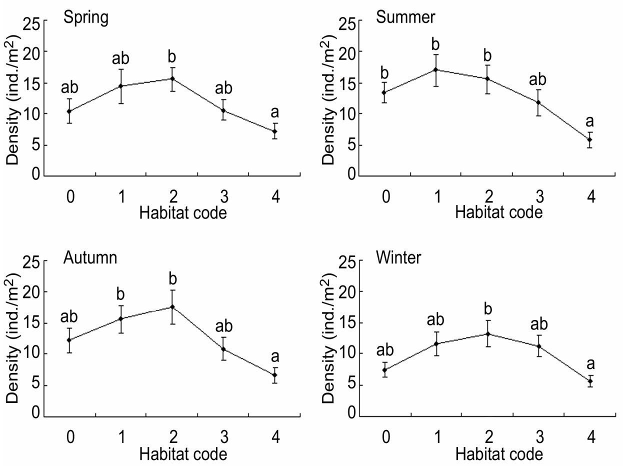

Fig. 2. Density (Mean ± SE) distribution of *C. cingulata*. 0, Naked mud flat; 1, No invasion; 2, Initial invasion; 3, Invasion underway; 4, Invasion completed. Means with different scripts are significantly different according to SNK test, α = 0.05.

DISCUSSION

Previous studies have shown that some gastropod species showed an aggregated spatial distribution pattern (Ye and Lu, 2001; Ge *et al.*, 2013). A similar result was observed in the current research. Significant seasonal differences in *C. cingulata* densities were observed; however, previous research has indicated that density variation can affect the distribution pattern (Hanberry *et al.*, 2011), as spatial disposition can be density dependent (Taylor *et al.*, 1978). However, the variation in *C. cingulata* densities observed in this study did not significantly impact on the underlying distribution pattern.

The comparisons of spatial distribution across seasons showed that higher densities of *C. cingulata* occurred at the no invasion and initial invasion patches in each season, whereas the lowest densities occurred in patches where invasion was completed. Different invasion statuses can lead to alterations in litter production, belowground biomass, sediment organic content, and nutrient cycling (Talley and Levin, 2001), and such features are associated with food availability for benthic fauna (Neira *et al.*, 2005). The trophic function of the wetland is also affected (Levin *et al.*, 2006). The distribution of bethos could be affected by the invasion stages in the tidal flat. During the initial invasion, the environment can offer a large variety of microhabitats for benthos as a result of the low density of *S. alterniflora*, and the environmental characteristics were suitable for gastropod survival (Neira *et al.*, 2007). However, changes occur in the habitat when roots of *S. alterniflora* harden the sediment, and stems and leaves develop above ground after the initial invasion stage; when such changes occur, the habitat becomes unsuitable for Bivalvia and Nemertina species (Wang *et al.*, 2010). Therefore, habitat changes caused by different *S.*

alterniflora invasion stages (Wang *et al*., 2006) were a significant influence on *C. cingulata* spatial distribution.

Although invasion of *S. alterniflora* changes the density of *C. cingulata*, there was no significant change of the distribution pattern (aggregated) among habitat with different invasion stages in each season (Table II). This phenomenon indicated that the distribution pattern should be determined by the biological characters of species. While the densities changed significantly with the factor of invasion stage and season (Table III, Fig. 2). *C. cingulata* density was lowest during winter (Fig. 2), temperature stress can be a driving force for the seasonal variation of distribution, although the effect of migratory birds on *C. cingulata* density during winter should also be considered (Ge *et al*., 2011). The western Pacific coast is an important wintering and migration stopover wetland for some bird species (Butler *et al*., 2001); thus, the benthos and birds can be affected each other because they are both involved in a complex food web (Mian, 1999). Of particular note is that in winter the coverage of *S. alterniflora* was lowest (Table I), the benthos including *C. cingulata* suffered higher predation risk than other seasons (Shepherd and Lank, 2004). The effect of temporal and spatial organization on interspecific associations should be considered when applying to ecosystem management practices of coastal wetlands.

ACKNOWLEDGEMENTS

This research was supported by the National Natural Science Foundation of China (31301871, 31300443); the Natural Science Foundation of Jiangsu Province (BK20130422); the Natural Science Foundation of the Jiangsu Higher Education Institutions of China (12KJB180016, 12KJA180009) and the Opening Foundation of Jiangsu Key Laboratory for Bioresources of Saline Soils (JKLBS2012026).

Statement of conflict of interest

There was no conflict of interest from the authors.

REFERENCES

AL-KANDARI, W.Y., ABDUL-SALAM, J. AND MEAKINS, R., 2000. Temporal variations in the infection of a population of *Cerithidea cingulata* by larval trematodes in Kuwait Bay. *J. Helminthol.,* **74**: 17-22.

ALPHIN, T.D. AND POSEY, M.H., 2000. Long-term trends in vegetation dominance and infaunal community composition in created marshes. *Wetl. Ecol. Manage.,* **8**: 317-325.

ANDERSON, M.J. AND UNDERWOOD, A.J., 1997. Effects of gastropod grazers on recruitment and succession of an estuarine assemblage: a multivariate and univariate approach. *Oecologia,* **109**: 442-453.

ARNALDO, P.S. AND TORRES, L.M., 2005. Spatial distribution and sampling of *Thaumetopoea pityocampa* (Den and Schiff) (Lep. Thaumetopoeidea) populations on *Pinus pinaster* Ait. in Montesinho, N. Portugal. *Forest Ecol. Manage.,* **210** :1-7.

BAGARINAO, T. AND LANTIN-OLAGUER, I., 2000. From triphenyltins to integrated management of the 'pest' snail *Cerithidea cingulata* in mangrove-derived milkfish ponds in the Philippines. *Hydrobiologia,* **437**: 1-16.

BRUSATI, E. AND GROSHOLZ, E.D., 2006. Native and introduced ecosystem engineers produce contrasting effects on estuarine infaunal communities. *Biol. Invasions,* **8**: 683-695.

BUTLER, R.W., DAVIDSON, N.C. AND MORRISON, R.I.G., 2001. Global-scale shorebird distribution in relation to productivity of near shore ocean waters. *Waterbirds,* **24**: 224-232.

CROOKS, J.A., 2002. Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. *Oikos,* **97**: 153-166.

DAEHLER, C.C. AND STRONG, D.R., 1996. Status, prediction and prevention of introduced cordgrass *Spartina* spp. invasions in Pacific estuaries, USA. *Biol. Conserv.,* **78**: 51-58.

GE, B.M., BAO, Y.X. AND CHENG, H.Y., 2011. Tempo-spatial variation of macrobenthic communities on a tidal flat of Wenzhou Bay, China. *Rev. Biol. Mar. Oceanog.,* **46**: 281-286.

GE, B.M., BAO, Y.X., CHENG, H.Y., ZHANG, D.Z. AND TANG, B.P., 2013. Temporal and spatial distribution pattern of *Bullacta exarata* in a tidal flat at south shore of Hangzhou Bay, China. *Iran. J. Fish. Sci.,* **12**: 96-104.

GREENBERG, R., MALDONADO, J.E., DROEGE, S. AND MCDONALD, M.V., 2006. Tidal marshes: a global perspective on the evolution and conservation of their terrestrial vertebrates. *BioScience,* **56**:675-685.

HANBERRY, B.B., FRAVER, S., HE, H., YANG, S.J., DEY D.C. AND PALIK, B.J., 2011. Spatial pattern corrections and sample sizes for forest density estimates of historical surveys. *Landsc. Ecol.,* **26**: 59-68.

HEDGE, P. AND KRIWOKEN, L.K., 2000. Evidence for effects of *Spartina anglica* invasion on benthic macrofauna in Little Swanport estuary, Tasmania. *Austral. Ecol.,* **25**: 150-159.

IWAO, S., 1968. A new regression method for analyzing the aggregation pattern of animal populations. *Res. Popul. Ecol.,* **10**:1-20.

JONES, C.G., LAWTON, J.H. AND SHACHAK, M., 1994. Organisms as ecosystem engineers. *Oikos,* **69**: 373-386.

KENDRICK, G.A. AND WALKER, D., 1995. Dispersal of propagules of *Sargassum spp.* (Sargassaceae: Phaeophyta): Observations of local patterns of dispersal and consequences for recruitment and population structure. *J. Exp. Mar. Biol. Ecol.,* **192**: 273-288.

LEVIN, L.A., NEIRA, C. AND GROSHOLZ, E.D., 2006. Invasive cordgrass modifies wetland trophic function. *Ecology,* **87**: 419-432.

LI, Y.B., LIANG, F.G. AND YAN, L.H., 2009. Vicissitude and response of exploitation of *Spartina alterniflora* Loisel in tidal flat of Wenzhou coast. *Marine Environ. Sci.,* **28**: 324-328. (in Chinese with English abstract)

LU, Y.J., LI, H.L., WANG, H.C. AND ZUO, L.Q., 2005. Back silting and regulation of waterway with sand bar in strong tidal estuary. *J. Hydraul. Engin.,* **36**: 1450-1456. (in Chinese with English abstract)

MENGE, B.A., BERLOW, E.L., BLANCHETTE, C.A., NAVARRETE, A.A. AND YAMADA, S.B., 1994. The keystone species concept-variation in interaction strength in a rocky intertidal habitat. *Ecol. Monogr.,* **64**: 249-286.

MIAN, A., 1999. On biology of houbara bustard (*Chlamydotis undulata macqueenii*) in Balochistan, Pakistan: food of some dominant bird species and food web. *Pakistan J. Zool.,* **31**: 167-174.

NEIRA, C., GROSHOLZ, E.D., LEVIN, L.A. AND BLAKE, R., 2006. Mechanisms generating modification of benthos following tidal flat invasion by a *Spartina* hybrid. *Ecol. Appl.,* **16**: 1391-1404.

NEIRA, C., LEVIN, L.A. AND GROSHOLZ., E.D., 2005. Benthic macrofaunal communities of three sites in San Francisco Bay invaded by hybrid *Spartina*, with comparison to uninvaded habitats. *Mar. Ecol. Progr. Ser.,* **292**: 111-126.

NEIRA, C., LEVIN, L.A., GROSHOLZ, E.D. AND MENDOZA, G., 2007. Influence of invasive *Spartina* growth stages on associated macrofaunal communities. *Biol. Invasions,* **9**: 975-993.

PENNINGS, S.C. AND BERTNESS, M.D., 2001. Salt marsh communities. In: *Marine community ecology* (eds. M.D. Bertness, S.D. Gaines, and M.E. Hay), Sinauer Associates Inc., Sunderland, Massachusetts, USA, pp. 289-316.

REID, D.G., DYAL, P., LOZOUET, P., GLAUBRECHT, M. AND WILLIAMS, S.T., 2008. Mudwhelks and mangroves: the evolutionary history of an ecological association (Gastropoda: Potamididae). *Mol. Phylogenet. Evol.,* **47**: 680-699.

SHEPHERD, P.C.F. AND LANK, D.B., 2004. Marine and agricultural habitat preferences of dunlin wintering in British Columbia. *J. Wildl. Manage.,* **68**: 61-73.

TALLEY, T.S. AND LEVIN, L.A., 2001. Modification of sediments and macrofauna by an invasive marsh plant. *Biol. Invasions,* **3**: 51-68.

TAYLOR, L.R., 1961. Aggregation, variance and the mean. *Nature,* **189**: 732-735.

TAYLOR, L.R., WOIWOD, I.P. AND PERRY, J.N., 1978. The density-dependence of spatial behavior and the rarity of randomness. *J. Anim. Ecol.,* **47**: 383-406.

VALIELA, I., RUTECKI, D. AND FOX, S., 2004. Salt marshes: biological controls of food webs in a diminishing environment. *J. Exp. Mar. Biol. Ecol.,* **300**: 131-159.

VINATIER, F., TICIER, P., DUYCK, P. F. AND LESCOURRET, F., 2011. Factors and mechanisms explaining spatial heterogeneity: a review of methods for insect populations. *Methods Ecol. Evol.,* **2**: 11-22.

WANG, Q., AN, S.Q., MA, Z.J., ZHAO, B., CHEN, J.K. AND LI, B., 2006. Invasive *Spartina alterniflora*: biology, ecology and management. *Acta Phytotaxon. Sin.,* **44**: 559-588. (in Chinese with English abstract)

WANG, R., YUAN, L. AND ZHANG, L., 2010. Impacts of *Spartina alterniflora* invasion on the benthic communities of salt marshes in the Yangtze Estuary, China. *Ecol. Eng.,* **36**: 799-806.

YE, S.F. AND LU. J.J., 2001. Analysis on the spatial distribution of *Bullacta exarata* (Mollusca: Gastropoda: Atyidae) population in Yangtze River Estuary, China. *Zool. Res.,* **22**: 131-136. (in Chinese with English abstract)

ZHENG, R.Q., ZHANG, Y.P., WANG, T. AND LI, C.Y., 2007. The Spatial Distribution of *Cerithideopsilla cingulata* Population in Yueqing Bay. *Chinese J. Zool.,* **42**: 134-139. (in Chinese with English abstract)

YUAN, Y., WANG, K., LI, D., PAN, Y., LV, Y., ZHAO, M. AND GAO, J., 2013 Interspecific interactions between *Phragmites australis* and *Spartina alterniflora* along a tidal gradient in the Dongtan Wetland, Eastern China. *PLoS ONE,* **8**: e53843.

(Received 26 July 2014, revised 6 November 2014)