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Full Length Research Paper

Can the new recorded species be established in Burullus protected area: A Ramsar site in Egypt

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Invasions by alien plant species are causing major conservation problems in many regions of the world and are viewed as an important component of human caused global change. Lake Burullus (one of the protected areas and RAMSAR site in Egypt) and its surroundings are subjected to ecological constraints that relate to excessive use of resources such as the construction of an International Highway that runs along its sand bar. This paper aims in evaluating the extent of the new invaded species in Burullus Wetland and in studying the demography of the populations of these species in terms of size structure, natality, mortality, survival and demographic flux. Such type of study helps in understanding the invasive ability of these species in this area, which consequently helps in managing their populations in the wetland. The questions addressed are: 1- How many invaded plant species does Burullus Wetland have? 2- What is the Egyptian geographical origin of these species? 3- Which population can be established and which can be excluded in this area? and 4- Which population can't be adapted? Thirteen perennial species were recoded in the last 8 years: four were recoded for the first time in 2001 at Kassarah site and were established up till 2008 (*Convolvulus lanatus, Artemisia monosperma*, *Cornulaca monacantha* and *Panicum turgidum*), Nine species were recoded in 2006 at Kassarah and along International Highway; five of them were established themselves up till 2008 (*Thymelaea hirsuta*, *Astragalus spinosus*, *Deverra tortuosa*, *Zygophyllum coccineum* and *Retama raetam*). Four species can't be adapted in this region (*Stipa capensis* in Kassarah site and *Salsola tetrandra, Astragalus Siberi* and *Zilla spinosa* along International Highway). The yearly variation in the demographic variables indicated that 2006 and 2008 had the maximum natality for all species, while 2004 had the maximum mortality. The size distribution at the end of the monitoring period indicated that the invaded species may approximate J-shape, stationary or inverse J-shaped size distributions. The number of individuals along the International Highway decreased from 2006 to 2008, but the individual dimensions (That is, size) increased for some species and decreased for another. The present study suggested that, carrying out long-term studies and monitoring on the vegetation and the invaded species of the International Highway and its surrounding habitats, especially Kassarah site (That is, conservation of biodiversity).

Key words: Invasive plants, demography, natality, mortality, size distribution.

INTRODUCTION

Invasions by alien plant species are causing major conservation problems in many regions of the world and are viewed as an important component of human caused global change (Vitousek et al., 1997). Results of the spread of alien plant species include the loss of biodiversity (Lodge, 1993; Huston, 1994), changes in disturbance regime (Van Wilgen and Richardson, 1985; D'Antonio and Vitousek, 1992) and the creation of new landscapes (Atkinson and Cameron, 1993; Vitousek et al., 1997). In most instances, the spread of alien species (invasion) is associated with the consequences of human activities, e.g. disturbance, fragmentation, urbanization, cropping and the use of alien plants for landscaping and erosion control (Vilà et al., 1999).

The success of an alien species depends on the degree of invasiveness, that is, the potentiality to establish and spread (Rejmanek and Richardson, 1996). A few simple biological attributes can be strong predictors of potential invasiveness of a species (Rejmanek, 2000). Plant height, relative growth rate and seed mass, as indicators of both the establishment and regenerative phases of the life cycle (Hodkinson and Thompson, 1997), are the most relevant traits that address competitive ability (Westoby, 1998; Hodgson et al., 1999; Leishman, 1999).

A full understanding of the invasion process requires information on the ecological attributes of the alien species as well as on the susceptibility of habitats to be invaded (Roy, 1990). Before detailed investigations on the ecological relationship between invader and invaded habitats can take place, information on the extent of naturalized species is needed. The composition and distribution of naturalized floras are fairly well documentted at the regional scale for European countries (Di Castri, 1990; Weber, 1997), while there is a lack of quantitative information on naturalized plants for major regions of the world, especially for those of Asia and Africa (Vilà et al., 1999). Floras of these regions are not existent or are incomplete, making it difficult to assess both native and alien plant diversity. There is an urgent need to have data on the distribution of native and alien species in order to perform a risk assessment of plant invasions (Cronk and Fuller, 1995). A global perspective of biological invasions needs to incorporate the distribution of alien species in these countries (Lonsdale, 1999).

The distribution and abundance of a plant species within a particular climatic zone is determined by environmental factors, especially soil conditions, interactions with other species and dispersal. To a large extent, the mechanisms through which the abundance and distribution of a species determined are demographic, that is, the birth and death of individuals. Survivorship and fecundity appear to be primarily determined by the size and the developmental stage, rather than age, of individuals within a plant population (Silvertown, 1981). Thus the status of a plant population will be reflected by its density and size or stage structure. Comparisons of the size/stage structure of populations of a species in different localities may provide an insight into the relationship between the species and the communities in which it lives (Weiner and Corlett, 1987).

Many studies on plant invasion have focused on the life history traits responsible for the invasive nature of a species (Roy, 1990; Rejmánek and Richardson, 1996), while others have examined the invasibility of habitats and communities (Lonsdale, 1999; Levine and D'Antonio, 1999). Recently, several authors have proposed the hypothesis that the successful establishment of an alien species depends on complex interactions between the species and its target community, so that biological invasions are essentially context-specific processes (Levine, 2000; Alpert et al., 2000). The implication of this theory is that small differences in the life-history traits of certain species, such as germination, establishment ability, length of the juvenile period (Rejmánek and ability, length of the juvenile period (Rejmánek and Richardson, 1996; Dietz et al., 1999) and competitive ability (Thébaud et al., 1996), may interact with habitat characteristics to produce distinct distribution and abundance patterns throughout a new range. There is considerable evidence that the emergence and establishment of plant invaders are generally favoured when communities are subject to disturbance (Burke and Grime, 1996). Moreover, disturbance can produce nutrient enrichment or a release of resources in the disturbed habitat, thus favouring the proliferation of the invading species (Davis and Pelsor, 2001). Most exotic species grow in disturbed and nutrient rich ecosystems (Meiners et al., 2002).

Lake Burullus and its surroundings are subjected to ecological constraints that relate to excessive use of resources. One of these constraints is the construction of the International Highway that runs along the sand bar. This Highway connects Sallum (at the Libyan border) with Rafah (at the Palestinian border), and traverses Burullus Wetland from east to west for a distance of 47 km. This highway is rapidly attracting new populations and settlements, the environmental impacts due to the increase of human activities along its sides are not properly assessed. The tools (machines) and materials (e.g. gravel, sand, fuel oil and concrete), that are used for its construction were stored in the western part of the sand bar (Kassarah site).

This paper aims in evaluating the extent of the new invaded species in Burullus Wetland and in studying the demography of the populations of these species in terms of size structure, natality, mortality, survival and demographic flux. Such type of study helps in understanding the invasive ability of these species in this area, which consequently helps in managing their populations in the wetland. The questions addressed are: 1- How many invaded plant species does Burullus Wetland have?, 2- What is the Egyptian geographical origin of these species?, 3- Which population can be established and which can be excluded in this area?, and 4- Which population can't be adapted?.

MATERIALS AND METHODS

Study site

Burullus Wetland is located along the Mediterranean Deltaic coast. It lies at a central position between the two branches of Nile: Damietta to the east and Rosetta to the west. Its coordinates are 31° 36' N and 30° 33' E in north - west, 31° 36' N and 31° 07' E in the north - east, 31° 22' N and 30° 33' E in the south - east, 31° 22' N and 31° 07' E in the south - east. It has a total area of 460 km^2, which includes the entire area of Lake Burullus with a shoreline of about 65 km. The study site lies in the western part of Burullus Wetland and called Kassarah site, its coordinates are: 31° 28' 33'' N and 30° 38' 79'' E (Figure 1) and has an area of about 4000 m^2 (200 X 200 m). The habitat of Kassarah site is sand sheets which cover vast area of the marine bar particularly along the North-western margins of the lake. These sheets have a few undulations and sometimes form the so called "sand ripples". They are dominated by halophytes including *Halocnemum strobilaceum, Phragmites australis, Arthrocnemum macrostachyum*, *Zygophyllum album* and *Salsola kali* (Al-Sodany, 1992; 1998; El-Kady et al., 2000). Another part of the study area is the International Coastal Highway which transverses Burullus Wetland from the east to the west.

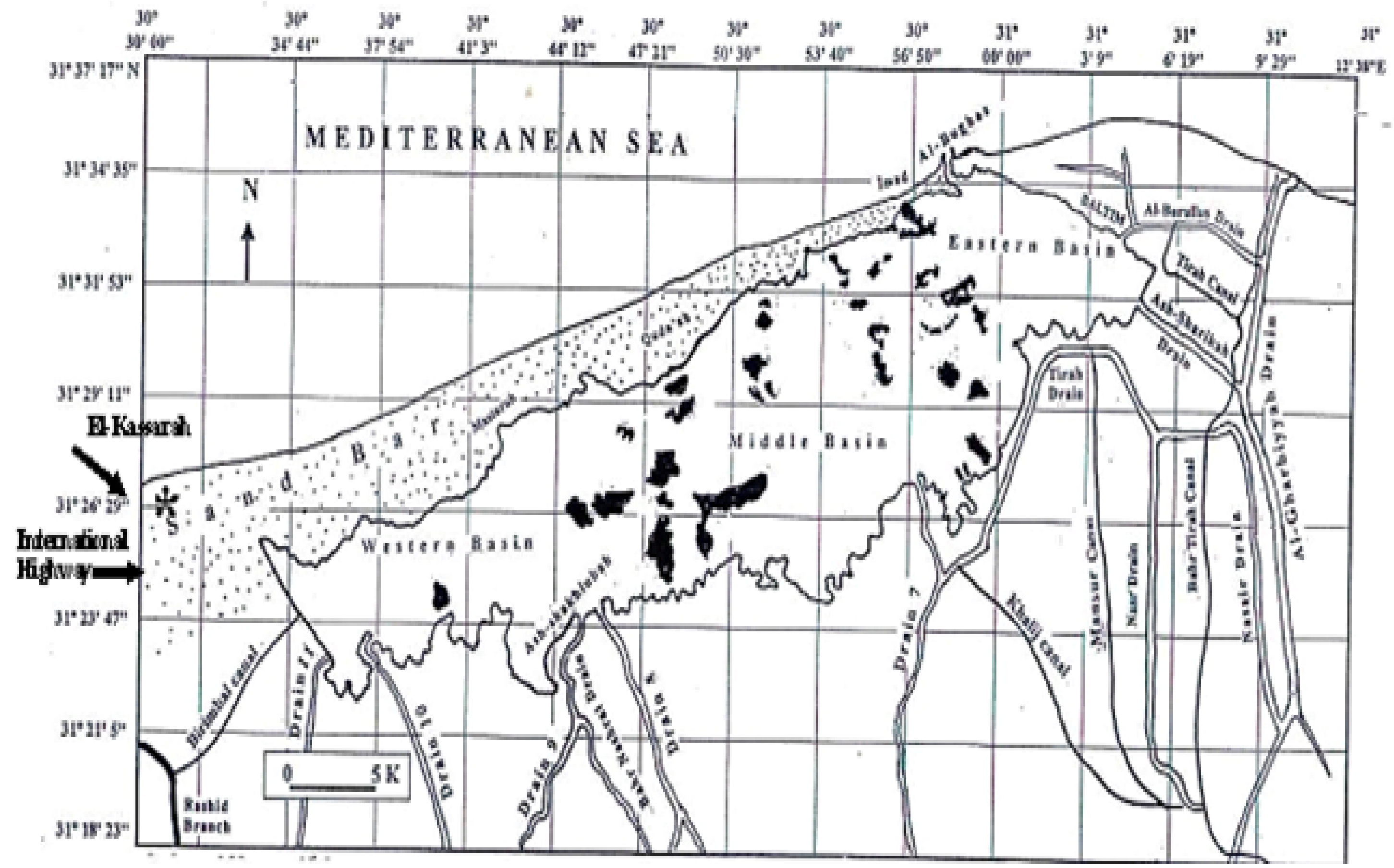

Figure 1. Map of the Burullus wetland showing the international highway and Kassarah site (*).

Table 1. Long-term averages (≥ 20 years) of the climatic records of two stations within Burullus Wetland (Anonymous 1980).

Metereological variable	Rosetta 31° 24' N, 30° 25' E		Baltim 31° 33' N, 31° 05' E	
	Range	Mean	Range	Mean
Maximum air temperature (℃)	18.1 - 30.4	24.6	17.4 - 29.7	24.0
Minimum air temperature (℃)	10.8 - 23.4	17.0	11.2 - 23.6	17.3
Mean air temperature (℃)	13.0 - 26.3	19.8	14.4 - 26.5	20.5
Relative humidity (%)	65.0 - 72.0	69.0	65.0 - 73.0	69.0
Evaporation (mm/day)	3.3 - 4.8	4.2	3.3 - 5.6	4.6
Rainfall (mm/month)	0.0 - 50.3	---	0.0 - 46.6	---

According to the map of the world distribution of arid regions (UNESCO, 1977), the northern Mediterranean part of the Nile Delta belongs to the arid region. The climatic conditions are warm summer (20 to 30℃) and mild winter (10 to 20℃). The aridity index (P/PET: where P is the annual precipitation and PET is the potential evapo-transpiration) ranges between 0.03 and 0.2 at the north Delta (arid region), and less than 0.03 at the south (hyperarid region). Long term climatic averages of two meteorological stations distributed within the study area are presented in Table 1 (Anonymous, 1980).

Demographic measurements

The invaded plants were distributed on about 200 m^2 (20 X 100 m) in Kassarah site (about 20% of its total area). This site and the International Highway were visited yearly for monitoring the new invaded species from 2001 to 2008. The population structure of these species was evaluated in terms of size distribution. For achieving this, the height from the ground (H) and the average diameter (D) of the canopy (based on three measures) for each individual in the whole site were estimated yearly. The size index of

Table 2. Characteristics of the new recorded species in Burullus Wetland. The life forms are: Ph: phanerophytes, Ch: chamaephytes, He: hemicryptophytes and GH: geophytes-helophytes. The global distribution are: ME: Mediterranean, SA: Saharo-Arabian, SU: Sudanian, ES: Euro-Sibarian, IT: Irano-Turanian and IN: Indian. The national distribution. Nd: Nile Delta, Nv: Nile Valley, Nf: Nile Faiyum, O: Oases of the Libyan desert, Mm: western Mediterranean coastal region, Mp: eastern Mediterranean coastal region, Da: Arabian desert, Di: Isthmic desert, D1: Libyan desert, R: Red sea coastal region, GE: Gebel Elba and surrounding mountains, and S: Sinai proper.

species	Family	Life form	Distribution	
			Global	National (after Täckholm 1974)
Artemisia monosperma Delile	Compositae	Ch	SA	Mm, Mp, Di, D1, S
Astragalus sieberi DC.	Leguminosae	Ch	ME + SA	Da, Di, S
Astragalus spinosus (Forssk.) Muschl.	Leguminosae	Ch	SA + IT	Mm, Di, D1
Convolvulus lanatus Vahl	Convolvulaceae	Ch	SA	Mm, Mp, Da, Di, D1, S
Cornulaca monacantha Delile	Chenopodiaceae	Ch	SA + SU + IN	Mm, Da, Di, D1, R, S
Deverra tortuosa (Desf.) DC.	Umbelliferae	Ch	SA	O, Mm, Mp, Da, Di, D1, R, S
Panicum turgidum Forssk.	Gramineae	GH	SA + SU	Nd, Nv, O, Mp, R, GE, S
Retama raetum (Forssk.) Webb & Berthel	Leguminosae	Ph	ME + SA+IT	Mm, Mp, Di, D1, S
Salsola tetrandra Forssk.	Chenopodiaceae	Ch	SA	O, Mm, Mp, Di
Stipa capensis Thunb.	Gramineae	He	ME + IT + ES	Nd, Nv, Mm, Mp, Da, Di, D1, R, GE, S
Thymelaea hirsuta (L.) Endl.	Thymellaeaceae	Ph	ME + SA	Mm, Mp, Da, Di, D1, S
Zilla spinosa (Turra) Prantl	Cruciferae	Ch	SA	Nv, Mp, Da, Di, D1, S
Zygophyllum coccineum L.	Zygophyllaceae	Ch	SA	Da, Di, R

each individual was calculated as the average of its height and diameter [(H+D)/2]. The size index estimates were then used to classify the population into 3 size classes: the first class (<25 cm for shrublets and <50 cm for shrubs) was chosen to represent the seedling and juvenile stages. The mean individual height, diameter, size index and height to diameter ratio of the invaded species for each year were then calculated.

At the start of the observation process, a map was drawn indicating the spatial distribution of individuals of each species. Each year, the emerged sprouts were recorded in each stand and added to the map. The means of sprout natality (the percentage of new sprouts in relation to the total number of sprouts), mortality (the percentage of dead sprouts in relation to the total number of sprouts) and survival (the number of sprouts present at the end of the year as a percent of the total number of sprouts) were calculated yearly. The estimation of annual change or demographic flux (Fr) occurring in each population is calculated according to Peter, 1980 (cf. Shaltout and El- Beheiry, 1997):

$$Fr = (N - M) / (N + M) = \text{change / flux}$$

Where N is the number of established individuals (natality) and M is the number of dead individuals (mortality) in the permanent site of study. The increase/decrease ratio (demographic flux: Fr) varies from 1.0 when there is sprouting and no mortality, to - 1.0 when there is mortality and no sprouting, with 0.0 value when mortality and natality are equal.

RESULTS

Thirteen species were recorded for the first in Burullus Wetland, during the period from 2001 to 2008 (Table 2): 2 phanerophytes (*Thymelaea hirsuta* and *Retama raetum*), 9 chamaephytes (*Artemisia monosperma*, *Astragalus sieberi*, *Astragalus spinosus*, *Convolvulus lanatus*, *Cornulaca monacantha*, *Deverra tortuosa*, *Salsola tetrandra*, *Zilla spinosa* and *Zygophyllum coccineum*), one geophytes (*Panicum turgidum*) and one hemicryptophytes (*Stipa capensis*). At Kassarah site: four species were recorded in 2001 till 2008 (*C. lanatus, A. monosperma*, *C. monacantha* and *P. turgidum*), while three species were recoded in 2006 till 2008 (*T. hirsuta*, *A. spinosus* and *D. tortuosa*). *S. capensis* was recoded only in 2003 and can't be adapted in the study area. The number of individuals for some species was decreased, during the monitoring period (2001 - 2008), such as *C. lanatus* (59 - 5 ind.), while those of *A. monosperma, P. turgidum* and *T. hirsuta* were increased (1 - 38, 1 - 5 and 0 - 5 ind., respectively).

On the other hand, two species (*A. spinosus* and *D. tortuosa*) had the same number of individuals during this period (one and 3 ind., respectively). Generally, the 2004 had the lowest number of individuals for all species, where the total number of individuals for all species was 13 ind. (Figure 2).

The yearly variation in natality (Figure 3) indicates that 2006 had the maximum natality for *A. monosperma, P. turgidum* and total species (80.8, 40.0 and 50.0%, respectively), while 2008 had the maximum natality for *C. monacantha* and *T. hirsuta* (50.0% and 60.0%). Generally, 2004 had the maximum mortality for all species (69.7%), while 2006 and 2008 had the lowest mortality (0.0 and 14.5%). The maximum sprout survival was during 2006 for all species except that of *A. monosperma* which had its maximum value in 2008 (47.4%). The maximum adult survival for total species was in 2001, 2003 and 2008 (82.4, 79.2 and 58.1%, respectively) and

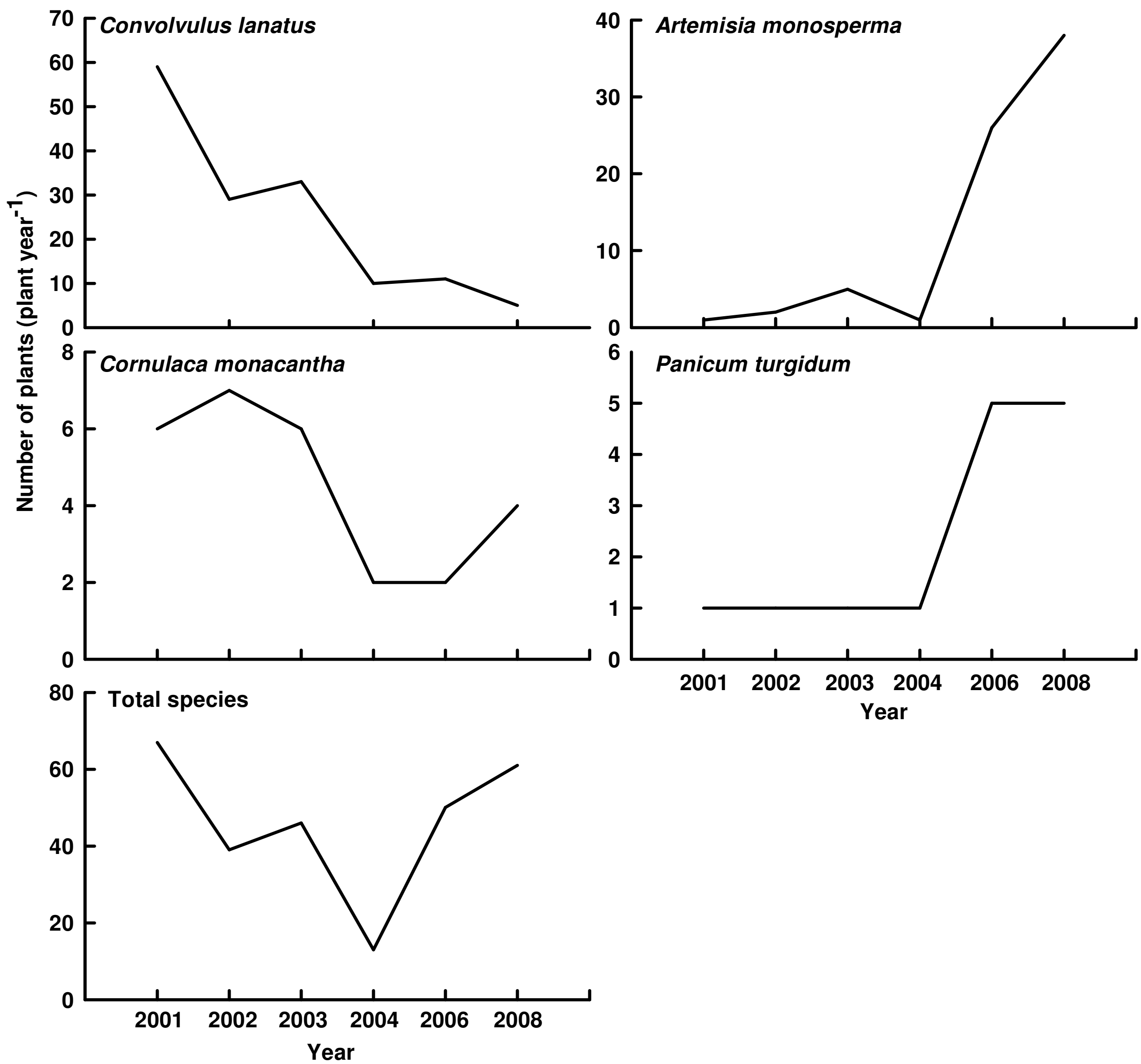

Figure 2. Variation in the number of the new invasive species at Kassarah site in Burullus wetland during the period from 2001 to 2008.

and the minimum was in 2004 (30.4%). *C. lanatus* had negative values of demographic flux as a result of the increasing mortality and decreasing natality in 2002, 2004 and 2008;, while *A. monosperma* and *C. monacantha* had their negative values of demographic flux in 2004. *P. turgidum* had the maximum value as it was the only species without sprout and adult mortalities during the monitoring period (Figure 4).

The size distribution at the end of the monitoring period (2008) approximated the J-shape towards the relative preponderance of the big individuals for *C. monacantha*, *P. turgidum*, *A. spinosus* and *D. tortuosa*, while that of *A. monosperma* had approximately stationary size distribution. On the other hand, the size distribution of *C. lanatus* and *T. hirsuta* had approximately inverse J-shape towards the relative preponderance of the small individuals (Figure 5).

In general, there was a continuous increase in the height, diameter and size index from the beginning of monitoring period in 2001 to its end at 2008 at Kassarah site (Table 3). *C. lanatus* had the lowest height, diameter and size index: its ranges from 2001 to 2008 were 7.8 - 29.4, 7.8 - 67.9 and 7.8 - 48.7 cm, respectively. While *P. turgidum* had the highest ones: its ranges were 118.0 - 120.4, 289.7 - 303.7 and 203.8 - 212.0 cm, respectively. On the other hand, the height to diameter ratio decreased for all species from 2001 to 2008 except that of *A. monosperma* and *P. turgidum*. Generally this ratio decreased than one for all the invaded species. The two-way ANOVA indicated that all the dimension variables had highly significant variations ($P < 0.01$) in relation to plant species, monitoring years and interaction between them, except that of interaction between them for height to diameter

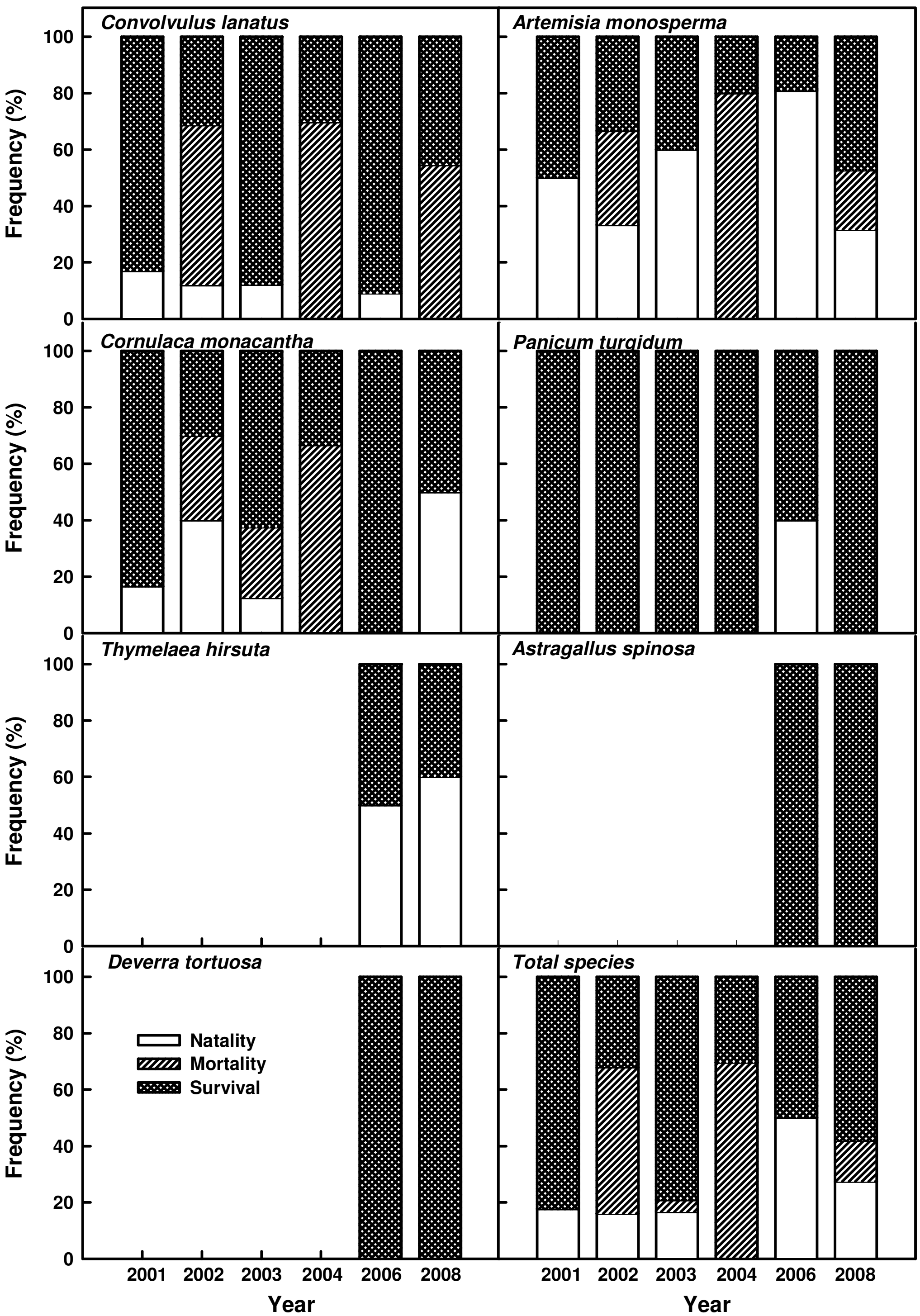

Figure 3. Variation in the natality, mortality and survival of the new invasive species at Kassarah site in Burullus wetland during the period from 2001 to 2008.

ratios (P > 0.05).

Regarding the International Highway: ten species were recorded in 2006 (*C. lanatus, A. monosperma*, *C. monacantha*, *P. turgidum*, *T. hirsuta*, *Z. coccineum, S. tetrandra, A. Siberi, Z. spinosa* and *Retama raetam*).

Three species of them were disappeared in 2008 (*S. tetrandra, A. Siberi* and *Z. spinosa*). Generally, the number of individuals decreased from 2006 to 2008 for all invaded species (Table 4), but the dimensions increased for some species (*C. lanatus, A. monosperma*, *C.* others

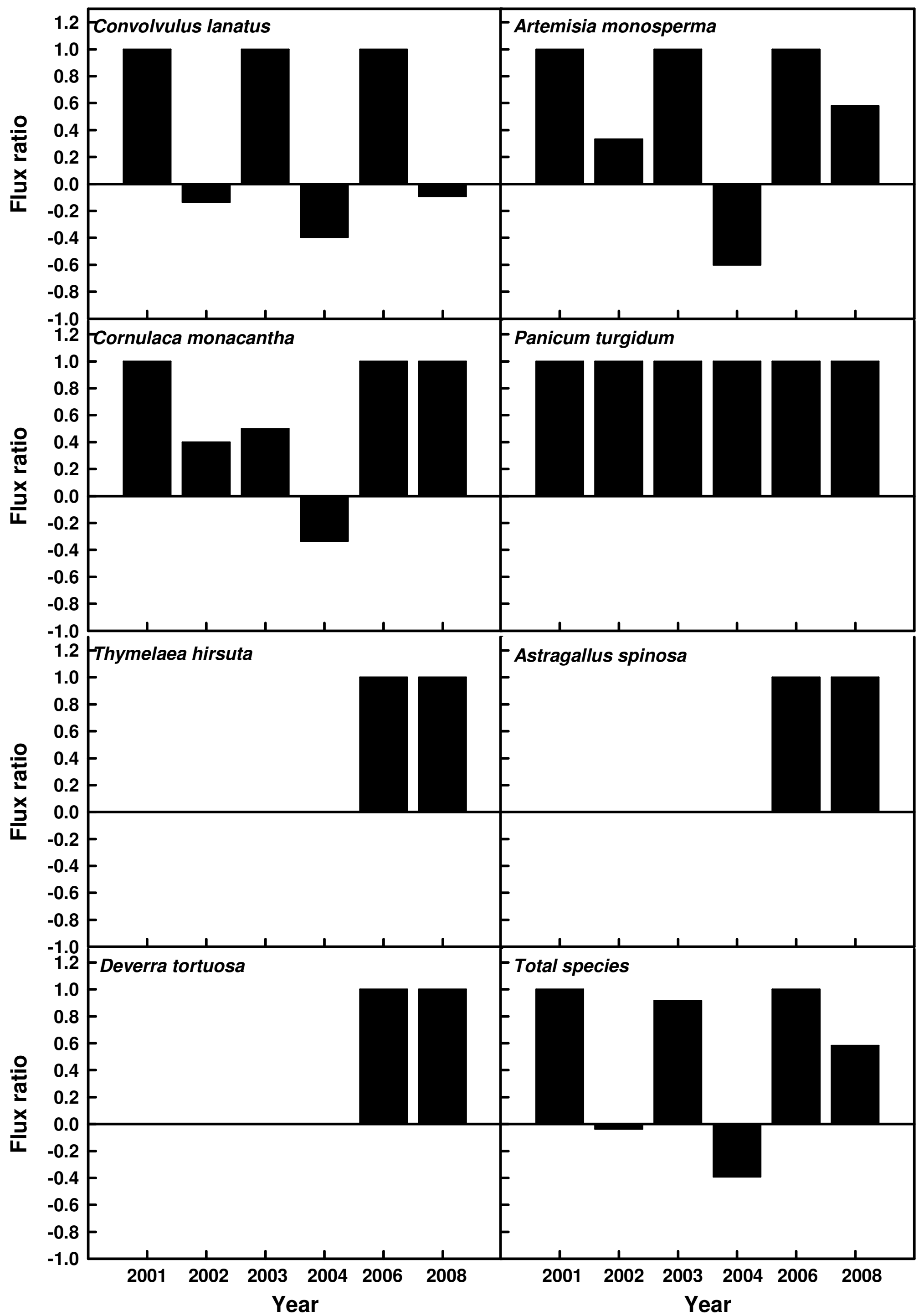

Figure 4. Variation in the demographic flux (Fr) of the new invasive species at Kassarah site in Burullus wetland during the period from 2001 to 2008.

monacantha and *T. hirsuta*) and decreased for some (*P. turgidum*, *Z. coccineum* and *R. raetam*). The two-way ANOVA indicated that all the dimension variables had highly significant variations ($P < 0.01$) in relation to plant species and monitoring period.

DISCUSSION

Changes in the floristic composition due to human disturbances (Abbott et al., 2000; Felfili et al., 2000; Ruhan et al., 2001) and/or climatic changes (Medina, 2003;

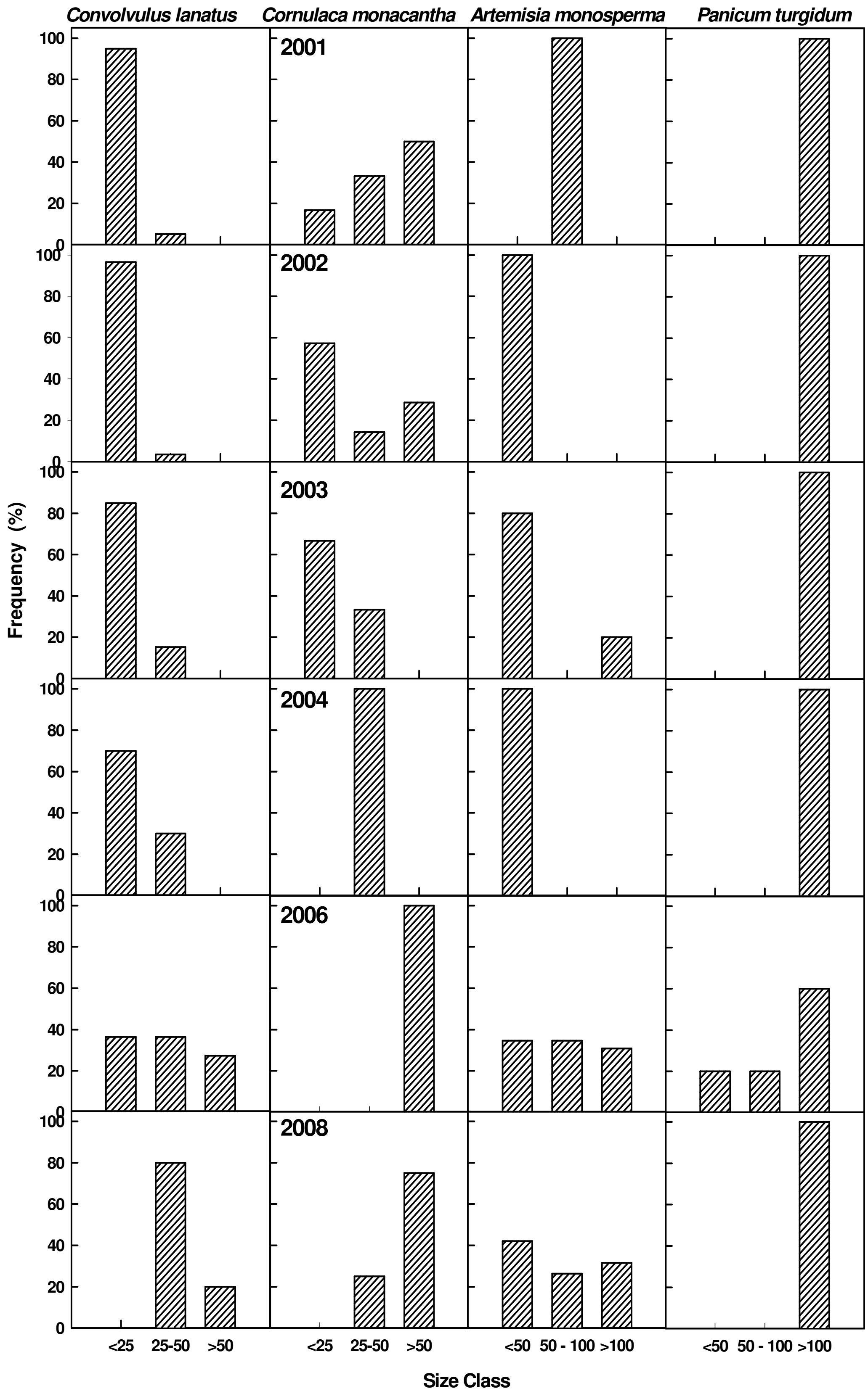

Figure 5. Size frequency distribution for the population of the new invasive species at Kassarah site in Burullus protected area.

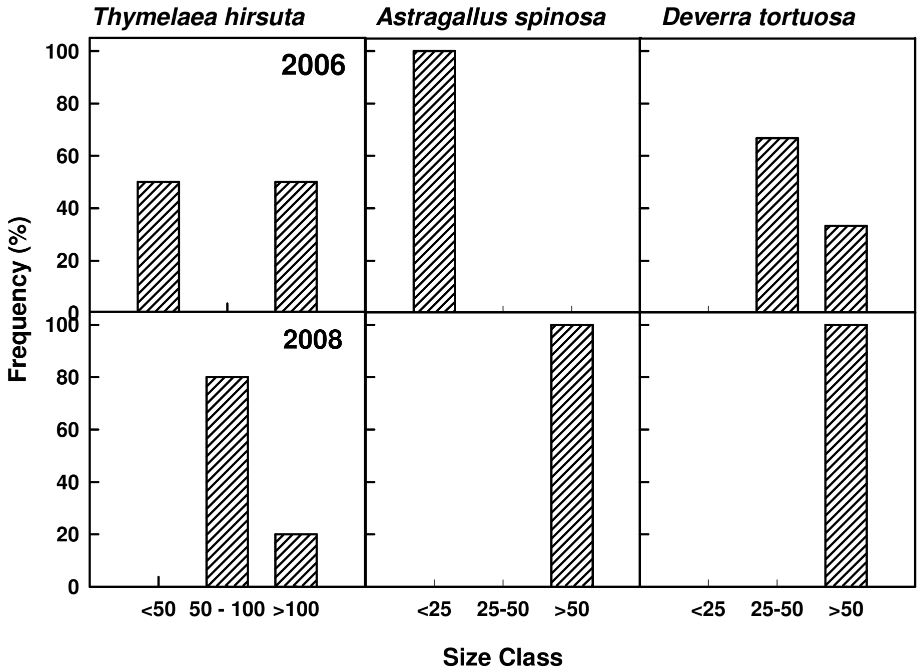

Figure 5. Continued.

Anenkhonov and Krivobokov, 2006) have been documented worldwide. In Egypt, the floristic composition of many regions have been changed due to human disturbances such as North Sinai (Kamal et al., 2008), South Sinai including Saint Catharine Protectorate (Moustafa et al., 1999, 2001), Western Mediterranean region including Omayed Biosphere Reserve (Shaltout and Al-Sodany, 2002; Kassas et al., 2002a), Red Sea Coast (Sheded and Shaltout, 1998; Shaltout et al., 2003), Nile Delta (Ahmed, 2003) and Mediterranean coast of Nile Delta including Burullus Wetland (Al-Sodany, 2006; Shaltout et al., 1995; Shaltout and Al-Sodany, 2008). Al-Sodany (2006) indicated that the vegetation of the Burullus Wetland had 29 species which seem to be the new record to this region due to the movement of trucks on the constructed International Highway which transfer the seeds of these species with sand and gravels used in the construction of this highway. Although pristine arid environments appear to be unfavorable for the establish-ment of alien species, disturbed arid ecosystems can be very sensitive to changes caused by established alien species (Brock and Farkas, 1997). In addition, riparian habitats within arid regions are often seriously invaded by alien trees and shrubs (Loope et al., 1988; Stromberg et al., 1997). In arid environments, alien species can cause strong ecological changes such as changes in fire frequency and intensity (Schmid and Rogers, 1988). In the present study, 13 perennial species were recoded in the last 8 years: four species were recoded for the first time at Kassarah site, which has sand and gravels used for paving of this highway, in 2001 and were established to 2008 and 9 species were recoded in 2006 at Kassarah and International Highway; five of them were established themselves to 2008. These species may be adapted and established in this region. On the other hand, four species can't be adapted in this region (*Stipa capensis* in Kassarah site and *S. tetrandra, A. Siberi* and *Z. spinosa* in International Highway).

The national geographical distribution of the recorded species indicated that only two species were previously recorded in Nile Delta (*P. turgidum* and *S. capensis*: Täckholm, 1974). Many species were restricted to the Mediterranean coastal strip from Sallum to Rafah and Sinai such as *C. lanatus, D. tortuosa, A. monosperma, R. raetum, T. hirsuta* and *Z. spinosa*. On the other hand, some other species were restricted to the western Mediterranean coastal region such as *A. spinosus* and *C. monacantha*, while others are restricted to the eastern Mediterranean coastal region such as *Z. spinosa.* Two of the recorded species were not previously recorded in the Mediterranean or Nile Delta (*Z. coccineum* and *A. sieberi).* The movement of truck, from east to west and vice versa and the constructing materials interpret the appearance of these species in this area. Similar conclusions were made by Al-Sodany (2006).

In fact, it is expected that population dynamics will vary from year to year, since it has been shown that demographic variation through time, especially in the desert, where weather conditions may vary dramatically from one year to the next (Golubov et al., 1999). Yet, the studied population in the present study showed an interesting biological features in the study area, such as the high

Table 3. Mean of the dimensions of the new invasive species on Kassarah site in Burullus wetland during the period from 2001 to 2008. sp: species, yr: year, *: P ≤ 0.05, **: P≤ 0.001, ***: P ≤ 0.001.

Species	Year	No. of Plants	Height (cm)	Diameter (cm)	H/D	Size index (cm)
	2001	59	7.8 ± 5.2	7.8 ± 8.5	1.57 ± 1.18	7.8 ± 6.7
	2002	29	4.5 ± 4.3	9.7 ± 11.2	0.56 ± 0.41	7.1 ± 7.6
	2003	33	12.3 ± 7.0	15.5 ± 14.4	1.51 ± 1.61	13.9 ± 10.1
Convolvulus lanatus	2004	10	11.1 ± 4.1	26.3 ± 15.6	0.76 ± 0.91	18.7 ± 9.2
	2006	11	18.8 ± 8.9	55.5 ± 31.9	0.40 ± 0.16	37.2 ± 20.1
	2008	5	29.4 ± 9.1	67.9 ± 16.9	0.44 ± 0.13	48.7 ± 11.8
	2001	1	46.0 ± 0.0	90.7 ± 0.0	0.51 ± 0.00	68.3 ± 0.0
	2002	2	13.0 ± 11.3	39.0 ± 43.8	0.46 ± 0.23	26.0 ± 27.6
	2003	5	53.6 ± 16.7	48.8 ± 49.6	1.56 ± 0.68	51.2 ± 33.0
	2004	1	43.0 ± 0.0	33.7 ± 0.0	1.28 ± 0.0	38.3 ± 0.0
Artemisia monosperma	2006	26	48.0 ± 23.2	98.0 ± 64.1	0.70 ± 0.50	73.0 ± 42.0
	2008	38	41.1 ± 21.7	95.7 ± 72.1	0.82 ± 0.82	68.4 ± 45.6
	2001	6	28.8 ± 10.3	58.9 ± 26.7	0.55 ± 0.17	43.9 ± 18.4
	2002	7	12.0 ± 9.4	32.2 ± 34.1	0.65 ± 0.35	22.1 ± 21.7
	2003	6	14.3 ± 5.9	32.0 ± 21.6	0.50 ± 0.13	23.2 ± 13.6
	2004	2	14.5 ± 3.5	62.5 ± 27.6	0.24 ± 0.05	38.5 ± 15.6
Cornulaca monacantha	2006	2	41.5 ± 16.3	127.5 ± 79.0	0.45 ± 0.41	84.5 ± 31.4
	2008	23	31.8 ± 13.1	109.3 ± 53.6	0.33 ± 0.17	70.5 ± 27.5
	2001	1	118.0 ± 0.0	289.7 ± 0.0	0.41 ± 0.00	203.8 ± 0.0
	2002	1	125.0 ± 0.0	287.3 ± 0.0	0.44 ± 0.00	206.2 ± 0.0
	2003	1	135.0 ± 0.0	291.7 ± 0.0	0.46 ± 0.00	213.3 ± 0.0
Panicum turgidum	2004	1	97.0 ± 0.0	120.7 ± 0.0	0.80 ± 0.00	08.8 ± 0.0
	2006	5	75.0 ± 38.4	157.8 ±108.2	0.55 ± 0.15	116.4 ± 70.1
	2008	9	120.4 ± 32.2	303.7 ± 80.9	0.40 ± 0.08	212.0 ± 52.7
Thymelaea hirsuta	2006	2	43.5 ± 47.4	83.2 ± 102.1	0.70 ± 0.29	63.3 ± 74.7
	2008	5	40.4 ± 27.4	82.6 ± 91.2	0.64 ± 0.24	61.5 ± 59.1
Astragalus spinosa	2006	1	17.0 ± 0.0	26.7 ± 0.0	0.64 ± 0.00	21.8 ± 0.0
	2008	1	44.0 ± 0.0	75.3 ± 0.0	0.58 ± 0.00	59.7 ± 0.0
Deverra tortusa	2006	3	24.7 ± 11.6	46.6 ± 14.7	0.53 ± 0.17	35.6 ± 12.5
	2008	3	44.7 ± 6.8	75.4 ± 3.2	0.59 ± 0.07	60.1 ± 4.8
Stipa capensis	2003	1	25.0 ± 0.0	27.0 ± 0.0	0.93 ± 0.00	26.0 ± 0.0
	sp	---	95.09|***	56.38***	3.17**	70.40***
F-Value	yr	---	3.44**	7.05***	7.11***	6.02***
	sp*yr	---	3.54***	2.68***	0.58	2.92***

resistance of seeds and seedlings to the harsh conditions that characterize arid ecosystems, the dependence of population growth rate on the survival and growth of intermediate and large adults, and the apparent ability of the population to take advantage of favourable environmental conditions (That is, presumably those prevailing during the study period) by achieving a high population growth rate during these intervals. These ecological characteristics may be in part responsible for the pioneer habit of some species such as *C. lanatus, A. monosperma*, *C. monacantha*, *P. turgidum*, *T. hirsuta*, *A. spinosus*, *D. tortuosa*, *Z. coccineum* and *R. raetam*, which are capable of colonizing empty spaces and acting as a nurse plant for other species. Another important characteristic in this respect is the high survival rates of adult plants. For instance, none of the adult individuals sampled in the present study died within the study period. According to our observations, mortality is size-dependent and reaches very small values once individuals reach the juvenile stage, which may be related to the fact that by this time they may have developed a deep and robust root system. Even if plants are grazed or cut for firewood, they may resprout and retain their vigour (unless the damage is too intense), thus contributing to the high survival probability of adults (Jime´nez-Lobato and Valverde, 2006). Despite these potential mortality

Table 4. Mean and standard deviation of the dimensions of the new invasive species along the International Highway in Burullus wetland in 2006 and 2008. Sp: species, yr: year, *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001.

Species	Year	No. of Plants	Height (cm)	Diameter (cm)	H/D	Size index (cm)
Convolvulus lanatus	2006	18	33.3 ± 10.0	76.2 ± 31.9	0.54 ± 0.38	54.8 ± 20.0
	2008	6	40.7 ± 11.3	107.3 ± 20.0	0.39 ± 0.11	74.0 ± 12.3
Artemisia monosperma	2006	9	84.2 ± 39.3	148.2 ± 95.4	0.62 ± 0.18	116.2 ± 65.8
	2008	8	109.3 ± 46.8	239.2 ± 85.2	0.48 ± 0.13	174.2 ± 64.0
Cornulaca monacantha	2006	2	83.5 ± 5.0	175.2 ± 18.2	0.48 ± 0.08	129.3 ± 6.6
	2008	1	88.0 ± 0.0	188.3 ± 0.0	0.47 ± 0.0	138.2 ± 0.0
Panicum turgidum	2006	1	93.0 ± 0.0	109.0 ± 0.0	0.85 ± 0.0	101.0 ± 0.0
	2008	1	90.0 ± 0.0	57.7 ± 0.0	1.6 ± 0.0	73.8 ± 0.0
Thymelaea hirsuta	2006	35	41.1 ± 30.8	70.5 ± 63.2	0.83 ± 0.45	55.8 ± 46.5
	2008	8	63.8 ± 39.0	122.8 ± 65.9	0.56 ± 0.20	93.3 ± 46.6
Zygophyllum coccineum	2006	4	67.8 ± 20.3	214.2 ± 92.3	0.34 ± 0.10	141.0 ± 55.8
	2008	1	67.0 ± 0.0	208.0 ± 0.0	0.32 ± 0.0	137.5 ± 0.0
Salsola tetrandra	2006	1	130.0 ± 0.0	300.0 ± 0.0	0.43 ± 0.0	215.0 ± 0.0
	2008	0	---	---	---	---
Astragalus Siberi	2006	2	42.0 ± 8.5	151.3 ± 9.9	0.28 ± 0.1	96.7 ± 0.7
	2008	0	---	---	---	---
Zilla spinosa	2006	1	95.0 ± 0.0	200.3 ± 0.0	0.47 ± 0.0	147.7 ± 0.0
	2008	0	---	---	---	---
Retama raetam	2006	1	43.0 ± 0.0	120.0 ± 0.0	0.36 ± 0.0	81.5 ± 0.0
	2008	1	40.0 ± 0.0	107.0 ± 0.0	0.37 ± 0.0	73.5 ± 0.0
F-Value	sp	---	6.17***	7.04***	2.94**	6.78***
	yr	---	4.15*	8.36**	3.72*	7.31**
	sp*yr	---	0.36	0.81	0.71	0.66

sources, large/old individuals appear to have high survival probabilities and to be very long-lived. In addition to resprouting, some species such as *P. turgidum* may propagate vegetatively, producing ramets from rhizomes. Our field observations suggest that ramet production could be more common in relatively more disturbed conditions (e.g. with higher soil erosion levels), which may be responsible for active vegetative spread under these circumstances (Radford et al., 2002). This highlights the importance of addressing clonal propagation in semi-desert shrubs and trees in order to fully understand their population dynamics.

The spatial structure and distribution of plants are influenced by the efficiency of seed dispersal and the subsequent seed recruitment. The spatial structure of plants is also influenced by the dynamics of the individuals. However, in the present study mortality rates of some plant populations seems to be related to the crown size, since high rates of mortality were recorded among small plants. However, a small size might be insufficient to withdraw the environmental and human stresses, since an important decrement was evident among large size individuals, too. The population dynamics and regeneration capacity of any plant species depends on a variety of biotic and physical factors (Shaltout, 1983). Gray (1975) reported that, topography, plantage, relative abundance of the plants, frequency and abundance of rainfall are among the important variables to be accounted for in attempting to quantify the regeneration capacity of species. The present study reported that, the variation in population natality varied in relation to time.

The structure of plant population can be assessed in terms of the ages, sizes and forms of the individuals that compose it (Lusk, 2003; Witt, 2004) and are functions of recruitment, growth, and mortality (Baker and Wilson, 2003), which were not differentiated by Kelly et al. (2001) or Kelly and Bowler (2002). The present study indicated that the size structure of some species (*C. lanatus* and *T. hirsuta*) had approximately inverse J-shape curves. The recruitment decline observed in our site, as evidenced by the relatively lower number of young individuals, could be speculated as a result of an undocumented increase in seed predation (e.g. migration birds) or seedling mortality, or conditions inhibiting germination of seeds, for example, lack of dormancy-breaking factors. Similar patterns occurred in the study of Srinivasan and Shenoy (2007) in the grassland sites. Such distributions may indicate also a high juvenile mortality (Harper, 1977), but nevertheless, they seem to represent long-term stability, since in most stable populations one would except an excess of juvenile over mature individuals (Shaltout and Ayyad, 1988). On the other hand, the J-shaped distribution of *C. monacantha*, *P. turgidum*, *A. spinosus* and *D. tortuosa* indicated the dominance of mature individuals over the juvenile ones. This distribution characterizes the declining populations, because the population has a large proportion of larger individuals than the smaller ones (That is, limited regeneration capacity). This may indicate that the recruitment of this species is rare which may be related to hyperaridity and low soil fertility.

In Burullus Wetland, the management plan had been done in 2002 and including five main long-term objectives (Kassas et al., 2002b; Shaltout et al., 2005):

1. To restore pristine ecological and landscape values.
2. To maintain and enhance ecological and landscape values.
3. To conserve the Burullus resources through sustainable management.
4. To improve socio-economic opportunities for local people.
5. To develop public awareness for nature conservation.

The second one includes six operational objectives:

1. Propose a scheme of zonation.
2. Take *in situ* measures of species conservation.
3. Initiate *ex situ* conservation measures.
4. Establish a system of data management.
5. Monitor species diversity.
6. Initiate a programme of research.

The present study hoped to activate these objectives in the next years and concluded that, given paucity of long-term studies on the vegetation of the International High-way and its surrounding habitats, especially Kassarah site, and the continuation of vegetation monitoring in Burullus Protected Area are justified and should provide valuable long-term information. Furthermore, the conti-nuation of vegetation monitoring is imperative to assess the most important objective of vegetation changes, that is, conservation of biodiversity. In addition, the invaded species may be also established in surrounding areas and will continue to be dispersed into the whole area of Burullus Protectorate. Since most alien plants probably cannot be eliminated in that area, follow-up maintenance treatments may be required indefinitely.

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