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The importance of dredge islands for breeding waterbirds. A three-year study in the Venice Lagoon (Italy)

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ABSTRACT

Since 1989, intertidal dredge islands have been constructed in the Venice Lagoon using sediments originating from regular dredging of lagoon channels and inlets. Between 2005 and 2007, 75 dredge islands were surveyed in each year and the number of breeding pairs of seabirds and shorebirds estimated. The results showed that, of the 13 species that nested at least once, eight represented more than 1% of their total Italian population, sometimes even higher than 10%. Our results indicated that the majority of birds prefer site dimensions of between 10 and 30 ha, even if some species use small or very small (<1 ha) sites particularly heavily. Most of the other environmental variables we measured concurred in explaining species' occurrence and abundance. Redshank and Shelduck selected sites with high vegetation coverage, whereas sites with lower vegetation were preferred by Kentish Plover and Little Tern. More pairs than expected were observed at sites between 25 and 30 ha. These sites have a considerable wealth of habitat types, becoming suitable for species with contrasting nesting habitat requirements. Density of breeding pairs ranged between one and four pairs/10 ha; these values compare well with those observed in natural habitats existing in the Venice Lagoon, and support the opinion that dredge islands are a good alternative to natural sites. Along coastal sites where human pressure on beaches is particularly heavy, man-made habitats such as dredge islands may become a valuable alternative breeding site for those seabirds and waders of conservation concern. The results presented allow an assessment of the importance of dredge islands for breeding waterbirds over a short to medium period. They may also be used to estimate the expected richness and abundance of breeding birds that will use intertidal man-made sites, when these are built in a temperate coastal marsh.

1. Introduction

Beneficial use of dredged material at coastal sites includes the creation of tidal flats or salt marshes, with the aim of restoring previous areas, creating new substrate for halophytic vegetation and providing new feeding and nesting sites for birds, in particular waterbirds (Parnell et al., 1988; Streever et al., 1996; Streever, 2000; Zedler, 2000; Yozzo et al., 2004). Artificial islands created by the controlled disposal of sediments dredged from sea inlets, channels and lagoons have often been termed "dredge islands", and several studies have been published about their use by birds. A large majority of the studies found in scientific literature deals with sites in the USA (Soots and Parnell, 1975; Soots and Landin, 1978; Melvin and Webb, 1998; Mallach and Leberg, 1999; Delaney et al., 2000; Shafer and Streever, 2000; Zedler, 2000; Erwin et al., 2001, 2003; Perry et al., 2001; Neckles et al., 2002; Darnell and Smith, 2004; Spear et al., 2007; Golder et al., 2008; Emslie et al., 2009). On the other hand, very few data exist for sites in Europe, where these particular kinds of man-made site seem far less common and of very small size (ABP Southampton, 1998; de Jonge and de Jong, 2002; Atkinson, 2003; Bakker and Piersma, 2006; Gallego Fernández and García, 2007). Data reported in the previously quoted literature indicate that birds rapidly colonize dredge islands, and that nesting populations at these sites may reach levels of regional or national importance, at least for some species. Relationships between habitat characteristics (e.g. site dimension, vegetation coverage and type, extension of ponds and creeks) of these man-made islands and occurrence or abundance of birds have been the subject of detailed study outside Europe (see literature quoted above), but very little is known for European sites. In the Lagoon of Venice (NE

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Italy), the total area of salt marsh has fallen from approximately 12,000 ha to less than 4000 ha between 1900 and the present day, due to reclamation, erosion, and natural and man-induced subsidence (Cecconi, 2005; D'Alpaos et al., 2007; Tiezzi et al., 2010; Day et al., 2011). A large dredging program undertaken for the Italian Ministry of Public Works has been underway since 1984 to maintain channel depths for purposes of navigation and to increase tidal flushing in the inner lagoon. The resulting dredged material has been used to build artificial salt marshes (hereafter called dredge islands) and tidal flats (Cecconi, 2005; Tiezzi et al., 2010). In 2011 (last available data), about 100 dredge islands occurred, providing an extent of dredge island area of about 1100 ha and using a total volume of sediments in excess of 12 million cubic meters. These dredge islands host tens or even hundreds of pairs of breeding waterbirds, including species of relevant conservation value, i.e. that are included in Annex 1 of the European Community "Birds" Directive (EC/147/2009) or listed as Species of European Conservation Concern by BirdLife International (2004).

From 2005 until 2007, breeding bird surveys were performed each year at 55–75 dredge islands occurring in the Venice Lagoon. As far as we know, this is the first study in Europe that takes in account such a large number of man-made sites. The aims of this paper are to:

- assess the importance attained by dredge islands as nesting sites for waterbirds;
- explore relationships between the main morphological and vegetation characteristics and the occurrence of breeding species;
- suggest criteria for the optimal management of existing sites and the planning of new ones.

Since we are interested in sites comparable in origin and extent with ours, we will not include here comparisons to small islands, some tens or hundreds of square meters in size, that have often been created at European sites to provide nesting, roosting or feeding sites for waterfowl. For these reasons, we will define dredge islands as "those constructed from the sediments displaced as navigation channels are built and maintained by dredging", according to the definition given by Turner and Strever (2002).

2. Study area

The Venice Lagoon is a large (550 km^2) shallow coastal lagoon, located on the north-western coast of the Adriatic Sea, 45°26′N, 12°19′E (Fig. 1). Two barrier islands, each one about 10 km long, separate the lagoon from the sea. Most of the lagoon consists of an open water body (about 400 km^2). The mean depth of the lagoon is 1.1 m and the tidal range during spring tides is about 1 m, with a mean tidal range of 0.6 m, one of the highest observed in the whole Mediterranean (Cecconi, 2005). There are extensive intertidal natural salt marshes in the lagoon, regularly flooded during high tides since they have a mean elevation of only 0.20–0.30 m above mean sea level. Hundreds of these islets, covered with halophytes, are common in the south-western and northern corners of the lagoon. The Venice Lagoon is of particular importance for waterbirds, both as a wintering site and as a breeding site (Scarton and Valle, 1999; Scarton, 2005, 2010; Scarton et al., 2009; Scarton and Bon, 2009). Due to its importance for birds, the whole Venice Lagoon has been recognized since 2007 as a Special Protection Area, according to the European Community Birds Directive.

Between 1985 and 2011 about 100 dredge islands were built in the lagoon, with a total area of almost 1100 ha. Each dredge island consists of a containment cell formed using piles of woody material along the exterior. These areas of shallow waters are then filled with sediments originating from the regular dredging of lagoon channels or inlets (Cecconi, 2005). Sediments discharged into dredge islands are thus confined by a row of posts, with a sheet of geotextile along the inner side or by two or three rows of gabions, filled with stones. At some dredge islands posts or gabions were removed along selected sectors, in order to promote tidal creek formation.

After sediment compaction, these islands reach a mean elevation above sea level of between 0.5 and 1 m. For this reason the area flooded by normal high tides is variable, ranging from most of the site surface for dredge islands with the lowest elevation, to less than 30% for the highest elevated sites. Despite their very low elevation, the topography of dredge islands is not completely flat; small mounds and depressions coexist, producing an array of microhabitats. Soil composition and elevation above sea level of dredge islands drive the processes of vegetation colonization and succession. Throughout the years, remarkable modifications occur to the vegetation coverage and structure of dredge islands. From almost a bare surface, with the occurrence of just a few annual species mostly of the genus *Salicornia*, several phases lead to an almost continuous coverage of halophytes (*Sarcocornia fruticosa*, *Aster tripolium*, *Limonium narbonense*, *Puccinellia palustris*) or, less commonly, ruderal and nitrophilous species (genus *Elymus*, *Oenothera*, *Atriplex*). Bushes or small trees (*Tamarix gallica* and *Populus alba*) are extremely rare, occurring only at a few sites that have higher elevations.

The 75 dredge islands (i.e. all those existing in the lagoon between the years 2005 and 2007) considered in this study ranged in size from 0.09 to 51.37 ha, had a mean surface area of 11.3 ha (1 SD = ±10.7 ha) and a total combined area of 846 ha. Most of the sites (44; 59%) were smaller than 10 ha, whereas only five sites (7%) were larger than 30 ha. In 2007 the mean age of the sites (i.e., time elapsed from the end of construction work or, for some sites, from disposal of fresh sediments over most or all of the area) was 8.2 years (1 SD = ±5.1), ranging from one to 19 years. Human disturbance at most of the sites was very low or absent; only a few sites were irregularly used by professional fishermen, bait collectors or occasional visitors.

3. Methods

Field data were gathered between spring 2005 and summer 2007. Since new dredge islands were built each year, the number of study sites increased accordingly. In the first year 55 sites were visited, 74 in 2006 and 75 in 2007. Area, perimeter and extent of tidal flats (within a radius of 1 km) were calculated for each site, through the use of recent aerial or satellite pictures and GIS software. Vegetation mapping at a scale of 1:2000 was carried out for 65 sites (10 sites were not mapped in the field for logistical constraints) in the years 2005–2006, between June and October, with the aid of aerial photos taken in the same years. For the remaining 10 sites, soil coverage categories were estimated only with the use of aerial or satellite pictures taken in 2007. Digitization took place using ArcGis 9.3 (ESRI, Redlands, California, USA); vegetation was classified according to the dominant species. We used the following classes: (1) *Salicornia* sp. dominated area, (2) *Sarcocornia* dominated area, (3) other halophytes, (4) other non halophytes. Other typologies of soil coverage were: (1) ponds + creeks, (2) bare ground, and (3) bare, marginal surfaces exposed only during low tides and originating from erosion processes occurring along the inner side of the containment dike. Discriminating between the two last categories in the field was not easy, and a subjective approach had to be followed. Tidal flat extent, i.e. the area of shallow bottoms with elevation between +0.05 m and −0.30 m around and

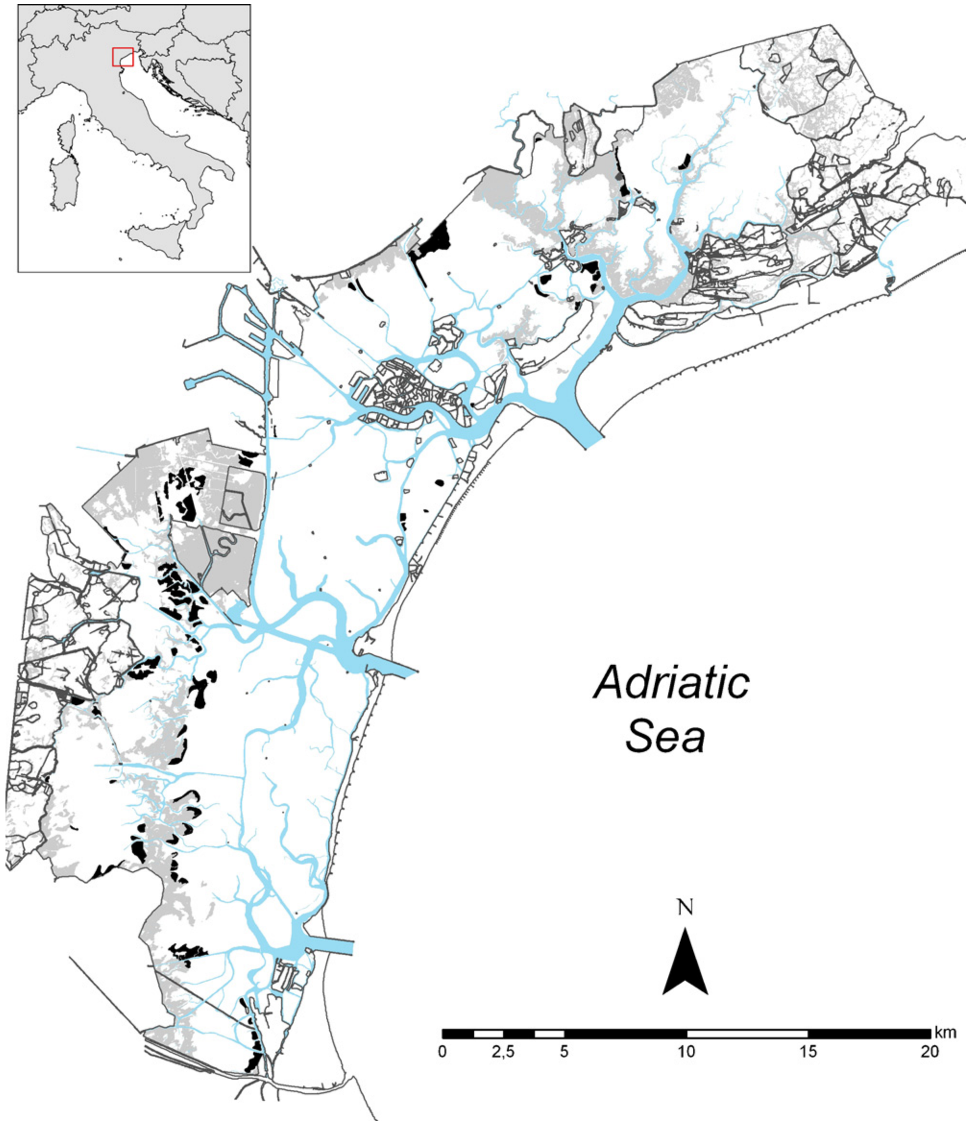

Fig. 1. The Venice Lagoon, with natural salt marshes in gray and the 75 dredge islands studied in 2007 marked in black.

within 1 km of each site, was estimated with the aid of detailed digital bathymetric maps produced by the Venice Water Authority. Elevation of dredge islands above sea level was obtained from topographic maps or field leveling transects made in the framework of other monitoring projects.

Field ornithological surveys were made annually at each site between March and July, when the occurrence of breeding pairs is the highest in our study area (pers. obs.); each site was visited every year three times. Two authors (F.S. and R.V.) reached the dredge islands by boat and walked slowly through the whole area, with binoculars or a telescope, looking for incubating or alarming adults and for nests. Field visits usually lasted 30–40 min (one hour at the largest sites) in order to avoid excessive disturbance to breeding pairs. Visits took place between 09.00 a.m. and 02.00 p.m., always in good meteorological conditions. Both “probable” and “confirmed” nesting pairs were considered in this study; definitions follow Hagemeijer and Blair (1997). Due to the large differences in dredge island size, richness and abundance were always expressed as density (no. of species or pairs/10 ha). In order to assess the importance of environmental variables in explaining the occurrence of breeding pairs, we selected the species occurring each year in at least three sites; from the eight resulting species we excluded the Mallard, since it may nest in very different habitat types (Drilling et al., 2002).

Data were expressed as mean ± standard deviation or ± standard error; a P value <0.05 was considered significant.

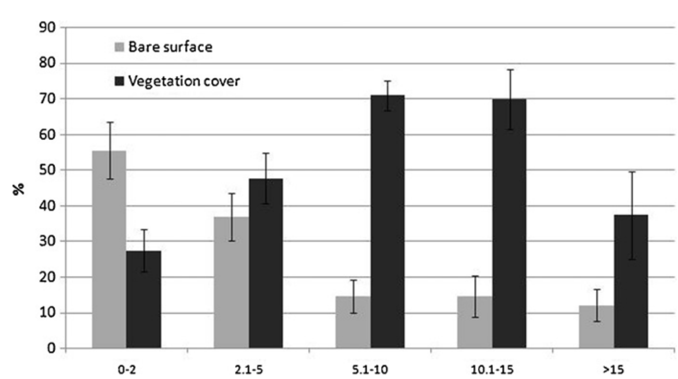

Fig. 2. Mean (+SE) extension of bare surface and vegetation cover (in % of the total dredge island area) at 75 dredge islands, grouped by age.

Non-parametric tests were used to treat data since they were not normally distributed. Categorical variables were expressed as percentages, and were compared using a Pearson chi-square test. The Mann–Whitney *U*-test was used to compare two independent samples. Spearman's rank correlation was utilized to detect associations between variables. A one-way ANOVA was employed to detect differences between variables (Zar, 1996). A ROC (receiver-operated curve) analysis was performed to identify parameters likely to be related to the presence of the species. The degree of dependence, at the level of the whole Venice Lagoon, of breeding waterbirds from dredge islands as nesting site was judged slightly modifying the criteria given by Soots and Parnell (1975): (1) heavily dependent, if more than 50% of estimated pairs nested at dredge islands; (2) moderately dependent, if nested between 10% and 50% of the pairs; 3) not dependent, if less than 10% of the pairs nested at dredge islands.

4. Results

The main vegetation and morphological characteristics of the dredge islands we studied are presented in Table 1. On average, dredge islands were covered with vegetation for 54.5% of their area, whereas bare ground comprised an additional 31.6%; the remaining 13.9% was occupied by ponds + creeks and marginal eroded areas. Considering only the vegetated area, the highest coverage comprised *Salicornia* spp. (29% of the total extent of the islands), with *S. fruticosa* and other halophytes forming an additional 16.6%. Species of the genus *Salicornia* (*S. patula* and *S. veneta*) can colonize dredge islands just a few months after completion of construction works. These species were extremely abundant on the youngest dredge islands, whereas their occurrence at older islands was restricted to the less elevated areas, frequently flooded by high tides. In contrast, biannual or perennial halophytes were more abundant at sites that were five or more years of age, sometimes covering almost all the available surface of the sites (Fig. 2).

Thirteen bird species nested at least once; the most abundant species were Yellow-legged Gull (800 pairs ± 252, on average over the three years), Little Tern (200 pairs ± 133) and Redshank (110 pairs ± 21; Table 2). The most widespread species were Oystercatcher (nesting at 32 ± 5 sites), Redshank (28 ± 6 sites) and Kentish Plover (23 ± 3 sites). The largest variations among years were shown by typical pioneering species such as Kentish Plover, Little Tern and Little-ringed Plover, which quickly colonized new sites available in 2006 and then increased in the following year. The remaining species showed irregular fluctuations.

Considering the results for the years 2006–2007, those with the highest number of study sites, eight species exceeded 1% of the total number of pairs breeding in Italy, a threshold which is usually accepted to qualify a site as being important at a national level for a given species (BirdLife International, 2004; see Table 3). At the local level, i.e. that of Venice Lagoon, four species may be considered as heavily dependent on dredge islands for nesting, five moderately dependent and only four were not depending on them. Site occupancy rate of dredge islands was high in each year, since 70–88% of them were used by at least one species. Only 8 sites out of 75 were never used during the three years of study; four of them were very low in elevation and often inundated by high tides, being unsuitable for nesting birds, whereas for the remaining four there were not clear reasons.

The number of breeding species at each site ranged between zero and nine, with a median value of two. The mean density of nesting pairs (all species considered) ranged each year between 17.8 and 20.9 pairs/10 ha of dredge island. The density observed at the study sites for the ten species that nested every single

Table 1
Morphological and vegetation characteristics for the 75 dredge islands studied. *: within 1 km from the perimeter.

	Mean elevation (m)	Perimeter (m)	Total area (ha)	Area of creeks + ponds (ha)	Marginal eroded surfaces (ha)	Bare ground (ha)	*Salicornia* dominated area (ha)	*Sarcocornia* dominated area (ha)	Other halophytes (ha)	Other non halophytes (ha)	Total area with vegetation (ha)	External intertidal areas (ha)*
Minimum	0.13	118.8	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Maximum	0.89	6927.2	51.37	7.76	5.89	40.00	20.02	15.35	7.37	12.31	39.20	134.62
Mean	0.41	1722.1	11.29	0.99	0.61	3.57	3.30	1.21	0.67	0.83	6.01	51.01
±1 SD	0.17	1110.8	10.73	1.64	1.23	6.47	4.18	2.65	1.51	1.98	7.11	31.19
Median	0.37	1468.8	8.70	0.37	0.00	1.40	1.77	0.31	0.01	0.07	3.98	48.72

Table 2
Nesting pairs and number of dredge islands used by each breeding species.

	2005	2006	2007
Tadorna tadorna			
Pairs	12	17	12
Dredge islands	11	7	7
Anas plathyrhynchos			
Pairs	5	30	19
Dredge islands	5	12	10
Anas clypeata			
Pairs	0	2	0
Dredge islands	0	1	0
Haematopus ostralegus			
Pairs	31	39	40
Dredge islands	27	32	37
Himantopus himantopus			
Pairs	96	69	62
Dredge islands	13	15	17
Recurvirostra avosetta			
Pairs	39	45	35
Dredge islands	4	9	7
Vanellus vanellus			
Pairs	0	2	5
Dredge islands	0	1	1
Charadrius dubius			
Pairs	8	3	18
Dredge islands	6	2	14
Charadrius alexandrinus			
Pairs	34	71	131
Dredge islands	19	25	25
Tringa totanus			
Pairs	94	136	110
Dredge islands	21	30	33
Larus michahellis			
Pairs	553	1057	796
Dredge islands	15	24	27
Sterna hirundo			
Pairs	8	10	0
Dredge islands	1	1	0
Sternula albifrons			
Pairs	115	213	379
Dredge islands	3	5	4
Total no. of pairs	995	1694	1607
No. of dredge islands	55	74	75

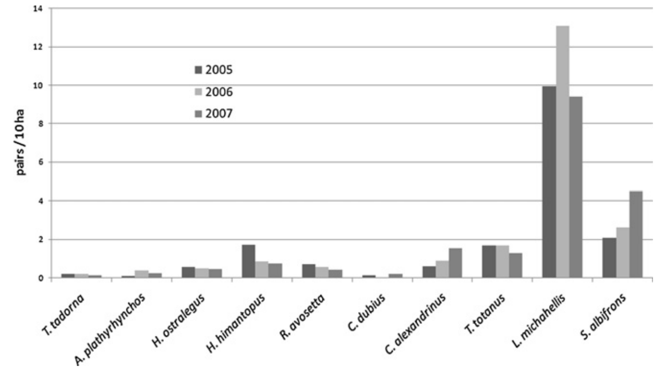

Fig. 3. Density of breeding pairs (breeding pairs/total dredge island area) in each year. Only species that nested every year are presented.

year is shown in Fig. 3. Apart from Yellow-legged Gull (10.7–12.7 pairs/10 ha), the remaining species had a density of below four pairs/10 ha. Only for Shelduck and Oystercatcher the number of pairs observed in 2006 and 2007 was not different from that expected if the density was the same than in 2005, i.e. density of breeding pairs/10 ha did not change across the years (Chi-square test, $P > 0.05$). On the contrary, for the remaining eight species density changed significantly over the years (Chi-square test, $P < 0.05$ in each case).

The total area of dredged islands was grouped either by site age (four classes: Fig. 4) or by site extension (11 classes: Fig. 5), in order to analyze if breeding pairs used some particular class more than was expected based only on availability. In each year a statistical significant association was found among number of breeding pairs and some particular class of site (Chi-square test: 3 d.f., $P < 0.001$ in each year). In particular, in 2005 the one to five year old sites had far more pairs than was expected; in 2006, the 15–20 year old sites had far fewer pairs than expected, whereas in 2007, the 10–15 year old sites were the preferred class. Considering site dimensions, a similar significant association was observed among number of breeding pairs and particular class size, in each year (Chi-square test: 3 d.f., $P < 0.001$ in each case). In 2005, the classes for 1–5 ha and 25–30 ha had more pairs than expected; in 2006, the classes with more pairs than expected were 25–30 ha and 41–45 ha. In 2007, the larger differences between observed and expected number of pairs were observed for the classes 10–15 ha and 25–30 ha.

4.1. Species habitat relationships

The relative importance of the variables we selected for the seven species are shown in Fig. 6(a)–(g). In addition to seven morphological variables, we also included the number of other species breeding at the same site. Vegetation coverage explained the occurrence of five breeding species (Shelduck, Eurasian Oystercatcher, Black-winged Stilt, Pied Avocet and Common Redshank), whereas

Table 3
Mean number of breeding pairs at dredge islands (only years 2006–2007 were considered) compared to the populations breeding in the whole Venice Lagoon (personal estimates) and in the whole of Italy. Species exceeding 1% of the Italian population are marked in bold.

Species	Dredge islands (no. of pairs)	Lagoon of Venice (no. of pairs)	Italy (no. of pairs)	Pairs in dredge islands/pairs in Venice %	Degree of dependence from dredge islands	Pairs in dredge islands/pairs in Italy (%)
Tadorna tadorna	15	50–70	300*	25	Moderate	**5**
Anas platyrhynchos	25	300–500	10000–20000	6	Absent	<0.1
Anas clypeata	1	2–5	150–200	–	Absent	<0.1
Haematopus ostralegus	40	50	150–180*	80	Heavy	**24**
Himantopus himantopus	66	300–400	3000–4000	19	Moderate	**2**
Recurvirostra avosetta	40	200–300	1800–2000	16	Moderate	**2**
Vanellus vanellus	4	10–15	1500–2500	33	Moderate	<0.1
Charadrius dubius	11	10–20	2300–4000	73	Heavy	0.5
Charadrius alexandrinus	101	130–170	1300–2000	67	Heavy	**9**
Tringa totanus	123	1800	1800–2000*	7	Absent	**6**
Larus michahellis	927	4000–4500	45000–60000	22	Moderate	**2**
Sterna hirundo	5	700–1000	4000–5000	<1	Absent	<0.1
Sternula albifrons	296	400–600	2000–3500	59	Heavy	**11**

Sources: Brichetti and Fracasso, 2003, 2004, 2006; personal estimates if marked with an asterisk.

Table 4
ROC analysis for morphological and prediction by vegetation parameters of the presence of seven species. AUC and CI values are reported.

Variables	Area	SE (a)	Asymptotic sig. (b)	Asymptotic 95% confidence interval	
				Lower bound	Upper bound
Vegetation coverage (ha)	0.908	0.059	0	0.792	1.023
Halophytes only (ha)	0.863	0.07	0.002	0.726	1.000
Area/perimeter (ha/m)	0.863	0.07	0.002	0.726	1.000
Ponds + creeks area (ha)	0.849	0.058	0.002	0.734	0.963
Total area (ha)	0.838	0.082	0.003	0.678	0.999
Sarcocornia fruticosa (ha)	0.834	0.082	0.004	0.673	0.995
Perimeter (m)	0.758	0.088	0.025	0.586	0.931
Salicornia sp. (ha)	0.731	0.124	0.045	0.487	0.975
Bare ground (ha)	0.664	0.089	0.155	0.49	0.838
Mean elevation (m)	0.613	0.108	0.325	0.403	0.824
Site age (years)	0.454	0.085	0.689	0.288	0.619
Marginal eroded surfaces (ha)	0.369	0.088	0.255	0.196	0.541

site extent and area of ponds + creeks each explained occurrence of four species (Shelduck, Eurasian Oystercatcher, Black-winged Stilt and Pied Avocet for the first variable; Oystercatcher, Black-winged Stilt, Pied Avocet and Common Redshank for the second). Site age was selected as significant only for Kentish Plover, a species that, together with the Yellow-legged Gull, had the lowest number of variables selected as significant. The occurrence of other species was the only variable that shows significant values in all cases. The ability of the selected morphological and vegetation parameters to discriminate between dredged islands colonized by the seven species is shown by the ROC analysis (Table 4 and Fig. 7). AUC values indicated the best discriminating power for vegetation coverage (0.90), followed by coverage of halophytes (0.86) and ponds + creeks (0.84). At the other extreme, site age and mean elevation had the lowest values (0.45 and 0.61).

5. Discussion

Within twenty years dredge islands built in the Venice Lagoon have gained considerably in importance to breeding waterbirds, both at a local and national level. The three-year long study we present here showed that, out of the 13 species that nested at least once, eight represented more than 1% of their estimated Italian population, sometimes even higher than 10%. Given the high conservation values of most of these species, one may conclude that these new man-made habitats are currently an extremely important and well established breeding habitat. Among the specie that were highly dependent on dredge islands it should be observed that for Kentish Plover and Oystercatcher, dredge islands account for more than 70% of the total estimated number of breeding pairs known for the whole Venice Lagoon. This high importance of dredge islands to waterbirds is in agreement with what has been observed at several other coastal sites (see references in Section 1) and, more generally, confirms that artificial sites may play an important role in conserving populations of threatened waterbirds, as is also the case for salt-ponds, rice fields and water treatment plants (Fasola and Ruiz, 1996; Guillemain et al., 2000; Tourenq et al., 2001; Warnock et al., 2002; Sebastián-González et al., 2010).

The most common species we found may be grouped according to their different life-history traits: (1) Little Tern, Kentish Plover, Little-ringed Plover and Eurasian Oystercatcher are true pioneer and opportunistic species, which use new sites as soon as they become available: on several occasions, dredge islands were used even before the completion of construction works; (2) on the other hand, Common Redshank and Shelduck select to nest in only highly vegetated sites: these species are therefore indicators of sites that have reached stable conditions; (3) Black-winged Stilt, Pied Avocet and, in particular, Yellow-legged Gull are more opportunistic, being found in sites with different proportions of bare ground and vegetated areas.

The reasons for the observed high suitability of Venice Lagoon dredge islands for waterbirds are many: (1) within a few years of their construction, most of the sites show an array of habitats (ponds, thick stands of halophytes, bare ground surfaces, etc.) that can host several species, even those with very different biological requirements. This is why at a single site we recorded nesting pairs of, for instance, both Common Redshank and Kentish Plover; (2) their elevation above sea level is slightly higher than that of the surrounding natural salt marshes, so they are less prone to flooding by high tides. Given the estimated sea level rise in the next decades and its possible effects on salt marsh nesting species (for a recent review of these see van de Pol et al., 2010), the man-made sites may become increasingly attractive to salt marsh birds. Indeed, their use of natural salt marshes may be seen as an adaptive response to changed environmental conditions. For instance, in the Venice Lagoon annual censuses conducted between 1989 and 2003 indicated that Little Terns have abandoned most of their traditional salt marsh nesting sites in favor of dredge islands (Scarton, 2008). A similar shift has also been shown more recently by Common Tern, most likely due to recent increases in the frequency of exceptionally high tides in April and May, the most important months in the nesting season (Scarton, 2010); (3) all the dredge islands are surrounded by tidal flats and shallow bottoms that represent suitable feeding places for both waders and gulls/terns. Availability of food in the surrounding waters is one of the most important factors that influences breeding success (Schippers et al., 2009); (4) dredge islands are usually little or not at all disturbed by man, due to their remoteness and low attractiveness for the general public. At coastal sites where human pressure is almost everywhere high, such as the Venice Lagoon, this factor may be crucial. In particular, during the breeding season, littoral habitats such as the beaches and dunes of the Venice Lagoon littoral strip are intensively used by sun bathers, and thus some bare soil nesters such as Kentish Plover and Little Tern have almost no place left to settle. For this reason, dredge islands may become an alternative and attractive nesting site.

Our results indicate that site dimensions between 10 and 30 ha are those preferred by the majority of birds, even if some species (such as Little Tern and Kentish Plover) may heavily use small or very small (i.e. less than 1 ha) sites. Most of the other environmental variables we measured concurred in explaining species' occurrence and abundance. Redshank and Shelduck selected sites with high vegetation coverage, whereas Kentish Plover and Little Terns preferred lower vegetated sites. This is in agreement with their well known ecological requirements, indicating that the same site selection processes that act at natural sites are adopted on these man-made islands. From being completely bare at the end of

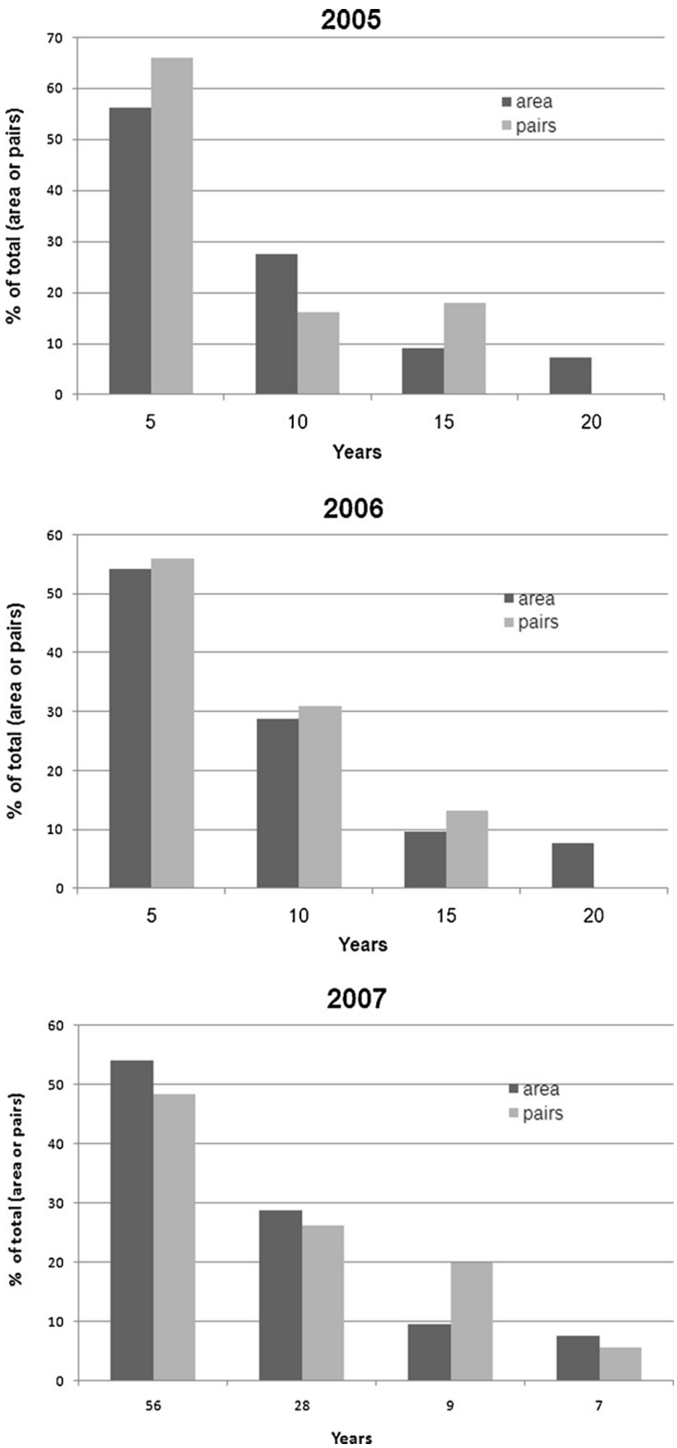

Fig. 4. Frequency distribution of site area and breeding pairs, according to site age (in years).

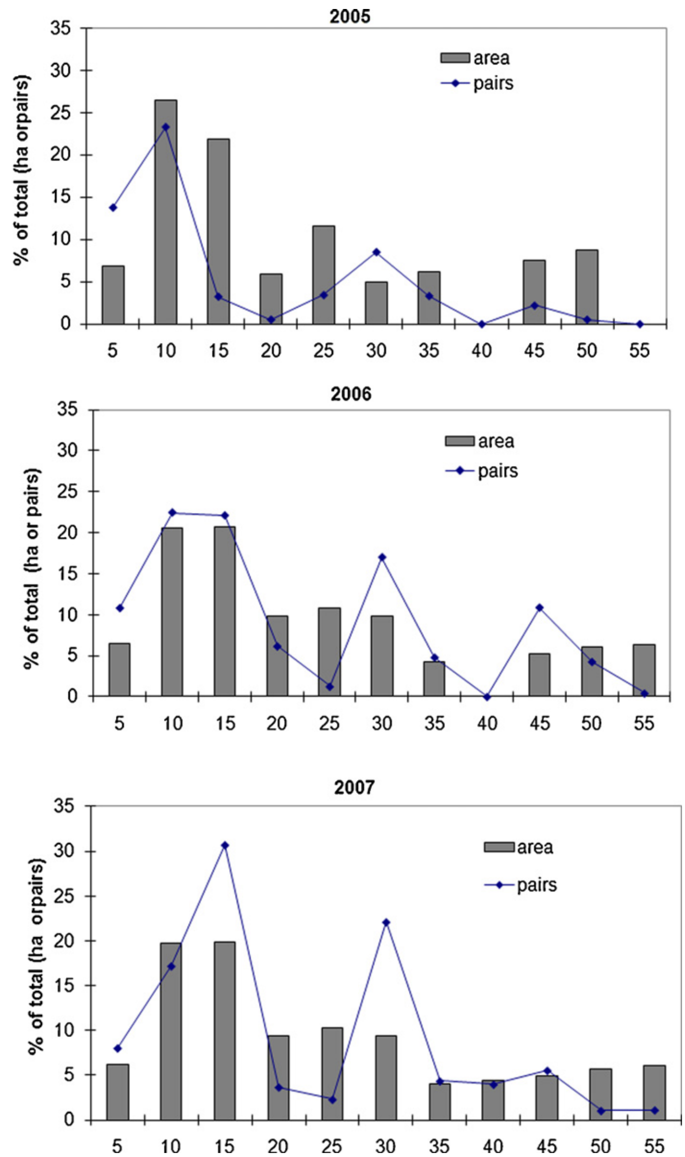

Fig. 5. Frequency distribution of sites according to total area and number of breeding pairs.

construction, dredge islands tend to be covered with vegetation over at least 70–80% of their surface with age. This leads to a succession of birds that use the same site, from those that prefer very low-vegetated surfaces (Kentish Plover, Little Tern, Oystercatcher, Little-Ringed Plover), to those that select densely vegetated sites (Mallard, Shelduck, Common Redshank). Nevertheless patches of bare ground can persist almost indefinitely at the dredge islands we studied, even after twenty years from construction, thus allowing some pairs of the former group to continue to nest at these sites.

We observed on several occasions that management works such as a localized spraying of slurry at well-vegetated dredge islands may be extremely useful in creating bare areas that are rapidly used to nest by several species in the following months.

Water surfaces inside dredge islands are made up of intertidal ponds, creeks and more ephemeral ponds originating from rainwater. All of them are a source of food for several species such as Common Redshank, Black-winged Stilt, Pied Avocet, both for adults and young. The importance for breeding birds of the occurrence of these morphological features at dredge islands has been confirmed by our results and support the importance of making, or promoting the formation, of tidal creeks and ponds at dredge islands.

Apart from purely morphological variables, our analysis showed that the occurrence of other nesting species is particularly important in explaining the use of a site by a given species. Since most of the waterbirds we studied nest colonially or semi-colonially, in single-species groups or with other species, this was not unexpected and warns against using only physical attributes in evaluating site selection. The clearest example is given by Kentish Plover and Little Tern; the largest numbers of the former

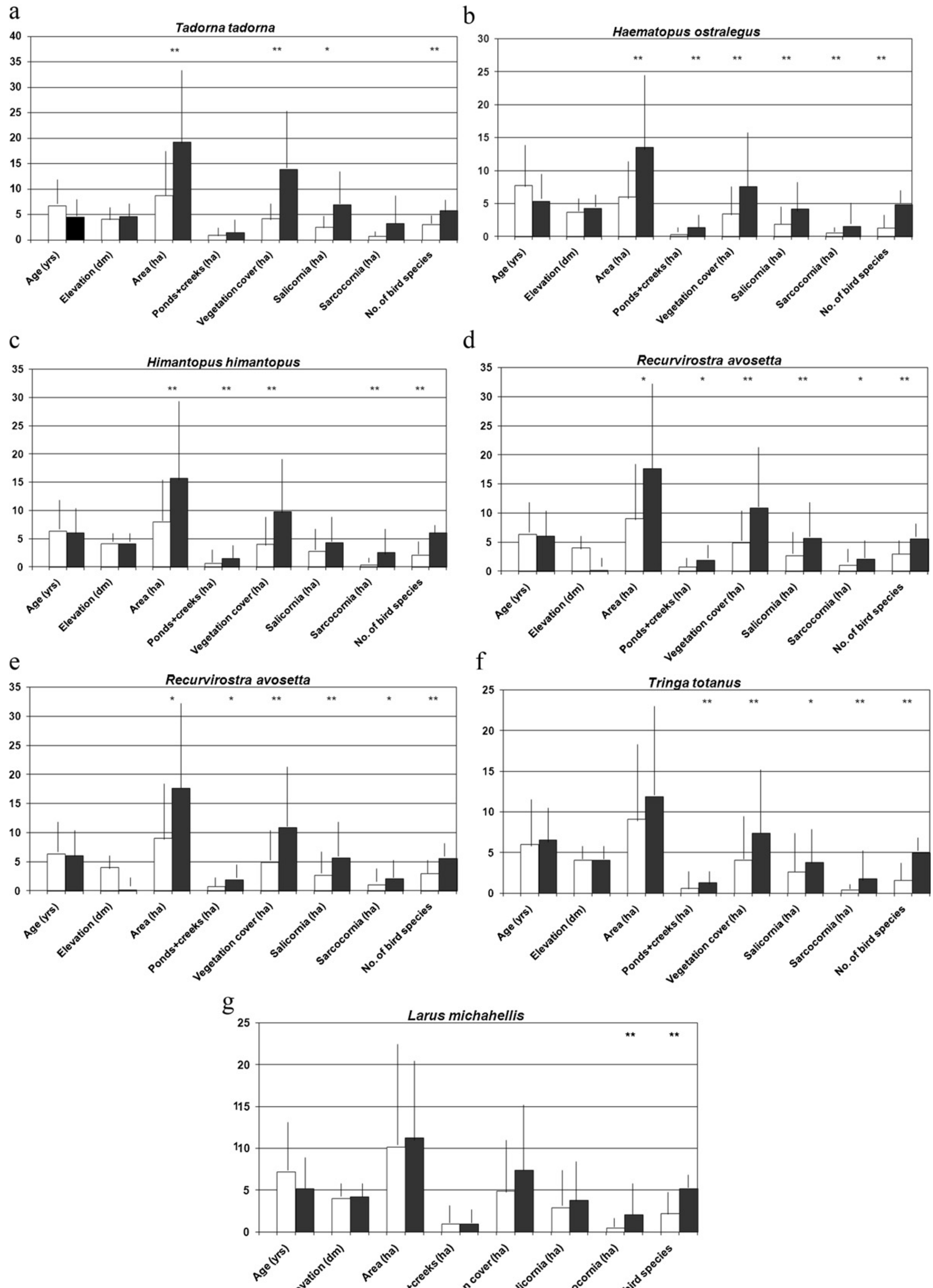

Fig. 6. (a)–(g). Biotic and abiotic parameters of occupied vs. non-occupied dredge islands for selected species. Significant differences are marked with *($P<0.05$) and **($P<0.01$).

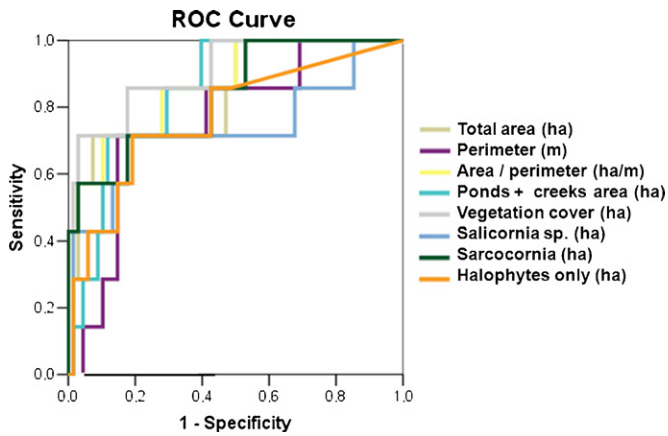

Fig. 7. The ROC curves for biotic and abiotic variables for the presence of seven species. AUC values are reported in Table 4. Only significant curves are shown.

were always found at sites where colonies of the latter also occurred.

Density of individuals and/or breeding pairs has been positively related to reproductive success in the majority of studies examined by Bock and Jones (2004); they concluded that birds are usually more abundant in habitats where reproduction is highest, confirming the appropriateness of using birds as indicators of breeding habitat quality and as a basis for management decisions. For this reason, density may be used in most cases as a sound ecological indicator of site quality. The density of breeding pairs at dredge islands was, for almost all species, different across the three years, showing that single-year study may not give reliable information about this important parameter. The observed values ranged between one and four pairs/10 ha; these compare well with those observed in the natural habitats existing in the Venice Lagoon (pers. obs., unpublished) and supports our opinion that dredge islands are suitable alternative nesting sites.

6. Conclusions

Breeding waterbirds colonized dredge islands made in the Venice Lagoon several years ago, and the results of this study give some insights about the use of these man-made habitats during the nesting season. Nevertheless, we recognize that the success of a salt marsh creation project, like many other nature development projects, should not be judged only by the number of breeding birds, as pointed out by Stienen et al. (2005). Other indicators such as, for instance, reproductive performance or fidelity to nesting sites shown by adults, should also be used. Despite the lack of such detailed studies for our study area, several findings suggest that nesting populations at our dredge islands are healthy and self-sustaining. New surveys made in more recent years (2008–2011) showed a regular increase in breeding numbers, following the availability of new dredge islands (pers. obs., unpubl.). Moreover, a recent detailed monitoring study spanning 18 months showed that about 100 species of birds, not only waterbirds, used the man-made islands during at least part of their biological cycle, both for feeding and resting (Scarton et al., 2011). For these reasons we can exclude any suggestion these man-made sites are acting merely as an “ecological trap” for adults.

Finally, we deem that creation of dredge islands similar to those we studied may be considered a valuable measure of environmental compensation, according to the prescriptions of the European Habitat Directive, in estuaries and lagoons where large engineering works such as harbor creation or enlargement and dredging of new waterways are to take place in the future (Palerm, 2006; Morris and Gibson, 2007; European Commission, 2011; Morris, 2011). Our data refer to a large number of dredge islands, with an age ranging from one to 19 years and with vegetation coverage ranging from almost zero to about 100%. We deem the results are useful in order to assess the importance of dredge islands for breeding waterbirds over a short to medium period. The results may also be helpful in estimating the expected richness and abundance of breeding birds that could use intertidal man-made sites, when these are built in a temperate coastal marsh.

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