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The distribution of *Spartina anglica* on estuarine mudflats in relation to wave-related hydrodynamic parameters.

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ABSTRACT

Spartina anglica is an invasive alien plant species whose spread threatens the biodiversity of Irish estuarine mudflats, sandflats and saltmarshes. Models have been developed to predict its distribution to facilitate population control and conservation management, but a more precise definition of the wave-related model parameters is required. This study investigates the distribution of established *Spartina anglica* in Strangford Lough, Northern Ireland, in relation to wave-related hydrodynamic parameters, generated using a numerical computer model for wave generation and propagation in shallow water.

The distribution of *S. anglica* was statistically associated with shorter waves. Longer waves are indicative of deeper water, affect a larger and deeper volume of water and travel at faster speeds than shorter waves. They are, therefore, more likely to disrupt Lough sediment surfaces and uproot *S. anglica* seedlings, thus limiting establishment. Other simulated wave-related hydrodynamic parameters showed little variation between sites with and without *S. anglica*.

Although input wave parameters were taken for storm conditions, the simulated wave parameters generated by the study did not pass recognised thresholds for initiating sediment transport. To further investigate the linkages between wave-related hydrodynamic parameters and *S. anglica* establishment, therefore, it may be necessary to re-assimilate the wave model using higher input waves (i.e. exceptional storm waves). This study forms a preliminary basis for understanding interactions between wave-related hydrodynamics and *S. anglica* establishment and for developing a predictive model of *S. anglica* distribution patterns.

ADDITIONALINDEXWORDS: *intertidal morphodynamics, saltmarsh ecology, estuarine physical evolution*

INTRODUCTION

The alien saltmarsh grass *Spartina anglica* C. E. Hubbard, was introduced to Strangford Lough, Northern Ireland during the 1940s to increase sediment accretion in coastal protection schemes (BLEAKLY 1979). It has subsequently colonised intertidal mudflat and sandflat locations beyond the lower limits of native saltmarsh vegetation, where it can reduce the availability of wildfowl and wader food resources (GRAY *et al*. 1991). *S. anglica* is, therefore, seen as a threat to the biodiversity of Strangford Lough. Despite recent control measures, *S. anglica* continues to spread.

Controlling an invasive alien species is dependent on knowledge of its ecological requirements and the spatial distribution of niche variables. Models have been constructed to predict the distribution of invasive species using ecological niche variables (GRAY *et al*. 1995; DAEHLER and STRONG 1996; HIGGINS *et al*. 1999). GRAY *et al*. (1995) described a regression model of the *S. anglica* niche based on 27 physical and tide-related variables. The model accounts for more than 90% of the upper and lower vertical limits of the species in terms of tidal range and modifying values such as fetch, estuary area and latitude. The lower limit of distribution was greater in areas with short seaward fetch (GRAY *et al*., 1995), suggesting that waves play a role in *S. anglica* establishment. MORLEY (1973), EERDT (1985) and GROENENDIJK (1986) have also suggested that hydrodynamic conditions influence the establishment of *S. anglica*. GROENENDIJK (1986) concluded that 'wave action is the main agent controlling the distribution of *Spartina* in the Oosterschelde', Netherlands. MORELY (1973), suggested that wave action was responsible for limiting the spread of *Spartina* at Bridgewater Bay, Somerset, England. Our paper investigates the distribution of establishing S. anglica populations in relation to wave-related hydodynamic parameters at Strangford Lough, Northern Ireland.

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STUDY AREA

The area investigated in this study is located in Strangford Lough, on the east coast of Northern Ireland (Fig. 1). The main body of the Lough is about 144 km^2 in area, 24 km long, and up to 6 km wide. There is an average tidal range of 3.0 m (spring tide range 3.5), but the north end of the Lough is not influenced by swell from the Irish Sea. The wave climate is dominated by locally generated wind waves originating most frequently from the south and west. Waves generated by westerly winds can build up over at least 6 km of open water before reaching the eastern shore. If winds are from the south, fetch may be as much as 12 km.

The distribution of *S. anglica* was recorded using thirty-two east-west transects located at intervals of 250 m. The transects were located on both the eastern and western sides of the Lough from Rough Island to Mount Stewart (Fig. 1). One north-south transect was also established at the northern end of the lough. The presence or absence of established S. anglica was recorded in a total of sixty-eight, 200 m2 square sample quadrats located along the transects. S. anglica was recorded as present if tussocks or clumps were present. Seedlings were not considered to be established populations as many die within the first year (pers. obs.). The first quadrat of each transect was positioned 10 m from the nearest saltmarsh vegetation or sea defence works. Subsequent quadrats were located 50 m apart along each transect to Mean High Water Neap tide (MHWS) level. The position of each quadrat was recorded using D-GPS (Differential Global Positioning System) accurate to within 30cm.

The numerical computer model HISWA (Hindcasting of Shallow Water Waves) (HOLTHUIJSEN *et al.*, 1989) was used to generate wave-related hydrodynamic parameters for the co-ordinates of each quadrat sample. The following wave parameters were calculated: wave energy dissipation; orbital velocity; significant wave height; wave length; amount of wave energy; and wave-induced stress. In the present study, wind speeds selected for simulating wave conditions were chosen for a high-energy or storm condition (initial significant wave height = 1.5 m.; significant wave period= 4.5 seconds; southeasterly approach) coupled with a 10 m s^{-1} wind from the southeast. RYAN and COOPER, (1998) demonstrated that waves in Strangford Lough are fetch limited and that the largest significant wave height likely to occur at the northern end of

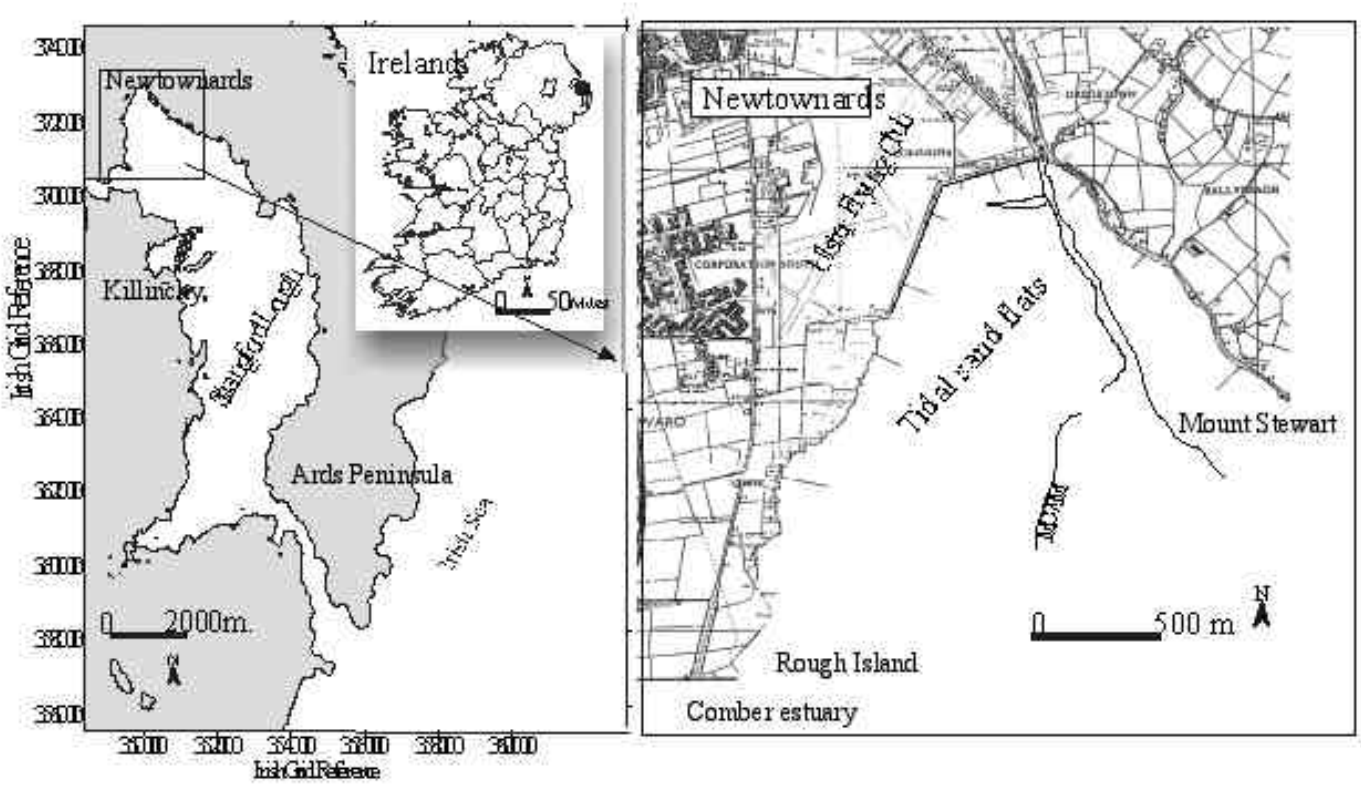


Figure 1. Study Area

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Strangford Lough is in the region of 1.5m. A comprehensive set of wave energy simulations derived from a wind data set recorded at Newtownards (MALVAREZ *et al*., 2000) showed that the most significant wave geometry in storm conditions is that referred to above.

The bathymetry and tidal flat morphology input for wave energy propagation was developed using a DGPS of higher accuracy (max of 0.5 mm). The DGPS was mounted on an all terrain vehicle to collect maximum number of data points from the field. However, the 3000 plus random points observed in the field were converted to a grid to achieve a resolution of c 10 m2 as input to the wave propagation model.

Wind data was recorded using a Weather Wizard III meteorological station installed at Ards Airfield (Ulster Flying Club Fig. 1) at an elevation of approximately 5 m above the ground to reduce turbulence. Wind velocity was logged at 30 minute intervals for the period 1997-1999. Data were retrieved using PC-LINK software via a modem. Data sets were analysed and high-wind speeds associated with storms were used as input to the wave propagation model.

The mean values of wave-related hydrodynamic parameters in quadrats with *S. anglica* present and in quadrats without *S. anglica* were compared with t-tests, carried out using the statistical computer package, SPSS version 9.

RESULTS

Spartina anglica was present in 11 sample quadrats and absent from 57. Levels of *S. anglica* establishment in the quadrats ranged from individual tussocks with no measurable cover, to clumps with approximately 51-75% cover.

There was a significant difference between wave length in quadrats with and without established *S. anglica* populations (Table 1). In quadrats where *S. anglica* was present, the mean wave length was 4.7 m, whilst in quadrats where *S. anglica* was absent a higher mean wave length of 7.5 m was recorded. Locations where S. anglica has colonised, thus have shorter wave lengths. The mean values of wave height, wave energy dissipation, wave orbital velocity, total wave energy and wave induced stress showed no significant difference between quadrats with and without *S. anglica* (Table 1).

DISCUSSION

There was limited variation in the simulated wave-related hydraulic parameters affecting the tidal flats and *S. anglica* in this study, which therefore represents a fine-tuned interpretation of relationships between *S. anglica* establishment and wave-related hydrodynamic parameters.

S. anglica did not establish in conditions associated with long waves. These waves produce less kinetic energy per unit volume at the surface than short waves in deep water, but they affect a larger and deeper volume of water (DENNY 1988). As wave length increases in deep water, celerity also increases (DENNY 1988). Longer waves are therefore more likely to disrupt substrate surfaces and uproot *S. anglica* seedlings during high tidal levels. Wave length may also be related to *S. anglica* establishment because wave propagation is greatly controlled by depth in this shallow-water lough environment. Variation in depth will reflect directly on shoaling by decreasing wave length in shallower water. *S. anglica* is thus more likely to establish in areas that receive shorter waves at higher elevation locations on the lough shore.

The resulting envelope of significant wave heights in the study area was small (approx. 0.21 – 0.25 m), making it difficult to judge what thresholds exist within which S. anglica could establish. Similarly, the orbital velocities of the simulated waves did not vary much between colonised and uncolonised sites. More importantly the orbital velocity values did not appear to pass the threshold for sediment entrainment.

Wave-induced stress acting on bed sediments is small under the effects of high frequency waves, typical of shallow water phases (i.e. at the beginning of a rising tide or

Table 1. Mean values and standard deviation (bracketed) of wave-related hydrodynamic parameters in sample quadrats with Spartina anglica present and quadrats without S. anglica. The significance of t-test results are also provided.*=Significant difference.

Wave parameter	Present		Absent		Sig.
Wave energy dissipation (watt/m^2)	0.025	(0.03)	0.047	(0.07)	0.325
Wave orbital velocity (m/sec)	0.09	(0.09)	0.12	(0.09)	0.271
Significant wave height (m)	0.21	(0.1)	0.25	(0.1)	0.333
Wave length (m)	4.73	(2.5)	7.52	(5.9)	0.014*
Wave energy (watt/m^2)	60.6	(45.4)	126.9	(171.0)	0.208
Wave induced stress (Newton/m^2)	0.16	(0.3)	0.16	(0.2)	0.960

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the end of a falling tide), because the orbital motions cannot penetrate to the bed. At an optimum water level, wave orbital velocity penetrates the water column making wave height (and associated energy and stress) more effective in moving sediments. This optimum water level has been described for low energy environments (MALVAREZ and COOPER, 2001) and its existence pointed out in estuarine environments (GREEN and MACDONALD, 2001). However, in the current preliminary experiment a single water level was used for modelling and therefore, wave penetration may have been at a point that did not enable wave orbital velocities and stress to entrain sediments and potentially affect plants. The roughness of the vegetated sandflat and saltmarsh would also have been higher than that of unvegetated surface and thus, wave energy dissipation would have been greater at locations where plants were present. Further development of our model is proposed to include bottom friction coefficients and roughness of bottom. It may also be necessary to re-assimilate the wave model using higher input waves (i.e. exceptional storm waves) and multiple water levels to points where they would initiate sediment transport. The model thus forms a preliminary basis for understanding interactions between wave-related hydrodynamics and S. anglica establishment and for developing a predictive model of S. anglica distribution patterns.

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