DIFFERENTIAL DECOMPOSITION PATTERNS OF MARINE AND TERRESTRIAL BIOMASS IN A COASTAL LAGOON

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Abstract. Lagoons are ecosystems where freshwater and marine organisms converge together with lagoonal specialists to form a mixed community that may vary spatially along a salinity gradient. Many organisms can only survive within relatively narrow bands of salinity. As a result of marine and freshwater inflows, together with exposure to variable salinity levels, dead marine and terrestrial biomass is accumulated in lagoons where it enters the detritic pathway. This study examined the *in situ* decomposition of marine (*Fucus vesiculosus*) and terrestrial (*Alder glutinosa*) biomass in Cuskinny Lagoon, South West Ireland. *F. vesiculosus* decayed rapidly and uniformly across the lagoon. *A. glutinosa* biomass loss varied throughout the lagoon, with the greatest loss occurring near the freshwater inflow. Thus, the spatial pattern of *A. glutinosa* decomposition differs from that of *F. vesiculosus* decomposition. Invertebrate abundances were not related to the amount of biomass loss of the marine and terrestrial material. This study demonstrates the differential decomposition patterns of marine and terrestrial biomass in the dynamic environment of a coastal lagoon.

Abbreviations: ppt (parts per thousand); AFDW (ash free dry weight)

Key words: lagoon, conservation, salinity, invertebrates, decomposition

1. INTRODUCTION

The European Habitats Directive (EEC, 1992) defines coastal lagoons as "*expanses of shallow coastal salt water of varying salinity and/or water volume, wholly or partially separated from the sea by sand banks or shingle, or less frequently, by rocks*" (CEC, 2003). Several different types of Irish lagoons have been identified including natural lagoons which are separated from the adjacent sea by a natural sand or shingle barrier or by a rocky sill/barrier and artificial lagoons separated from the sea by an anthropogenic construction such as a sea wall (Barnes 1989, Joyce *et al.*, 2005). Lagoons have been included as "priority habitats" in the Habitats Directive *i.e.* the lagoon habitat is in particular need of protection (CEC, 2003). In order to develop effective lagoon management strategies, there is an urgent need to increase knowledge and understanding of the exceptionally complex and dynamic environmental and biological characteristics of these habitats.

Salinity has a major impact on the biological functioning of lagoons (Aké-Castillo and Vázquez, 2008). Salinity varies considerably between lagoons from nearly freshwater to hypersaline (Oliver, 2005) and within lagoons, both spatially and temporally. Large salinity gradients often occur between the sea water and freshwater inflows and, sometimes, vertically, due to stratification in deeper lagoons. Generally, however, stratification is limited due to the shallow nature of many lagoons. Temporal variations are due to changes in rates of precipitation and evaporation (Healy *et al.*, 1997) and due to changes in the balance between freshwater inflow (ground or surface water and precipitation) and sea water influx (Aké-Castillo and Vázquez, 2008). Salinity regimes have been used to classify lagoons, based on their typical average salinity. A low salinity or brackish lagoon has a salinity range of 6 – 10 parts per thousand (ppt), a range of 18-35 ppt indicates a lagoon with intermediate salinity and salinity recordings of 35 ppt or greater imply that a lagoon is hyper-saline (English Nature, 2003).

Coastal lagoons are ecosystems where freshwater and marine invertebrates converge and form a mixed community that may vary spatially along the salinity gradient (Aké-Castillo and Vázquez, 2008). Potentially, organisms that occur in a lagoon can be exposed for prolonged periods to either saline or freshwater conditions. Many organisms can only survive and flourish within relatively narrow bands of salinity (Kefford *et al.*, 2004) whereas others can survive a broad range of salinity conditions such as *Phragmites australis* (Mauchamp and Mesleard, 2001). Lagoons, therefore, contain marine species that are tolerant of low salinities, freshwater species that are tolerant of high salinities and, most importantly, lagoonal specialists. Lagoonal specialists are those species that have specifically evolved to survive the highly dynamic nature of lagoons. As lagoonal specialists are quite rare, many are legally protected and of great conservation importance (Barnes, 1989).

Many freshwater or marine species, either plant or animal, that are washed into lagoons via the tide or freshwater streams are unable to survive the change in salinity (higher or lower) and die. If the tidal inflow to a lagoon is quite powerful, a considerable amount of saline macrophytes (*e.g. Ulva* spp., *Fucus* spp.) may be carried in (Vizzini and Mazzola, 2006). Only a very small fraction of this biomass is consumed by herbivores and, therefore, the majority of the biomass is accumulated in the sediment and plays a crucial role in the ecology of coastal lagoons via the detritic pathway (Menéndez *et al.*, 2003; Lloret and Marin, 2009). Similarly, significant freshwater inflows can carry freshwater macrophytes, periphyton and leaf litter into lagoons. Moreover, lagoons can also host vast beds of submerged macrophyte species which die off seasonally further adding to the detritus loading (Menéndez *et al.*, 2003). Both washed-in terrigenous organic matter and marine detritus can contribute to accumulation of organic matter in lagoons (Vizzini and Mazzola, 2006). The extent of accumulation of organic matter depends on how restricted the outflow of a lagoon is. Dead and dying material may not be flushed out, but will settle in the sediment and decompose (Healy, 1998).

Decomposition is the disintegration of plant and animal material, to the stage where the cell structure is destroyed and organic compounds are metabolised into inorganic forms. Decomposition involves biological (invertebrate and microbial activity), chemical and physical factors (mechanical breakdown) (Boulton and Boon, 1991). Decomposition and detritus recycling are the source of the majority of nutrients consumed by grazers and filter feeders in a lagoon (Menéndez, 2009). The most common and abundant decomposers recorded in Irish lagoons include *Neomysis integer*, *Gammarus* spp, *Palaemonetes varians* and *Lekanesphaera hookeri* (Oliver, 2005).

Lagoons tend to be nutrient rich and are similar to estuaries in that they represent environments of high productivity. Nutrients such as phosphates and nitrates enter the lagoon via the inflowing river, direct catchment runoff and the sea (Aveytua-Alcázar and Camacho-Ibar, 2008). The restricted flow out of lagoons, especially in times of low rainfall, can lead to a gradual build up of nutrients because they are not flushed out of the lagoon as quickly as they enter. Healy (1998) proposed that lagoon productivity is increased by the substantial accumulation of decaying plant material which remains trapped.

This study investigated the *in situ* decomposition of terrestrial plant biomass and marine algal biomass in an Irish lagoon. It also examined the spatial pattern of the decomposition of biomass in the context of the variable salinity levels and the abundance of invertebrates associated with the decay process.

2. MATERIAL AND METHODS

2.1. SITE SELECTION

This study was undertaken at Cuskinny Nature Reserve, Cobh, Co. Cork, Ireland (51^{0}21'30"N, 08^{0}15'49"W). Cuskinny Lagoon lies within this reserve. It is one of Ireland's 87 lagoons. Cuskinny is an artificial lagoon, formed when a road was built parallel to Cuskinny Bay in the mid 1950s. It is a shallow lagoon with a maximum depth of 1.5 m. It is separated from the adjacent sea by a road causeway. Cuskinny Nature Reserve is privately owned and under the management of Bird Watch Ireland, which, is a conservation organisation dedicated to protecting Irish wild birds and their habitats. Cuskinny Lagoon covers approximately 4 ha and lies 1.5 m below the high tide level of the adjacent Cuskinny Bay. The maximum tidal range at Cuskinny Bay is 4.3 m. Sea water flows into the lagoon at each high tide via a channel that connects the south western end of the lagoon with the intertidal area of Cuskinny Bay (see Fig.1). This is the same channel through which the water in the lagoon flows out after high tide. The channel runs for approximately 100 m from the lagoon to the road causeway and the intertidal area of Cuskinny Bay. Freshwater enters the lagoon at its northern end through the Ballyleary Stream which originates approximately 3 – 4 km upstream of the reserve and drains a rich agricultural grassland catchment area of approximately 8 km^2.

2.2. CHARACTERISATION OF SALINITY REGIME

The salinity regime for Cuskinny lagoon was characterised over an 18 month period, in 2008 and 2009, as part of a broader study. Four stations labelled A to D were used (Fig. 1), with A being closest to the freshwater inflow and furthest from the sea water inflow, B being halfway between the two inflows, and C and D being either side of the sea water inflow.

Salinity was measured *in situ* from a boat using a salinity meter (a Wissenschaftlich – Technische Werkstatten (WTW) Meter, Model 330i, with a WTW TetraCon 325/C probe attached), at two points: 10 cm below the surface and just above the sediment, every six weeks. Salinity was measured approximately 2 hours before high tide when the water in the lagoon was still flowing out of the lagoon to the intertidal area of Cuskinny Bay.

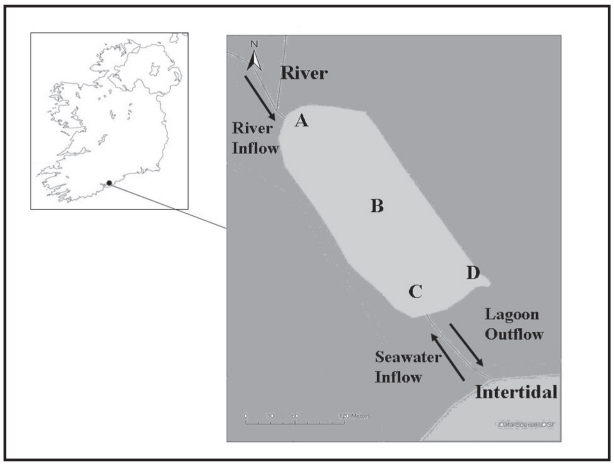

Fig. 1 Map of Cuskinny Lagoon, South-west Ireland, indicating the river and seawater inflows and the lagoon outflow, as well as the positions where salinity was measured and decomposition bags were placed.

2.3. In situ decomposition

In order to study decomposition patterns in Cuskinny six different sites were selected. These included four sites within the lagoon (A, B, C, D), one site approx. 40 m upstream in the Ballyleary river entering Cuskinny lagoon and one site in the inter-tidal area outside the lagoon at Cuskinny Bay. The litter bags at the intertidal site were exposed at very low tides (<0.5 m), this occurred on approximately 10 occasions during the study. A total of 36 decomposition bags were placed in and near the lagoon, for a period of six weeks in May and June 2010, 18 were filled with alder (*Alnus glutinosa*) leaves collected during leaf fall in the area and stored at 4°C until used and 18 were filled with seaweed (*Fucus vesiculosus*) collected from the shore of the adjacent beach just prior to the experiment. *A. glutinosa* and *F. vesiculosus* were selected for this study as both species were common in the area and very frequently ended up in the lagoon as detritus.

Decomposition bags were 15 cm^2 in size, had a mesh size of 1 mm^2 and were constructed, filled, placed and removed from Cuskinny according to the methods outlined in Boulton and Boon (1991). In each decomposition bag 25g of *A. glutinosa* leaves (fresh weight) or 25g of *F. vesiculosus* (fresh weight) was placed. Five replicates of each of the sample bags were taken and the contents oven dried at 50°C to constant weight to correct for water content and to get a corresponding mean dry weight for *A. glutinosa* and *F. vesiculosus* before any of the bags were submerged in the lagoon. Similarly, the oven dried biomass was then placed in a furnace at 450°C and dried to constant weight to get a corresponding mean ash free dry weight (AFDW).

Decomposition bags were removed from the lagoon after six weeks. Bags were removed from the benthic surface using a d-shaped net on a long pole enabling any invertebrates that were present in or around the bag to be trapped in the net. These, along with any invertebrates remaining in the bags at the time of processing, were collected, stored in 70% alcohol, identified according to Quigley (1986); Heyward and Ryland (1995); Nilsson (1996); Olsen *et al.*, (1999) and counted.

The plant material from the bags was carefully rinsed clean with deionised water and oven dried at 50°C to a constant weight and then re-weighed. It was then placed in a furnace at 450°C and dried to a constant weight and reweighed to obtain the AFDW using the method of Menéndez (2009) and Gavlak *et al.,* (1994). This was necessary due to contamination of decomposing material by inorganic material, such as silt.

All data were analysed using univariate and non-parametric univariate techniques contained in SPSS [PASW® (Predictive Analytics Software) Statistics 17] software. ANOVAs and Kruskal – Wallis tests were applied, where appropriate.

3. RESULTS

3.1. Salinity and rainfall

Salinity in the lagoon ranged from 0.2 ppt to 30.8 ppt, over the summer months, in 2008 and 2009. Salinity levels just above the sediment of the lagoon were higher than at the surface at the same time point. In 2008, salinity just above the sediment peaked at 29.6ppt, 30.8 ppt and 31.5ppt in April, May, and July, respectively, whilst surface salinity was typically lower with peaks of 25ppt 20.7ppt, 34.1ppt, respectively (Fig. 2a, 2b). Similarly, in 2009, salinity just above the sediment peaked at 19.9ppt, 26.8ppt and 29.9ppt in April, June and July respectively, whilst surface salinity was 8.6ppt, 19.5ppt, 4.5ppt, respectively (Fig. 2c, 2d).

The site furthest from the sea water inflow and nearest to the freshwater inflow (A) generally experienced the lowest salinity throughout the water column during the study period (ranging from 0.2ppt to 10.8ppt). Sites B, C and D, situated nearer to the sea water inflow, all experienced higher salinity. Site C, situated on the eastern side of the lagoon (Fig.1), tends to experience a lower salinity at the bottom than site B or D.

3.2. Decomposition

An average of 64.4% of *F. vesiculosus* was lost over the six weeks while only 33.9% of the *A. glutinosa* biomass was lost (Fig. 3), across all sites, both inside and outside of the lagoon (Fig.1). The loss of *F. vesiculosus* biomass was significantly greater ($p<0.001$) than the loss of *A. glutinosa* biomass.

A more detailed analysis of the percentage biomass loss in decomposition bags containing *A. glutinosa* leaves (Fig. 4) reveals that by far the greatest biomass loss occurred at site A, near the freshwater inflow (83.9%) with much smaller losses throughout the rest of the lagoon at sites B, C and D (13%, 31.4%, 25.1%, respectively) and in the intertidal zone outside of the lagoon (46.4%). The loss experienced at site A was significantly greater ($p<0.001$) than at the rest of the sites. The

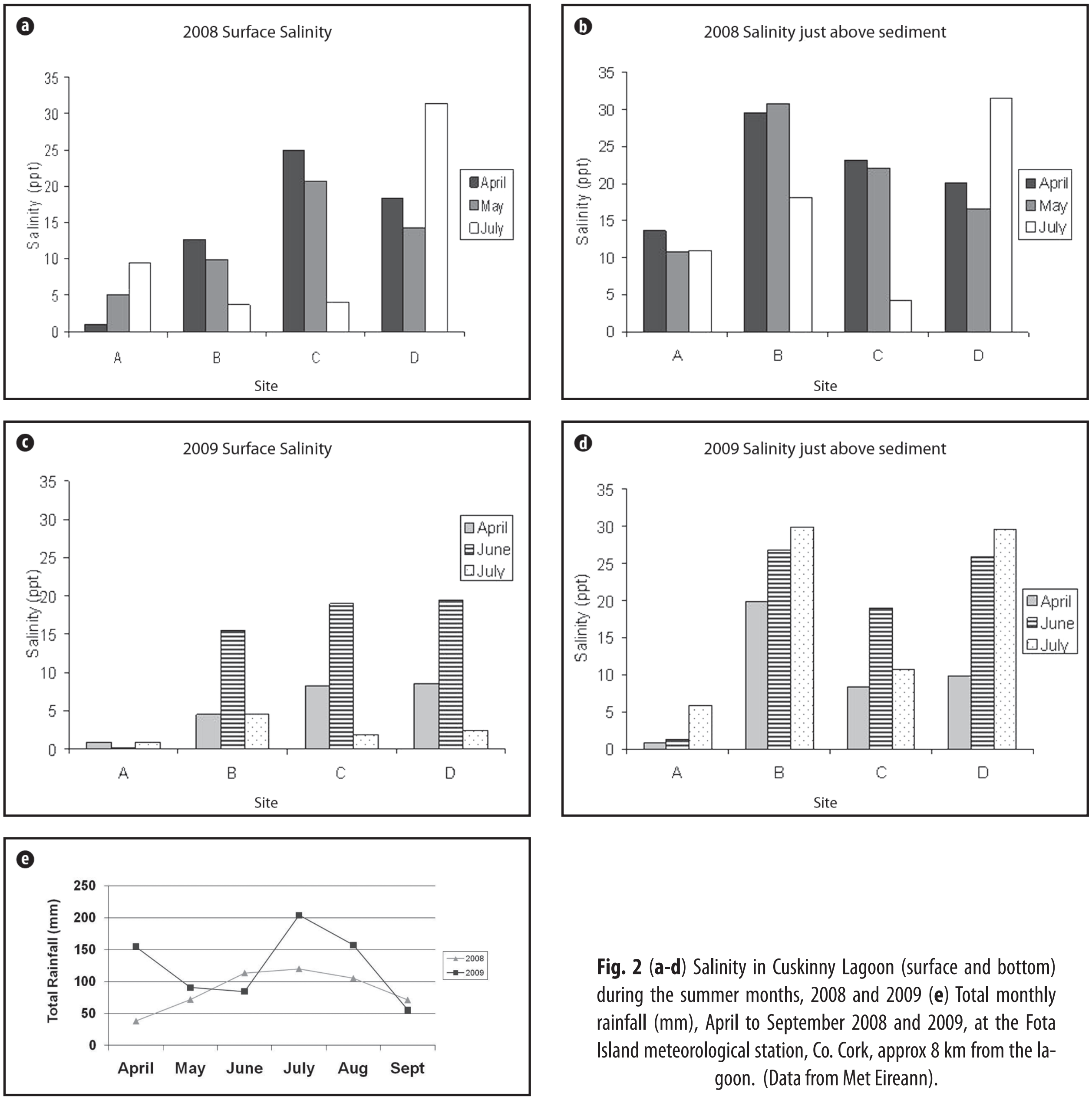

Fig. 2 (**a-d**) Salinity in Cuskinny Lagoon (surface and bottom) during the summer months, 2008 and 2009 (**e**) Total monthly rainfall (mm), April to September 2008 and 2009, at the Fota Island meteorological station, Co. Cork, approx 8 km from the lagoon. (Data from Met Eireann).

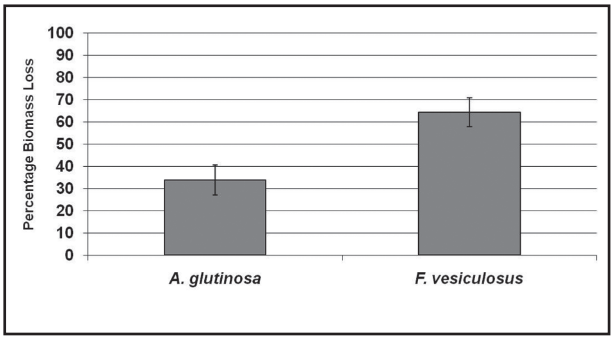

Fig. 3 Mean Percentage Loss in Ash Free Dry Weight of *A. glutinosa* and *F. vesiculosus* after six weeks in Cuskinny Lagoon, summer 2010. Vertical bars indicate standard error.

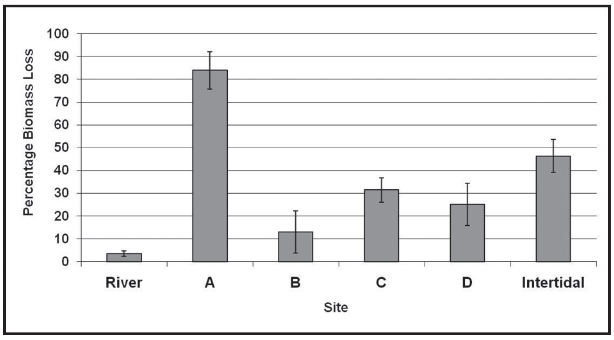

Fig. 4 Mean percentage loss in Ash Free Dry Weight of A. glutinosa at six different sites (see Fig. 1 for site locations) near and within Cuskinny Lagoon after six weeks, summer 2010. Vertical bars indicate standard error. Any value sharing a common letter is not significantly different using the Tukey Test (P<0.001).

lowest percentage loss of biomass, 3.5%, was in the River. The loss at this site was significantly less (p<0.001) than that of site A or the intertidal site.

A high percentage of biomass was lost from decomposition bags containing *F. vesiculosus*, irrespective of position within the lagoon or in the River or intertidal sites (see Fig. 5). No statistical difference was found between the percentage losses of *F. vesiculosus* (Fig. 5).

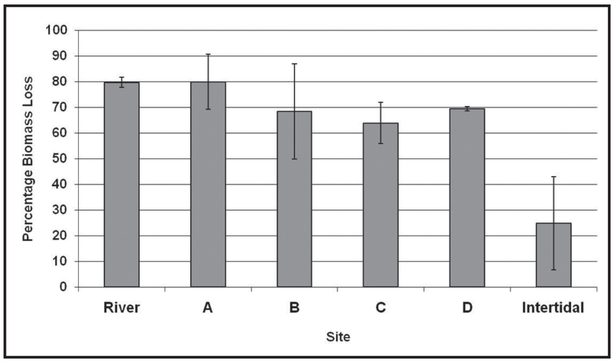

Fig. 5 Mean Percentage Loss in Ash Free Dry Weight of F. vesiculosus at six different sites near and within Cuskinny lagoon, after six weeks, summer 2010 (for location of sites, see Fig. 1). Vertical bars indicate standard error. There is no significant difference between sites using the Tukey Test (P<0.001).

3.3 Invertebrates associated with decomposition bags

Approximately 13 invertebrate species were found to be associated with the decomposition bags through all six sites. Seven species were found within the lagoon itself, of which three species are known to be salinity tolerant. These were *Chironomidae* larvae/pupae, *Carcinus maenas* and *Lekanesphaera hookeri*. *Chironomidae* larvae/pupae are generally considered to be freshwater species but are able to tolerate brackish conditions (Oliver, 2005; Silva *et al.*, 2008) and were most numerous at sites A, B and D, while *Gammarus* spp. were most abundant in the middle at site B. Furthermore, two individuals of *Carcinus maenas,* a species usually associated with the seashore were found at sites C and D near the sea water inflow *i.e.* the site which usually had the highest salinity. One lagoonal specialist, *Lekanesphaera hookeri* was also found in low numbers at sites B and C. The most abundant taxa occurring in the lagoon was *Chironomidae* larvae/pupae, closely followed by *Gammarus* spp. Of the seven species in the lagoon, six are known to be grazers or decomposers (see Table 1).

Chaetogammarus marinus which is known to be salinity tolerant was only found at the intertidal site outside of the lagoon. Marine invertebrate species were found either at the intertidal site outside the lagoon or near the sea water inflow inside the lagoon. No freshwater invertebrate species were identified at the intertidal site with the exception of a small number of chironomids.

Table 1. Invertebrate species associated with decomposition bags (A.G – *A. glutinosa* bags and F.V – *F. vesiculosus* bags) in Cuskinny Lagoon, summer 2010. (Species found within lagoon are marked in bold, while the others were found at the river or intertidal site).

Species	Position in or near Cuskinny Lagoon											
	River		Site A		Site B		Site C		Site D		Intertidal	
	A.g	F.v	A.g	F.v	A.g	F.v	A.g	F.v	A.g	F.v	A.g	F.v
Asellus aquaticus*	1	13	**1**									
Carcinus maenas**								**1**		**1**		1
*Chaetogammarus marinus****											17	22
Chironomidae* larvae/pupae**	11	25	**33**	**13**	**28**	**21**	**6**	**2**	**78**	13	5	5
Gammarus* spp**	1	1	**2**	**1**	**59**	**67**	**15**	**13**	**22**	5	4	
Glossiphonia complanta	1	2										
Hydrobidae operculum											1	
Lekanesphaera hookeri***					**1**			**2**				
*Limnea spp**	1											
*Littorina littorea**												6
*Mytilus edulis***												2
Potamopyrgus Jenkins*		1					**1**					
Oligocheata*	16	9		**8**						**2**		
Total	32	51	**36**	**22**	**87**	**88**	**22**	**18**	**100**	**20**	27	46
Site Total	82		**59**		**175**		**40**		**120**		73	

A.g – A. glutinosa, F.v – F. Vesiculosus
* Known grazer/decomposer
** Known to be somewhat salinity tolerant
*** Known grazer/decomposer and known to be salinity tolerant

4. DISCUSSION

4.1. Lagoon salinity and rainfall

The salinity in Cuskinny Lagoon was found to range from 0.2 ppt to 30.8 ppt during the summers of 2008 and 2009 (Fig. 2). The salinity just above the sediment was found to be higher than that just below the surface. Based on these data, the salinity of Cuskinny can be classified as intermediate using categories outlined by Barnes (1989) and Joyce *et al.*, (2005). The salinity in Cuskinny lagoon fluctuates considerably compared with other lagoons in south-west Ireland (Data not shown). Some lagoons in the east of the British Isles are known to become hypersaline reaching peaks of up to 52 ppt (Joyce *et al.*, 2005). However, this was not observed in Cuskinny in 2008 and 2009, when salinity levels did not reach full sea water levels (35 ppt). Although no full hydrological analysis was carried out on the balance between freshwater inflow (ground or surface water and precipitation) and sea water influx (Aké-Castillo and Vázquez 2008), it can be surmised that the reason for a lack of hypersalinity in Cuskinny Lagoon was due to extensive rainfall (71.8 - 119.9 mm/month, in 2008, and 55. 4 – 203.8 mm/month, in 2009) during the monitoring period (Fig. 2).

Cuskinny Lagoon has a freshwater input at the northern end. The entry point of the Ballyleary stream into Cuskinny Lagoon (site A) is an area with low salinity throughout the water column. Sites B, C, D, which are further away from the freshwater inlet, had relatively higher salinities (Fig. 2). Site C, possibly because of its more sheltered location near the eastern corner of the lagoon, had lower salinity levels (surface and just above the sediment) than sites B and D. Bianchi *et al.*, (2003) found that, when freshwater inputs into a lagoon are significant, spatial variability of salinity levels, nutrients and macrophyte distribution become more pronounced.

4.2. Salinity and salinity stress

Marine and terrestrial biomass (such as macrophytes, marine algae, and phytoplankton) is known to be carried into lagoons by freshwater and tidal inflows (Vizzini and Mazzola, 2006). In the course of this study, it was frequently observed that substantial amounts of marine and terrestrial biomass were accumulated in particular areas of Cuskinny Lagoon.

Marine species that were regularly identified in Cuskinny Lagoon were *F. vesiculosus* or *Ulva* spp. Both species are known to be tolerant of variable salinity levels. *Ulva* spp. is a euryhaline species that can survive salinities of just 5ppt (Choi *et al.*, 2009). *F. vesiculosus* has a salinity threshold of 4ppt, below which it dies (Torn *et al.,* 2006). Thus *F. vesiculosus* is tolerant to short periods of low salinity conditions which it will encounter in its habitat on the rocky seashore and within estuaries (Pearson *et al.,* 2000). During this study, the salinity in some areas of Cuskinny Lagoon fell below the identified tolerance levels for both species (Fig. 2). Therefore, it is likely that much of the *Ulva* spp.and *F. vesiculosus* biomass being flushed into Cuskinny is unable to survive and enters the detritic pathway. Likewise, it can be surmised that many marine organisms washed into lagoons will die because they are not able to tolerate hyposalinity.

Terrestrial biomass entering the lagoon comes in the form of freshwater organisms, as well as organic debris, including abscised leaves or broken reeds. Terrestrial debris that was identified in Cuskinny Lagoon included *A. glutinosa* and *P. australis* leaves. Cuskinny Lagoon has extensive beds of *P. australis*, a species which can tolerate a wide range of salinity levels (Marks *et al.,* 1994).

The local accumulation of biomass, both marine and terrestrial, and either dead or dying, due to poor salinity tolerance, may induce substantial decomposition activity, which in turn can facilitate rapid biomass loss from dead material (Healy 1998).

4.3. Decomposition of organic matter

The greatest loss of *A. glutinosa* biomass in Cuskinny Lagoon occurred at site A, closest to the freshwater inflow and furthest from the sea water channel (Fig. 4). The biomass loss at site A was statistically greater ($p<0.001$ level) than at all other sites. After six weeks submerged at this site an average biomass loss of 83.9% was measured, which was high in comparison with the second greatest loss of 46.4% at the intertidal site outside the lagoon. Just 4% of *A. glutinosa* biomass was lost at the upstream river site. The river site is characterised by a continuous flow of water. In contrast, site A in the lagoon is quite a still environment, with any disturbance from the inflowing river dissipated by the reed beds possibly constituting a zone of deposition. It can be speculated that high deposition leads to decomposer activity, and that this is consistent with the rapid *A. glutinosa* biomass at this site (Fig. 4).

After only 6 weeks submergence in Cuskinny Lagoon, up to 83.9% of the *A. glutinosa* biomass had been lost. Dilly and Munch (1996) showed that *A. glutinosa* decomposes more rapidly when placed in wet sites as opposed to dry, terrestrial sites. In their study, after 12 months exposure at a freshwater site, 90% of the *A. glutinosa* leaf biomass had been lost. Similar losses of *A. glutinosa* were also found by Bocock (1964) in a terrestrial environment, where 90% of *A. glutinosa* leaf biomass was lost after 148 days. Thus, compared with published studies, Cuskinny Lagoon appears to display particularly rapid rates of *A. glutinosa* decomposition, indicating that decomposer activity is particularly well evolved.

F. vesiculosus was degraded at a high rate at all sites with 79.7%, 80%, 68.4%, 63.9% and 69.4% of biomass lost at the River and sites A, B, C and D, respectively. The lowest biomass loss was measured at the intertidal site outside the lagoon (Fig. 5). Thus, decomposition was found to be equally rapid in the river, near the freshwater inlet, the centre of the lagoon and near the sea water channel. Other studies have also found no clear pattern of decomposition loss along a salinity gradient in an estuary (Quintino *et al.*, 2009).

Thus, the spatial pattern of *A. glutinosa* decomposition differs from that of *F. vesiculosus* decomposition (Fig. 4 versus Fig. 5). The two types of biomass constitute very different food sources for decomposers. *F. vesiculosus* biomass provides a food source relatively high in nitrogen as it had been freshly harvested from the seashore. In contrast, *A. glutinosa* leaves had been collected at leaf senescence, the time at which nutrients in the leaf such as nitrogen, phosphorus and metals would have been removed (Aerts, 1996; Quirino *et al.*, 2000). Also, tree leaves contain cellulose and lignin which influence decomposition rates (Dilly and Munch, 1996), while *F. vesiculosus* contains polygalactans (Østgaard *et al.*, 1993). Therefore, these results suggest that different decomposer communities exist in Cuskinny Lagoon, each with a preference in terms of substrate, resulting in the observed differences in spatial pattern of decomposition.

4.4. Decomposition and invertebrates

Seven taxa were associated with the *A. glutinosa* and *F. vesiculosus* decomposition bags in the lagoon. Of these, six taxa are known grazers or decomposers (Table 1). It is possible that these invertebrates played a role in the decomposition of *A. glutinosa* and *F. vesiculosus* biomass. However, Vizzini and Mazzola, (2006) and Menéndez (2009) concluded that in shallow aquatic ecosystems biomass loss from dead plant material cannot be attributed to the macroinvertebrate community alone. Rather, other factors such as physical fragmentation and microorganism activity play a key role in biomass loss. Boulton and Boon (1991) are in agreement with this and propose that invertebrates associated with litter bags may only be using them as a means of shelter. Therefore, it is likely that biomass loss of *A. glutinosa* and *F. vesiculosus* in Cuskinny Lagoon can be attributed to microbial and epiphytic activities (Menéndez, 2009). The heterotrophic microorganisms initially colonize the biomass surface making it more palatable for the detritic invertebrates. Subsequently, invertebrates consume and fragment the decaying biomass leading to further decomposition loss (Menendez *et al.*, 2003).

Joyce *et al.*, (2005) and Lloret and Marín (2009) suggest that, because lagoons represent "naturally stressed environments", they have a restricted species abundance of macroinvertebrates. Healy *et al.,* (1997) also observed that lagoons have a low species diversity compared with their freshwater or marine counterparts. Low species diversity was observed in Cuskinny Lagoon (Table 1). Seven different invertebrate taxa were identified. Joyce *et al.*, (2005) studied 28 similarly sized lagoons in England and the species richness ranged from 8 to 27 taxa. Four of the seven species found in Cuskinny Lagoon are known to possess some degree of tolerance to variable salinity. These include *Carcinus maenas, Chironomidae* larvae/pupae, *Gammarus* spp. and *Lekanesphaera hookeri*. The isopod, *L. hookeri,* is a recognised lagoonal specialist (Joyce *et al.*, 2005, Oliver, 2005). There has been only one study on the ecology of *L. hookeri* in an Irish lagoon by Norton and Healy (1984) who found that its distribution in a lagoon had no relationship with salinity. This was confirmed in Cuskinny Lagoon, where *L. hookeri* was found in low numbers at sites C and D.

Total invertebrate abundance at site A, where *A. glutinosa* decomposition was fastest, is relatively low compared with other sites (Table 1). Thus, the analysis of the invertebrate assemblages in Cuskinny Lagoon shows that overall invertebrate abundance does not relate to biomass loss. The most numerous decomposers at site A were the *Chironomidae*. Detritivore chironomids generally feed on fine organic matter (<1mm) (Silva *et al.*, 2008). It is not clear whether the chironomids contributed to the biomass loss at this site and in this study. The *A. glutinosa* and *F. vesiculosus* biomass in the litterbags would have been physically too large for the chironomids to break down. However, the presence of the chironomids may well reflect relatively high deposition of organic debris at this still site.

Decomposition is an important process in the recycling of nutrients. Healy (1998) proposed that substantial amounts of decaying biomass remain trapped and accumulate in lagoons due to an absence of vigorous flushing. Decomposition of such biomass can increase lagoon productivity (Healy, 1998). This study further highlights the important role of decomposition, by showing an intricate pattern of decomposition across a lagoon and for different types of biomass.

5. CONCLUSION

Cuskinny Lagoon is an interesting environment of extremes, a heterogeneous system, where different areas demonstrate different patterns of water circulation and biological and chemical activity. Salinity is classified as low – intermediate and decomposition rates are high throughout the lagoon for *F. vesiculosus*. The most active zone for decomposition of *A. glutinosa* was nearest to the freshwater inflow and furthest away from the sea water inflow. This study demonstrated the spatial difference in decomposition patterns of marine and terrestrial biomass in Cuskinny. It also showed that *A. glutinosa* biomass is degraded less rapidly than *F. vesiculosus* biomass in the dynamic environment of Cuskinny Lagoon.

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