

L A B COASTAL ANNUAL REPORT 2000

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CONTENTS

About LAB Coastal	3	
MISSION STATEMENT	3	
VISION STATEMENT	3	
OBJECTIVES	3	
CLIENTS	4	
ACTIVITIES IN 2000	4	
Programme Performance	5	
RESEARCH STRATEGY	5	
RESEARCH PROJECTS		6
EUROSAM	6	
ISLED	10	
BRAUNTON	13	
SEILEBOST	13	
RESEARCH ARTICLE Comparative processes and functions in salt marshes and mangrove forests and their role in coastal ecosystems	15	
Financial Statement	33	
Facilities and services	34	
Links with other organisations	35	
Contact Points	36	
Publications	38	

ANNUAL REPORT 2000

L A B COASTAL

About LAB Coastal

MISSION STATEMENT

To harness ecological research to integrated land management especially in the coastal zone.

VISION STATEMENT

L A B Coastal initiates, conducts and publishes high quality research into ecological processes, particularly in the coastal zone, and undertakes commissioned research and consultancy into specific land management problems with special reference to the coastal zone. This facilitates the integrated management of the natural resources of the living coastline.

OBJECTIVES

LAB Coastal offers a client-orientated and flexible approach to survey, research, monitoring and management. The company aims to provide the highest quality services for the assessment of the effects of environmental change on ecosystems, environmental impact assessments, system design for environmental monitoring and simulation modelling for habitat restoration and creation.

LAB Coastal is, however, at the same time deeply committed to basic research. It is often assumed that this can be side-stepped in order to get down to commissioned research. This is to neglect the fundamental scientific truths which must underpin any work in the applied field.

CLIENTS

Clients include the EU (CEE DG XII), within the EUROSAM and ISLED programmes, the MOD and civil engineering firms.

ACTIVITIES IN 2000

In the third full year of its existence LAB Coastal has undergone further technical consolidation coupled with continuing progress on the current and future research activities. Further developments have taken place in laboratory and computing facilities to ensure maximum efficiency as regards both client-oriented and basic research. There has also been a continuing flow of scientific papers and contract reports (see 'Publications', p.35). The year 2000 has seen the completion of the 'EUROSAM' project (see under Research Projects, p. 5) and the final field season of the ISLED project (see under Research Projects, p. 9). At the same time it has seen co-operative efforts between L A B Coastal and various partners to secure funding for future projects to build on current achievements and to provide the scientific background for future coastal zone management.

Another important milestone for L A B Coastal was the registration of its domain name (labcoastal.co.uk) and the establishment of its own website (www.labcoastal.c.uk). The aim of this was to provide a focus for publicity and an accessible source of information for potential clients and for the scientific community and coastal zone managers generally. The website gives on-line access to details of the full range of activities and services of L A B Coastal (Fig. 1).



Figure 1. Header and major components of the new LAB Coastal webpage.

Programme Performance

RESEARCH STRATEGY

The philosophy of LAB Coastal is that the foundation of all its work is basic research. While the primary objective must remain the application of this high grade research to practical problems of ecological and conservation management this can only be done if the basic scientific information is available. LAB Coastal is currently engaged in research into coastal problems both in the UK and abroad. Added urgency is given to such work by the threat of rising sea level and the consequent encroachment of the sea on to areas which are valuable for wild life as well as on to economically sensitive areas, such as industrial and residential zones.

RESEARCH PROJECTS

EUROSAM

The first objective of these studies, for L A B Coastal, had been to define the main parameters of the various organic carbon and nitrogen cycles in the salt marsh ecosystem and to identify the key environmental factors which control them. The second objective was to construct models of these processes in order to facilitate the development of a decision support system to assist in effective salt marsh management. Two models were constructed: 'ANCOSM' for the organic fluxes and 'NITROMOD' for fluxes of various forms of nitrogen.

A new experimental approach to the study of the organic fluxes was based on the use of *'in situ'* mesocosms in the salt marsh at Tollesbury, Essex. The area had already been used for salt marsh studies and there was a considerable body of data already available. The experimental approach used was to isolate large cores of salt marsh, subject them to different management treatments, and to determine the changes in the soil organic content by taking small core samples at three-monthly intervals.

Considerable physical and chemical changes occur to mineral matter and organic matter after they have been deposited on the salt marsh as shown by the changes in both organic content and bulk density (by soil compaction) of the soil with depth. The process of soil compaction was studied by using markers anchored at different depths in the marsh and by monitoring their relative movements. These showed that the differential soil compaction affected the incorporation of sediment and organic matter into the salt marsh soil (Fig. 2).

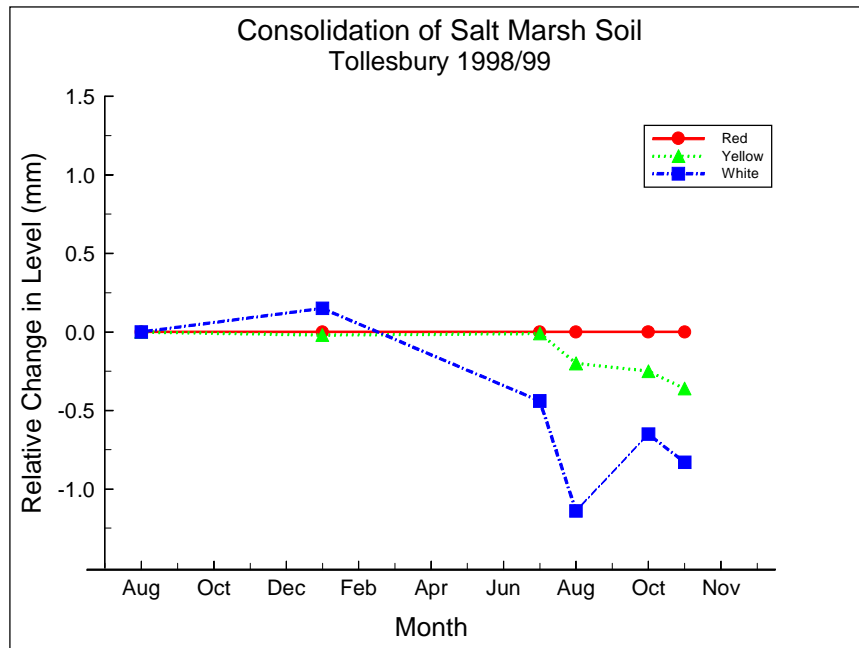


Figure 2. Consolidation of a salt marsh soil at Tollesbury, Essex. The red marker, taken as the reference level is anchored at a depth of 1000 mm, the yellow at 600 mm and the white at 400 mm.

In order to broaden the applicability of conclusions reached from the studies in East Anglia, data was also collected from a range of Scottish sea lochs where there are discrete areas of salt marsh connected to relatively self-contained water bodies but with varying proportions of salt marsh and water. The four lochs studied showed contrasting patterns of vegetation development under a wide range of sedimentary conditions.

The model 'ANCOSM' was constructed, integrating the various fluxes of organic matter under different environmental scenarios. The model showed that below-ground primary productivity contributed significantly to the vertical development of the salt marsh particularly when rates of sedimentation were low. It was estimated that under typical marsh conditions in East Anglia the accumulation of organic matter below ground could contribute up to 10% of the vertical growth of the

marsh (Fig. 3). Under less favourable conditions with low sedimentation rates organic matter could contribute as much as 35% to marsh growth. There are considerable implications for marsh management here but complex processes, involving the cycling of nitrogen, control the rates of loss of soil organic matter by mineralization. However it was considered possible that while mineralization of organic matter could reduce the contribution to vertical growth, the effect could largely be cancelled out by the release of nutrients improving plant productivity.

The nitrogen cycle was examined by constructing a model 'NITROMOD'. This was built by examining published nitrogen models and using appropriate segments of them, amended where necessary, to build a model applicable to salt marshes. The model was based on data collected previously in Essex, supplemented by additional data from Tollesbury collected in conjunction with the ANCOSM studies, and validated by using data from Norfolk. The model was constructed to fit the available data concentrating therefore on the processes for which sufficient data were available.

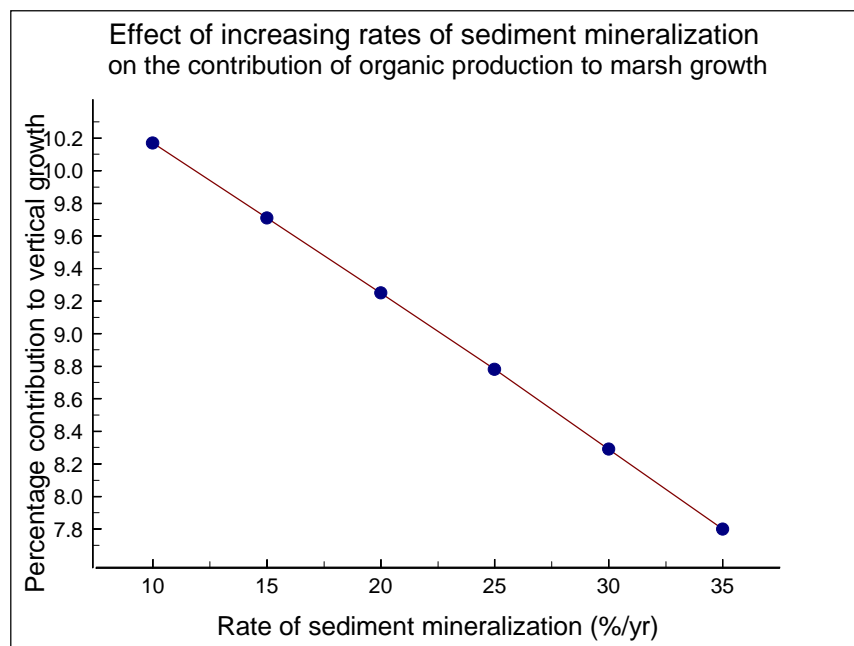


Figure 3. *Effect of rates of mineralization of organic matter in salt marsh soils on the contribution of organic production to marsh growth.*

'NITROMOD' predicted well the changes in the soil $\text{NO}_3\text{-N}$ concentrations (Fig. 4) but the levels of $\text{NH}_4\text{-N}$ were more variable and less easy to predict. The model used a monthly time step reflecting our data but there are also considerable changes on a much shorter time scale. The use of a time scale of a day or even a few hours would have been better but sufficiently detailed data were not available. Differences between salt marsh plant species in C:N ratio and in the rates of breakdown of plant litter and variations in soil moisture were critical factors here. It was concluded that longer runs of data collected at shorter intervals would greatly improve the model but the model also needs to be developed to enable spatial differences in nitrogen cycling to be taken into account.

Although the project is now at an end work is continuing on key aspects of the project, particularly on the long term monitoring of the processes of soil consolidation and on the integration of the NITROMOD and ANCOSM models as there are close links between the metabolism of carbon and nitrogen cycling.

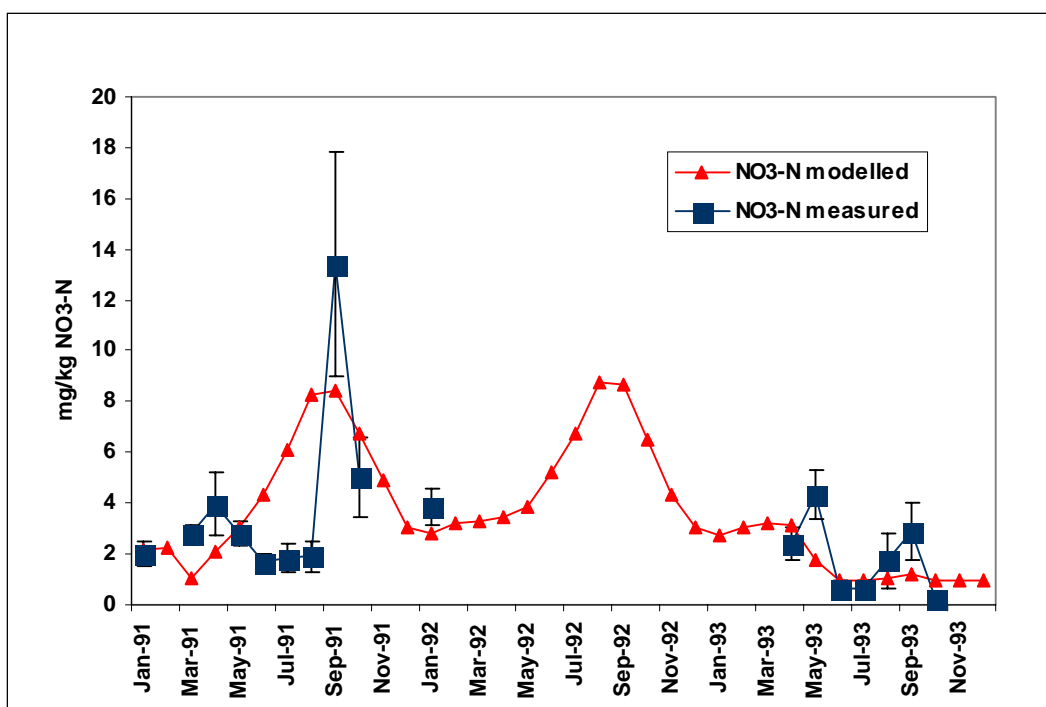


Figure 4. Comparison of modelled and real soil $\text{NO}_3\text{-N}$ data (\pm SE) for Tollesbury Lower Marsh

ISLED

The sedimentation studies done by L A B Coastal under Work Package 3 of the ISLED programme included the following three items:

- 1.) annual salt marsh accretion rates were determined by the use of erosion/accretion transects at the three Westerschelde sites;
- 2.) daily sediment deposition rates at these sites were determined directly using filter paper sediment traps,
- 3.) interactions between the effects of sediment deposition rates and duration of tidal inundation on seedlings of selected salt marsh plants were studied in experimental mesocosms in the greenhouse.

Erosion/accretion transects were established in June 1998 at Ritthem (9 transects in 3 rows across the whole site), Ellewoutsdijk (10 transects in 4 rows across the west end of the marsh) and Waarde (11 transects in 3 rows across the east end of the marsh). These transects were recorded nine times in the following two years.

The rates of accretion were the most variable at Ritthem where there were changes in surface level varying from -22.8 mm to +17.4 mm over 27 months. Large seasonal and local variations were concealed in the overall mean annual rate of accretion of 2.1 mm. The results from Ellewoutsdijk were less variable and higher with a mean annual rate of 7.4 mm from individual transect results which varied between 4.2 and 35.5 mm (over 27 months).

Although the average altitude of the transects was the highest at Waarde, the site showed the fastest annual accretion rate averaging 12.2 mm. The end results from individual transects were much less variable than from other sites varying between 13.1 and 40.0 mm. Overall the middle marsh transects showed the highest rates of accretion with lower average rates in both the pioneer marsh and the high marsh.

The deposition of sediment over two consecutive tides was measured directly using

filter papers pinned to the surface of the mud. Measurements were done near the seaward edge of the marshes at all three sites in the Westerschelde during September 1998, July 1999, September 1999 and September 2000. The depth of sediment deposited was determined from sediment weight and, after allowing for the frequency of tidal inundation, an estimate was made of annual rates of accretion.

The highest annual rate of accretion was from Ellewoutsdijk (24.0 mm) with the lowest at Ritthem (16.9 mm); Waarde was intermediate (21.6 mm). Waarde showed the least variation between the four sampling periods (Max. = 26.7 mm - September 1998, Min. = 16.5 mm - July 1999) and Ritthem the greatest variation (Max. = 44.7 mm - July 1999, Min. = 5.5 mm - September 1998).

At Ellewoutsdijk the turbidity at the marsh edge was up to fifteen times greater than a few metres offshore indicating that the sediment was primarily of local origin. The very high rates of sediment deposition recorded at Ritthem in July 1999 can be explained by the increase in sediment load caused by wave action from on-shore winds.

The effects of high rates of sedimentation on seedlings of key salt marsh plant species when under stress from high rates of inundation were tested in specially constructed tidal mesocosms. Tidal regimes of 2.50, 1.75 and 1.00 hours inundation per tide were used. Sediment was added every fourteen days corresponding to 0, 10, 30 and 60 mm accretion per year. Seedlings of *Aster*, *Salicornia*, *Limonium* and *Triglochin* were tested over periods of approximately two months.

Plants of *Aster* showed a marked increase in shoot weight with increasing rates of sediment addition (Fig. 5). The plants subjected to sediment deposition responded by producing new roots from the buried section of the stem. *Salicornia* plants showed a similar response to *Aster* but without visible effects on the roots. The plants appeared to be benefiting from the improved anchorage as a result of burial even in the sheltered conditions in the mesocosms.

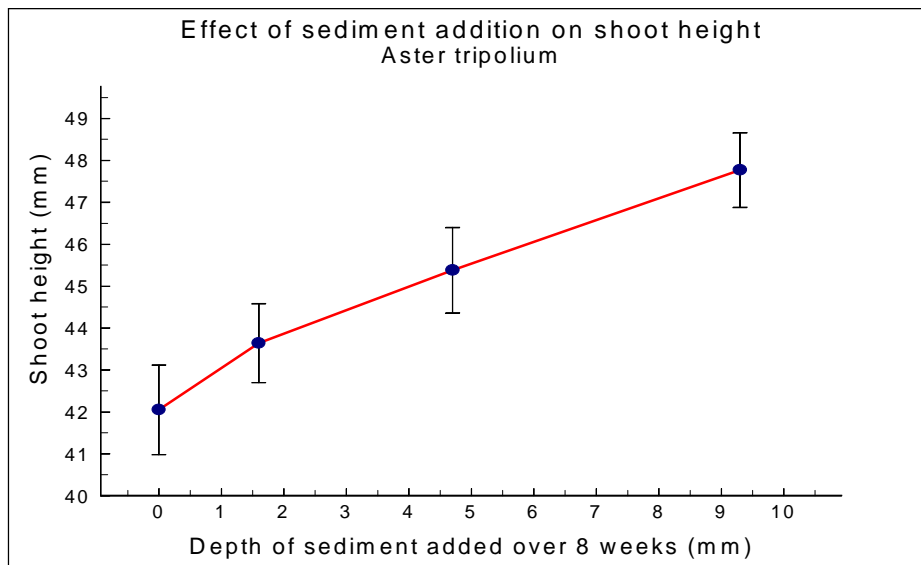


Figure 5. *Effect of different rates of sediment deposition of the growth of Aster tripolium in the tidal mesocosms.*

The growth and survival of *Limonium* plants were significantly reduced by sediment addition. The highest rate of sediment addition reduced the percentage survival of plants during the experiment from 90 % to 10 %. This was explained by the repeated loss of leaves by burial. Root growth was also greatly inhibited.

Triglochin was largely unaffected by sediment addition, although leaves grew longer. It grows best when submerged for the shortest period. *Triglochin* appeared to be the most tolerant of both inundation and sediment deposition of the four species which were tested. This tolerance is reflected by its widespread distribution under different conditions in the marshes.

GRAZING MANAGEMENT AT BRAUNTON BURROWS

The experimental grazing management of the dunes at Braunton Burrows continued in 2000 and L A B Coastal maintained its assessment of the "appropriateness and accuracy" of the botanical monitoring in order to ensure that the work had been carried out in a sound and objective way and "that the conclusions are scientifically valid". It is believed that the botanical diversity of the area can only be maintained if the intensity of grazing cattle and sheep is sufficient to keep the more vigorous grasses, herbs and shrubs under control.

This should have been the final year of the study but because of the high rainfall and the consequent good growing conditions in the dunes the vigour of the plant growth in 2000 meant that the impact of the grazing regime was so reduced that it was not possible to reach definite conclusions by the end of the year and the work is now continuing for a further two years.

CHANGES IN THE MACHAIR AT SEILEBOST

Environmental pressures are affecting coastal habitats around the entire coast of the British Isles. In many places the main causes are increasing human pressure on delicate coastal ecosystems with the impact of ever-increasing industrial or recreational developments or the effects of pollution and eutrophication. The Western Isles may seem far removed from all this but at Seilebost, on the Isle of Harris, there is a long spit of machair which is continually subject to the process of change under the influence of the wind and the waves (Fig. 6). Over recent years there appear to have been considerable losses from erosion and with the help of staff and pupils of Seilebost School, situated on this spit, L A B Coastal has been monitoring changes here for the past three years.

This work continued in 2000 and during this time the work has been extended by the study of aerial photography and old maps of the area. It seemed clear from the maps that a hundred years ago the spit was much more extensive than at present,

extending well towards the northern shore of the estuary. The current losses seemed to be a continuation of a very long process of erosion. However, the study of aerial photographs from the past 50 years showed a rather different picture with spells of erosion being followed by significant periods of growth and recovery. The data gathered during 2000 contrasted with that gathered in the previous two years and showed a marked slowing of the erosion processes. This could suggest that a switch from erosion to growth is possible although with the threatened rise in sea levels and predicted increase in storminess there must still be uncertainty regarding future changes. The large amount of data gathered in 2000 is currently being analysed.



Figure 6. *View of the machair at Seilebost, Harris showing the beginning of new dune*

growth following extensive erosion at the northern end of the peninsula.

RESEARCH ARTICLE

Comparative processes and functions in salt marshes and mangrove forests and their role in coastal ecosystems.

By *Laurie Boorman*, L A B Coastal

INTRODUCTION

Flowering plants can make great contributions to both biological and physical processes in coastal ecosystems through their ability to withstand regular flooding by salt water and thus to colonise and grow in intertidal areas. The presence of these plant species contributes directly to the physical stability of the habitat and to many biological processes.

In cool-temperate regions of the world the plant communities in these intertidal areas are familiar as salt marshes; herbaceous communities covering extensive areas along most low-lying coastal areas (Fig. 7).



Figure 7. *Typical salt marsh vegetation, growing in the south west of The Netherlands, with annuals and herbaceous perennials.*

They are notable for the general absence of woody plants with the exception of a few species of low-growing shrubs such as *Halimione portulacoides*. Salt water is usually fatal to all temperate tall-shrub and tree species. A few species, e.g. *Hippophae rhamnoides* or *Ligustrum vulgare*, can withstand a certain degree of salt spray but any increase in soil salinity results in dehydration and death.

In contrast in tropical, subtropical and warm-temperate intertidal areas the growth of woody species of plants is possible; consequently salt marshes are replaced by mangrove forests (Fig. 8). The term "mangrove" is defined as "woody trees and shrubs which flourish in mangrove habitats" (Hogarth, 1999) and true mangroves comprise some 54 species in 20 genera, belonging to 16 families, although 25 of the 30 major species belong to just two families Avicenniaceae and Rhizophoraceae. The salt marsh vegetation, dominated by a limited range of species, mainly short herbs and grasses, is replaced by very different communities dominated by shrubs and trees (Tomlinson, 1994). There is thus a complete visual contrast in the vegetation of the intertidal between the cool and warm areas of the world.



Figure 8. *Young mangroves growing on sand and rock in north Queensland.*

Nevertheless some of the biological and bio-physical processes are common to both types of habitat whereas for other processes there are fascinating differences. This article will examine similarities and contrasts in salt marshes and mangroves particularly in relation to the contribution made by plant productivity and the accumulation of organic matter in the physical and biological development of the respective habitats. It will also consider the part they play in relation to other coastal and marine ecosystems.

ABOVE-GROUND BIOMASS AND PRODUCTIVITY

Even with salt marshes, where the primary productivity can be measured directly by harvesting techniques, there can be considerable variation in estimates obtained both through the method used and as a result of difficulties in determining losses from the litter component. Nevertheless the estimates of productivity derived from monthly sampling can usually provide a reasonably reliable figure. Some salt marshes in Western Europe can show an aerial productivity in excess of 1 kg dry matter per square metre per year with some pioneer and middle marsh communities producing up to 2 kg annually (Boorman, 2000). However, some communities are rather less productive and the overall mean productivity may be taken to be of the order of 0.50 - 0.75 kg m⁻² yr⁻¹. The relation between biomass and productivity is a complex one but for ungrazed marshes in north-west Europe there is a close numerical similarity between the peak aerial biomass at the end of the growing season and the net annual above-ground (aerial) productivity (Boorman & Ashton, 1997).

The biomass of mangrove stands is clearly very much higher than that found in salt marshes with mangroves having a large woody component in the form of the standing timber of the major tree species. In north Queensland, Australia, typically the biomass falls within the range 10 to 60 kg m² (Clough, 1998) with the higher figures coming from stands dominated by large individuals of the genus *Rhizophora*. Values of 50 - 55 kg m² are typical for south east Asia but in Florida,

for example, dwarf *Rhizophora* may have a biomass as low as 0.8 kg m^{-2} (Hogarth, 1999). The biomass of mangroves decreases as the latitudinal limits are approached.

It is not usually practical to determine the biomass or annual productivity of mangroves directly for obvious reasons but there are indirect methods, based on the relationship between stem circumference and dry weight, which can be used over time intervals to determine the accumulation of biomass. The increase in the total above-ground biomass averaged $0.59 \text{ kg m}^{-2} \text{ yr}^{-1}$ in the north Queensland mangroves stands referred to above (Clough, 1998). In Florida biomass production of *Rhizophora* was estimated to be between 0.3 and $0.4 \text{ kg m}^{-2} \text{ yr}^{-1}$ and more fertile stands of *Laguncularia* were estimated to produce 1.2 to 1.7 kg m^{-2} of wood annually. In other mangrove systems higher figures are involved, e.g. $1.8 \text{ kg m}^{-2} \text{ yr}^{-1}$ in Malaysia, 1.4 to $3.3 \text{ kg m}^{-2} \text{ yr}^{-1}$ in Thailand in managed forests, but in an unmanaged section biomass production was only $0.6 \text{ kg m}^{-2} \text{ yr}^{-1}$ and 0.6 to $4.5 \text{ kg m}^{-2} \text{ yr}^{-1}$ in other Australian *Rhizophora* stands (Hogarth, 1999).

This yearly increase in organic matter is contributing to the build up of the high above-ground woody biomass. It is not generally available to the associated components of the mangrove ecosystem, such as the invertebrate food chain, or adjoining marine ecosystems which, in both mangroves and salt marshes, are largely dependant on the annual production of non-woody material such as leaves and young shoots which fall as litter (Fig. 9).

One measure of the annual production of plant material is the use of traps to catch falling litter. In *Rhizophora* stands in Vietnam annual litter fall varied between 0.94 and 1.88 kg m^{-2} (Clough, *et al.*, 2000). These figures are similar to that of $1.13 \text{ kg m}^{-2} \text{ yr}^{-1}$ obtained from *Rhizophora* stands in Florida (Dawes, *et al.*, 1999). The material shed includes fruit and twigs as well as leaves. Leaves amounted to 68% of the Florida material. However, in the stands in Vietnam the proportion contributed by leaves decreased as stands increased in age, falling to 38% in 35 year-old stands with propagules accounting for a similar proportion.

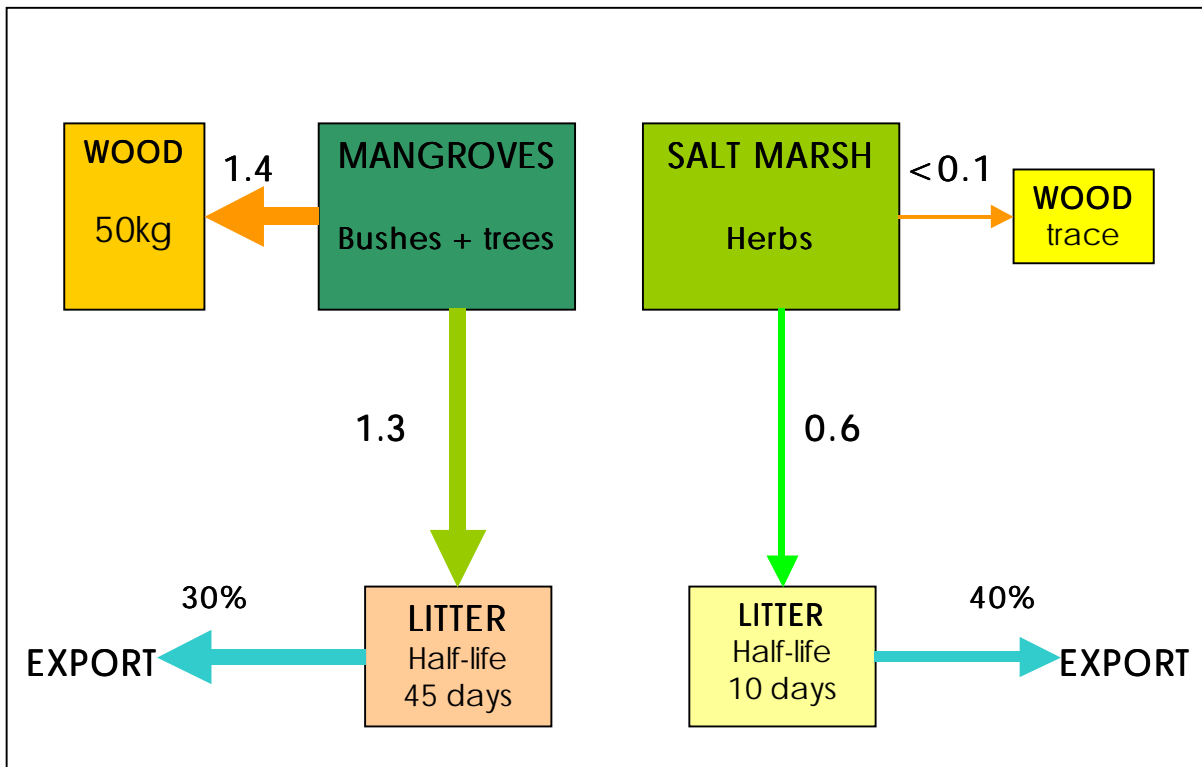


Figure 9. Fluxes of organic matter from above-ground primary production in salt marshes and mangroves. Figures by the arrows refer to the annual biomass production of wood and litter and are in kg m^{-2} . Standing crop of wood is kg m^{-2} . Percentages refer to the proportion of litter production exported.

Short term rates of litter production in salt marshes and mangroves are not dissimilar. The maximum daily rate of litter production (averaged over a period of 4 weeks) in Essex marshes was estimated at $4.7 \text{ g m}^{-2} \text{ d}^{-1}$ (Boorman, *et al.*, 1996). Daily litter production under *Rhizophora* in Florida reached a peak at $8.7 \text{ g m}^{-2} \text{ d}^{-1}$ but this was immediately following tropical storms and the average over a month was below $6 \text{ g m}^{-2} \text{ d}^{-1}$ (Dawes, *et al.*, 1999).

The production of litter by mangroves may be seen as analogous to the net aerial productivity of cool-temperate salt marshes and typical values are broadly comparable for both processes (Fig. 9). The key difference is that there is long-

term accumulation of organic matter in the form of the wood of the mangroves while there is very little long-term accumulation of organic material on the surface of the salt marsh. In both salt marshes and mangroves the production of litter, in whatever form, provides an important source of organic matter for other components of the ecosystem. In both systems the production of litter is seasonal with the only difference being the autumnal release of above-ground material in the salt marsh as compared with the seasonal leaf-fall in mangroves. The fate of this material is crucial in both ecosystems and particularly as an energy source for other organisms. It does, however, also have to be noted that in mangrove systems a whole tree will occasionally fall and the organic matter be released. This material will suffer similar fates to that released annually, although the rate of decay of the timber is relatively slow and dependant on animal activity (Hogarth, 1999).

FATE OF AERIAL PRODUCTION

In salt marshes the above-ground primary productivity is released in three main ways. There is a continual shedding of senescent material particularly in the form of leaves, there is the action of invertebrate grazers and also the effects of wind and wave action on weakened plant material. In the autumn and winter most of the season's growth is lost by either by grazing or decay *in situ*, or through partial decay and the release of pieces of stem and leaves (Samiaji & Barlocher, 1996). In addition whole plants can be washed away to decay elsewhere.

The proportion of organic material that is recycled within the marsh as compared with the proportion exported has been the topic of considerable research. Part of the problem is that while a large proportion of material is moved within the marsh itself, much is simply being recycled. There have been rather different estimates of the proportion of organic matter exported in studies in north American marshes and western European ones but it would seem that this may partly be explained by the lower level and thus more frequent inundation of the American marshes facilitating the export of material. Often in the higher level marshes the export of

organic matter is largely limited to infrequent storm tides which can move large quantities of both organic matter and sediment (Boorman, 1999).

The plant material from salt marshes is relatively soft and can decay quite quickly. The half-life of plant litter has been estimated as being in the range 18 - 350 days (Marinucci, 1982) and recent studies in Essex, England suggest that under favourable conditions it can be as low as 7 days (Boorman, *et al.*, 1996). These studies, however, showed the importance of optimum levels of moisture and temperature for the decay of plant litter.

Mangrove litter with a higher tannin content and more lignified tissue would appear to be more resistant to decay although the warmer conditions will favour the activities of the organisms that break down plant material. The half-life of *Avicennia* leaves has been shown to be of the order of 25 days in tidal areas but as long as 200 days in non-tidal areas (Dick & Osunkoya, 2000). Permanently submersed leaves of *Avicennia* have a half-life of 11-20 days while in the intertidal zone half life is around 90 days. In the intertidal zone *Sonneratia* leaves have a half-life of around 20 days. (Hogarth, 1999). However, it appears that *Rhizophora* leaves are rather more resistant than those of *Avicennia*, breaking down at half the rate (Robertson, *et al.*, 1992).

Just as with salt marsh litter, the breakdown processes result from the combined activity of fungi and bacteria with the former probably being more important in the breakdown of cellulose. The major difference in litter breakdown between the two systems is the major role played by leaf-eating crabs in the mangrove ecosystem (Fondo & Martens, 1998). Not only do they eat the leaves but they themselves provide a food source for predators (Sheaves & Molony, 2000). They also influence energy flow by removing a high proportion of the litter to their burrows preventing the material being flushed out by tide or currents (Hogarth, 1999). In addition the crab gut is very efficient in breaking down mangrove litter, accelerating the process by up to two orders of magnitude (Robertson, *et al.*, 1992).

BELOW-GROUND PRODUCTION

The estimate of below-ground productivity in salt marshes is handicapped by practical difficulties in separating the root mass from the often highly cohesive soil. Early high estimates of below-ground productivity have been challenged by recent isotope tracer methods and it is suggested that the production below-ground is in general significantly lower than that above-ground, typically being of the order 500-600 g m⁻² yr⁻¹ (Boorman & Ashton, 1997) *i.e.* about 50% to 100% of the above-ground productivity.

Practical difficulties in estimating below-ground productivity are even greater for mangrove stands which have extensive underground root systems. Current estimates suggest figures varying between 20% and 50% of that above-ground for *Rhizophora* and up to 62 % for *Avicennia* (Hogarth, 1999). Nevertheless, given the high above-ground biomass figures for mangroves the actual quantities of material below-ground are considerable. However, as with the standing-crop a considerable proportion of this material is in the form of relatively inert woody material. Nevertheless it should be noted that the total stocks of organic carbon in the form of below-ground organic matter can be considerable.

Mangrove forests in north Queensland have an estimated 5.2 kg m⁻² of organic matter (approximately 11.6 kg m⁻² dry matter) as root biomass (Matsui, 1998). What is even more striking is the large quantity of organic matter in the soil itself. In the example above the organic carbon in the top 0.5 m of the soil amounted to 29.6 kg m⁻² giving, with the root biomass, a total soil organic carbon content of 34.8 kg m⁻² (approximately 77 kg m⁻² dry matter). This is higher than in comparable tropical forests where the breakdown of carbon is more rapid in the better drained soils. Nevertheless in temperate salt marshes the soil organic content, although much less, is also quite considerable given the shorter growing season. Recent studies by L A B Coastal suggest that in typical Essex salt marshes there is approximately 17.3 kg m⁻² dry matter in the top 0.2 m of sediment and a total of around 27 kg m⁻² dry matter in the top 0.5 m of soil although at least half of this probably comes from the import of organic-rich sediment. Nevertheless the soils under mangroves have a considerably higher organic content than do soils of salt marshes (Fig. 10).

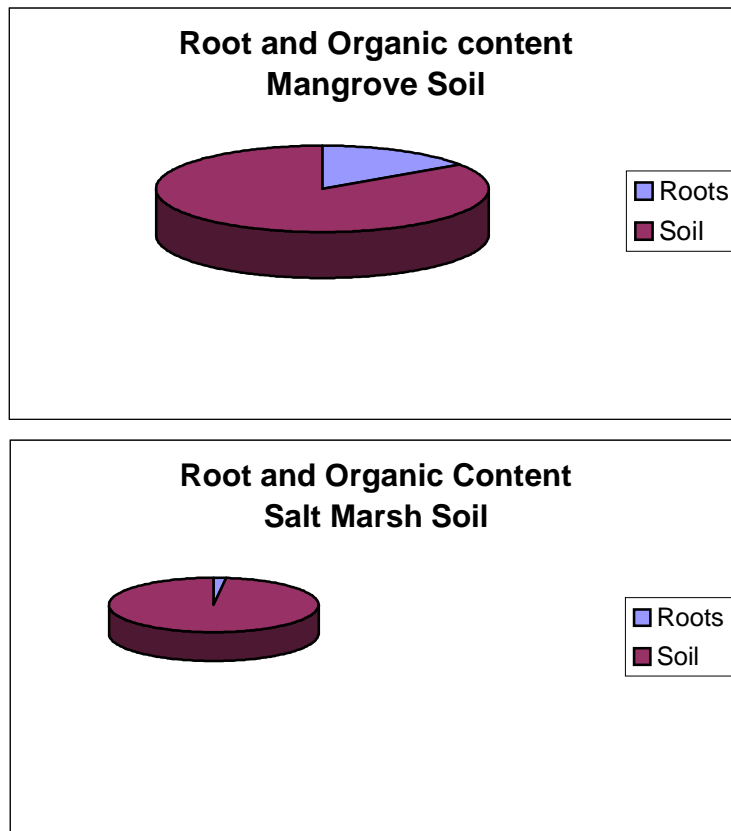


Figure 10. Organic content of salt marsh and mangrove soils showing contribution of root material and other soil organic matter. The relative sizes of the two pie charts indicate the relative total soil organic content (dry matter in mangrove soils = 77 kg m^{-2} , dry matter in salt marsh soils = 28 kg m^{-2}).

FLUXES OF SEDIMENT AND ORGANIC MATTER

The transport of sediment to and within a salt marsh by the tidal flow is the key to the vertical development of the marsh surface. The salt marsh vegetation enhances this process both by slowing the near-bed water velocities, thus enhancing sediment accretion, and by reducing any erosion of the accreted sediment. The nature of the sediment which accumulates will depend both on the nature of the

sediment supply and on the velocities of the water flow over the marsh. Fine sediments are only deposited when the water velocities approach zero. Annual rates of salt marsh accretion vary considerably but typical rates are of the order of 2 - 5 mm yr⁻¹ (Boorman, 2000) although they can exceed 10 mm yr⁻¹. However, current research by L A B Coastal suggests that rates higher than this would have significant negative impacts on the vegetation.

Fluxes of organic matter are also driven by tidal flows although fluxes of floating material (coarse organic matter) tend to be wind-driven. As already referred to, the outward fluxes of organic matter seem to be higher in American salt marshes, where they can be up to 40% of the primary production, than in European marshes where a typical figure is of the order of 10% (Boorman, 2000). Studies of European salt marshes have also indicated that the import and export of both organic matter and sediment is dependant on the degree of maturity of a marsh. Young marshes actively import sediment and produce increasingly large quantities of organic matter which is available for export. The degree of biological activity also makes them exporters of plant nutrients. Senescent marshes, on the other hand, have a lower productivity and through degeneration can actually export sediment as the structure of the marsh itself breaks down. In addition they tend to be low in available plant nutrients and this has reduced productivity and they have become dependant on nutrient imports.

Sediment accretion rates under mangroves are broadly similar to those in salt marshes. In a mixed mangrove and salt marsh site in Brazil the *Spartina alterniflora* dominated salt marsh showed an accretion rate of 1.8 mm yr⁻¹, while the *Rhizophora*/*Avicennia* mangrove was accreting at 1.3 mm yr⁻¹ (Smoak & Patchineelam, 1999). A rather higher estimate was reported for mixed stands of *Rhizophora*, *Bruguiera* and *Nypa* with a mean sedimentation rate of 7.0 mm yr⁻¹ (Wolanski, *et al.*, 1998), and even higher for *Avicennia* with rates up to 8 mm yr⁻¹ (Woodroffe, 1992). Data from Malaysia suggested rates of accretion under mangroves of 6.6 to 14.6 mm yr⁻¹, but with a strong seasonal component and rates outside the monsoon season equivalent to only 1.2 mm yr⁻¹ (Saad, *et al.*, 1999). All these accretion rates are, however, very much within the same range as those

determined for salt marshes.

It might be expected that the density of mangrove forest and particularly the network of roots above and below the soil surface would severely limit the export of organic matter but it has been shown that in a *Sonneratia* forest in Zanzibar 22% of the annual litter production was exported (Machiwa, 1999). In studies from three sites in north Queensland it was found that 25% of the litter of *Bruguiera* was exported, 24 % of the leaf litter of *Ceriops*, and 21 % of the litter of *Avicennia* (Robertson & Daniel, 1989). However, figures for a mid-intertidal stand of *Rhizophora* in north Queensland suggested that over 70% of the litter fall was exported (Hogarth, 1999). Some other estimates suggest figures nearly as high as this but it is not always clear from the literature whether these exports are being expressed as a percentage of the annual litter production or of the total annual dry matter production.

THE ROLE OF INTERTIDAL VEGETATION

Salt marshes and mangroves are a visibly significant component of the intertidal ecosystem in their respective areas but their overall importance is wider than that.

As we have just seen very significant quantities of organic matter are exported into the adjoining coastal waters where they enter the food chain thus increasing the productivity of these habitats. Salt marshes and mangroves also contribute to the food chains of adjacent habitats by the direct export of various invertebrate species which contribute to the food chain. It has been shown that mangrove defoliation leads to decreases in the associated macrofauna and consequent losses in fish and invertebrate populations in adjoining communities (Fondo & Martens, 1998). In addition to this both mangroves and salt marshes are important in the way that they provide sheltered nursery areas particularly for fish. Salt marshes form a dynamic buffer in physical, chemical and ecological respects between the land and the sea in cool temperate zones; in warmer areas of the world mangroves perform much the same function.

Salt marshes, as long as they remain relatively stable depositional environments, hold increasing quantities of plant nutrients as they develop. They can also accumulate significant levels of organic pollutants and heavy metals (Leggatt, *et al.*, 1995) and it is clear that they act as sinks for pollutants circulating in the environment (Boorman, 1999). Recent studies have demonstrated that mangroves can act in the same way but, with their greater stability, their importance as sinks is potentially greater.

Heavy metals are efficiently and rapidly trapped by mangroves and although leaf litter is exported this only represents a very small proportion of the total sediment reservoir of pollutants (Silva, *et al.*, 1998). These authors conclude that the "mangrove ecosystems are probably efficient biogeochemical barriers to the transport of metal contaminants in tropical coastal areas". However, the value of salt marshes and mangroves as sinks for pollutants will only hold while these habitats remain physically intact; any habitat degeneration is likely to result in the release of these pollutants back into the environment.

COAST PROTECTION

Salt marshes have been shown to perform a vital function in the way they act as a wave break. Studies in Norfolk showed that 180 m of salt marsh reduces wave energy by 80% (Möller, *et al.*, 1996). In Essex most of the coast is protected by sea walls fronted by salt marsh. These marshes protect the sea walls from direct wave action. Fifty metres or more of healthy salt marsh in front of a sea wall can be of major economic importance for sea defence (Boorman, 1999).

Experimental work in Vietnam has shown that mangroves can perform a similar function (Mazda, *et al.*, 1997). Where mangrove trees were sufficiently tall the rate of wave reduction was 20% per 100 m. After as little as six years a belt of planted *Kandelia* 1500 m wide reduced 1 m high waves to 0.05 m (without the mangrove the waves were only reduced to 0.75 m over a similar distance). The considerably

greater height of mangroves means that the protective function of the vegetation remains effective with increasing water depths unlike the situation with salt marshes and their shorter vegetation. In other words, mangroves can provide better protection against wave action than salt marshes although the development of this protection is slower than in salt marshes.

HABITAT CREATION

Both salt marshes and mangroves have suffered considerably from the effects of pollution and various forms of human exploitation (Bridgewater & Cresswell, 1999). In recent years the effects of global warming and the consequent rise in sea level have been recognised as further threats. In Britain and some other places in both Europe as well as in the United States the re-creation of salt marshes by breaching or moving sea walls has been recognised as an appropriate response to the loss of existing salt marsh from sea level rise and other causes (Fig. 11). Generally the establishment of salt marsh vegetation has been left to natural regeneration after re-opening the area to tidal influence. So far techniques of planting or sowing have been too labour intensive for use on a wide scale.

Given suitable conditions mangroves will also re-establish if there is a sufficient supply of propagules. The propagules are generally freely distributed by the tide. However, predation of the propagules by snails and crabs can significantly reduce establishment rates of *Avicennia* particularly at the lower (seaward) end of its range (Patterson, *et al.*, 1997). Defoliation of seedlings by caterpillars has been shown to limit the regeneration of *Avicennia germinans* in Columbia with seedling losses of up to 100% (Elster *et al.*, 1999). Exposure to extreme wave action can also restrict the establishment of mangroves (Riley & Kent, 1999).

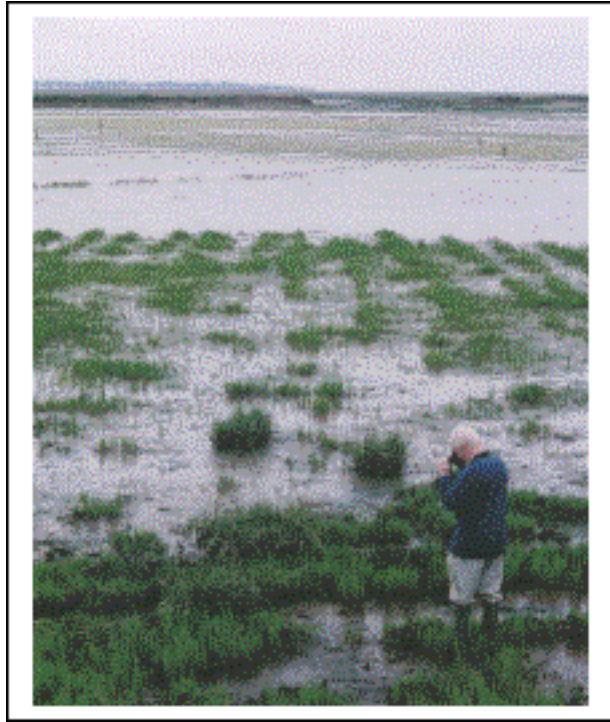


Figure 11. *Newly established salt marsh vegetation at Tollesbury, Essex, England, five years after the deliberate breaching of the sea wall (breach can be seen in the centre of the back of the photo) allowed tidal flooding again after an interval of over 200 years.*

The supply of propagules is very much dependant on the age of the stand. In the case of *Rhizophora apiculata* significant numbers of propagules are only produced when the trees are 21 years old and production is then only a half of that of 36 year old trees (Clough, *et al.*, 2000). This also means that if older stands of *Rhizophora* are destroyed by a tropical storm or by the intervention of man (accidental or otherwise) natural regeneration can be very slow and the opportunities for planting are limited in scope by lack of propagules. Because of the rapid loss of mangrove forest by an increasing human population new methods for mangrove restoration have been developed.

A common problem is that conditions are sub-optimal in areas where stands of mangroves are most needed. Mangrove restoration has mainly been successful in areas with low wave energy and conditions similar to those where natural recruitment occurs. Plantings in areas subject to high-wave energies have had low success rates. One answer to this has been to develop a method of encasement of the planted seedlings to protect them from erosion while they become established (Riley & Kent, 1999). Their method is based on the insertion of seedlings in individual translucent PVC tubes which protect the seedlings and allows them to root down into the sediment even when the sediment is below the optimum level for natural establishment. Experimental results indicate that these encased seedlings survived well even in areas of comparatively high wave energy (Kent & Lin, 1999). Nevertheless the authors conclude that biodegradable alternatives to the PVC tubes would be preferable and that further research is needed.

CONCLUSIONS

Despite the very visible physical differences between salt marshes and mangroves there are clear biological, biochemical and biophysical parallels leading to close functional similarities. Both mangroves and salt marshes are under threat from a variety of direct human influences as well as from the increasing effects of rising sea levels. Both are important with respect to their role as a natural resource with their primary productivity, directly and indirectly, supporting adjacent marine ecosystems. Both can reduce wave attack on low-lying coasts and thus frequently play a major role in coastal defence. Both have direct economic value although mangroves have a rather greater role in many developing areas as sources of fuel, construction and food. Both salt marshes and mangroves support many specialised animal and plant communities thus contributing directly to biodiversity on the world scale (Table 1).

If these unique resources are to survive it is essential that new ways are found for

habitat creation, conservation and management in salt marsh and mangrove communities. The underlying principle of habitat creation is to produce conditions that will most favour plant establishment and growth. This can be achieved either by using ways of protecting individual seedlings from erosion or predation, such as the used of planting tubes, or by using techniques for the protection of the sediment surface from erosion until seedlings are sufficiently well grown and established. Whatever techniques are used it is essential to ensure that they are environmentally friendly and cost-effective - the use of local materials is particularly important in this respect. There is a range of opportunities for devising, developing and applying the best and most cost-effective of new technologies which are appropriate to different conditions in various parts of the world.

ATTRIBUTE	BENEFIT	SALT MARS H	MAN- GROVE
Unique species of animals and plants	Contribution to world biodiversity	+	+
Reduces water velocities over soil surface	Encourages sediment deposition and surface accretion	+	+
Develops extensive root systems	Protects accreted sediment from erosion	+	+
Acts as wave break	Shore protection	+	+
Able to regenerate naturally	Automatic adjustment to changes in sea level	±	±
Exports organic matter	Food source for adjacent marine ecosystems	+	+
Processes plant nutrients	Links terrestrial and marine ecosystems	+	+
Provides sheltered environment	Nursery for important fish and invertebrates	+	+
Absorbs pollutants	Sink for pollutants	+	+
Accumulation of woody tissue	Source of wood for fuel for coastal communities	-	+

Table 1. *Comparison of the properties of salt marshes and mangroves (+ = benefit present, ± = benefits only to a limited degree, - = benefit absent).*

REFERENCES

- Boorman, L.A. 1999. Salt marshes - present functioning and future change. *Mangroves and Salt Marshes*, 3, 227-241.
- Boorman, L.A. 2000. The functional role of salt marshes in linking land and sea. In: *British Saltmarshes*. Ed. B.R. Sherwood, B.G. Gardiner and T. Harris. Forrest Text for the Linnean Society. 1-24.
- Boorman, L.A. & Ashton, C. 1997. The productivity of salt marsh vegetation at Tollesbury, Essex and Stiffkey, Norfolk, England. *Mangroves and Salt Marshes*, 1, 113-226.
- Boorman, L.A., Pakeman, R.J., Garbutt, R.A. & Barratt, D. 1996. Results for the Institute of Terrestrial Ecology, England. In: Lefeuvre, J.C. (ed), *The effects of environmental exchange on European salt marshes: structure, functioning and exchange potentialities with marine coastal water*. Vol. 5. University of Rennes, France.
- Bridgewater, P.B. & Cresswell, I.D. 1999. Biogeography of mangrove and salt marsh vegetation: implications for conservation and management in Australia. *Mangroves and Salt Marshes*, 3, 117-125.
- Chen, R. & Twilley, R.R., 1999. Patterns of mangrove forest structure and soil nutrient dynamics along the Shark River Estuary, Florida. *Estuaries*, 22, 955-970.
- Clough, B. 1998. Mangrove forest productivity and biomass accumulation in Hinchinbrook Channel, Australia. *Mangroves and Salt Marshes*, 2, 191-198.
- Clough, B., Tan, D.T., Phuong, D.X., & Buu, D.C. 2000. Canopy leaf area index and litter fall in stands of the mangrove *Rhizophora apiculata* of different age in the Mekong Delta, Vietnam. *Aquatic Botany*, 66, 311-320.
- Dawes, C., Siar, K., Marlett, D. 1999. Mangrove structure, litter and macroalgal productivity in a northern-most forest of Florida. *Mangroves and Salt Marshes*, 3, 259-267.
- Dick, T.M. and Osunkoya, O. 2000. Influence of tidal restriction floodgates on decomposition of mangrove litter. *Aquatic Botany*, 68, 273-280.
- Elster, C., Perdomo, L. Polania, J. & Schnetter, M-L. 1999. Control of *Avicennia germinans* recruitment and survival by *Junonia evarete* larvae in a disturbed mangrove forest in Columbia. *Journal of Tropical Ecology*, 15, 791-805.
- Fondo, E.N. & Martens, E.E. 1998. Effect of mangrove deforestation on macrofaunal densities, Gazi Bay, Kenya. *Mangroves and Salt Marshes*, 2, 75-83.
- Hogarth, P.J. 1999. *The Biology of Mangroves*. Oxford University Press.

- Kent, C.P.S. & Lin, J. 1999. A comparison of the Riley-encased methodology and traditional methods for planting red mangroves (*Rhizophora mangle*). *Mangroves and Salt Marshes*, 3, 215-225.
- Leggatt, D., Bubb, J.M. & Lester, J.N. 1995. The role of pollutants and sedimentary processes in flood defence. A case study: salt marshes of the Essex coast, UK. *Environmental Technology*, 16, 457-466.
- Machiwa, J.F. 1999. Lateral fluxes of organic carbon in a mangrove forest partly contaminated with sewage wastes. *Mangroves and Salt Marshes*, 3, 95-104.
- Marinucci, A.C. 1982. Trophic importance of *Spartina alternifolia* production and decomposition to the marsh-estuarine ecosystem. *Biological Conservation*, 22, 35-58.
- Matsui, N. 1998. Estimated stocks of organic carbon in mangrove roots and sediments in Hinchinbrook Channel, Australia. *Mangroves and Salt Marshes*, 2, 199-204.
- Mazda, Y, Magi, M., Kogo, M, & Hong, P.N. 1997. Mangroves as a coastal protection from waves in the Tong King delta, Vietnam. *Mangroves and Salt Marshes*, 1, 127-135.
- Möller, I., Spencer, T. & French, J.H. 1996. Wind wave attenuation over salt marsh surfaces: preliminary results from Norfolk, England. *Journal of Coastal Research*, 12, 1009-1016.
- Patterson, S., McKee, K.L., & Mendelssohn, I.A. 1997. Effects of tidal inundation and predation on *Avicennia germinans* seedling establishment and survival in a sub-tropical mangal/salt marsh community. *Mangroves and Salt Marshes*, 1, 103 - 111.
- Riley, R.W., & Kent, C.P.S. 1999. Riley encased methodology: principles and processes of mangrove habitat creation and restoration. *Mangroves and Salt Marshes*, 3, 207-213.
- Robertson, A.I. & Daniel, P.A. 1989. The influence of crabs on litter processing in mangrove forests in tropical Australia. *Oecologia*, 78, 191-198.
- Robertson, A.I., Alongi, D.M. and Boto, K.G. 1992. Food chains and carbon fluxes. In: *Tropical Mangrove Ecosystems* (ed. Robertson, A.I. and Alongi, D.M.). American Geophysical Union: Washington D.C.
- Saad, S., Hussein, M.L., Yaacob, R. & Asano, T. 1999. Sediment accretion and variability of sedimentological characteristics of a tropical estuarine mangrove: Kemaman, Terengganu. Malaysia. *Mangroves and Salt Marshes*, 3, 51-58.
- Samiaji, J. & Barlocher, F. 1996. Geratology and decomposition of *Spartina alterniflora* Loisel in a New Brunswick salt marsh. *Journal of Experimental Marine*

Biology and Ecology 201:233-252.

Sheaves, M. & Molony, B. 2000. Short-circuit the mangrove food chain. *Marine Ecology Progress Series*, 199, 97-109.

Silva, C.A.R., Lacerda, L.D., Ovalle, A.D. & Rezende, C.E. 1998. The dynamics of heavy metals through litter fall and decomposition in a red mangrove forest. *Mangroves and Salt Marshes*, 2, 149-157.

Smoak, J.M. & Patchineelam, S.R. 1999. Sediment mixing and accumulation in a mangrove ecosystem: evidence from ^{210}Pb , ^{234}Th , and ^7Be . *Mangroves and Salt Marshes*, 3, 17-27.

Tomlinson, P.B. 1994. *The Botany of Mangroves*. Cambridge University Press.

Wolanski, E., Gibbs, R.J., Spagnol, S., King, B. & Brunskill, G. 1998. Inorganic sediment budget in the mangrove-fringed Fly River Delta, Papua New Guinea. *Mangroves and Salt Marshes*, 2, 85-98.

Woodroffe, C. 1992. Mangrove sediments and geomorphology. In: *Tropical mangrove ecosystems. Coastal and estuarine studies no 41* (ed: A.I. Robertson & D.M. Alongi. American Geophysical Union, Washington, D.C.

FOOTNOTE - it is intended that a keynote article will
become a regular feature of these Annual Reports.

Financial Statement

Although the annual turnover was less than the previous year investment in equipment and facilities continued. Over 90% of income was for basic or near-basic research.

Facilities and services

LAB Coastal uses the full range of modern survey equipment and has the experience of an extensive network of specialists at its disposal. It has state of the art laboratory facilities available to complement the field monitoring equipment. Greenhouse facilities including tidal mesocosms with sophisticated control and monitoring systems are provided for experimental work.

LAB Coastal offers customised surveys to gather information on, for example, species, amount, distribution and habitats of the most important elements of the natural flora and fauna of an area.

Research is carried out to fill the numerous gaps which still remain in the understanding of ecosystem functions and interactions. The company can offer a range of tailor-made research programmes for specific clients.

Modern field techniques coupled with sophisticated data handling enable scientifically rigorous data to be obtained for providing baseline information for future management plans or for making an impact assessment. Ongoing programmes of monitoring can be maintained efficiently to ensure the effective implementation of management strategies or to confirm the validity of impact assessments.

LAB Coastal can provide management advice and programmes for natural habitats. The company also participates actively in habitat creation schemes and this experience is at the disposal of clients. In addition advice is available on low cost erosion control for coastal habitats which provides an acceptable substitute for man-made sea defence works.

Links with other organisations

LAB Coastal is a full partner in the EU-funded EUROSAM project, part of the IVth Framework, on:

1. The development of a range of models of ecological and hydrodynamic processes to predict the likely responses of various salt marsh ecosystems to environmental changes. These can include the potential impacts of predicted rise of sea level or of human activities on the functioning of salt marshes and on the fluxes of various nutrients between the salt marshes and the marine coastal waters;
2. The calibration of the process models to specific conditions encountered in various European salt marshes;
3. The linking of the process models and the hydrodynamic models through the development of a decision support system.

The other scientific partners in EUROSAM are:

University of Rennes 1, France
Centre for Ecology and Hydrology, UK
Alterra, Den Burg, The Netherlands
IMAR Marine Institute, University of Lisbon, Portugal
IMAR, University of Evora, Portugal
Higher Technical Institute, Lisbon, Portugal
Institute of Oceanography, Lisbon, Portugal
IFREMER, Brest, France.

LAB Coastal is a subcontractor in the EU funded programme Influence of rising Sea Level on Ecosystem Dynamics of salt marshes (ISLED).

The other scientific partners in ISLED are:

Centre for Estuarine and Coastal Ecology, Yerseke, The Netherlands
Laboratory of Plant Ecology, University of Ghent, Belgium

Southampton Oceanography Centre, Southampton, UK

Institute of Biology, University of Odense, Denmark

Dept. of Evolution of Natural and Modified Systems, University of Rennes 1,
Rennes, France

Institute of Terrestrial Ecology (now Centre for Ecology and Hydrology), Monks
Wood, Abbots Ripton, UK

Department of Plant Biology, Faculty of Science, Lisbon, Portugal

Links are also being maintained with the Australian Institute of Marine Research, Cape Ferguson, Queensland, and the Universities of Cambridge and Essex. LAB Coastal is looking forward to further co-operation with these and other research departments in the future.

Contact Points

WEB SITE

Full information about L A B Coastal including previous Annual Reports can be found on its Web Site at <http://www.labcoastal.co.uk>

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POSTAL

While no movement has been involved the Address and Post Code of L A B Coastal has changed during 2000. Please note especially the changes (in red):-

L A B Coastal,
The Maylands,
Holywell,
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PE27 4TQ U.K.

Publications

IN PRESS

Boorman, L.A. 2001. The Role of Nutrients in Salt Marsh Processes in an Essex Estuary. ECSA Essex Meeting. (in press).

Boorman, L.A. & Boorman, M.S. 2001. The Spatial and Temporal Effects of Grazing on the Species Diversity of Sand Dunes. In: *Coastal Dune Management. Shared Experience on European Conservation Practice*. Ed. J.A. Houston, S.E. Edmondson and P.J. Rooney. Liverpool University Press. 161-167. (in press)

Boorman, L.A., Hazelden, J. & Boorman, M. 2001. The effect of rates of sedimentation and tidal submersion regimes on the growth of salt marsh plants. ELOISE Conference, Noordwijkerhout, December 1999. (in press).

Hazelden, J.H. & Boorman, L.A. 2001. Soils and 'managed retreat' in South East England *Soil Use and Management*, 17, 1-15. (in press)

PUBLISHED

Boorman, L.A. 2000. The functional role of salt marshes in linking land and sea. In: *British Saltmarshes*. Ed. B.R. Sherwood, B.G. Gardiner and T. Harris. Forrest Text for the Linnean Society. 1-24.

Boorman, L.A. 2000. *L A B Coastal Annual Report 1999*. L A B Coastal: Holywell, Cambridgeshire. 24 pps.

Boorman, L.A. 2000. *ISLED Summary Progress Report, February 2000*. L A B Coastal: Holywell, Cambridgeshire. 4 pps.

Boorman, L.A., Hazelden J. & Boorman, M.S. 2000. *EUROSAM - Task 6. Final Report. Analysis of the nutrient control of the organic carbon cycle in a salt marsh (ANCOSM) and the modelling of the nitrogen cycle (NITROMOD)*. June 2000. L A B Coastal: Holywell, Cambridgeshire. 58 pps.