EFFECTS OF MECHANICAL CLEANING, AND ITS CESSATION, ON THE STRANDLINE FAUNA AT SAND BAY

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SUMMARY

Seven years of mechanical beach cleaning to improve amenity at Sand Bay ceased in 2000. This was in response to previous research on this site that highlighted the deleterious effects of strandline removal on invertebrate life, habitats, embryo sand dunes and colonizing plants. This paper examines effects of the cessation of cleaning on strandline fauna at Sand Bay as determined by comparison of studies done by Hazel Willmott (from April 1 to July 16 in 1999) and Tony Smith (from June 14 to August 15 in 2002, and from May 31 to December 31 2003). Results showed little annual change in amphipod numbers of three species between equivalent dates in 1999 and 2002; but numbers increased dramatically in late summer of both 2002 and 2003. The data from the survey in 2003 are being extended by continuing fieldwork; this should enable differences in the population dynamics of the amphipod species to be elucidated.

INTRODUCTION

The beach at Sand Bay

Sand Bay lies within the area of the Severn Estuary and is 3km long. It is an embayment between Swallow Cliff to the north and Anchor Point and Birnbeck Island to the south (Fig. 1; Grid ref: 31/63–33/66).

This beach is used by dog walkers, horse riders and others on foot for recreation. For seven years the Local Authority periodically removed anthropogenic litter and tidal deposits ('strandlines'), but this ceased in 2000. In contrast, the neighbouring beach, Weston-Super-Mare proper, is used for bathing and is kept clean, i.e. clear of litter and strandlines.

Sand Bay has a broader range of wildlife and a greater variety of habitats. It is a key habitat in the Severn Estuary ecosystem, which is of national and international importance for bird populations. It forms part of the Severn Estuary SSSI (Site of Special Scientific Interest) and the saltmarsh at its northern end provides a habitat for overwintering and migrating birds. The Severn Estuary is a candidate SAC (Special Area of Conservation), important for its sub-tidal banks, Atlantic saltmarshes, estuaries and intertidal flats. The Severn Estuary is also a RAMSAR site – Wetland of International Importance – especially as a waterfowl habitat. The area is

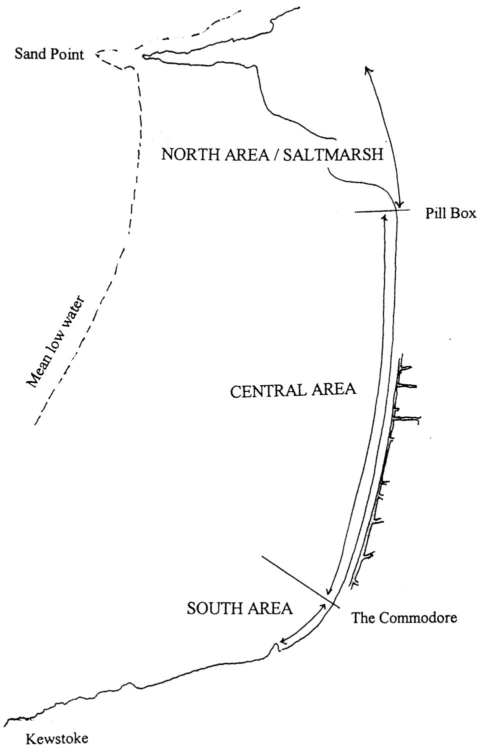

Fig. 1. Location plan

designated as a SPA (Special Protection Area EC Directive 79/409 on the Conservation of Wild Birds: Special Protection Area). It qualifies by supporting internationally important wintering populations of Bewick's Swan *Cygnus columbianus*, Shelduck *Tadorna tadorna*, Dunlin *Calidris alpina*, and Redshank *Tringa totanus*. It also sustains nationally important migratory, passage and wintering birds, for example Lesser Black Backed Gull *Larus fuscus*, Ringed Plover *Charadrius hiaticula* and Curlew *Numenius arquata* respectively.

Our research sought to contrast the invertebrates of the three distinct parts of Sand Bay: the extensive saltmarsh at the northern end, the central area mainly of sand and shingle, and the southern end of sand, rocks and shingle.

Strandlines

The strandline harbours a variety of invertebrate life from permanent residents like the familiar sandhoppers (A*mphipoda*), rove and other beetles, fly larvae and isopods to the transient fauna including other beetles, flies, worms and mites, which use the strandline during part of their life cycle. The strandline is composed of a variety of organic materials which provide a refuge, habitat and food for invertebrate species and birds. The strandline is very important for the following reasons:

1. It supports invertebrates by providing organic matter, especially seaweed as a food resource, and driftwood as shelter. Invertebrates in turn provide food for birds.
2. The strandline provides nutrient input to the substrate beneath it as a result of decomposition. This role in the food web of the shore is little known (Spicer pers. comm.).
3. The strandline produced at Extreme High Water Spring (EHWS) tides may be significant in acting as an initiator of sand dunes by increasing the organic material, holding moisture, trapping sand and allowing plant colonization to occur (Llewellyn and Shackley 1996; Crawford 1998). Pioneer plants include Sea Beet *Beta maritima*, Cord Grass *Spartina anglica* and Orache *Atriplex patula*. Ultimately the foredunes provide a barrier to rising tide levels.

The strandline at Sand Bay

The strandline habitat comprises marine algae, for example Knotted Wrack *Ascophyllum nodosum* and Bladder Wrack *Fucus vesiculosus*; Cord Grass *Spartina anglica* straw, fruits and seeds and small shells of *Hydrobia ulvae* and *Tellina tenuis* and other debris such as driftwood. The strandline composition of about 10% *S. anglica* and 90% fucoids in the central sand/shingle area differs from the northern saltmarsh end with 75% *S. anglica* and 25% fucoids. At the equinoxes in March and September (EHWS) there are vast accumulations of *S. anglica* stalks, logs, driftwood, fucoids and anthropogenic litter occupying the upper shore adjacent to the sea wall and sand dunes. This provides a very extensive and valuable refuge for both marine and terrestrial invertebrates, particularly during the winter.

Beach cleaning

Sand Bay accumulates a vast amount of strandline debris such as plastic bottles and bags, cans, broken glass and tyres, which prompted the Council to instigate a cleaning regime. Accumulation of debris is caused by the funnel shape of the estuary and its south-west orientation which makes it susceptible to extreme weather conditions from the Atlantic Ocean.

Mechanical beach cleaning started in 1993 and stopped in 2000 in response to the results and recommendations of the first project (Willmott 1999). Mechanical beach cleaning removes not only all the anthropogenic litter, but also the strandline itself, as well as *c*. 100mm of the top sand. Note that hand picking of beach litter by volunteers has been carried out since 2000 with the exception of the removal of larger anthropogenic debris by machine.

PURPOSE OF THE RESEARCH STUDIES

The focus of the first study (Willmott 1999) was the impact of mechanical beach cleaning on the invertebrate populations and associated bird life at Sand Bay. The later studies (Smith 2002; 2004) aimed to determine the changes associated with its cessation in 2000. Amphipods were studied as they formed a permanent constituent of the strandline fauna.

BIOLOGY OF THE STUDY ORGANISMS

Amphipods belong to the Phylum Arthropoda, Sub Phylum Crustacea, Class Malacostraca, Order Amphipoda and range in size from 6mm to 26mm (Fish and Fish 1986). They are commonly known as sandhoppers.

One of their characteristics is that they move away quickly when disturbed. They are mobile both up and down and along the shore. The maximum distance across the shore, recorded by Scapini *et al*. (1992), was 200m in one night. Eighty five per cent of Amphipod movement is in this direction. Amphipods retain a degree of adherence to their own territory although some genetic exchange might occur through lateral movement with adjacent populations (Llewellyn 1996). Many species remain hidden in burrows or under strandline deposits during the day, only active at night when they emerge to feed on seaweed (Fig. 2). For example *Talitrus sultator* (family Talitridae) is a semi-terrestrial amphipod inhabiting non-permanent burrows 100–300mm deep in sand, above high water mark (Brafield 1978; Williams 1980). Amphipods are found above the high water mark when moulting or mating (Llewellyn 1996) and this was confirmed by Willmott (1999). In the summer, the zone occupied by the animals moves down-shore with the strandline to between HWS and High Water Neap (HWN) tide marks and up-shore again as the Spring tide approaches. Amphipods are most active three to four days after the Spring Tides with peak activity, between 01.00 and 03.00 GMT, regardless of the state of the tide (Williams 1980). Around dawn the animals return to the burrow region, perhaps guided by solar navigation, but mainly by visual stimuli from the sand dunes (Bregazzi 1972; Williams 1978; Williamson 1951b).

Amphipods need a relative humidity of 85–90% to survive (Williamson 1951a). High temperature and low humidity may inhibit migration, and surface activity is also reduced in the rain (Bregazzi and Naylor 1972). A temperature of 10ºC was observed to be critical for seasonal activity in a South Wales population.

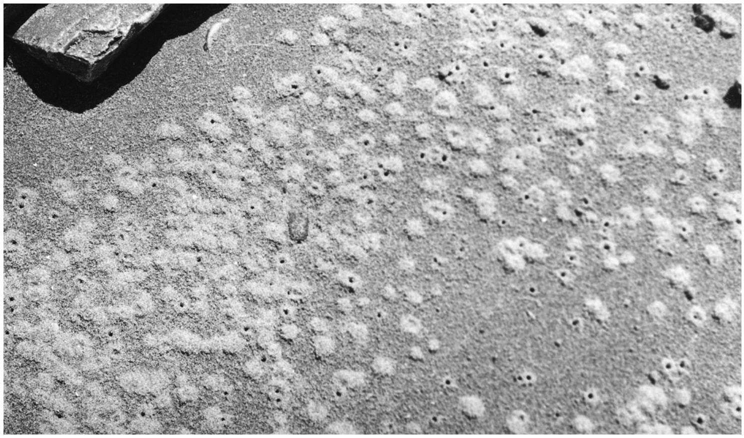

Fig. 2. Burrows of amphipods, note the tiny piles of sand with the central entrance hole

Amphipod life span varies from one to three years, depending on species.

The amphipods found at Sand Bay were:

1. *Talitrus saltator* (Fig. 3) which is active by night, remaining hidden in burrows or under strandline deposits by day. It over-winters in burrows 0.3–1m deep above high water mark and appears from the end of April to October on the shore. *T. saltator* exhibits a simple annual univoltine reproductive cycle, one generation reaching maturity each year with gravid females occurring in the population between May and August (Williams 1978). Juveniles are sexually differentiated in three to four months and two cohorts are present throughout the year. Recently hatched juveniles are considered physically incapable of burrowing to avoid desiccation and seek refuge among the freshly deposited strandline algae (Fig. 2)
2. *Orchestia gammarellus* (Fig. 4) is found under stones and rotting seaweed particularly on shingle shores and the upper shore terrestrial fringe and also extending into estuaries. It also inhabits saltmarsh areas hiding among the swathes of dead *S. anglica* and seaweed, which forms the drift line on which it feeds. It spends most of its time out of water.
3. *Talorchestia deshayesii* (Fig. 5) lives on soft sediment beaches, burrowing in the sediment, and is found amongst strandline debris. It also occurs beyond the range of the high tide strandline and can be found beneath stones at and above the high water level. It is often found with *T. saltator* and was present at Sand Bay.

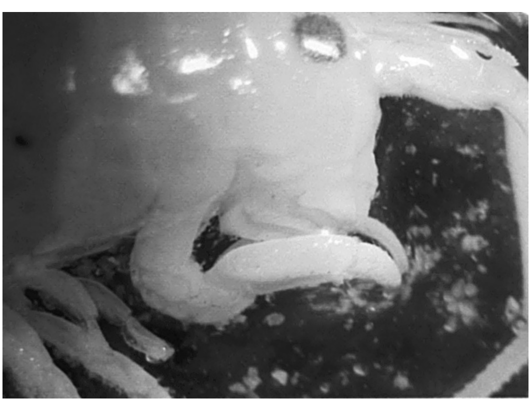

Fig. 3. *Talitrus saltator,* anterior end of male

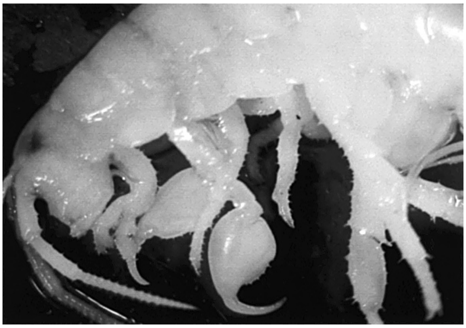

Fig. 4. *Orchestia gammarellus,* anterior end of male

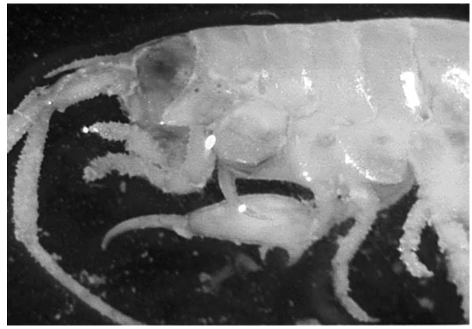

Fig. 5 *Talorchestia deshayesii,* anterior end of male

EXPERIMENTAL AREAS

After a preliminary survey in the late winter of 1998/9, Sand Bay was divided into three areas for the main survey (Fig. 1).

South area (260m) extended from the South Rock face to the Commodore Hotel and included a sandy/shingle beach and rocks. This was a control area.

Central area (*c*. 2000m) extended from the Commodore Hotel to the first pill box towards the saltmarsh. This area had been mechanically cleaned and was predominantly sand with shingle.

North area (750m) extended from the first pill box to the northern end of Sand Bay by the sea wall. This area included saltmarsh and a small stretch of sandy beach. This was a second control area.

METHOD

Sampling

Baseline site surveys were carried out during February, March and April 1999 to determine the profile of the seashore and sampling procedures. Sampling sites were selected in each area using random coordinates to set the number of walking steps to each point. Sampling of the strandline was carried out using a 0.11m² square wooden box which was placed over the strandline material. Samples were collected a few days after Spring tides (when amphipods are most active) and usually every two weeks subsequently. In the first study, sampling was carried out from April to July 1999. Samples were taken from the EHWS strandline or from the recent HWS line.

In order to monitor the progress of re-colonisation after mechanical beach cleaning had stopped, the samples for the second study were taken from June, July and August 2002. This was repeated in 2003 from May to December. Random numbers were used to locate three sample sites in each area

Collection details

A strict protocol was followed in all surveys. The quadrat was placed over the designated area and the seaweed/debris scooped up by hand (wearing plastic gloves) into a lidded bucket. This procedure could be carried out quickly and was applicable to all substrates.

Hot water (60–65 °C) was poured into the bucket, and the contents washed through a set of four sieves (11.2, 4.5, 1.0 and 0.5mm) to separate animals from substrate. Specimens were picked out individually, counted and placed into labelled screw-capped bottles containing 70% alcohol. Where samples contained more than 300 juveniles they were counted separately and placed in collecting bottles.

Where necessary individual specimens of amphipods were identified to species and the number recorded for each area. Identification was carried out using Lincoln (1979), Hayward (1994), Fish and Fish (1996) and Hayward *et al.* (2000).

RESULTS

Table 1 gives the figures for the mean numbers of amphipods found during the 1999 season and for the two years of post-cessation monitoring, 2002 and 2003. In each section of the beach, south, central and north, on each sampling date, three samples were obtained; the means are calculated from the total number collected. Figures 6, 7 and 8 compare these means. A logarithmic scale was used on the graphs to emphasise the lower values. The time scale (days after April 1st) was based on the origin of the first study (Willmott 1999) to enable comparisons from one year to another.

In the South area, there is an increase in population in late summer that is clearly shown in the two monitoring surveys of 2002 and 2003. In both the original study and in 2003 there is considerable variation in sample sizes between sampling dates.

In the Central area, there is a considerable increase in mean totals in 2002 compared with the 1999 survey, and the mean values for 2002 are almost all higher in the overlap period. Those for 2003 are very much higher again over a slightly greater overlap period. The results indicate that there has been marked recovery from the very low values of the time of mechanical beach cleaning.

In the North area, the overall pattern is less clear. All three study periods showed that there is a larger mean total on all sampling dates, except for the final ones of 2003, compared with those of the central section in 1999. In both 2002 and 2003 there was difficulty in finding strandline suitable for amphipoda.

Table 1 Total numbers of amphipods expressed as means derived from each of sets of three samples taken in each area at each date.

Weeks after April 1	SOUTH AREA			CENTRAL AREA			NORTH AREA		
	1999	2002	2003	1999	2002	2003	1999	2002	2003
1	41			14			87		
3	3			1			43		
5	64			5			88		
7	76			1			48		
9	12			1			20		
11	197		460	1			112		
13	339	118	1062	12	30	432	98	172	235
16	361	548	64	26	23	411	194	8	22
18		613	2448		68	1329		80	679
20		1263	66		281	425		1	377
22		2735	1009		123	741		1	376
23			2104			1334			68
25			307			327			113
28			1704			1321			113
30			662			504			0
32			830			156			0
36			962			885			0
39			297			19			0

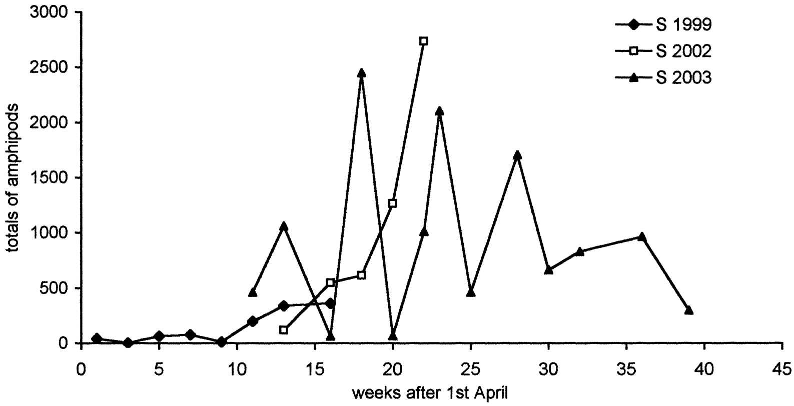

Fig. 6 Total numbers of amphipods expressed as means derived from sets of three samples taken at each date from the strandline in the South area

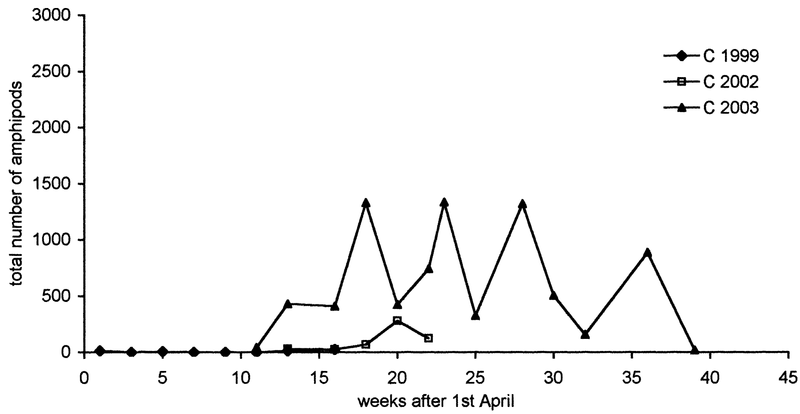

Fig. 7 Total numbers of amphipods expressed as means derived from sets of three samples taken at each date from the strandline in the Central area

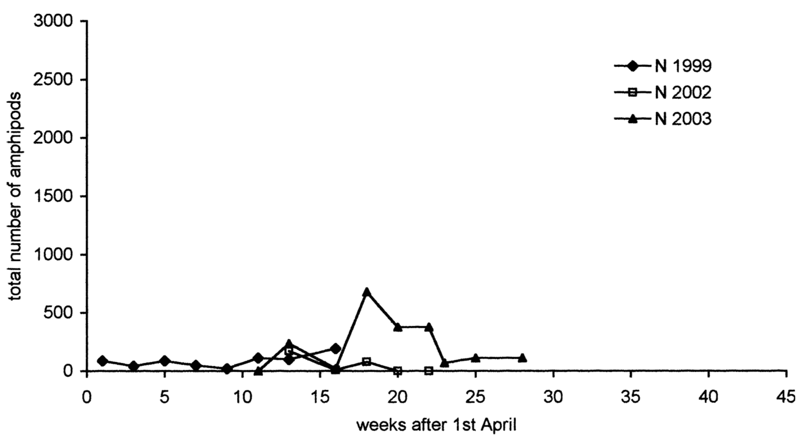

Fig. 8 Total numbers of amphipods expressed as means derived from sets of three samples taken at each date from the strandline in the North area

These results show that the low mean numbers of amphipods of the cleaned beach in 1999 increased to ample populations once strandlines were allowed to re-form and remain.

DISCUSSION

Abundance of amphipods 1999–2003

The time-sequences of the mean numbers of amphipods for virtually all years and beach areas (but not South or Central in 2002), show violent fluctuations, from tens into thousands (Table 1).

However, a low mean number of amphipods in the sample does not necessarily mean that there is a permanent low population there. There were, in both the low and the abundant populations, all stages of growth.

A casual walk along a strandline shows that the numbers of animals does not seem to vary much and any suitable material including wooden and plastic sheet, damp seaweed, and damp sand can be turned over to reveal lots of active amphipods. The collection method was designed to collect all amphipods in the quadrat and the numbers were often quite staggering. It is therefore of interest to try to account for the large variations in counted numbers of amphipods seen on the graphs. Habitat variability is always a possible cause of sample variation. But this study established means of minimizing it.

1 Timing

Fieldwork was kept to a single procedure as far as possible. Samples were taken at the same time in the tide cycle, and samples were dealt with in the same time scale to reduce the number of variable factors and enable results for numbers and distribution to be more accurately correlated. For example, the time of sampling would affect amphipods in that differences in freshness and dryness of algae and the effect of tides may suit or not suit the animals. Therefore sampling has to take place 'three or four days after the spring high tide' and the strandline selected be, in almost every case, the topmost that had been drifted by the recent tides. Around the equinoxes the spring tides are highest and strongest; in mid-summer and late December the spring tides are at their weakest but the tides at the appointed time are similar in height(s) over a day or two. By taking these precautions the wetness of the strand material should be similar as should the state of decomposition.

2 Inherent factors in species biology

Some inherent differences in species and habitat characteristics which could result in variation in the numbers collected; for example, differences in a species' jumping ability, the diurnal migration up or down the beach above or below the seaweed line, the different-sized components of the substrate which may allow animals to descend out of reach, and range of materials in the strandline. The use of the high-sided box quadrat reduces the possibility of escape, and field worker's experience and a rapid method of working enables efficient collecting. The losses are estimated unlikely to exceed a maximum of 5%.

3 Substrate

The line of seaweed provides a more constant humidity and temperature but its composition provides variation in water-holding capacity. In addition, it is impossible to find exactly the same material in all the seaweed piles because of several factors related to drift and position along the beach. The material in the strandline comes from two sources, the flotsam and the beach substrate. The beach consists of larger and smaller, rounded shingle as well as the various sizes of sands. It should also be noted that sand was delivered to Sand Bay following the winter storms of 1980 when dunes and sea defences were washed away and properties beyond were flooded.

This project makes no attempt to correlate distribution and numbers with substrate particle size. However, it needs the expertise of the hydrologist and geologist to understand the processes involved in water movement over the beach and explain the simplest questions. It is unclear why the particles of sand do not fall through the shingle and, although understood in general terms of shoreline drift the heterogeneity of particles is not in terms of a simple gradation from silt and fine sand at one end through to shingle pebbles at the southern end; although there is more silt the further north one goes and the most obvious substrate in the south is large pebbly shingle. At any point there is a mixture and very often a very wide mixture of sizes. The suitability of a substrate type for amphipods must vary along the strandline.

The seaweed, straw and twig components (with anthropogenic material) are part of the flotsam and do vary in amount from place to place; however, there is usually at least one strandline in which there is a preponderance of seaweed over other types of material. Wave action on this usually low-energy beach has an important role in mixing the finer particles of substrate with the organic, more broken pieces of seaweed, grass and twig. Different amounts of integration of substrate and organic matter would be expected to affect the suitability of habitat for populations of amphipods.

4 BEHAVIOUR

The movements of the populations of amphipods and up and down the strandline (i.e. from mean high-water neaps to the highest spring tides) are described above. There is a very limited understanding of these diurnal migrations with regard to the effect on the probability of finding the animals in a standard survey.

Because there is migration of amphipods up and down the beach, and, in addition, males can be found separate from females and juveniles, collecting on the strandline can result in missing populations or sexes. There is an opportunity here for further investigation. Thus the current method *sui generis* produces a numerical variability, despite the means taken to minimize it.

Comparisons between years and areas

In 1999, the Central area contained none or very few amphipods except when collecting close to the boundaries with the South and North areas.

The results in 1999 showed a significant difference in amphipod abundance between the controls and mechanically cleaned areas. Using one-way Analysis of Variance (ANOVA), $F = 6.33$ and $P = < 0.05$. There is also a seasonal difference in abundance, with the greatest abundance being in June and July, probably correlated with recruitment of juveniles.

Other invertebrate populations were also absent in the mechanically cleaned areas although remnant patches of seaweed supported Diptera species. Not only were the adult and juvenile populations destroyed in the cleaned area but the burrows as well.

Amphipod distribution

The most dramatic evidence of the impact of mechanical beach cleaning was demonstrated on a night visit to Sand Bay between 11.30pm and 12.45am on Saturday, 17 July 1999. This was two days after HWST.

In the South area hundreds of amphipods of the species *T. saltator* and *T. deshayesii* were found under the seaweed and moving on the shoreline. Individuals of all life stages were present. Also hundreds of Diptera flying among the fucoids and a few Staphylinidae beetles were foraging. Even in the North area, although there were adult amphipods under the refuges at the saltmarsh end and both adults and juveniles under the new HWST strandline, they were not present under all the debris and did not approach the abundance of the South area. There were Diptera and Staphylinidae beetles present and a millipede.

In contrast, in the Central area there were no amphipods under either the HWST strandline or the new strandline. However, there were Diptera present.

CONCLUSIONS

Mechanical beach cleaning effectively destroys the habitats of whole populations of amphipods and other invertebrates.

Habitat conditions for amphipods are very precise and once conditions become unfavourable they move to a new habitat. They require optimum levels of humidity of 85–90% for survival, and during summer months these conditions can only be maintained in new strandline and under refuges in 150mm deep decomposed *Spartina* stalks and seaweed. Seasonal changes affected the amphipod abundance in cleaned and controlled areas similarly and are related to degrees of temperature, humidity and appropriate algal food resource in the strandline.

The significance of these results is that the integrity of suitable amphipod habitats is vital to their survival. In an organism that only has a life span of one to three years and in the case of *T. saltator* only one brood per year, their continued existence depends on a healthy abundance of individuals and optimum conditions for breeding.

Amphipod movement is predominantly up and down the beach and loss of an upper refuge again reduces the population.

Horizontal dispersal distance was found to be only 137m over a month. This is a slow re-colonisation period and it may be that movement to new areas only occurs if there is a reliable supply of food and refuge material. If this is periodically removed by mechanical beach cleaning amphipod resettlement will not occur.

The effect of mechanical beach cleaning was that the top 100–150mm of substrate was removed which frequently included amphipod burrows above HWST, e.g. *T. saltator* burrows, often containing animals ready to moult or breed. Removal of the breeding individual seffectively eliminates the next population.

The supra-littoral zone is vital also for overwintering amphipods and other invertebrates. Where mechanical beach cleaning occurs, strandline populations are obliterated; all life stages are affected with *in situ* mortality. The food is removed, microhabitats are destroyed and any shore food web obliterated. Potentially valuable food for birds is also removed.

The positive outcomes of the cessation of mechanical beach cleaning can be summarised as increased amphipod abundance, strandline left as a resource for bird feeding, increased colonization and stabilisation of the dune line. Over the time of monitoring an extra 1m of sand dune has been stabilised by vegetation and the normal nutrient flow through the strandline food-web has been re-established.

ABOUT THE AUTHORS

Hazel Willmott is a marine biologist, an experienced scuba diver and currently is organising work at BTCV. She runs classes in marine ecology and studied the amphipods of Sand Bay for her MSc. Tony Smith is a retired teacher and environmental consultant. He is pleased to find that his year-long work on amphipods has not been tackled elsewhere.

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