Effects of Gallant for *Spartina* control

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Background

Environment Waikato has given the Department of Conservation a resource consent to trial *Spartina* control in Kawhia Harbour using Gallant herbicide. The consent is subject to several monitoring conditions including:

i) to assess the sub-lethal effects of Gallant, including its bioaccumulation in invertebrates;

ii) to assess the acute effects of Gallant on non-target species and macro-invertebrates;

iii) to assess the effects of decaying and/or dead plant material on the environment;

iv) to assess the effects of sediment release on the immediate environment and the potential effects on the wider environment.

NIWA was commissioned to design a monitoring programme to comply with conditions (iii) and (iv) above. Our brief was as follows:

a) the monitoring programme should be applicable in other estuaries around the country;

b) on the basis of the data contained in the BoP (1994) report, the sampling intensity was to be designed to detect a 50% change in the three most abundant taxa;

c) enough detail regarding the statistical testing procedures was to be included for field staff to do the necessary statistics using Excel functions or an ordinary calculator.

DESIGN OF A MONITORING PROGRAMME TO COMPLY WITH CONDITIONS (III) AND (IV) IN THE RESOURCE CONSENT TO TRIAL *SPARTINA* CONTROL.

Ecological and biological monitoring can be defined as the systematic use of ecological and biological responses to evaluate changes in the environment with the intent to use this information within a quality control programme (Thrush *et at*., 1988; Spellerberg, 1991). A major reason for operating any monitoring programme is the necessity for resource managers to document change, and to relate ecological changes to management practises and ascribe ecological significance to these changes. No one monitoring programme will answer all questions, and the final programme will necessarily be selected on the basis of considerations of time, resources and money (Thrush *et al*., 1988).

The proposed monitoring programme (see Figure 1) is designed around a time series analysis to assess the overall effects of (1) decaying and/or dead plant material and (2) sediment release on the environment. Time series analysis allows variations as a result of cyclical changes (e.g. recruitment) and other irregular fluctuations to be identified and thus prevent these factors from confounding underlying trends (Chatfield, 1980). Time series are the most appropriate analyses for monitoring changes in biological populations (Thrush *et al.*, 1988). The programme will monitor the decline of *Spartina* both above and below the sediment, together with sediment deoxygenation, sediment transport and depth of sediment disturbance. To provide information on the ecological effects of these changes following a spraying operation, the proposed monitoring programme will provide information on changes in:

a) macroinvertebrate abundances and community structure;

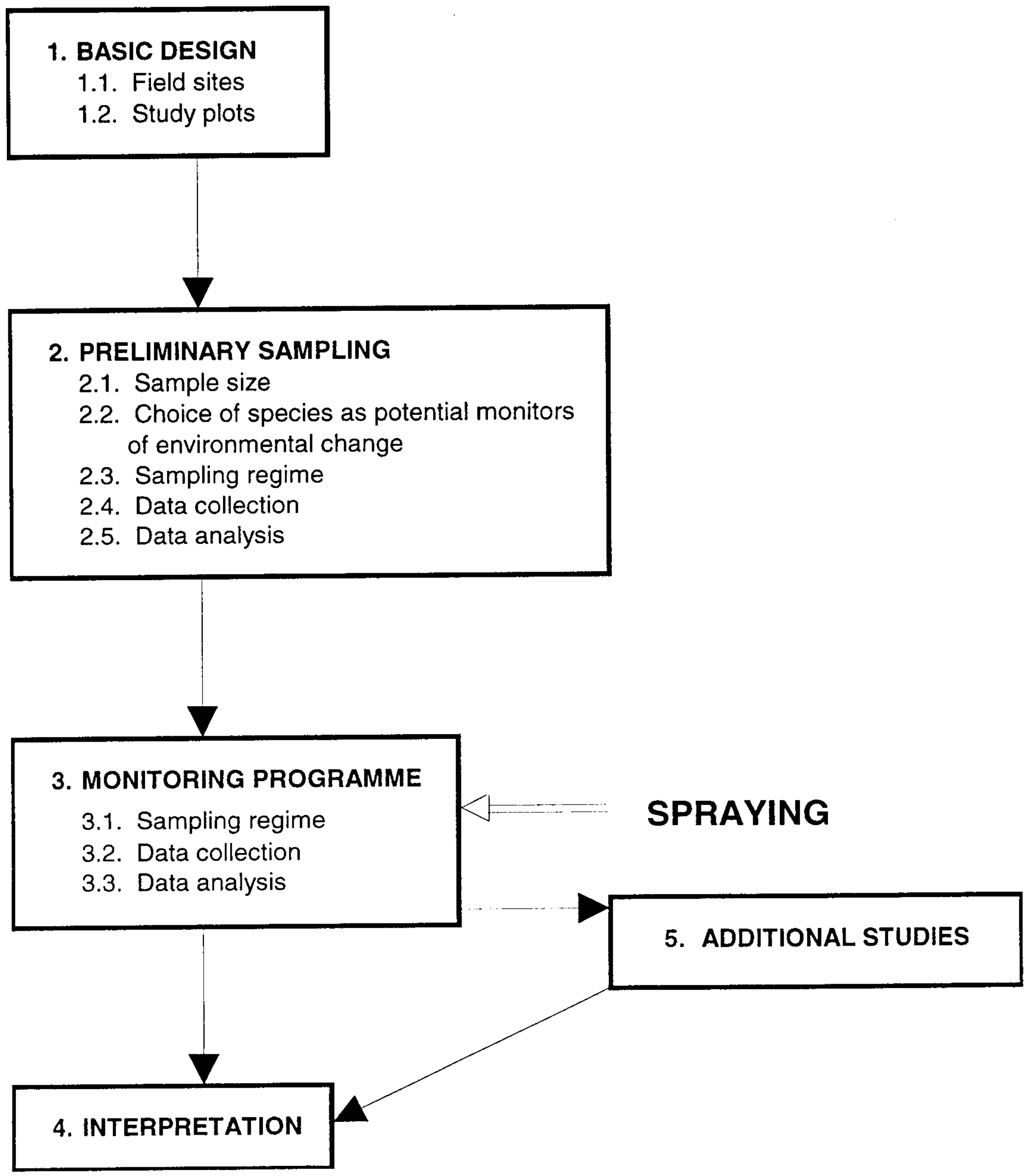
b) fish abundances and assemblage structure;

c) non-target vegetation.

Information on the decline of *Spartina* cover, together with sediment deoxygenation, sediment transport and depth of sediment disturbance will allow these variables to be used as explanatory variables in analysis and interpretation of the time series data from a),.b) and c) above.

The effect of both the death and decay of plant material and sediment release on macrofaunal invertebrates, fish and non-target vegetation is likely to be highly dependent on the size of the area sprayed. While the information gained from small-scale field studies must ultimately be related back to natural ecological systems, the direct extrapolation (i.e. scaling-up) to address larger-scale management issues is not straightforward (Thrush *et al.*, in press, in prep). We, therefore, recommend monitoring relatively large areas of sprayed *Spartina*. Changes in macrofaunal invertebrate communities, fish assemblages and non-target vegetation over time within this area, should be compared with changes within similar-sized areas of non-sprayed *Spartina* and bare sediment to identify the continuum of effects from non-sprayed *Spartina* to sprayed *Spartina* to bare sediment. These results will identify environmental effects at a more relevant scale than would conducting small-scale experimental trials that examine a number of different effects individually.

Figure 1. Design of a monitoring programme



1. Basic design

1.1. FIELD SITES

Control plots (i.e. one non-vegetated sand and one non-sprayed vegetation) and a treatment plot (i.e. Gallant sprayed *Spartina*) should be located at each of the field site(s) to be monitored. Changes in plant material and sediment conditions, as well as macrofaunal invertebrate abundances, fish assemblages and non-target vegetation over time within the treatment plot, can thereby be compared with changes within similar-sized areas of non-sprayed *Spartina* and bare sediment, to enable an assessment of the ecological effects of plant death and decay and sediment release. The non-vegetated and *Spartina* plots should be selected to be similar in terms of tidal level, wave exposure etc., and should be no farther apart than the length of the plot. If local site conditions are inappropriate for including a non-vegetated plot that is close to the *Spartina* plots and at the same tidal height etc., then a second non-sprayed vegetated plot should be set-up. Increasing the number of control plots increases the generality of the analysis. If there are different densities of *Spartina* present within the site, for example, or different Gallant application levels are to be trialled, then treatment plots must reflect this, with a low and a high density treatment plot, or different application level treatment plots also included.

To increase the generality of the results from such a study the monitoring programme should be set up in at least three sites within the estuary/harbour of interest. Monitoring common species, in similar habitats at a number of sites in an estuary/harbour, allows changes in a major component of the ecosystem to be quantified, and departures from a general common pattern to be documented. There can often be important differences in community composition from place to place in harbours (e.g. Pridmore et at., 1990). This is particularly important if the results from a monitoring programme in any one estuary/harbour are to be developed as national guidelines for the use of Gallant as a means of controlling *Spartina*.

This programme has been designed to be applicable in the range of locations where *Spartina* eradication programmes may be implemented. Nevertheless the specific details (e.g. number of samples, species to be monitored) are likely to vary between harbours/estuaries. Studies only relate to the area under investigation and the results must be cautiously generalized to other areas. Any programme therefore needs to be preceded by an intensive pilot study.

1.2. STUDY PLOTS

Each control and treatment plot should be no smaller than 300 m^2 in area, with the linear dimensions (e.g. 12 m x 25 m, 10 m x 30 m) depending on which geometry is best suited to the area. This size experimental plot has been successfully used to document the effects of the organochlorine pesticide technical chlordane on populations of intertidal macrofauna (Pridmore et at., 1991, 1992). The corners of each plot should be permanently marked by posts driven into the substratum.

2. Preliminary sampling

2.1. SAMPLE SIZE

A crucial part of the design of ecological monitoring programmes is selecting the sample size (i.e. the numbers of replicates) which will ensure that sufficient information is gathered to enable changes to be detected at the required level of precision. In this case the programme is to be capable of detecting a 50% change in the three most abundant taxa. Because of the small sample sizes and highly variable results in the BoP report it is not possible to reliably identify the three most abundant macro invertebrate taxa or to calculate the numbers of samples that would be necessary to detect a 50% change in their abundances. We therefore detail a method that can be used with a preliminary survey to provide information on the appropriate number of samples required to detect predetermined changes in abundance.

2.2. CHOICE OF SPECIES AS POTENTIAL MONITORS OF ENVIRONMENTAL CHANGE

One of the specifications for this monitoring programme was that the programme should be designed "...to detect a 50% change in the three most abundant taxa...". However, the detection of effects through a monitoring programme should not be based solely on the most abundant species in a community, species should also be chosen so that changes in their abundance are likely to reflect important changes within the ecosystem. Two aspects need to be considered when choosing species to monitor: their ecology and the practicality of sampling (Thrush *et al.*, 1988). The preliminary study will provide information on the practicality of sampling and will identify numerically dominant species. The key issue, however, is the involvement of species in ecological processes. This is considered vital in the selection of species as it is the basis of our understanding of ecology that: changes in population structure must be considered; their importance interpreted; and possible causes inferred. Common species are preferable because higher abundances simplify sample collection.

Two of the most abundant species identified in Roberts (1992) and BoP (1994) (*Amphibola crenata* and *Helice crassa*) and used as monitored species in these studies, are tolerant of environmental stresses and contaminant loads, and may not therefore, be the most appropriate species to monitor (e.g. they occur in highly contaminated areas of Manukau Harbour; Roper *et al*., 1988). Monitoring of species which are considered to be of special ecological importance or indicative of the presence/absence of particular environmental conditions is considered more appropriate, as changes in the abundance of these species can be inferred to be of ecological significance. Species which are likely to be of value in a monitoring programme to document the effects of death and decay of plant material and sediment release, include those sensitive to sediment deoxygenation, sediment transport and changes in sediment organic content. For example, smaller, surface-living fauna are likely to be most affected by sediment erosion processes.

2.3. SAMPLING REGIME

The preliminary survey should be undertaken at least 2-3 months prior to spraying with Gallant to allow sample processing. It will then be possible to describe community structure, identify the numerically dominant species and those species which may have potentially important biological roles in the salt-marsh community, and to document within and between site variability to allow for the design of a statistically appropriate study. The preliminary study will also form the start of the before impact data.

2.4. DATA COLLECTION

2.4.1. Macro Invertebrates

Fifteen core samples (previous surveys in intertidal areas indicate this is an appropriate number) should be taken from random positions within each study plot. In considering the size of the sampler to be used in this programme it is necessary to balance the practicalities of sample collection (effort, weight of sediment, cost to sort etc.) with the highest possible precision in statistical estimates of population abundance. Consideration of this problem usually results in a decision to collect either a few large samples (e.g. 0.1 m^2) or many smaller ones (e.g. 10 cm diameter cores). Collecting of more small samples allows more of the variation within the study area to be accounted for in descriptions of population and community structure. Sampler size should be determined during the preliminary sampling phase.

As a pre-requisite to the statistical analysis, the samples need to be collected from random positions within each study plot. It is conceivable that chance may result in most of the samples ending up in one part of the study plot. To provide adequate dispersion, each plot should therefore be divided into 15 equal sectors and one core taken from each sector. The locations of the cores within each of the 15 sectors are obtained from randomly derived cartesian co-ordinates.

After collection, samples should be sieved (500 mm mesh) and the residue fixed in 70% alcohol and 0.1% Rose Bengal. Macrofauna should be sorted and identified to the lowest possible/practicable taxonomic level and counted. Ideally the preliminary survey should be undertaken during the summer period when most communities are likely to be at their most abundant and diverse.

The size of changes to be detected within the fish assemblages and non-target vegetation were not specified in the brief, however similar preliminary surveys need to be undertaken to provide the information with which to select the most appropriate levels of replication required to adequately address changes in fish assemblage structure and non-target vegetation.

2.4.2. Fish

We recommend the use of throw or drop traps similar to those used in overseas studies to assess fish and mobile macro invertebrate (e.g. crabs, shrimps) abundances in areas of submerged vegetation (e.g. Jacobsen and Kushlan, 1987; Sogard *et al.*, 1987; Fonseca *et al.*, 1990). These nets are less destructive than, for example, otter trawls. Fonseca *et al.* (1990), for example, used drop nets consisting of a 23 cm high, 1.5 x 1.5 m sheet metal square, with a 1.5 m high net (0.16 cm mesh) attached to the top edge of the square. After the drop net is manually positioned in a given study plot, hollow metal poles are placed through U-shaped clamps attached to the outside of the metal square, and pushed into the sediment to a depth of approximately 50 cm. The net is then lifted and pins inserted through holes in the poles to support the net until it is dropped. Lines running from each pin to anchors 15 m away are used to release the pins and drop the net. Nets should be dropped no less than 12 hours after deployment. Fish and mobile macroinvertebrates are then recovered from the nets with dip nets; recovery efforts are terminated after no fish are recovered with 5 successive scoops with the dip net. At each site, at least 10-15 trap samples will need to be taken to estimate the number of samples needed to document pre-determined levels of change in the monitoring programme.

2.4.3. Non-target vegetation

The establishment of natural salt-marsh vegetation in areas previously occupied by *Spartina* may be a significant effect following the death and decay of *Spartina* from the area; this may have concomitant effects on the macroinvertebrate and fish populations and sediment dynamics and should therefore also be monitored.

Line intercept transects are a simple, reliable and relatively rapid method for detecting spatial and temporal differences in cover of abundant species, and which have been widely used in impact studies (e.g. Loya, 1978; John *et al.*, 1980; Kirkman, 1990; Mundy, 1990). The cover of a species within a specified area is calculated as a fraction of the total length of the line that is intercepted by the species of interest.

The study site should be carefully examined during the preliminary survey and representative areas chosen through which transect lines are to be laid to traverse areas that are considered important (e.g. across the boundaries between areas of natural salt-marsh and *Spartina*). At each site, at least 10-15 replicates of each of 4 lengths (e.g. 50 m, 100 m, 150 m, 200 m - the lengths selected will be determined by changes in the vegetation, terrain etc.) are surveyed, and the data used to calculate the number and length of transects necessary to document pre-determined levels of change (cf. Mundy, 1990).

Salt marshes are very prone to damage by trampling and repeated access to sites can cause intense local damage (Dalby, 1987); it is therefore important, particularly during the intensive preliminary survey, that human disturbance is minimized.

2.5. DATA ANALYSIS

2.5.1. Sample size determination

The following procedure for optimising sample size for patchily distributed data reduces the risk of oversampling (Hewitt *et al.,* 1993) and balances precision against effort (cost). A number of samples (N) are collected from a site in a preliminary survey and this data is used to estimate variance for a range of sample sizes (e.g. n=2,..., N/2; this range can be extended by bootstrapping, Manly 1992). A random selection is made from all the possible combinations of data for each sample size. For each of these random draws, the standard deviation and standard error is calculated. Following this, the 95th percentile of the standard deviations, or standard errors, for each sample size can be calculated. At this stage, the decrease in standard error with increasing sample size can be used for assessing trade-offs between increased information and increased cost. To determine the number of samples required to identify a change of a certain magnitude, the 95th percentile of the standard deviation and its respective sub-sample size can be substituted into a minimum detectable difference equation (Zar, 1984). Given a random number generator, a computer package capable of merging data sets and performing statistics using a "by" column, and a reasonably powerful computer, this procedure can be completed for a number of different variables in a few hours.

2.5.2. Preliminary differences between plots

Data collected from the preliminary survey, before the Gallant spraying operation, should be analysed for differences between plots by parametric or non-parametric one-way ANOVA, with treatment as a fixed factor. If significant differences between the areas of *Spartina* designated as sprayed and non-sprayed are found, or if no differences are found between the non-vegetated and vegetated areas, the form of the study would have to be re-evaluated.

3. Monitoring programme

3.1. SAMPLING REGIME

It is generally recommended with a study like this that the sampling programme should be run for the same length of time before the impact is initiated, as it is to be run after the impact (Schmitt and Osenberg, 1996). Overseas studies suggest that *Spartina* takes some time to be decomposed by physical fragmentation, ingestion and tearing apart by detritivores and bacterial decomposition. Valiela (1984), for example, reports that decomposition of plant material such as *Spartina alterniflora* may take months to years. We recommend therefore that one year would be a suitable period over which the plots should be monitored prior to spraying with Gallant. At the very least, the preliminary survey should be undertaken 2-3 months prior to spraying and the monitoring programme initiated immediately (within one week) prior to spraying and sampled at regular intervals thereafter. A minimum 3-monthly sampling interval would be appropriate to assess the effects of decaying and/or dead plant material and the effects of sediment release on the environment. The site should be re-visited at least once in the three months following spraying (e.g. after one month) and if there is evidence that appreciable changes in the death and decay of the plant material and sediment release are occurring over shorter time intervals, then the monitoring programme should be re-scheduled with shorter sampling intervals.

If an assessment of the acute effects of Gallant on macro invertebrates and fish (condition (ii) of the resource consent) is to be incorporated into the monitoring programme, then shorter sampling intervals following spraying would be appropriate (e.g. 1, 2, 7, 14, 30, 60, 100 days etc. after spraying). It is important that the proposed monitoring programme is continued to assess the full effects of *Spartina* death and decay and sediment release. A reasonable number of data points are necessary before trends and changes in trends are apparent, and obviously more than one year of data is necessary to indicate seasonal changes.

3.2. DATA COLLECTION

3.2.1. Plant death and decay

Changes in the above and below ground plant biomass should be monitored to provide a measure of the rates of plant death and decay which can be related to the observed changes in macro invertebrate abundances and fish assemblage structure. Replicate (the final number would be selected on the basis of biomass estimates made during the preliminary survey) 25 cm x 25 cm quadrats should be sampled. The above ground plant material should be removed first, followed by the below ground material which is collected by digging up the quadrat and sieving the material through a coarse sieve (1-2 cm mesh) to remove all the sediment.The plant material should be dried at 60°C for 48 hours (until there is no further loss in weight) and above and below ground biomass calculated (g dry weight m^{-2}).

One of the most likely effects of accumulations of dead and decaying plant material is the development of anoxic conditions caused by the high quantities of organic matter present, and an accompanying reduction in the depth of the redox layer. The depth of the anoxic layer in the sediment from which macrofaunal invertebrate samples are to be taken should be routinely recorded.

3.2.2. Sediment characteristics

To be able assess the effects of sediment release on the immediate environment, we recommend monitoring a number of sediment characteristics which are likely to change following the death and decline of *Spartina*.

3.2.2.(a) Depth of sediment disturbance

Depth of disturbance rods can be used to provide an time-integrated measure of the erosion or accretion of sediment and the depth to which sediments are disturbed (for example by wave activity, tidal currents) (Dolphin, 1992; Dolphin et al., 1995). Disturbance rods consist of stainless steel rods, 5 mm in diameter and up to 1.0 m long, driven approximately 0.8 m into the sediment, with a loose fitting washer placed over each rod. When the sediments are reworked and carried into suspension, the washer falls to the new surface level and is buried as the sediments are deposited. At each sampling time, the distance from the top of the rod to the sediment surface should be measured (indicating elevation changes), as well as the distance to the washer. By subtracting each successive washer measurement, the maximum depth of disturbance between visits can be established. Following each recording, the washer should be returned to its new surface level.

We recommend deploying 4-6 disturbance rods in each study plot.

3.2.2.(b) Sediment transport

Changes in the transport of sediment can be measured using bedload traps deployed in the study sites for short (1-3 day) periods throughout the monitoring programme. Suitable bedload traps have an aspect ratio of >10:1 (e.g. 50 cm lengths of PVC pipe with an inside diameter of 4.0 cm have an aspect ratio of 12.5:1). The traps are buried flush with the sediment surface and used to collect sediment moving in the bedload. After the designated sampling period, the contents of the traps are removed, the dry weight of sediment in each trap is measured and grain size analysis performed whenever sufficient sediment is collected in the traps.

We recommend deploying 4-6 traps in each study plot.

3.2.2.(c) Surficial sediment grain size

Changes in sediment grain size in each plot can be determined using pipette-analysis (see Folk, 1968) on a composite of 15 (one from each sector in the plot) evenly spaced samples. Only the top 2 cm of sediment should be sampled as this is considered to be the sedimentologically recent and active layer most likely to influence the distribution and abundance of macroinvertebrates. Sediment samples should be collected at 6-monthly intervals over the duration of the monitoring programme.

3.2.3. Floating wrack

Overseas studies have found that floating rafts of decaying *Spartina* become concentrated by currents and then float up to rest on the top of grass in the high marsh. The vegetation is smothered and a bare zone is created, within which colonization may be inhibited for a time. If rafts of decaying *Spartina* are likely to be an issue in the area under study (for example, back-water areas of harbours and estuaries), they also need to be monitored. If significant rafting is observed to be occurring in the area of interest, then at this stage the monitoring programme should be adjusted to address this issue. If funding is available, low level aerial photography, in conjunction with transects across the high tide areas, would provide large-scale information on the distribution of any rafts.

3.2.4. Macrobenthic invertebrates (see section 2.4.1)

The requisite number of core samples should be taken from random positions within each of the study plots. In selecting sample locations within each sector of the study plot, co-ordinates should be redrawn if the selected location falls within a 0.5 m radius of a previously sampled area to preclude any localized modification of the sediment or resident populations.

By including routine size measurements of selected species (for example bivalves) in the core samples collected as part of the monitoring programme, it would also be possible to assess sublethal effects such as decreased growth rates and recruitment into the population. With the use of a simple digitising pad connected to the microscope, measuring and identifying can be done at no extra cost in time.

3.2.5. Fish assemblages (see section 2.4.2)

The requisite number of trap samples should be taken from each study plot at a similar state of the tide for each sampling date.

3.2.6. Non-target vegetation (see section 2.4.3)

The requisite number of permanent transects of the optimum length should be set-up at each site. At regular intervals (e.g. 5 - 10 m) along each transect, a post is driven into the substratum as a permanent marker. Each time the transect is traversed, a tape measure is laid between the posts, and changes in vegetation along the tape recorded. Descriptions should include 50 cm on each side of the transect line. The resulting record may take the form of a profile or a table showing changes from one period to another. Video photography should be used to produce a permanent record of changes along the transects. Video film is suitable for detailed analysis at a later stage if this is considered appropriate.

The posts marking the position of the permanent transects can also be used to document changes in sediment accretion and erosion, by measuring the successive differences between the sediment surface and the tops of the posts (Dalby, 1987). This will provide information on changes in sediment erosion and deposition over a larger scale than the study plots.

3.3. DATA ANALYSIS

3.3.1. Routine data analysis

Ongoing graphs of the measured variables (e.g. plant biomass, sediment erosion/deposition, macro invertebrate abundances, fish abundances) against time should be produced for each study plot. From these, changes of the order of 50% in the measured variables should be clearly visible, providing an indication of the effects following spraying. The graphs will also provide a guideline as to when the more detailed analyses should be initiated prior to the termination of the study.

3.3.2. Final data analysis

The full time series should be then be analysed in three main ways. Firstly, comparisons between time series for the sprayed versus the non-sprayed *Spartina* area and the sprayed *Spartina* versus the non-vegetated area should be made. Statistics are generated from the number of data points from the sprayed area that fall within the envelope created by the 'control' area (Loehle and Smith, 1990). By using the non-sprayed *Spartina* as the start point and the non-vegetated area as the expected end-point, we can track the movement of the sprayed area over time from one habitat type to the other. Secondly, differences between the sprayed and non-sprayed *Spartina* should be calculated and the time series of the differences analysed (Stewart-Oaten, 1996). Thirdly, on the vegetated areas, a repeated measure ANOVA (Green, 1993) with treatment (i.e. sprayed vs. non-sprayed) as a fixed factor and location (i.e. x and y co-ordinates) as continuous variables should be carried out. If this analysis cannot be carried out with the statistical packages available, then a simplified two-way ANOVA could be run with time and treatment as fixed factors. A significant time treatment interactive term would indicate an impact.

If any of these above analyses indicated an impact, then another analysis (based on linear modelling) should be carried out to indicate potential causes. Explanatory variables would include: location; biomass of *Spartina* above and below ground; date; sediment transport and depth of disturbance; and depth of the redox layer. Non-significant terms should be removed, one at a time, starting with the least significant, from the analysis. Power analysis should be carried out for those variables not showing significant treatment effects, to determine the power available to detect changes.

Changes in sediment grain size between the start and end of the study in the treatments should be analysed by two-way ANOVA with treatment as a fixed factor and time as a random factor.

4. Interpretation

It is necessary to address the significance of documented changes not only statistically but also ecologically. The final stage of the monitoring programme, therefore, is the interpretation of the results and an assessment of the effects of decaying and/or dead plant material and sediment release on the environment, thereby enabling resource managers to relate ecological changes to management practices. The ability to relate ecological change to management practices will depend upon an understanding of ecological processes, their relationship with changing environmental conditions, and the design of the monitoring programme (Thrush *et al.*, 1988).

Integration of the results from other areas in the estuary/harbour and with general observations of the sites over the duration of the monitoring programme and knowledge of the study area (e.g. hydrodynamic regime, prevailing wind and wave conditions) will enable an assessment of the wider environmental effects following *Spartina* control. Environmental management decisions can thereby be made and justified within the framework of information provided through the monitoring programme.

5. Additional studies

The monitoring programme proposed here is what we consider to be the minimum required to adequately address the effects of decaying and/or dead plant material and sediment release on the environment. With relatively little increase in resources, time or cost, however, a number of other factors could easily be incorporated into the monitoring programme to further improve our understanding of the salt-marsh environment and how we are modifying it, thereby allowing greater confidence in the interpretation of changes documented as part of the monitoring programme.

Examples of additional work include:

1. Small (1-5 g) sub-samples of the decaying vegetation and surficial sediment collected as part of the routine monitoring (see sections 3.2.1 and 3.2.2.(c)) could be frozen for chemical analysis of the active ingre dient in Gallant (haloxyfop acid). Analyses could be undertaken at the end of the study, if examination of the ecological data indicated that information regarding the temporal variability in concentrations of Gallant in the plant material over the duration of the monitoring programme would contribute to explaining observed changes in macroinvertebrate abundances, fish assemblages and non-target vegetation.

2. If funding and time permits, relative water velocity integrated over each bedload trap deployment period (see section 3.2.1) can also be easily estimated using the gypsum dissolution technique (e.g.Yund *et al*, 1991). Plaster of Paris blocks (2 cm thick, 7 cm diameter) of known weight are placed in holders of PVC pipe of similar diameter, and pushed into the sediment so that the top of each block is 5 cm above the bottom (to estimate flow close to the bedload traps but avoiding abrasion from sediment movement along the sediment-water interface in the bedload) (Commito *et al*., 1995).

3. Low-level aerial photography (in conjunction with an appropriate ground-truthing programme) provides an excellent means for assessing changes in vegetation over larger scales (see section 2.4.3).

4. Additional information on the effects of Gallant on macro invertebrate and fish community structure could be obtained using multivariate analysis of community composition. This need not necessarily involve de tailed taxonomic information, as a number of recent studies documenting the impact of anthropogenic disturbances on benthic communities have shown that very little information is lost by working at taxonomic levels higher than species.

5. Precise measures of the decomposition history of *Spartina* by means of litter bag experiments.

If concerns regarding the eradication of *Spartina,* in terms of reduction in productivity, alteration of available habitat (e.g. loss of cover, loss of plant detritus) and physical changes resulting from sediment release following plant decay are considered to be major factors limiting the advantages of a *Spartina* eradication programme (cf. Roberts, 1992), then the potential of enhancing the establishment of native estuarine vegetation, through the implementation of a transplant and restoration programme, may be an option for further consideration. If the effects of Gallant on non-target vegetation are minimal as indicated from the preliminary reports, such a restoration programme could be implemented early on following eradication, thereby minimizing the potential effects arising from the loss of vegetation in the environment.

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