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Monitoring The Effects of Saline Inundation On The Aquatic Dyke Flora In An Area of Broadland Grazing Marsh

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1. INTRODUCTION

1.1 General introduction

The Broadland region of Norfolk and Suffolk has long been recognised as an area containing a wide and valuable range of aquatic habitats in which diverse and often unique assemblages of flora and fauna are to be found (Ellis 1965, Ratcliffe 1977). However, this wildlife interest is not the only reason for which Broadland has national importance. Tourism, waterborne recreation and agriculture have interacted to create extensive problems in this region, and in the past human pressures have taken precedence over ecological concerns. Since World War II extensive conversion to arable farming has occurred throughout Broadland. This has increased the levels of fertilisers entering the network of broads and rivers, which, in conjunction with rises in total sewage emissions (from urban populations and boats), has caused nutrient loading (George 1992). The loss of aquatic plants connected with this widespread eutrophication has been furthered by higher levels of pesticide use and boating activity, which both damage vegetation. The rich and ecologically important macrophyte flora characteristic of Broadland has generally disappeared from the Norfolk Broads and rivers, and has now been confined almost exclusively to the drainage dykes of the grazing marshes (George 1977).

Although the majority of present Broadland dykes were dug between 1800 and 1900, permanently wet ditches have existed to drain the land and act as wet fences to prevent livestock straying for at least eight hundred years (Burgess and Evans 1990). This habitat continuity together with land management that has varied little over the past century is probably responsible for the development and survival of the diverse dyke flora (Driscoll 1982). However, since the late 1960s the land use of the marshes has altered. Cattle grazing became less economic in the wake of changes to UK agricultural policy, leading to increased pressure from improved (deep) drainage and conversion to arable in grazing marsh areas. It is now understood that the nature of intensive agriculture (particularly arable) threatens the fragile natural dyke communities, reducing floral diversity (Doarks 1984) and adversely affecting characteristic Broadland plant species (Driscoll 1985).

The loss of grazing marsh to arable slowed during the 1980s and has now virtually ceased as policy has shifted focus from conversion to conservation in Broadland (George 1992). It is now the widely held belief that it is necessary for marshland to be kept under non-intensive grass and the dykes cleared in an ecologically friendly manner on approximately a five year rotation, for the aquatic plant communities within the dyke system will be retained.

Over the last decade research has ascertained that there are a definite range of aquatic communities in Broadland. Doarks and Leach (1990) constructed the most recent dyke community classification (which is applied in this report) using the TWINSPAN computer program. TWINSPAN (Two Way INdicator SPecies ANalysis) is an analytical program devised by Hill (1979) to classify vegetation assemblages according to their species affinities. Utilising data from a 627 dyke survey conducted throughout Broadland by the England Field Unit in 1988, they produced a dichotomous key identifying ten aquatic vegetation endgroups. Specific endgroups are treated as distinct dyke communities.

The ecological value of an endgroup is assessed in terms of its infrequency of occurrence in Broadland and the presence of national and local rarities and scarcities. Valued communities correlate with mesotrophic/mesoeutrophic water quality, whilst eutrophic conditions give rise to less valued species assemblages. The community deterioration caused by increases in trophic status is most obvious in freshwater; however, where conditions become incresingly saline, degradation may also occur. This potentially results in the appearance of brackish type communities. The occurrence of these endgroups (A7a and A7b) correlates at the 0.1% significance level with both mesohaline and oligohaline conditions (see **Table 1**). More valued communities (A1,A2,A3a,A3b) correlate negatively with higher salinities, preferring freshwater habitats.

Communities reflect the physical, chemical and biological requirements of their component species, and thus act as sensitive environmental indicators. Whilst dyke communities are also affected by a combination of vegetational sucession (George 1977), dyke management regime (Newbold et al 1989) and dyke profile, aquatic endgroup is primarily indicative of, and therefore determined by, water quality (Driscoll 1975, Doarks 1986). It is recognised that in additon to environmentally sensitive farming practises, the protection of important endgroups and their related species is dependent on preserving dykes from the influence of both eutrophic and saline conditions. This is most successfully achieved by maintaing river walls to prevent intrusion onto the marshes.

1.2 The 1993 flood of the Cantley level.

Before the spring tide that opened the large breach in the flood wall of the Cantley level, the previous spring tide had already caused a smaller breach. This was under repair when the surge event occured, opening up an entire rond as the breach widened, and flooding about two square kilometres of grazing marsh. Overtopping of water over the flood banks also occurred (see **Map 1**). Two separate surges had in fact happened during the 23rd of February. A smaller sugre kept water levels in the river high, then during the night a massive surge followed, breaching the flood wall and covering the Cantley level north and south of the railway line to a mean depth of 1.2m. The flood water entered the northern marsh via two main culverts under the railway line (see **Map 1**).

The flood lasted for three weeks until the water level on the marsh was pumped as low as possible. To remove residual salt from the dyke system (salt enters the soil and sediments), river water was flushed through the marsh three times. The tidal flaps at the mouth of the Fleet main drain were wedged open, a channel cut through the flood wall (see **Map 1**), and river water allowed to enter the marsh flowing 'backwards' up the Fleet. A smaller quantity of water was also taken from Hassingham Broad with the river water. Each flushing consisted of raising the water level to the tops of the dykes. The water was given time to percolate through the system (to dilute the salinity) before being pumped back to the river from the pumping station indicated on **Map 1**.

The low fluvial flow in the Yare at the time of the surge event meant that salt-water had invaded further upstream than at any time in recent years. This accounted for the high salinity of the flood waters which on average were 40% sea water. RSPB measurements ranged from 30-47% sea water, with the highest recordings in the north-eastern marsh. Indeed before flushing with river water of background conductivity 800uS/cm, the conductivity on the level was measured as 24000uS/cm. After the third flushing, conductivity had generally decreased to 2000-3000uS/cm. The salinity is expected to decline further as a result of dilution, especially in the northern marsh where a degree of flushing occurs naturally under gravity.

The breach and damage where overtopping occured were repaired during the summer of 1993, dredging and widening dykes to generate spoil for the flood banks.

1.3 Project Objectives

The ecological value of Broadland is linked mainly to its freshwater habitats. It is considered the most important freshwater complex in England. However, over a long period, the area has become increasingly influenced by marine conditions with brackish habitats replacing freshwater. In addition, sea-level rise and deteriorating/sinking flood banks have increased the frequency of flooding incidents both in currently fresh and brackish areas. Considering the importance of preserving freshwater communities, and current investigation by the National Rivers Authority into a strategy for the alleviation of flooding in Broadland, the ecological impacts of saline flooding events on grazing marsh habitats need further research.

It is the aim of this project to examine the effects of the saline flooding of the Cantley level. Detailed investigation has been made possible as this was an area of freshwater grazing marsh for which in depth data existed from before the flooding. Additionally a data base was to be created to initiate the longer term monitoring of the ecological response to the stress of saline inundation and increased background salinity and the disturbance effects of sediment and detritus deposition in the dykes.

Only the aquatic dyke flora has been studied in this report. Changes to other habitats have however occurred. Clive Doarks of English Nature examined the peaty marshes north of the railway line finding no drastic changes in the sward. However, south of the line on the clay marshes the sward was discovered to be noticeably altered. Additionally, the RSPB outlined that there had been changes to the ground flora in parts of the adjacent woodland that had been inundated.

In order to study the short term effects a dyke by dyke survey of the Cantley level was conducted in August 1993. Since the previous survey in 1988, until February 1993, the level had been maintained as freshwater. It was aimed to comprehensively classify the Cantley grazing marsh dykes to endgroup level. This information could be subsequently used to identify changes in community and environmental conditions since 1988 (endgroups act as environmental indicators).

The use of TWINSPAN aquatic endgroups is however rather inflexible. It relies on combinations of indicator species presence with specified DAFOR scores for species abundance in order to key new samples to their correct endgroup. In situations where few indicator species occur, or species are present, but at low frequency, then endgrouping can prove an unsubtle tool. Such a situation was observed to have arisen in the dyke system at Cantley in the summer following the flood in 1993. Macrophyte impoverishment was apparent, although not extreme. Therefore, in order to examine the full impact of the flooding, individual species extinctions/existence and percentage occurrence were analysed for all species recorded in either survey. Also the distribution and frequency where present (DAFOR value) were examined for a range of species indicative of certain endgroups and environmental conditions. [See **Appendix I** for species constancy for each endgroup as determined by Doarks and Leach (1990)]. The effects on species of national rarity/scarcity were particulary important to highlight, especially for the Sharp-leaved pondweed (Potamogeton acutifolius). This nationally rare and declining species is found in less than 15 10km grid squares in the UK, of which the part of the Yare valley including Cantley is a significant species stronghold.

To complete the monitoring of the effects of the saline inundation a comprehensive conductivity survey of the level was conducted. Increases in conductivity would be expected after saline flooding, although comparison with the 1989 data would yield the magnitude of the floods' effects.

2. METHODS

2.1 Background

The botanical importance of the grazing marsh ditches has attracted much attention from ecologists over the past two decades. The significance of such studies in illuminating the problems threatening this sensitive habitat is undeniable. However, varying methodology has invalidated the objective comparison of many of these old data sets. The accurate monitoring of dyke communities through time and in response to variations in environmental conditions (of which the flood at Cantley is an extreme example) requires established methods to overcome problems of inconsistent data. The major EFU survey in 1988/89 (which included the Cantley level) utilised what has now been adopted as the standard methodology for dyke survey.

This report is essentially a data comparison, drawing information from the survey of Cantley in 1988/89 to compare with the results of a survey conducted after the saline inundation. The consistency of data collection in 1993 was therefore crucial. Hence, to ensure valid comparison, the standard NCC methodology (outlined below) was adopted for the 1993 resurvey of the level.

2.2 The standard NCC methodology for dyke survey

The minimum sampling area for marsh dyke plant communities (ie the smallest area in which the species composition of the community is adequately represented) was determined to be equivalent to an 18m dyke length (Doarks 1986). Standard survey requires the selection of a 20m section of dyke. [A dyke is defined here as the unit of drainage channel between two junctions or termini]. Due to the variable nature of communities, the most representative section of vegetation is surveyed. Siting the section at the mid-point between junctions is less accurate.

For each dyke sampled a full aquatic species list is compiled, together with DAFOR abundance ratings for all species occurring within the representative 20m length. Aquatic species are defined as any plant that is submerged, free-floating, rooted but floating-leaved, or has the bulk of its biomass below the water surface during the summer. TWINSPAN endgroup classification relies not only on indicator species, but also their abundance, hence the estimation of percentage cover values for species within the aquatic zone is precisely prescribed (see **Table 1**). The aquatic zone denotes the space available for aquatic plant growth and is measured as the total area of water surface in the ditch section not occupied by emergent vegetation. Local cover values often better represent species distribution and are recorded in order to modify the DAFOR score (see **Table 2**).

Additionally the various stuctural components of the ditch vegetation are assessed, again using a five-point DAFOR scale. Details of adjacent land use, soil type and the condition of the banks in relation to grazing level,shelf formation and the extent of wet poaching by livestock are also noted. The following physical parameters are also measured: water width; water depth; freeboard; turbidity and conductivity.

Once surveyed, the dyke community can be classified to the level of aquatic endgroup manually using the key outlined in Doarks and Leach (1990).

2.3 The 1988/89 survey of the Cantley level

In 1988 and 1989 the England Field Unit of the NCC undertook a survey of Broadland's drainage dykes, with a total of 2684 (about one in four) being sampled. This survey covered 54 of the 191 grazing marsh dykes found on the Cantley level. The location of these dykes is given in **Map 2**). Dykes 1 to 12 were surveyed on the 3rd and 4th of August 1988, whilst the remaining 42 were visited the following year, on the 1st and 2nd of August. All dyke species including emergent as well as aquatic vegetation were recorded in this survey.

2.4 The 1993 survey of the Cantley level

Between the 5th and 16th of August 1993 the aquatic flora was surveyed within every dyke of the Cantley level. The location of these 191 dykes is shown in **Map 3**. Whilst standard methodology suggests that only dykes possessing both an aquatic and emergent component to their vegetation should be sampled, in order to construct a detailed picture of the conditions at Cantley in the summer following the flooding, all dykes were sampled. However, ditch record cards were only completed where aquatic species existed. In those dykes devoid of aquatic flora, conductivity was measured at the mid-point between junctions or termini, and notes describing the general condition of the ditch compiled.

Contrary to full dyke survey methods, only aquatic species were recorded. All vascular plants were identified to specific level, although this was not necessary for the bryophytes, algae and charaphytes. Additionally, all other aquatic species occurring within the dyke, but outside the 20m survey section, were recorded. Although their presence was noted, they were not included in endgroup calculation.

A range of slide photographs were also taken at selected sites across the level in an attempt to visually capture the general characteristic of the grazing marsh dyke system following the flood.

3. RESULTS

3.1 Endgroup data

3.1.1 The 1993 survey

Although it was not possible to derive aquatic endgroups for the dykes where no aquatic species were present, the remaining 170 ditches on the level have been classified. **Map 4** shows the spatial distribution of aquatic communtiy as determined in 1993. Each point represents an individual dyke community.

The dominance of both eutrophic and brackish-type endgroups is apparent, whilst the more botanicaly valued mesotrophic and mesoeutrophic communities are only occasional. In regards to individual endgroups, the eutrophic A5b communities are located mainly in the northern third of the level (the majority north of the railway line), with the exception of the dykes forming the south-eastern margin. A7a communities, an indicator of both eutrophic and brackish water quality, are widespread throughout the grazing marsh. The exception is the central level where A7b (an indicator of oligohaline/mesohaline conditions) is the predominant endgroup. Whilst there is no discernable pattern for the mesotrophic/mesoeutrophic endgroups, it is noticeable that the majority (89%) are found within 300m either side of the railway line. Four A3a communities occur in dykes actually bordering the line. There is also a slight clustering of this endgroup in the north-eastern corner.

The majority of marginal dykes possessed no species, or were A5b communities. However, the endgroups characterised by high constancy of <u>Ceratophyllum demersum</u> (A4) or <u>Callitriche spp</u> (A6), where present occurred predominantly along the north-eastern margin.

The number of dykes identified in each endgroup class in 1993 is shown in **Figure 1**. Again the abundance of the A5b, A7a and A7b endroups is obvious. The relative abundance of A7a is significant. Also notable is the absence of the mesotrophic A1, the mesoeutrophic A3b and the eutrophic, but botanically important, A5a communities.

3.1.2 The 1988/89 survey

Map 5 gives the distribution of aquatic communities across the Cantley level as identified from the results of the 1988/89 survey. In contrast to 1993, brackish communities were rare. Eutrophic communities were still abundant, although most were absent from the central marsh block. Interestingly, A5a communities were present (there is a cluster in the south-east). Whilst A6 was still rare and confined to marginal dykes, A4 was more widely spread through the north-eastern marsh.

Another important result is the prevalence of mesotrophic/mesoeutrophic endgroups, especially A2. Their distribution was wider and they achieved relative dominance in the central level.

3.1.3 Combined 1988/89 and 1993 endgroup data

3.1.3.1 Changes in frequency of aquatic endgroup

All 54 dykes located on **Map 2** were resurveyed in 1993, although six were found to possess no aquatic vegetation. The frequency of each aquatic endgroup in both surveys has been plotted in **Figure 2**.

Brackish communities have increased greatly at the expense of A1, A2 and A3a. The eutrophic communities have also declined. The reduction in A4 and the total loss of the A5a and A6 endgroups from the sample is of more importance than the decrease in the proportion of A5b communities. A4, A5a and A6 are significantly less frequent throughout Broadland in comparison to A5b (Doarks and Leach, 1990).

Considering the level as a whole (see **Figure 1**), it becomes apparent that A5a and A1 are not at present represented at Cantley. The absence of the A3b Stratiotes aloides - Hydrocharis morsus-ranae endgroup from both surveys reflects the fact that Stratiotes aloides does not occur on this level.

3.1.3.2 **Figure 3** outlines the specific changes to aquatic endgroup occurring between the two surveys of the Cantley level. Each arrow represents a single dyke surveyed in both years.

As would be expected from previous results, the majority of dykes have shown endgroup degradation (77.1%). 20.1% have maintained endgroup (stability), whilst only one dyke improved. All but two of the degraded dykes declined to eutrophic/brackish communities, with almost half (48.6%) degrading to A7a, mainly from A2, A5a and A5b. Another main pathway of degradation was from A4 to A5b. Although the A5b communities appear to be the most stable, it should be considered that there was a high frequency of A5b in the 1988/89 survey. Both A7a communities found in 1988/89 were stable.

The spatial distribution of endgroup changes/stability introduced in **Figure 3** is depicted in **Map 6**. Every dyke surveyed in 1988/89 has been identified by a symbol. Whereas endgroup has degraded in locations throughout the level, there is a concentration of stable communities in the northern half of the marsh.

3.2 Individual species data

3.2.1 Species distribution

The 1993 survey of Cantley covered every dyke recording all aquatic species present in the entire ditch, hence all species distributions (see **Maps 7-15**) are comprehensive.

3.2.1.1 Potamogeton natans is an indicator of mesotrophic/mesoeutrophic water quality, being primarily reflective of the A1/A2/A3a endgroups (see **Appendix I**). The species distribution is given in **Map 7**, along with an indication of DAFOR score where P.natans occured within the 20m survey section. Generally the species is confined to a narrow central strip that runs in a north-south direction. Where present P.natans is rare.

3.2.1.2 Hottonia palustris (distribution given in **Map 8**) has been included essentially as an indicator of environmental conditions suitable for the A2 endgroup, although more broadly it indicates mesotrophic/mesoeutrophic water quality.Again this species, where present, is generally rare in occurence, however its distribution is wider than P.natans, forming two major clusters in the north-west and central marshes.

3.2.1.3 Sagittaria sagittifolia (see **Map 9**) is again indicative of good water quality and its distribution reflects that of Hottonia palustris quite closely. There are slight differences. The more central location of the northern cluster and the wider range in the south may reflect the fact that Sagittaria sagittifolia also has a relatively high constancy for the eutrophic A5a endgroup.

3.2.1.4 Myriophyllum verticilatum was mapped to show the distribution of a mesotrophic/freshwater species, but also as a nationally scarce plant. In 1993 this species was restricted in occurrence to only a small area of the Cantley level (see **Map 10**).

3.2.1.5 Although Hydrocharis morsus-ranae occurs wth relatively high constancy in five endgroups, it is most strongly associated with the mesoeutrophic A3a and A3b and slightly eutrophic A4. This species was found to be located mainly alongside or north of the railway line, with the north-eastern corner rich in terms of species presence and abundance (see **Map 11**).

3.2.1.6 Potamogeton fresii is a nationally scarce species with its major locus in Broadland being the A5a endgroup. Its distribution is widespread through the central to northern level at Cantley (see **Map 12**), although the species only occured occasionally at frequencies above rarity.

3.2.1.7 Map 13 shows the distribution of Potamogeton pectinatus, a brackish water quality indicator species especially indicative of A7b. The majority of sites for the species are in the south-western marsh alongside the river, adjacent to the point of breach during the flooding.

3.2.1.7 Utricularia vulgaris does not show high constancy in any endgroup, although usually it is found in eutrophic, and occasionally brackish, water. This species was not recorded at Cantley in 1988/89. Its range (see **Map 14**), whilst sparse in the central marsh, is concentrated in the north, wher it is present in high frequencies.

3.2.1.8 The distribution of Potamogeton acutifolius (see **Map 15**) is similar to Hottonia palustris and Sagittaria sagittifolia. Additionally it occurs frequently in dykes beside the railway line, with 55% of these dykes containing the species. Whilst P.acutifolius mainly occurred as rare, it was noted at high frequency in several dykes.

3.2.2 Changes in species occurrence

A direct comparison of the occurrence (and existence) of species between the survey and re-survey of the Cantley level is given in **Table 4**. This table lists percentage occurrence for every species present within either survey. [Percentage occurrence =

number of dykes containing species y / total number of dykes in the sample]. Results are presented for the occurrence of species within the 20m survey section only and also for occurrence within the entire dyke length.

The most significant data are those comparing the same 54 dykes in both surveys. From these sets subjective appraisals of the change/stabilty in the occurrence of each species have been drawn (see **Table 4**, final column). The overall species occurrence for 1993 has also been included. The key results are summarised below.

(a) There have been four species extinctions. The most notable are Elodea canadensis and Zanichellia palustris, both becoming extinct from previously high occurrence. Riccia fluitans and Lemna polyrhiza although extinct, were only recorded once in 1988/89.

(b) Two new species were recorded in the 1993 survey, Utricularia vulgaris and Myriophyllum spicatum.

(c) Of those species showing a significant decrease in 1993, Potamogeton natans, Sparganium emersum and Myriophyllum verticillatum are important as all three are mesotrophic water indicator species. One of the most obviously adverse effects of the flood has been the extreme reduction in M.verticillatum.

(d) Of the other nationally important species at Cantley, P.fresii and P.tricoides do not appear to have been affected so radically. Both species were stable. However, P.acutifolius was only located in seven of the twelve dykes where it had been present in 1988/89. **Map 16** examines this situation, demonstrating that whilst P.acutifolius was recorded at two new sites in 1993, it had become extinct in six.

(e) Other species indicating good water quality, but not purely mesotrophic conditions, were not affected to the extent of those species outlined in (c). Sagittaria sagittifolia and Hydrocharis morsus-ranae were stable. Hottonia palustris increased in occurrence.

(f) P.pectinatus and P.pusillus, both brackish water indicators especially related to A7b, showed conflicting results. P.pectinatus slightly decreased in occurrence, whilst P.pusillus demonstrated a large increase in 1993.

(g) Lemna minor and Lemna trisulca, found at high constancy in most endgroups, both significantly decreased in occurrence.

(h) Enteromorpha spp increased in occurrence in 1993. These algae are indicative of eutrophic endgroups, and the brackish A7a.

(i) The changes that occurred to the physical environment during and after the flood appear to have left the marsh dyke habitat less suitable for a range of aquatic plant species. Seventeen species had decreased in occurrence by 1993 (including extinctions),out of a total of thirty-two recorded between both surveys. Conditions may have become more favourable for certain species, however. Of the fifteen plants not adversely effected, six occurred in more dykes in 1993.

3.2.3 Changes in species frequency

For the subset of 54 dykes surveyed in 1988/89 and 1993, bar charts have been plotted representing the number of occurrences in each DAFOR score division for certain key species.

P.natans, S.emersum and M.verticillatum occurred at lower frequencies where present in 1993 in comparison to 1988/89 (see **Figures 4 - 6**). Hottonia palustris, whilst increasing in ocurrence in 1993, where present was at a slightly lower cover (**Figure 7**). S.sagittifolia became slighlty more frequent, being recorded within the 20m survey more often in 1993 (**Figure 8**).

Ceratophyllum demersum has been examined because this species shows high constancy in the A4 and A5a endgroups. **Figure 10** clearly shows a shift from C.demersum abundant and dominant dykes in 1988/89, to communities where the species is less frequent.

Figure 9 shows that in 1993 P.fresii occurred as 'rare' in an increased number of dykes. This apparent reduction in the number of dykes containing the nationally scarce species at higher frequencies has been mirrored by the nationally rare P.acutifolius (**Figure 11**). P.acutifolius occurs at a DAFOR score of two or above in only one dyke in 1993, as opposed to eight occasions when the dykes were first surveyed.

The frequencies of all other species that were present in at least four dykes were also analysed. Valid results could not be obtained where the species occured in too few dykes. The results indicated that there had been no other significant and identifiable changes frequency species between 1988/89 and 1993.

3.3 Environmental conditions

3.3.1 Conductivity

Conductivity is a measure of total dissolved ion content in the water, approximating to salinity. During the two day survey in 1989, 27 measurements were taken. A map showing conductivity isopleths has been constructed from this data (see **Map 17**).

During the 1993 survey conductivity was measured in all the dykes. The number of samples was 190 as one dyke had totally dried up. Readings were taken over a period of twelve days during which heavy rain fell on three days (the 9th, 11th and 12th of August). This may have had the effect of diluting the dyke water, decreasing readings on subsequent days. Whilst a same day conductivity survey would have been more accurate, it has still been possible to construct conductivity isopleths with surprisingly few discrepancies (see **Map 18**).

A comparison of the spatial distribution of conductivity in 1989 and in the summer following the flood yields interesting results. In 1989 the dykes on the level were predominantly freshwater (conductivity less than 2000uS/cm), although a band of oligohaline conditions was identified flanking the river in the southern and western marsh. This probably indicates that river water was seeping through into the marsh under hydrostatic pressure from the river. The lowest conductivities were measured north of the railway line.

In 1993 a similar pattern was discovered, with the lowest conductivities above the railway line, along the marshes northern and eastern margins. Again isolated areas of lower conductivity were found within the central marsh with conductivity generally increasing towards the river in the south and west. However, in 1993 the measurements were mainly higher with the majority south of the railway line in the oligohaline range (2000 to 10000uS/cm). Values towards the river reached the upper limits of this range, with mesohaline conditions (above 10000uS/cm) being detected adjacent to the location of the breach.

The frequency of occurrence of conductivity for the subset of 27 dykes sampled in 1989 and 1993 is depicted in **Figure 12.** This further illustrates the general increase in salinity that has occurred. In 1989 the mean conductivity was 773 +257 uS/cm. In 1993 it was significantly higher and more variable equalling 3208 +1667 uS/cm.

3.3.2 The physical condition of the dykes in 1993

The location of over grown dykes (where emergent vegetation is dominant) and dykes found to bear large quantities of ochre deposit (formed when iron sulphide is oxidised in the soil) are given on **Maps 19** and **20**. The majority of the overgrown dykes were found on margins of the level, mainly being the soak dykes beside the flood walls, or alongside the railway. There was a well defined central cluster of 'ochred' dykes.

It was expected that the environmental stress and disturbance caused by the flood would result in significant numbers of dykes bearing no aquatic flora in the following flowering season. **Map 21** establishes the distribution of dykes bearing no aquatic species in 1993. Interestingly 33% of these dykes were overgrown, whilst 19% had been recently cleared. This indicates that over half of these dykes possessed no aquatic flora for reasons not directly related to the flooding.