Alison Campbell and **Gary E. Bradfield**
Department of Botany, The University of British Columbia, Vancouver, B.C. V6T 2B1, Canada

Short-term Vegetation Change After Dyke Breaching at the Kokish Marsh, Northeastern Vancouver Island

Abstract

Total or partial removal of dykes (termed breaching) to allow re-entry of tidal water is being used in some areas along the British Columbia coast to enhance previously dyked marshland for fish and waterfowl. To assess the extent of habitat change following dyke breaching at the Kokish River tidal marsh on northeastern Vancouver Island, we examined vegetation and soil conditions before and fifteen months after the dyke was breached. A low salinity undyked area of the Kokish marsh was used as a "control" to assess the impact of the breaching on the more saline dyked area's vegetation and soils. Little breaching related change was observed in the cover and frequency of most plant species, and in the soil salinity and organic content which remained high in the dyked area. Small changes in the main plant communities were detected by multivariate analysis, the largest change occurring in a dyked area plant community where *Carex lyngbyei*, a desired fish habitat species, increased noticeably following the breaching. The breach allows low salinity river water (ca. 2 ppt) to enter the dyked area, but not until a considerable amount of seawater (ca. 22 ppt) has already entered through an existing opening in the seaward section of the dyke. These results suggest that some coastal marsh plants (e.g. *Carex lyngbyei*) are sensitive to small changes in habitat conditions following dyke breaching. Greater changes in plant communities would require more substantial habitat change than was observed at the Kokish.

Introduction

In the early days of British Columbia's coastal settlement, dyke building was a major activity. Dykes were built to exclude sea water from pastures and cultivated fields, for causeways to permit transportation over waterlogged lands, and to prevent flooding in areas used for the storage and handling of logs (R.A. Hunter and L. E. Jones pers. comm.). Recently, with increased awareness of the need for suitable fish and waterfowl habitat, some dykes are being considered for total or partial removal (termed breaching). The aim of such an undertaking would be to restore previously dyked marshland to intertidal habitat thus increasing the area available to juvenile anadromids en route to the sea and augmenting natural food sources for waterfowl.

Little published information exists on the effects of dyking and dyke breaching in marshlands along the northern Pacific coast of North America. Taylor (1983) concluded that dyking led to vegetation change and land subsidence at a coastal site in Oregon. Bradfield and Campbell (1986) described different plant communities in adjacent dyked and undyked portions of two northern Vancouver Island marshes. Mitchell (1982) and Dawe and McIntosh (1987) noted vegetation changes within one year following sea-dyke breaching, including mortality of salt intolerant upland species, and the appearance of newly colonizing halophytes. A pre-restoration study of a dyked area which will be converted to estuarine intertidal habitat has been reported by Dawe and Jones (1986).

Previous studies at the Kokish marsh on northeastern Vancouver Island have proposed vegetation classifications for habitat inventory (Jones 1982, Kennedy 1982, Campbell 1986). The classifications are all similar, stressing different levels of detail in the marsh vegetation. The classification established by Campbell (1986) is used in this paper. Wayne (pers. comm.) discussed various rehabilitation options for the Kokish estuary in connection with salmon enhancement. Bradfield and Campbell (1986) reported stronger correlations between vegetation patterns and elevation gradients in the undyked than in the dyked portion of the Kokish marsh.

This paper describes the vegetation changes occurring by the second growing season following dyke breaching at the Kokish marsh. The objective of the dyke breaching was to allow river water to re-enter a dyked, saline area, thereby lowering salinity levels and expanding the habitat available for juvenile salmon. Our role in the restoration project was purely observational; the planning and implementation of the dyke breaching were part of a co-operative agreement between Fisheries and Oceans Canada and Canadian Forest Products Ltd. We used a multivariate analytical approach to determine the extent of vegetation change: comparison of the main plant communities using data from pre- and post-breaching surveys in adjacent dyked and undyked portions of the Kokish marsh permitted the assessment of vegetation change due to dyke breaching.

Study Area

The Kokish River estuary is located in Beaver Cove, ca. 15 km south of Port McNeill on the northeastern coast of Vancouver Island (Figure 1). The Kokish estuary has developed on fluvial-fluvioglacial sediments and volcanically derived bedrock (Howes 1981). The climate is mild, with an average yearly air temperature of 8.5°C (average maximum temperature of 11.6°C; average minimum temperature of 5.4°C). The average annual precipitation is 1555 mm, 95 percent of which falls as rain (Anonymous 1981a). Monthly climate data during the study period 1984-1986 are given in Table 1.

TABLE 1. Meteorological data for the Kokish marsh during the period of study.

	Total Precipitation (mm)			Mean Temperature (°C)		
Month	1984	1985	1986	1984	1985	1986
January	247.4	95.0	369.0	4.8	4.7	5.4
February	160.0	158.7	85.5	5.8	3.6	3.3
March	81.0	92.6	168.4	7.6	5.0	7.2
April	117.0	125.3	114.9	7.4	6.5	6.9
May	120.4	45.5	142.8	9.0	10.0	9.9
June	52.3	56.1	92.4	11.6	11.9	12.0
July	59.5	7.1	41.8	13.9	14.8	14.0
August	113.7	20.6	1.2	14.1	13.7	14.7
September	118.9	46.0	103.8	11.7	11.3	12.1
October	262.1	235.5	198.8	7.9	7.9	11.4
November	201.5	76.4	375.3	4.5	0.3	5.9
December	185.4	92.0	213.4	1.7	3.4	5.0

Source of data:
Anonymous, 1984-1986.

A dyke bisecting the Kokish marsh was constructed during the early 1900's to facilitate log handling in the area. In the early 1940's, Canadian Forest Products Ltd. (Canfor) acquired lease to the site, and in 1954 a rail line was installed along the dyke with a trestle bridge spanning a narrow channel in the seaward section of the dyke which has permitted regular flooding of the dyked area by seawater (Figure 1). The rail line has since been removed, and part of the dyke is now used for burning wood debris. The only freshwater input into the dyked area before 1985 was from precipitation and a few small creeks.

Prior to the dyke breaching, the plant communities in the dyked and undyked areas were very different (Bradfield and Campbell 1986). In addition, the biomass of the dyked area was clearly lower than that of the undyked area. The dyke was breached 19 April 1985, allowing river water to enter the dyked area on a rising tide. The original seaward channel was left open, however, to allow tidal water to flow through both openings. It was predicted that the soil salinity of the dyked area would eventually decline, thus leading to greater productivity and a change in the vegetation from species such as *Salicornia virginica*[1] and *Triglochin maritimum,* to more desirable species from a fisheries perspective such as *Carex lyngbyei.*

Methods

Field work

The Kokish marsh vegetation was surveyed in July 1984 (nine months before the dyke was breached), and again in July 1986 (fifteen months after the dyke was breached). In July 1984, 214 0.25 m^2 quadrats were surveyed along 18 transects: 10 transects (126 quadrats) in the dyked area and 8 transects (88 quadrats) in the undyked area. Transect length ranged from 10 m to 145 m. The transects were subjectively placed in order to sample the entire elevation range and vegetation diversity (Figure 1). Quadrats were placed every 5 m along the transects, and, within each quadrat, the cover of each vascular plant species was subjectively estimated using a modified Braun-Blanquet cover/abundance scale (1 = <5%; 2 = 5-25%; 3 = 26-50%; 4 = 51-75%; 5 = 76-100%). This method of coverage estimation is not suitable for detailed studies on separate species, but is appropriate in vegetation surveys of large areas, such as ours, where constraints imposed by time and using different observers to record the data must be taken into account. The elevations of all quadrats above chart datum also were determined for the

---

[1] Nomenclature follows Hitchcock and Cronquist (1973).

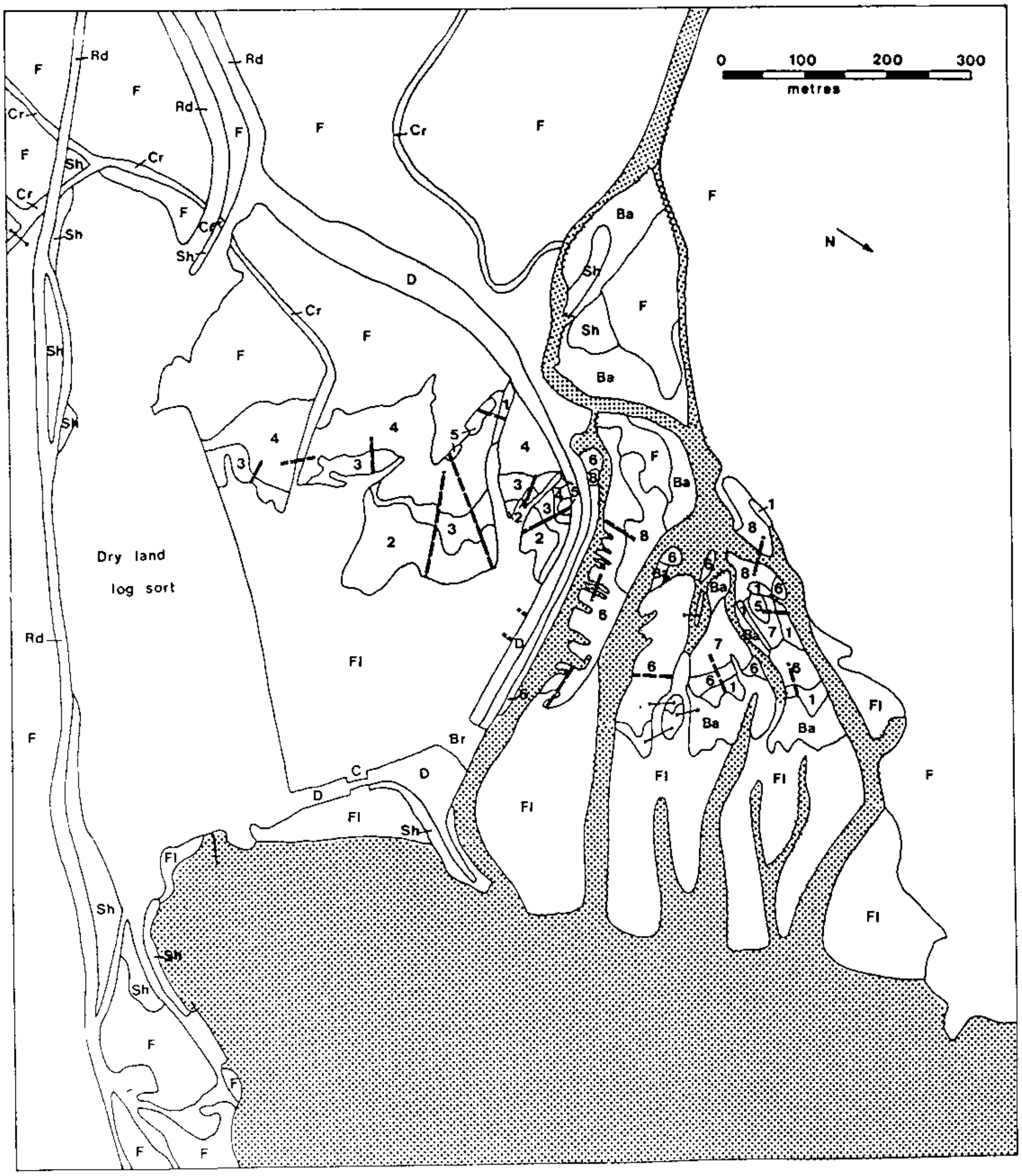

Figure 1. Map of the Kokish marsh showing the major plant communities and locations of transects used in the vegetation surveys. The undyked area lies to the north of the dyke; the dyked area lies to the south. Numbers denote plant communities described in Table 2. Other map symbols: Ba (bar), Cr (creek), D (dyke), F (forest), Fl (mudflat), Rd (road), Sh (shrub), C (original channel through seaward section of dyke), Br (breach opening created 19 April 1985).

purpose of relating vegetation pattern to tidal gradients. Additionally, 24 soil samples were randomly collected in the main plant communities recognized in the field (16 samples in the dyked area and 8 samples in the undyked area). A further 28 soil samples (10 dyked, 18 undyked) were collected during a brief visit to the Kokish marsh in July 1985.

In July 1986, exactly two years after the initial survey, the vegetation of the Kokish marsh was resampled. The original transects were relocated using air photos, 35 mm slides, and marker stakes remaining from the 1984 survey. Quadrats were placed along the transects as close as possible to their original locations. As in 1984, species cover was estimated using a 5-class coverage scale; however, the estimates were made by a different observer in 1986.

Water salinity measurements were periodically taken using an American Optical refractometer during a rising tide on 22 July 1986, to assess the salinity of the water entering the dyked area.

Thirty-two soil samples were collected in 1986: 14 in the dyked area and 18 in the undyked area. The 84 soil samples from 1984, 1985, and 1986 were analysed for percent organic matter by the loss on ignition method (Hesse 1971), and for electrical conductivity using the method described in the University of British Columbia Pedology Laboratory manual (Anonymous 1981b).

Data analysis

The plant community classification for the Kokish marsh described by Campbell (1986) was used in the assessment of vegetation change. Communities were originally defined subjectively by aerial photograph interpretation immediately following transect sampling in the field. Subsequent investigation with multivariate analysis of variance demonstrated that the communities explained high proportions of variance in the field data, and thus could be used as valid units for further study (Bradfield and Campbell 1986). Plant community changes were examined directly by comparing species cover and frequency data from the 1984 and 1986 transect surveys, and indirectly by using principal components analysis (PCA) to display changes in the multivariate pattern of the vegetation over the two year period. PCA is an appropriate technique for our purpose (i.e. to describe changes in groups); we did not attempt an environmental interpretation of the PCA axes. In the PCA's the species cover class data were treated as being continuous, quantitative variables. The results are similar to those from PCA of $\log_{10}$ transformed percent coverage data. Two separate PCA's were performed for the dyked and undyked areas using both the 1984 and 1986 coverage class data to assess within-area changes. PCA's were run using both presence-absence and quantitative (cover class) data but community changes were detected only using the cover class data. Ninety-five percent confidence ellipses for communities, calculated by the method of Owen and Chmielewski (1985), assisted in the visual assessment of the degree of change in communities that had occurred. To further examine the extent of overall change in the vegetation, irrespective of communities, four additional PCA's were performed, one for each combination of area (dyked or undyked), and year (1984 or 1986). Pearson correlation coefficients calculated between the 1984 and 1986 PCA axis scores for the separate areas were then examined based on the rationale that the area showing the greatest vegetation change would have lower correlations between PCA axes.

Results and Discussion

Community Change

Data permitting a detailed comparison of the major plant communities in 1984 and 1986 are given in Table 2. Most species increased in both frequency and cover over the two year period. These changes occurred in both the undyked and dyked areas and therefore reflect general expansion of populations within the marsh unrelated to dyke breaching. Nevertheless, a substantial increase in *Carex lyngbyei*, an important species from a fisheries perspective, occurred following breaching in dyked community 4 (Table 2b), with no corresponding increase in the undyked community, suggesting that this species was favoured by the dyke breaching.

The PCA ordinations illustrating the degree of change in communities are shown in Figure 2. Based on a visual assessment of these graphs, the extent of change in the undyked area communities (Figure 2 a & b) appears no less than that in the dyked area communities (Figure 2 c & d); thus, the dyke breaching *per se* appears to have had minimal short-term impact on the vegetation.

TABLE 2: Percent frequency (F) and mean coverage classes (C) of prominent[1] species in the main plant communities recognized at the Kokish marsh before (1984) and after (1986) dyke breaching occurred. Range of cover classes shown in parenthesis. Numbers on the left refer to plant communities shown in Figures 1 and 2.

a) Undyked area communities	1984		1986	
	F	C	F	C
1. *Carex lyngbyei*	100	2.7 (1-4)	100	2.7 (1-5)
5. *Elymus mollis*	100	5.0 (5-5)	100	5.0 (5-5)
Potentilla pacifica	100	3.0 (3-3)	100	3.7 (3-5)
Trifolium wormskjoldii	75	3.0 (3-3)	100	2.7 (2-3)
Hordeum brachyantherum	25	0.7 (0-1)	25	2.0 (0-3)
Deschampsia cespitosa	—	—	25	2.3 (0-5)
Agrostis alba	—	—	25	0.7 (0-2)
6. *Carex lyngbyei*	91	2.4 (0-4)	96	3.3 (0-5)
Deschampsia cespitosa	88	2.2 (0-4)	96	3.2 (0-5)
Potentilla pacifica	61	1.6 (0-4)	77	2.1 (0-5)
7. *Deschampsia cespitosa*	100	3.8 (3-5)	100	5.0 (5-5)
Potentilla pacifica	100	3.3 (2-4)	100	3.5 (1-5)
Hordeum brachyantherum	75	1.3 (0-3)	100	2.3 (2-3)
Carex lyngbyei	25	0.3 (0-1)	25	0.5 (0-2)
Trifolium wormskjoldii	—	—	25	0.5 (0-2)
Agrostis alba	—	—	25	0.3 (0-1)
8. *Deschampsia cespitosa*	100	3.2 (1-5)	100	4.6 (2-5)
Agrostis alba	95	1.5 (0-3)	100	4.0 (2-5)
Achillea millefolium	89	2.6 (0-4)	77	3.3 (0-5)
Potentilla pacifica	89	2.4 (0-4)	100	3.4 (1-5)
Festuca rubra	84	0.9 (0-2)	86	1.7 (0-4)
Trifolium wormskjoldii	79	1.6 (0-3)	73	1.8 (0-4)
Plantago macrocarpa	53	1.5 (0-5)	23	0.9 (0-5)
Hordeum brachyantherum	32	0.4 (0-2)	27	0.6 (0-3)
Stellaria humifusa	32	0.4 (0-3)	14	0.3 (0-2)
Maianthemum dilatatum	21	0.4 (0-3)	14	0.3 (0-2)
Conioselinum pacificum	16	0.2 (0-1)	23	0.3 (0-2)
Aster subspicatus	16	0.2 (0-2)	14	0.4 (0-3)
Juncus balticus	16	0.2 (0-2)	23	0.9 (0-5)
Heracleum lanatum	11	0.2 (0-2)	—	—
Sisyrinchium angustifolium	11	0.1 (0-1)	5	0.1 (0-1)
Elymus hirsutus	11	0.1 (0-1)	5	0.1 (0-2)
Carex lyngbyei	5	0.1 (0-1)	18	0.2 (0-2)

b) Dyked area communities	1984		1986	
	F	C	F	C
1. *Carex lyngbyei*	100	4.3 (2-5)	100	5.0 (5-5)
2. *Salicornia virginica*	78	2.2 (0-5)	71	2.3 (0-5)
Triglochin maritimum	64	1.4 (0-4)	69	1.8 (0-5)
Glaux maritima	31	0.4 (0-2)	51	1.3 (0-5)
Plantago maritima	22	0.4 (0-3)	9	0.2 (0-3)
Puccinellia pumila	22	0.4 (0-4)	46	1.5 (0-5)
Spergularia canadensis	22	0.2 (0-1)	57	1.1 (0-3)
3. *Triglochin maritimum*	97	2.2 (0-4)	100	2.6 (1-5)
Carex lyngbyei	94	3.2 (0-5)	96	3.5 (0-5)
Glaux maritima	53	0.6 (0-2)	54	1.1 (0-3)
Salicornia virginica	44	0.8 (0-4)	50	1.0 (0-5)
Puccinellia pumila	31	0.3 (0-2)	50	1.5 (0-5)
Stellaria humifusa	39	0.6 (0-3)	46	1.1 (0-4)
Plantago maritima	28	0.6 (0-4)	39	0.8 (0-4)
Deschampsia cespitosa	17	0.3 (0-4)	11	0.3 (0-3)
Hordeum brachyantherum	14	0.2 (0-2)	14	0.4 (0-5)
Spergularia canadensis	11	0.2 (0-3)	39	0.7 (0-5)
4. *Hordeum brachyantherum*	84	2.1 (0-5)	85	2.5 (0.5)
Agrostis alba	61	1.3 (0-4)	63	2.2 (0-5)
Deschampsia cespitosa	55	1.7 (0-5)	61	2.4 (0.5)
Potentilla pacifica	52	1.2 (0-4)	63	2.0 (0-5)
Stellaria humifusa	52	0.8 (0-4)	71	2.3 (0-5)
Triglochin maritimum	42	0.8 (0-3)	71	1.9 (0-4)
Glaux maritima	39	0.5 (0-2)	51	1.1 (0-4)
Plantago maritima	39	0.7 (0-3)	54	1.1 (0-4)
Festuca rubra	32	0.3 (0-1)	17	0.3 (0-2)
Salicornia virginica	23	0.4 (0-4)	15	0.3 (0-4)
Puccinellia pumila	19	0.3 (0-3)	17	0.6 (0-5)
Atriplex patula	10	0.1 (0-1)	5	0.1 (0-2)
Carex lyngbyei	6	0.1 (0-1)	49	1.6 (0-5)
5. *Elymus mollis*	89	3.9 (0-5)	100	4.1 (2-5)
Hordeum brachyantherum	33	0.6 (0-3)	70	2.0 (0-4)
Deschampsia cespitosa	33	1.1 (0-4)	30	0.8 (0-5)
Festuca rubra	33	0.3 (0-1)	—	—
Triglochin maritimum	22	0.3 (0-2)	—	—
Agrostis alba	11	0.6 (0-5)	30	1.3 (0-5)
Poa pratensis	11	0.1 (0-1)	—	—
Salicornia virginica	11	0.2 (0-2)	10	0.2 (0-2)
Plantago maritima	11	0.3 (0-3)	20	0.5 (0-3)
Potentilla pacifica	11	0.1 (0-1)	30	0.5 (0-2)
Puccinellia pumila	11	0.2 (0-2)	—	—
Atriplex patula	11	0.1 (0-1)	20	0.3 (0-2)
Holcus lanatus	—	—	10	0.2 (0-2)
Stellaria humifusa	—	—	10	0.2 (0-2)
Spergularia canadensis	—	—	10	0.1 (0-1)
Cochlearia officinalis	—	—	10	0.1 (0-1)
Sonchus uliginosus	—	—	10	0.2 (0-2)
Vicia gigantea	—	—	10	0.2 (0-2)

[1] Frequency ≥ 10%. Other species recorded with less than 10% frequency include *Cerastium vulgatum, Fritillaria camschatcensis, Honkenya peploides, Hypochaeris radicata, Poa annua,* and *Puccinellia nuttalliana.*

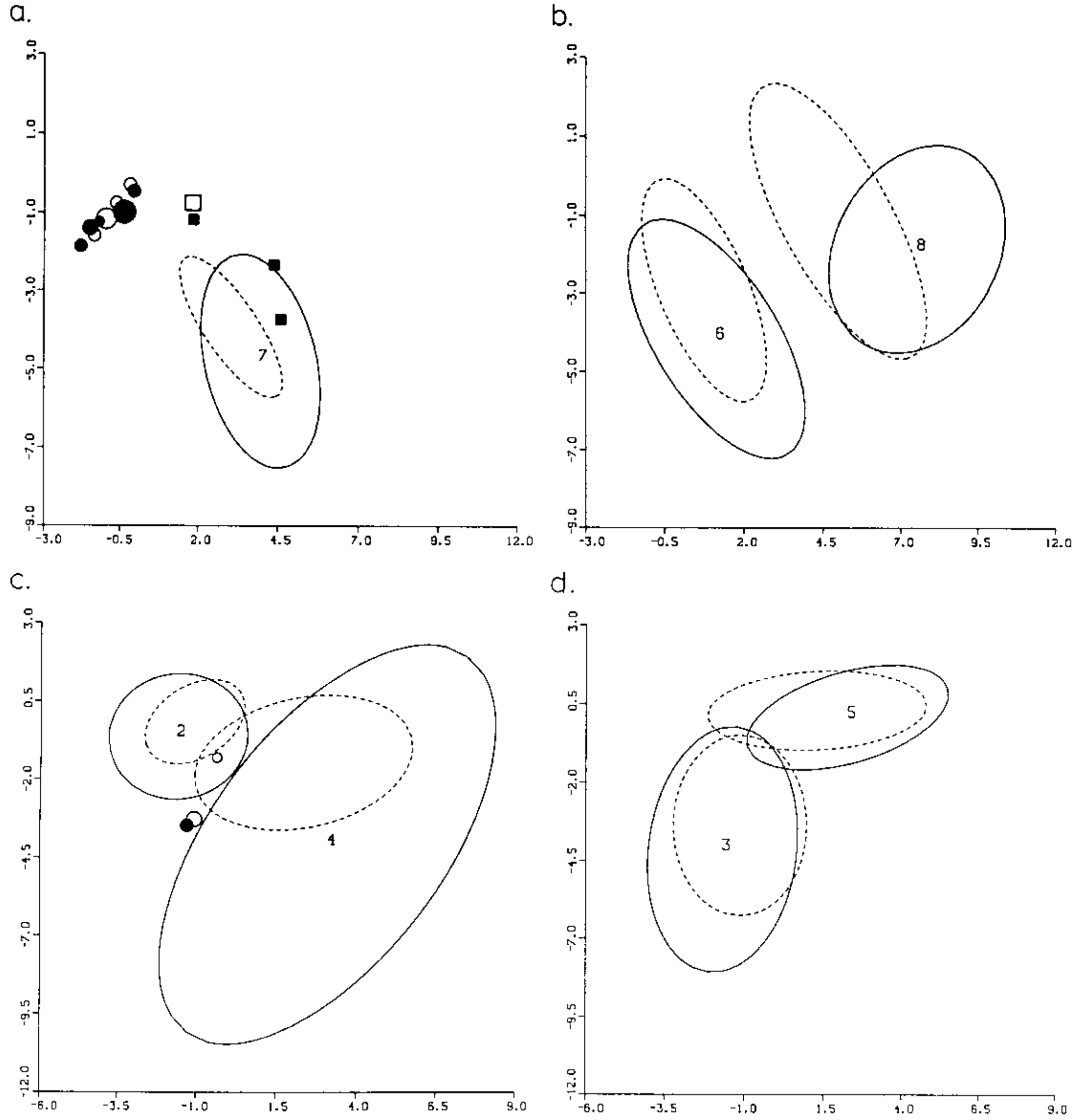

Figure 2. Changes in plant communities of the undyked (a,b) and dyked (c,d) areas at the Kokish marsh as shown by locational shifts in 95 percent confidence ellipses in the plane of the first two PCA axes. The single PCA's for each area are shown in two separate graphs to avoid cluttering of symbols. The first two PCA axes explain 59 percent of the variance in the undyked area and 42 percent of the variance in the dyked area. Broken outlines (1984 data); solid outlines (1986 data). Communities with small sample sizes are shown by the locations of separate quadrats: (a) undyked community 1 in 1984 and 1986, open and closed circles, respectively; undyked community 5 in 1984 and 1986, open and closed squares, respectively; (c) dyked community 1 in 1984 and 1986, open and closed circles, respectively. Numbers in ellipses refer to communities described in Table 2 and Figure 1.

The greatest changes are evident in undyked community 8, and dyked community 4. Both are mixed grass-forb "high marsh" types exhibiting moderate to substantial increases in species cover over the two year period (Table 2).

The correlations of PCA axes I and II from separate analyses of the 1984 and 1986 data allowed further comparison of the dyked and undyked areas (Table 3). The dyked area correlations were lower (0.47, 0.36) than those in the

TABLE 3. Correlations between principal components analysis (PCA) axis scores for the 1984 and 1986 data. The lower correlations in the dyked area suggest that a greater degree of vegetation change has occurred there than in the undyked area.

	PCA axes	
	I	II
Dyked area	0.47	0.36
Undyked area	0.83	0.52

undyked area (0.83, 0.52), suggesting that greater vegetation change had occurred in the dyked area.

Environmental change

Based on observations in the field during the early stages of tidal inundation on 22 July 1986, water began entering the dyked area through the original channel in the seaward portion of the dyke. Not until a considerable amount of saline water (22 ppt) had entered through that channel did river water (2 ppt) begin entering through the breach. Evidently, the breach channel was not deep enough to allow earlier entry of river water. After mixing, only a slight decrease in water salinity in the dyked area was observed (20 ppt).

The results of the soil salinity and organic matter analyses are given in Table 4. The salinity of the dyked area soil samples had not decreased over the years and remained twice as high as the salinity of soils in the undyked area. The higher percent organic content of the dyked area soils, noted by Bradfield and Campbell (1986) for the 1984 and 1985 samples, was also evident in the 1986 samples.

The dyked marsh at the Kokish also occurs at higher elevations than the undyked marsh (Bradfield and Campbell 1986). This contrasts with reports from other studies (Eilers 1980, Mitchell 1982, Taylor 1983) where the area behind the dykes had subsided. The subsidence noted elsewhere could be due to water loss and shrinkage of dyked area soils, or to different land use practices (e.g. compaction from livestock and equipment). No soil compaction was noted at the Kokish marsh and the high precipitation would tend to offset soil drying and shrinkage.

The lack of decline in salinity of the dyked area soils at the Kokish marsh could explain why the vegetation has not changed substantially. In order to lower the salinity in the dyked area the breach channel would have to be deepened to allow fresh water to enter the area sooner on a rising tide. However, it is uncertain whether any effective lowering of salinity levels could be achieved so long as seawater continues to enter through the original channel. Even if salinity were lowered it would be difficult to predict the eventual species composition. Species such as *Carex lyngbyei* may dominate for a while, but since the dyked area may be increasing in elevation owing to a lack of tidal flushing, the expansion of forest margin species into the high marsh seems a likely outcome.

Acknowledgements

Funding for this study was provided by the Canadian Wildlife Service, Pacific and Yukon Region,

TABLE 4. Average organic matter and electrical conductivity for the dyked and undyked areas in 1984, 1985, and 1986. Standard deviations are given in parentheses.

Location	Year	Sample Size	Average organic matter (%)	Average electrical conductivity (mmho/cm)
Dyked Area	1984	24	38.1 (14.7)	33.2 (10.7)
	1985	28	31.8 (37.4)	58.0 (21.0)
	1986	32	37.4 (13.8)	39.9 (12.8)
Undyked Area	1984	24	6.2 (4.1)	12.1 (8.9)
	1985	28	9.9 (6.9)	20.1 (6.4)
	1986	32	7.9 (7.4)	22.2 (6.6)

and the Natural Sciences and Engineering Research Council of Canada. To the following staff of the Canadian Wildlife Service, Pacific and Yukon Region, we express our heartfelt thanks for advice and encouragement: Neil Dawe, Don Trethewey, and Sean Boyd. Soil analyses were conducted in laboratories of the B.C. Ministry of Environment (1984 & 1985 samples), and the Soil Science Department, U.B.C. (1986 samples). The hospitality of Mrs. Helen O'Brien in Port McNeill is greatly appreciated.

Literature Cited

Anonymous. 1981a. Canadian climate normals 1951-1980. Temperature and precipitation, British Columbia. Atmospheric Environment Service, Environment Canada.

Anonymous. 1981b. Methods manual. University of British Columbia Pedology Laboratory, Department of Soil Science, Vancouver.

Anonymous. 1984-1986. Meterological observations in Canada, monthly records for Alert Bay. Atmospheric Environment Service, Environment Canada.

Bradfield, G. E., and A. Campbell. 1986. Vegetation-elevation correlation in two dyked marshes of northeastern Vancouver Island: a multivariate analysis. Can. J. Bot. 64:2487-2494.

Campbell, A. 1986. Vegetation-environment relationships and plant community classification and ordination in British Columbia coastal salt marshes. The University of British Columbia, Vancouver. M.S. thesis.

Dawe, N.K., and L. E. Jones. 1986. Vegetation of the Koksilah marsh, Cowichan Estuary: a pre-restoration study, July, 1985. Technical Report Series No. 9. Canadian Wildlife Service, Environment Canada.

Dawe, N.K., and J. D. McIntosh 1987. Changes in vegetation following dyke removal on the Englishman River estuary (1979-1986). Northw. Envir. J. 3:150-151.

Eilers, H. P. 1980. Ecology of a coastal salt marsh after long-term absence of tidal fluctuation. Bull. South. Calif. Acad. Sci. 79:55-64.

Received 28 March 1987
Accepted for publication 24 November 1987

Hesse, P. R. 1971. A textbook of soil chemical analysis. Murray.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Howes, D. E. 1981. Terrain inventory and geological hazards: northern Vancouver Island. A.P.D. Bulletin 5, B.C. Ministry of Environment, Victoria.

Hunter, R. A., and L. E. Jones. 1982. Coastal waterfowl and habitat inventory program: summary report. B.C. Ministry of Environment and Ducks Unlimited (Canada), Victoria, B.C.

Jones, L. E. 1982. Kokish estuarine habitat inventory map. Surveys and Resource Mapping Branch, B.C. Ministry of Environment, Victoria.

Kennedy, K. 1982. Plant communities and their standing crop on estuaries on the east coast of Vancouver Island. The University of British Columbia, Vancouver. M.S. thesis.

Mitchell, D. L. 1982. Salt marsh reestablishment following dyke breaching in the Salmon River estuary, Oregon. Oregon State University, Corvallis. Ph.D. Dissertation.

Owen, J. G. and M. A. Chmielewski. 1985. On canonical variates analysis and the construction of confidence ellipses in systematic studies. Syst. Zool. 34:366-374.

Taylor, A. H. 1983. Plant communities and elevation in a dyked intertidal marsh in the Coos Bay Estuary, Oregon. Northw. Sci. 57:132-142.

Wayne, M. M. 1984. Kokish River estuary rehabilitation and enhancement options: a discussion paper. S.H.I.P. Project. H. Paish and Associates Ltd.