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A PILOT STUDY TO COMPARE CREATED AND NATURAL WETLANDS IN WESTERN WASHINGTON AND EVALUATE METHODS

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ABSTRACT

Nine created wetlands were paired with nine natural wetlands and compared for species composition, species diversity, wetland function and other site characteristics. The sites were located in western Washington and sampled during July of 1987. The created wetlands selected were mitigation projects for permits issued under Section 404 of the Clean Water Act (33 U.S.C.A. Section 1344 (1978)). Each site was sampled by two or four teams comprised of personnel from federal, state, and local government agencies. Methods used for data collection included a procedure suggested by Pielou for comparing the diversities of two communities (Pielou 1986), and the Wetland Evaluation Technique (WET) (Adamus et al. 1987) which was used to assess potential wetland functions. The goals of the study were to evaluate the methods used for data collection, compare the created and natural wetlands, and evaluate the consistency of results obtained by teams sampling the same site.

Concerns were voiced about the utility of WET and Pielou. The teams had difficulties answering some of the questions posed by WET. They felt that the questions were complicated and hard to interpret, or did not make sense for the wetland type that was being sampled. For the Pielou method, choosing the appropriate number of species to sample was problematic.

Results from comparisons of species composition and species diversity indicated that some differences existed between the created and natural sites. However, because differences also existed in the data collected from different teams sampling the same site, the created and natural site differences were confounded. In addition to the possible heterogeneity within the sites, low replicability between the teams may have been due to insufficient training prior to field work, different botanical skill levels, or the subjectivity of some of the data collection forms.

A comparison of species composition also found some similarities with respect to the native/introduced and indicator status of the species (Reed 1988) found at the created and natural sites. Generally, the species classified as obligate, facultative wetland, and wetland were native to the Pacific Northwest, while those species classified as facultative upland and upland were introduced.

SECTION 1

INTRODUCTION

Concern over loss of wetland area and function has accentuated the need to assess how well created wetlands replace natural wetlands that are destroyed. To address this issue, the U.S. Environmental Protection Agency's (EPA) Wetland Research Program (WRP) at the Environmental Research Laboratory in Corvallis (ERL-C), Oregon, conducted a pilot study in western Washington to determine the effectiveness of methods that could be used by agencies to evaluate created wetlands. Additional goals of the study were to compare the characteristics of paired created and natural wetlands and to compare the results obtained by field crews sampling the same wetland.

Creating wetlands as compensation for wetland losses is a relatively new procedure and few studies comparing created and natural wetlands have been conducted. This lack of scientific research has resulted in limited information on wetland creation and restoration projects (Kusler and Kentula 1990). The overall status of the literature on wetland creation and restoration remains uneven by region and topic. The most quantitative and best documented information is available for Atlantic coastal wetlands. In addition, most investigations of mitigation are case studies with no sites included for comparison (Quammen 1986). Consequently, the WRP implemented studies in four states (Washington, Oregon, Florida, and Connecticut) to compare natural wetlands with similar wetlands that had been created as compensatory mitigation under Section 404 of the Clean Water Act (33 U.S.C.A. Section 1344 (1978)).

Field data were collected in July of 1987 from nine paired created and natural wetlands located in Washington. Field crews sampled three pairs of freshwater marshes, three pairs of saltwater marshes, two pairs of mudflats, and one pair of eelgrass bed. The study tested methods of data collection and the utility of the methods for use by personnel from resource agencies. The methods employed relatively inexpensive and simple means of describing and evaluating wetlands, and attempts were made to use methods that were the least damaging to the study sites. A vegetation sampling technique suggested by Pielou (1986) was tested and used to compare the plant communities on each of the paired fresh- and saltwater marshes. The use of the Wetland Evaluation Technique (WET) (Adamus et al. 1987) to compare mitigation and reference wetlands was proposed by Adamus (1988) and it was used to assess the wetland functions on the paired sites. In addition, a form for recording estimates of the natural features on the wetland and the land uses in the surrounding area was filled out. The results from WET, the Pielou method, and the site description form were used to compare the created and natural wetlands, and to compare teams sampling the same wetland.

SECTION 2

METHODS

SITE SELECTION

Nine created wetlands were paired with nine natural wetlands and compared for species composition, species diversity, wetland function, and other site characteristics (e.g., natural features of the wetland and the surrounding area). The sites were sampled during July of 1987 by either two or four teams comprised of four individuals each. Time constraints, and the desire to decrease the amount of trampling and degradation to the sites by sampling, prevented all teams from visiting all sites as was originally planned.

The created wetlands were created as functional replacement for wetlands lost under Section 404. They were chosen from the Section 404 permit files of the Seattle District of the U.S. Army Corps of Engineers (COE) and the Regional Office (Region 10) of the EPA. Four character codes (e.g., KOLL) were used as pseudonyms for the permit numbers to preserve the anonymity of the sites. All created wetland projects which had been completed by the summer of 1987 were included in this study. The wetlands ranged in age from 7-28 months and in size from 0.1 to 5.3 acres (0.4 to 2.1 ha). They represented four wetland types: freshwater marsh, salt marsh, mud flat, and eelgrass bed (**Zostera marina L.**) (Appendix I). The criteria used for pairing the created and natural wetlands were type, size, and proximity. The regulatory personnel involved in permitting assisted in finding natural wetlands as similar as possible to the destroyed wetland. Four of the site pairs were adjacent to each other. For these sites, natural wetlands were remnants of the wetlands destroyed (i.e., the wetlands for which the created wetlands were to compensate). The rest of the natural wetlands were located from 1-30 miles (0.6-18 km) from the created sites (Appendix I). Six of the paired wetlands were located in the Puget Sound area, one was located outside of Olympia, and two were located in Gray's Harbor (Figure 1).

DATA COLLECTION

The study was a cooperative effort with EPA Region 10 and other federal, state and local agencies in the area. The teams were comprised of personnel from these agencies and individual members varied to a certain extent in their levels of field experience. The teams performed a WET evaluation of the site, filled out a site

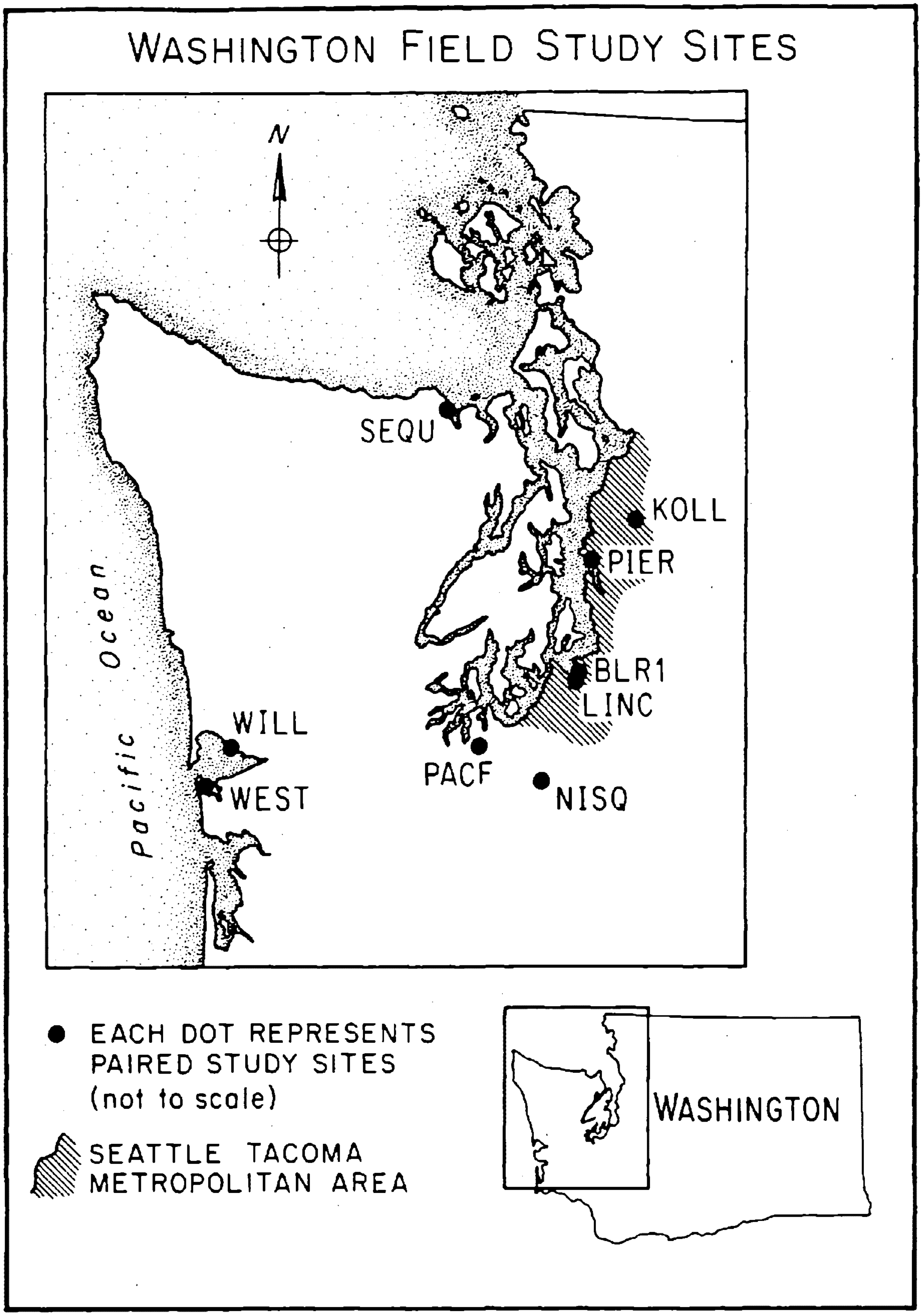

Figure 1. The locations of the sites used in the Washington field study.

description form, and collected vegetation data necessary for comparing the paired sites using a method devised by Pielou (1986) (Table 1). The sites were sampled by more than one team so that their results could be compared and the comparability of the methods ascertained.

WET was used to assess the wetland's functions and values. The technique assigns ratings of high, medium, and low to the following wetland functions and values: groundwater recharge, groundwater discharge, floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, aquatic diversity/abundance (d/a), habitat suitability for fish and wildlife, wildlife breeding, migration and wintering, uniqueness/heritage, and active recreation. The ratings are assigned to the functions and values in terms of three different categories: significance (value to society), opportunity (whether a wetland has the opportunity to perform a function or value), and effectiveness (the probability of a wetland being able to maximize the opportunity to perform a function or value) (Adamus et al. 1987). To perform the evaluations, the teams collected map, background, and field data on the wetlands and answered the questions on the WET forms in the office and field.

The site description form consisted of 11 questions quantifying the percent of natural features and land uses on the site and in the surrounding area (Table 2). The percent and type of disturbance were also recorded.

The Pielou method was used to compare the diversities of six pairs of wetlands. The mudflats were excluded because they were not vegetated, and the eelgrass bed was excluded because it was a monotype. One to six transects were established at each wetland to sample the vegetation. Rectangular quadrats (1 m^2) were placed at regular intervals along the transects and the six species closest to the center of the quadrat were recorded. Forty quadrats were sampled per site. The transects were located to best typify the vegetation communities on the site. If an environmental gradient was present (e.g., an elevation gradient), the transects were placed parallel to the gradient to representatively sample the plant communities.

QUALITY ASSURANCE AND DATA VERIFICATION

To increase the likelihood of accurate and comparable data collection, the teams were trained in field protocols prior to field work. Representatives from EPA and COE held a one week training session in Olympia, Washington, to explain the methods for data collection and to provide an opportunity to practice filling out WET forms in the field.

During the field season, a quality assurance audit was performed to evaluate the performance of the four field crews. The auditor checked the field crews to

Table 1. Summary of the information gathered by teams sampling each of the nine pairs of created and natural wetlands.

Wetland type	Freshwater marsh			Saltwater marsh			Eelgrass bed	Mudflat	
Site acronym	KOLL	NISQ	PACF	LINC	WEST	WILL	SEQU	BLRI	PIER
Number of teams sampling wetland	4	2	2	4	2	2	2	4	4
WET evaluation performed?	yes	yes	yes	yes	yes	yes	yes	yes	yes
Pielou/vegetation patterns analysis performed?	yes	yes	yes	yes	yes	yes	no	no	no
Site descriptions form filled out?	yes	yes	yes	yes	yes	yes	yes	by 1 of 4 teams	by 1 of 4 teams

Table 2. Form used to document the natural features on the site and land uses in the surrounding area.

FORM A. Qualitative site information [to be used with sketch map]

Site Name ____________________________________

Personnel __________________________ Date __________

Mappable wetland characteristics: Sketch or label the following items on the base map. Indicate associated percentage values on this form where requested.

1. Indicate north.
2. Access point.
3. Hydrologic features: (a) locations of inlet/outlet, (b) major channels (where applicable), (c) direction of water flow, (d) obstructions to water flow.
4. __________ % open water : vegetation
5. __________ % wetland inundated
6. __________ % wetland that is disturbed
7. Vegetation zonation or patches
8. Label dominant vegetation types, indicate % relative cover for:
    - (a) __________ % trees
    - (b) __________ % shrubs
    - (c) __________ % emergent herbs
    - (d) __________ % submergent herbs
    - (e) __________ % nonvegetated area (natural)
    - (f) __________ % nonvegetated area (disturbance related)
9. Label surrounding area, indicate % relative cover.
    - (a) __________ % forest
    - (b) __________ % meadow/field
    - (c) __________ % shrubs
    - (d) __________ % human disturbance
        - (1) __________ % cultivation
        - (2) __________ % industrial, specify ________________
        - (3) __________ % housing
        - (4) __________ % highway
        - (5) __________ % grazing
        - (6) __________ % commercial

        *1-6 should total the precentage value in (d)
10. Draw in transects on the sketch map. Indicate the length and direction of each from its origin.
11. Comments: Other pertinent site information may be written on the back of this form.

determine whether they followed protocols and directions thoroughly and collected the data in the correct order.

The botanists on each team identified the vegetation species in the field and specimens were brought back to the EPA's ERL-C to be verified. All specimens were archived at the Laboratory.

To ensure that errors did not occur in transferring the data from the field sheets to computer files, field data were double entered by two individuals working independently. After entry, the two data sets were electronically compared. Discrepancies were corrected by comparison with the field sheets until both data sets were in exact correspondence.

DATA ANALYSIS

Vegetation data

The vegetation data were compiled and analyzed using a method suggested by Pielou (1986). The method compared the most typical quadrat (i.e., the quadrat most similar to the other quadrats sampled on a site) from each of a pair of created and natural wetlands. Two tests were performed. The null hypothesis of the first test was that the created and natural sites had similar diversities. If the null hypothesis was rejected, then the second hypothesis tested that the plant community associated with the created wetland was a subset of the plant community of the natural wetland. Alternatively, if the null hypothesis of the first test was not rejected, the second hypothesis tested was that communities from the created and natural wetlands were from the same parent population. The analysis was used to compare the site pairs and the results obtained by different teams sampling the same sites.

The vegetation data were also used to summarize and compare the species composition at the created and natural sites. The plants which could not be identified to species were included in the analysis. Species that were found only once at any paired site were deleted from the analysis because they were considered rare. The total number of times that each species was found by each team at each site was tallied. This included the number of species found only on the created site, the number of species found only on the natural site, and the number of species found on both members of a site pair. Thus, comparisons were made between the six paired sites, between the three paired freshwater sites, and between the three paired saltwater sites.

The dominant species on each site were compared to see if the species characterizing the created wetlands were similar to those characterizing the natural wetlands. Dominance was determined by the total number of times a species was found at each site by all teams sampling the site. The species found the greatest number of times (i.e., those species found in the quadrats most often) were considered dominant. This procedure inherently involved some degree of subjectivity, however, in all cases, similar methods of determining dominant species were used.

The National List of Plant Species that Occur in Wetlands: Northwest (Region 9) (Reed 1988) was used to determine the indicator status, and Hitchcock and Cronquist (1981) was used to determine whether the species were native or introduced. The indicator categories are:

- obligate wetland--estimated 99% probability of occurring in wetlands
- facultative wetland--estimated 67-99% probability of occurring in wetlands
- facultative--estimated 34-66% probability of occurring in wetlands
- facultative upland--estimated 34-66% probability of occurring in nonwetlands
- obligate upland--may occur in wetland in another region, but 99% estimated probability of occurring in nonwetlands.

For the purposes of this report, those species which were in the obligate or facultative wetland categories were considered to be wetland species, those species in the facultative category were considered to be facultative species, and those species in the facultative and obligate upland categories were considered to be upland species. A list of the species found in the field study and their indicator and native/introduced status can be found in Appendix II.

Finally, the data were also used to perform a cluster analysis for each paired site to determine whether the plant community on the created site differed from that on the natural site, and if the answer depended on which team did the sampling.

WET data and site description data

The ratings obtained from the WET assessment for the different functions and values were compared for the pairs of sites and for the different teams which sampled the same site. Only the ratings from the effectiveness category were compared because it was considered the most objective category (P. Adamus, ManTech Environmental Technology Inc., Corvallis, OR, pers. comm.). Similarly, the results from the analysis of the site description data compared the percentages on the forms for each pair of sites and for the different teams sampling the same site.

SECTION 3

RESULTS

COMPARISON OF CREATED AND NATURAL WETLANDS

The following section compares the vegetation found on the created and natural wetlands by wetland pairs. The pairs are grouped into salt- and freshwater marshes. Results from the site description form, Pielou (1986), and WET (Adamus et al. 1987) are also described for the fresh- and saltwater wetlands.

Freshwater sites

Vegetation patterns--

KOLL--Eighty-seven species were found by the four teams that sampled the KOLL paired wetlands: 22 species were unique to the created wetland, 33 species were unique to the natural wetland, and 32 species were found on both wetlands (Table 3a). The percent of wetland and facultative species found on the created and natural sites was similar: 61% for the created and 58% for the natural. The wetland and facultative species were predominately native to the Pacific Northwest rather than introduced. Ten of the 54 species found on the created site, and 12 of the 65 species found on the natural site, were classified as dominant. Six of the ten dominant species on the created site were introduced however, most (9/12) of the dominant species found on the natural site were native.

NISQ--Fifty-two species were found by the two teams that sampled the NISQ paired wetlands (Table 3b). The majority of the species were found on either the created or natural wetland: 42% of the species were unique to the created site and 38% of the species were unique to the natural site. Ten species (19%) were found on both of the sites. The combined percents of wetland and facultative species indicated a difference between the two wetlands: 44% of the species on the created site were wetland and facultative compared with 63% on the natural site. Most of the wetland and facultative species were native (79%), while the upland species were primarily introduced (69%). Eight of the 32 species found on the created site and seven of the 30 species found on the natural site were classified as dominant. Four of the eight dominant species found on the created site were both upland and introduced species.

PACF--Fifty species were found by the two teams that sampled the PACF paired wetlands (Table 3c). Of these, 12 species were found only on the created site, 19 species were found only on the natural site, and 19 species were found on both sites. The combined percent of wetland and facultative species found on the created

TABLE 3a-c. Number of species found on the paired freshwater wetlands and the number of dominant species categorized by indicator status (IND. STAT.) and native/introduced (N/I) (Reed 1988). NAT is the number of species found only on the natural site, CR is the number of species found only on the created site and BOTH is the number of species found on both paired sites. Dashes (--) indicate that the species was not found at the site(s). Numbers in parentheses after NAT and CR indicate the total number of species found at the natural and created sites, respectively. The numbers in parentheses following the TOTALS are the percent of the total number of species or the dominant species, found at the natural, created, or both sites. OBL is an obligate wetland species; FACW is facultative wetland species; FAC is a facultative species; FACU is a facultative upland species; UPL is an upland species; N is a native species; I is an introduced species; UNKNOWN means the indicator status could not be determined for the plant.

Table 3a. KOLL

IND. STAT.	ALL SPECIES (87)			DOMINANT SPECIES (19)		
& N/I	NAT(65)	BOTH	CR(54)	NAT(12)	BOTH	CR(10)
OBL/N	1	4	1	--	--	--
OBL/I	1	1	--	--	--	--
FACW/N	4	11	1	1	--	3
FACW/I	--	4	1	--	2	1
FAC/N	8	2	3	4	1	--
FAC/I	--	2	3	--	--	--
FACU/N	5	2	--	3	--	--
FACU/I	4	5	6	1	--	3
UPL/N	2	--	--	--	--	--
UPL/I	5	--	2	--	--	--
UNKNOWN	3	1	5	--	--	--
TOTALS	33 (38%)	32 (37%)	22 (25%)	9 (47%)	3 (16%)	7 (37%)

TABLE 3b. NISQ

IND. STAT.	ALL SPECIES (52)			DOMINANT SPECIES (14)		
& N/I	NAT(30)	BOTH	CR(32)	NAT(7)	BOTH	CR(8)
OBL/N	4	1	2	2	--	--
OBL/I	1	--	--	--	--	--
FACW/N	4	3	4	1	1	--
FACW/I	1	--	1	--	--	--
FAC/N	2	1	1	--	--	2
FAC/I	2	--	1	2	--	--
FACU/N	3	--	1	--	--	--
FACU/I	1	2	3	1	--	2
UPL/N	--	--	1	--	--	--
UPL/I	--	2	3	--	--	2
UNKNOWN	2	1	5	--	--	1
TOTALS	20 (38%)	10 (19%)	22 (42%)	6 (43%)	1 (7%)	7 (50%)

TABLE 3c. PACF

IND. STAT.	ALL SPECIES (50)			DOMINANT SPECIES (15)		
& N/I	NAT(38)	BOTH	CR(31)	NAT(8)	BOTH	CR(7)
OBL/N	1	3	1	2	--	2
OBL/I	2	2	--	1	--	--
FACW/N	5	8	6	2	--	4
FACW/I	--	2	1	1	--	--
FAC/N	4	3	1	2	--	1
FAC/I	1	--	--	--	--	--
FACU/N	2	--	--	--	--	--
FACU/I	3	--	1	--	--	--
UPL/N	--	--	--	--	--	--
UPL/I	1	--	1	--	--	--
UNKNOWN	--	1	1	--	--	--
TOTALS	19 (38%)	19 (38%)	12 (24%)	8 (53%)	-- (0%)	7 (47%)

and natural wetlands were similar: 87% for the created site and 82% for the natural site. The wetland and facultative species also had a greater number of native than introduced species. Seven of the 31 species found on the created wetland and eight of the 38 species found on the natural wetland were classified as dominant. All of the dominant species on the created and natural sites were facultative or wetland species, and all of the species found on the created site were native to the Pacific Northwest.

Summary--The number of species found at the three paired wetlands varied as did the percentage of wetland and facultative species on the sites. However, similarities were also found between the wetlands. Most of the wetland and facultative species were native, and the majority of upland species were introduced. The percent of species classified as dominant ranged from 18-25% for each site. The majority of the dominant species were found on either the created or the natural site; few, if any, dominant species were found on both of the paired sites.

Site description form--

Comparisons were made of the results from the same team evaluating the paired created and natural wetlands for three questions of interest on the site description form: percent of site covered by open water, percent of site that was disturbed, and percent of surrounding area that was disturbed (Table 4). There were eight comparisons for each of the three questions (i.e., the three freshwater sites were visited by more than one team each). Differences between the paired sites were indicated by answers which differed by at least 40%. Two of the eight comparisons (25%) differed for the percent of the site covered by open water. In both cases the created wetland had more open water than the natural wetland. Three of the comparisons (38%) differed for the percent of the site that was disturbed. In all three cases, the created wetland was more disturbed than the natural wetland. Three of the comparisons (38%) also differed for the percent of the surrounding area that was disturbed and again, in all three cases, the created wetland was more disturbed than the natural wetland.

Pielou--

The results from the Pielou evaluations did not always agree for the three pairs of freshwater wetlands (Table 5). At the KOLL sites, the results from three of the four teams rejected both of the hypotheses associated with test 1 and test 2 concluding that the plant community on the created site was less diverse, and not a subset of the plant community on the natural site. For the NISQ sites, the results from one team suggested that the two communities had similar diversities but were not from the same parent population, while the results from the other team suggested that the plant community on the created site was less diverse, and not a subset of the community on the natural site. The evaluations of the two teams agreed that the

Table 4. Summary of site characteristics and surrounding land uses from the site description form for the freshwater marshes. C = created, N = natural, OW = % open water, DIST = % wetland disturbed, SUR DIST = % surrounding area that is disturbed.

SITE	C/N	TEAM	OW	DIST	SUR DIST
KOLL	C	1	10	80	60
KOLL	N	1	10	10	60
KOLL	C	2	10	100	15
KOLL	N	2	5	40	50
KOLL	C	3	10	0	85
KOLL	N	3	10	5	40
KOLL	C	4	10	100	45
KOLL	N	4	10	100	50
NISQ	C	2	60	50	75
NISQ	N	2	5	0	30
NISQ	C	4	50	50	50
NISQ	N	4	1	15	70
PACF	C	1	5	10	50
PACF	N	1	5	5	20
PACF	C	3	30	0	70
PACF	N	3	15	25	30

Table 5. Summary of the results of the Pielou (1986) analysis of three pairs of freshwater marshes sampled by two or four teams. For test one, values of Z > 1.28 (one tailed test, alpha = 0.10) caused the hypothesis that the two communities had the same diversity to be rejected, and supported the conclusion that the created site was less diverse than the natural site. If test one was not rejected, then values of Z > 1.282 for test two caused the hypothesis that the created community was a subset of the natural community to be rejected. Alternately, if test one was not rejected, then values of $Z > \pm 1.65$ for test two (two tailed test, alpha = 0.10) caused the hypothesis that the created and natural communities were from the same parent population to be rejected. * = rejected.

SITE	TEAM	TEST 1 Z VALUE	TEST 2 Z VALUE	IMPLICATIONS
KOLL	1	* 3.56	* 4.36	The created site is less diverse than the natural site. The created site is not a subset of the natural site.
	2	0.39	* 3.08	The two communities have similar diversities but are not from the same parent population.
	3	* 2.79	* 4.99	The created site is less diverse than the natural site. The created site is not a subset of the natural site.
	4	* 2.95	* 2.58	The created site is less diverse than the natural site. The created site is not a subset of the natural site.
NISQ	2	0.98	* 2.26	The two communities have similar diversities but are not from the same parent population.
	4	* 1.82	* 2.31	The created site is less diverse than the natural site. The created site is not a subset of the natural site.
PACF	1	-0.01	* 8.59	The two communities have similar diversities but are not from the same parent population.
	3	0.90	* 10.00	The two communities have similar diversities but are not from the same parent population.

plant communities on the paired PACF wetlands had similar diversities but were not from the same parent population.

WET--

WET evaluations were also compared for the three pairs of freshwater wetlands (Table 6). At the KOLL sites, the created and natural wetlands were rated similarly for many of the functions, however, there did seem to be a difference between the paired sites for floodflow alteration, sediment/toxicant retention, and general fish habitat. The created and natural sites were rated exactly the same at the NISQ sites for all but sediment stabilization and general fish habitat. At the PACF sites, the created and natural wetlands were rated similarly by the teams for all but sediment/toxicant retention and wildlife (d/a) wintering. In general, all sites were low for groundwater recharge, aquatic d/a and wildlife d/a breeding, and medium for production export.

Saltwater sites

Vegetation patterns--

LINC--Fifty-seven species were found by the four teams that sampled the LINC paired wetlands: 21 species were unique to the created site, 23 species were unique to the natural site, and 13 species were found on both sites (Table 7a). The percent of wetland and facultative species was not similar for the paired wetlands: 71% were found on the created site and 56% were found on the natural site. This difference may be partially attributed to the percentage of species (28%) which could not be identified. Most wetland and facultative species were native to the Pacific Northwest, however, most upland species were introduced. Seven of the 34 species on the created site and seven of the 36 species on the natural site were classified as dominant. All of the dominants were wetland species except for one unknown. Also, all of the dominant species were native except for one introduced species on the natural site.

WILL--Thirty-seven species were found by the two teams that sampled the WILL paired wetlands (Table 7b). Nearly half (43%) of the species were found on both sites. The created and natural sites had a total of 26 and 27 species, respectively. The combined percent of wetland and facultative species was similar for the two wetlands: 81% for the created and 74% for the natural. Most (79%) of the wetland and facultative species were native. Four of the 26 species on the created wetland and three of the 27 species on the natural wetland were classified as dominant. All of the dominant species were also wetland species except for one upland species found on the natural site.

Table 6. Ratings [high (H), medium (M), low (L), unknown (U)] of the effectiveness of the three pairs of freshwater marshes for 12 functions and values as determined by the Wetland Evaluation Technique (WET) (Adamus et al. 1987). The WET evaluations were generated by two or four teams per site during the summer of 1987 in Washington. C = created, N = natural, GWR = groundwater recharge; GWD = groundwater discharge; FFA = floodflow alteration; SS = sediment stabilization; S/TR = sediment/toxicant rentention; NR/T = nutrient removal/transformation; PE = production export; AD/A aquatic diversity/abundance; GFH = general fish habitat; WB = wildlife diversity/abundance breeding; WM = wildlife diversity/abundance migration; WW = wildlife diversity/abundance wintering.

SITE	TEAM	C/N	GWR	GWD	FFA	SS	S/TR	NR/T	PE	AD/A	GFH	WB	WM	WW
KOLL	1	C	L	M	L	H	H	L	M	L	M	L	H	H
		N	L	M	M	H	L	L	M	L	M	L	H	H
	2	C	L	M	L	H	H	L	M	L	M	L	H	H
		N	L	M	M	H	L	L	M	M	L	L	H	H
	3	C	L	M	L	H	H	L	M	L	M	L	H	H
		N	L	M	M	M	L	L	M	L	L	L	L	L
	4	C	L	H	L	M	L	L	M	L	M	L	H	H
		N	L	M	M	H	L	L	M	L	L	L	H	M
NISQ	2	C	L	L	L	H	H	H	M	L	M	L	M	M
		N	L	L	L	H	H	H	M	L	M	L	M	M
	4	C	L	L	L	M	H	H	M	L	M	L	M	M
		N	L	L	L	H	H	H	M	L	L	L	M	M
PACF	1	C	L	M	L	H	L	L	M	L	M	L	H	M
		N	L	M	L	H	H	L	M	L	M	L	H	H
	3	C	L	M	L	H	L	L	M	L	M	L	M	M
		N	L	M	L	L	H	H	M	L	M	L	H	H

TABLE 7a-c. Number of species found on the paired salt marshes and the number of dominant species categorized by indicator status (IND. STAT.) and native/introduced (N/I) (Reed 1988). NAT is the number of species found only on the natural site, CR is the number of species found only on the created site and BOTH is the number of species found on both paired sites. Dashes (--) indicate that the species was not found at the site(s). Numbers in parentheses after NAT and CR indicate the total number of species found at the natural and created sites, respectively. The numbers in parentheses following the TOTALS are the percent of the total number of species or the dominant species, found at the natural, created, or both sites. OBL is an obligate wetland species; FACW is facultative wetland species; FAC is a facultative species; FACU is a facultative upland species; UPL is an upland species; N is a native species; I is an introduced species; UNKNOWN means the indicator status could not be determined for the plant.

Table 7a. LINC

IND. STAT.	ALL SPECIES (57)			DOMINANT SPECIES (14)		
& N/I	NAT(36)	BOTH	CR(34)	NAT(7)	BOTH	CR(7)
OBL/N	4	4	7	2	--	5
OBL/I	--	--	1	--	--	--
FACW/N	3	3	4	4	--	1
FACW/I	1	1	3	1	--	--
FAC/N	2	--	--	--	--	--
FAC/I	1	1	--	--	--	--
FACU/N	1	--	--	--	--	--
FACU/I	2	1	--	--	--	--
UPL/N	--	--	--	--	--	--
UPL/I	2	--	--	--	--	--
UNKNOWN	7	3	6	--	--	1
TOTALS	23 (41%)	13 (23%)	21 (36%)	7 (50%)	-- (0%)	7 (50%)

TABLE 7b. WILL

IND. STAT.	ALL SPECIES (37)			DOMINANT SPECIES (7)		
& N/I	NAT(27)	BOTH	CR(26)	NAT(3)	BOTH	CR(4)
OBL/N	4	5	3	2	--	1
OBL/I	--	1	1	--	--	--
FACW/N	--	5	3	--	--	1
FACW/I	1	2	1	--	--	2
FAC/N	2	--	--	--	--	--
FAC/I	--	--	--	--	--	--
FACU/N	2	--	--	--	--	--
FACU/I	--	1	1	1	--	--
UPL/N	1	--	--	--	--	--
UPL/I	--	--	--	--	--	--
UNKNOWN	1	2	1	--	--	--
TOTALS	11 (30%)	16 (43%)	10 (27%)	3 (43%)	-- (0%)	4 (57%)

TABLE 7c. WEST

IND. STAT.	ALL SPECIES (27)			DOMINANT SPECIES (8)		
& N/I	NAT(22)	BOTH	CR(23)	NAT(4)	BOTH	CR(5)
OBL/N	1	6	--	3	--	2
OBL/I	1	--	--	--	--	--
FACW/N	--	9	2	--	1	2
FACW/I	--	3	--	--	--	--
FAC/N	--	--	--	--	--	--
FAC/I	--	--	--	--	--	--
FACU/N	--	--	--	--	--	--
FACU/I	--	--	1	--	--	--
UPL/N	1	--	1	--	--	--
UPL/I	--	--	--	--	--	--
UNKNOWN	1	--	1	--	--	--
TOTALS	4 (15%)	18 (67%)	5 (27%)	3 (38%)	1 (13%)	4 (50%)

WEST--Twenty-seven species were found by the two teams that sampled the WEST paired wetlands (Table 7c). Five species were found on the created site, four species were found on the natural site, and 18 species were found on both. The percent of wetland and facultative species on the paired wetlands was similar: 87% were found on the created and 91% were found on the natural. More native than introduced wetland species were found. Of the 23 species found on the created site, five were classified as dominant and of the 22 species found on the natural site, four were classified as dominant. All of the dominant species were also wetland species.

Summary--The results indicated differences between the paired wetlands. The percent of the species found on both the created and natural sites ranged from 23-67% and the percent of the species classified as dominant ranged from 11-22%. However, similarities were also found. For example, all dominant species were also wetland species, except for the WILL natural site which had one dominant species that was upland. In general, the dominant species were found on either the created or the natural sites.

Site description form--

Comparisons were made of the results of the same team evaluating the paired created and natural wetlands for the three questions of interest on the site description form (Table 8). There were 12 comparisons for each of the three questions. Differences between the created and natural saltwater wetlands were indicated by answers which differed by at least 40%. Eight percent of the comparisons were different for the percent of the site covered by open water. For this comparison, the created wetland had more open water than the natural wetland. Thirty three percent of the comparisons differed for the percent of the site that was disturbed. In three of the comparisons, the created wetland was more disturbed than the natural wetland, and in one of the comparisons, the natural wetland was more disturbed. One of the 12 comparisons differed for the percent of the surrounding area that was disturbed. For this comparison, the created wetland had a higher percent of disturbance in the surrounding area than the natural wetland.

Pielou--

The results from the Pielou evaluations performed by both of the teams that sampled the WEST and WILL paired wetlands agreed that the plant communities on the paired wetlands had similar diversities, but were not from the same parent population (Table 9). However, the team's evaluations were not in agreement for the LINC paired wetland. The evaluations from two of the teams concluded that the two communities had similar diversities but were not from the same parent population, while the evaluations from the other two teams suggested that the community on the created site was less diverse, but not a subset of the community on the natural site.

Table 8. Summary of site characteristics and surrounding land uses from the site description form for the saltwater wetlands. C = created, N = natural, OW = % open water, DIST = % wetland disturbed, SUR DIST = % surrounding area that is disturbed.

SITE	C/N	TEAM	OW	DIST	SUR DIST
LINC	C	1	50	5	80
LINC	N	1	50	10	0
LINC	C	2	60	0	100
LINC	N	2	0	100	90
LINC	C	3	35	0	75
LINC	N	3	50	0	55
LINC	C	4	70	0	30
LINC	N	4	60	0	50
WEST	C	1	10	70	50
WEST	N	1	20	10	50
WEST	C	2	10	0	30
WEST	N	2	10	0	30
WILL	C	1	10	75	0
WILL	N	1	20	10	10
WILL	C	2	30	0	10
WILL	N	2	10	0	10
SEQU	C	3	100	0	25
SEQU	N	3	75	0	40
SEQU	C	4	75	5	5
SEQU	N	4	66	0	10
BLRI	C	3	90	100	100
BLRI	N	3	85	15	80
PIER	C	3	100	0	100
PIER	N	3	100	0	70

Table 9. Summary of the results of the Pielou (1986) analysis of three pairs of saltwater marshes sampled by two or four teams. For test one, values of $Z > 1.28$ (one tailed test, alpha = 0.10) caused the hypothesis that the two communities had the same diversity to be rejected, and supported the conclusion that the created site was less diverse than the natural site. If test one was not rejected, then values of $Z > 1.282$ for test two caused the hypothesis that the created community was a subset of the natural community to be rejected. Alternately, if test one was not rejected, then values of $Z > \pm 1.65$ for test two (two tailed test, alpha = 0.10) caused the hypothesis that the created and natural communities were from the same parent population to be rejected. * = rejected.

SITE	TEAM	TEST 1 Z VALUE	TEST 2 Z VALUE	IMPLICATIONS
LINC	1	*	*	The created site is less diverse than the natural site.
		2.55	4.94	The created site is not a subset of the natural site.
	2		*	The two communities have similar diversities
		0.48	4.56	but are not from the same parent population.
	3	*	*	The created site is less diverse than the natural site.
		1.55	4.66	The created site is not a subset of the natural site.
	4		*	The two communities have similar diversities
		1.27	6.27	but are not from the same parent population.
WEST	1		*	The two communities have similar diversities
		-0.86	8.06	but are not from the same parent population.
	2		*	The two communities have similar diversities
		1.18	7.12	but are not from the same parent population.
WILL	1		*	The two communities have similar diversities
		-2.98	2.37	but are not from the same parent population.
	2		*	The two communities have similar diversities
		-1.91	5.39	but are not from the same parent population.

WET--

Similarities between the created and natural sites were found in many of the WET evaluations (Table 10). In general, all of the evaluations of the saltwater sites (i.e., salt marshes, mudflats and eelgrass beds) (>97%) had low ratings for groundwater recharge, floodflow alteration, sediment/toxicant retention, nutrient removal/transformation, and wildlife d/a breeding. Many of the evaluations of the sites (>83%) were also low for groundwater discharge. More than 88% of the evaluations had a medium rating for production export and general fisheries habitat. The four remaining functions, sediment stabilization, aquatic d/a, wildlife d/a migration and wildlife d/a wintering, varied by team, created or natural site pair, site within a wetland type, and wetland type. The salt marshes had primarily mediums and highs for these functions. The eelgrass sites were low for aquatic d/a, primarily high for wildlife d/a migration and varied for wildlife d/a wintering and sediment stabilization. The mudflats were medium for aquatic d/a, but varied by created and natural site for the other functions.

COMPARISON OF TEAMS

Vegetation Patterns

Two paired wetlands (KOLL and LINC) were sampled by all four teams. Comparisons between these sites showed that variability existed among the teams with respect to the number of times a species was found on a site. The comparisons showed that 35-54% of the total number of plant species recorded were found by only one of the teams (i.e., the other three teams did not find the species).

Using only the species that the teams agreed were on the sites (for KOLL and LINC, three of the four teams had to have found the species; for the remaining four pairs, the species had to be found by both teams six or more times), coefficients of variation (CV) were calculated to determine how similar each team's findings were. The results indicated that variability existed between the number of times each species was found by each team at each site. The average CV for each site ranged from 16-74 (Table 11). Three wetlands had an average CV of 27 or less, the remaining nine had an average CV of 45 or more. The NISQ sites had similar between team findings as indicated by a CV of 25 or less for 80% and 86% of the species found on the created and natural sites, respectively. The percent of species having a CV of 25 or less at the remaining sites ranged from 6-69%.

The average CV for the freshwater wetlands was 56 for the created sites and 41 for the natural sites. The average CV for the saltwater wetlands was similar: 51 for the created sites and 50 for the natural sites.

Table 10. Ratings [high (H), medium (M), low (L), unknown (U)] of the effectiveness of the six pairs of saltwater wetlands for 12 functions and values as determined by the Wetland Evaluation Technique (WET) (Adamus et al. 1987). The WET evaluations were generated by two or four teams per site during the summer of 1987 in Washington. C = created, N = natural, GWR = groundwater recharge; GWD = groundwater discharge; FFA = floodflow alteration; SS = sediment stabilization; S/TR = sediment/toxicant rentention; NR/T = nutrient removal/transformation; PE = production export; AD/A aquatic diversity/abundance; GFH = general fish habitat; WB = wildlife diversity/abundance breeding; WM = wildlife diversity/abundance migration; WW = wildlife diversity/abundance wintering.

SITE	TEAM	C/N	GWR	GWD	FFA	SS	S/TR	NR/T	PE	AD/A	GFH	WB	WM	WW
LINC	1	C	L	L	L	H	L	L	M	H	M	L	H	H
		N	L	L	L	H	L	L	U	H	M	L	H	M
	2	C	L	L	L	M	L	L	M	H	M	L	H	H
		N	L	L	L	H	L	L	M	M	M	L	H	M
	3	C	L	L	L	M	L	L	M	H	M	L	H	H
		N	L	L	L	H	L	L	M	M	M	L	M	M
	4	C	L	L	L	H	L	L	U	H	M	L	M	M
		N	L	L	L	H	L	L	M	H	M	L	H	H
WEST	1	C	L	L	L	H	L	L	M	M	M	L	H	M
		N	L	L	L	H	H	L	M	M	M	L	H	M
	2	C	L	L	L	M	L	L	U	M	M	L	H	H
		N	L	L	L	M	L	L	U	M	M	L	H	H

Table 10. continued

SITE	TEAM	C/N	GWR	GWD	FFA	SS	S/TR	NR/T	PE	AD/A	GFH	WB	WM	WW
WILL	1	C	L	L	L	H	L	L	M	H	M	L	H	H
		N	L	M	L	H	L	L	M	M	M	L	H	H
	2	C	L	M	L	H	L	L	M	M	M	L	H	H
		N	L	M	L	H	L	L	M	M	M	L	H	H
SEQU	3	C	L	L	L	H	L	L	M	L	M	L	H	M
		N	L	L	L	M	L	L	M	L	M	L	H	H
	4	C	L	L	L	H	L	M	M	L	M	L	L	L
		N	L	M	L	L	L	L	M	L	L	L	H	H
BLR1	1	C	L	L	L	L	L	L	M	M	M	L	L	L
		N	L	L	L	H	L	L	M	M	M	L	H	M
	2	C	L	L	L	L	L	L	M	M	M	L	M	M
		N	L	L	L	H	L	L	M	M	M	L	H	M
	3	C	L	L	L	L	L	L	M	M	M	L	M	M
		N	L	L	L	H	L	L	M	M	M	L	H	M
	4	C	L	L	L	L	L	L	M	M	M	L	L	L
		N	L	L	L	H	L	L	M	M	L	L	H	M
PIER	1	C	L	L	L	L	L	L	M	M	M	L	L	L
		N	L	M	L	L	L	L	M	M	M	L	L	L
	2	C	L	L	L	L	L	L	M	M	M	L	M	M
		N	L	M	L	L	L	L	M	M	M	L	L	L
	3	C	L	L	L	L	L	L	M	M	M	L	L	L
		N	L	L	L	L	L	L	M	M	M	L	L	L
	4	C	L	L	L	H	L	L	M	M	M	L	L	L
		N	L	L	L	H	L	L	M	M	M	L	L	L

Table 11. A comparison of the number of species found by all teams sampling the created (C) and natural (N) marshes. CV is the coefficient of variation.

	FRESHWATER						SALTWATER					
	KOLL		NISQ		PACF		LINC		WILL		WEST	
	N	C	N	C	N	C	N	C	N	C	N	C
No. of species found on wetlands	24	17	15	7	16	12	12	7	7	11	9	11
No. of species having a CV less than 25.0	2	1	12	6	11	5	1	2	4	2	2	3
% of species having a CV less than 25.0	8	6	80	86	69	42	8	29	57	18	22	27
Average CV for wetland	72	74	18	16	47	54	66	48	27	45	66	59

A cluster analysis was performed on the six paired wetlands. The dendrograms from the analysis show that the different teams sampling the same site consistently clustered before the paired sites (Figures 2 and 3). This suggests that the species found by different teams at the same site were more homogeneous or similar than the species found on the paired created or natural sites.

Site description form

Comparisons were made of the results obtained by different teams visiting the same site (Table 4 and Table 8). There were seven pairs of sites evaluated by two or four teams (the remaining two site pairs were sampled by one team each). Again, differences greater than or equal to 40% were noted for the percent of the site covered by open water, percent of the site that was disturbed, and the percent of the surrounding area that was disturbed. One of the 14 sites (7%) had differences of at least 40% for the percent of the site covered by open water, five sites (36%) for the percent of the site that was disturbed, and four sites (29%) for the percent of the surrounding area that was disturbed.

Comparisons were made of the results obtained by different teams evaluating seven of the pairs of created and natural wetlands. Whether the teams found similar percent differences between the paired sites was determined. Again, differences greater than 40% were noted for the three variables listed above. One of the 7 pairs (14%) had differences greater than 40% for the percent of the site covered by open water, four pairs (57%) for the percent of the site that was disturbed, and two pairs (29%) for the percent of the surrounding area that was disturbed.

Finally, whether the mean difference between the created and natural sites was greater than the mean difference between the teams was examined for those wetlands sampled by only two teams. This was determined by taking the average of the absolute value of the difference between the answers given for the 19 questions on the site description form. The data were compared for sites where two teams sampled the same site and for the pairs of sites. Forty percent of the site difference averages were greater than the team difference averages, 15% were approximately equal (within 1%), and 45% were less. Therefore, for the sites which were sampled by two teams, it appears that there was about as much difference observed between created and natural sites as there was between teams.

Pielou

For three of the pairs of sites (evaluated by two teams each), the teams came to the same conclusion for both test 1 and test 2. For one pair of sites (evaluated by two teams), and for two pairs of sites (evaluated by four teams each), the teams came to different conclusions for test 1. The teams did not always agree on whether the sites had similar diversities.

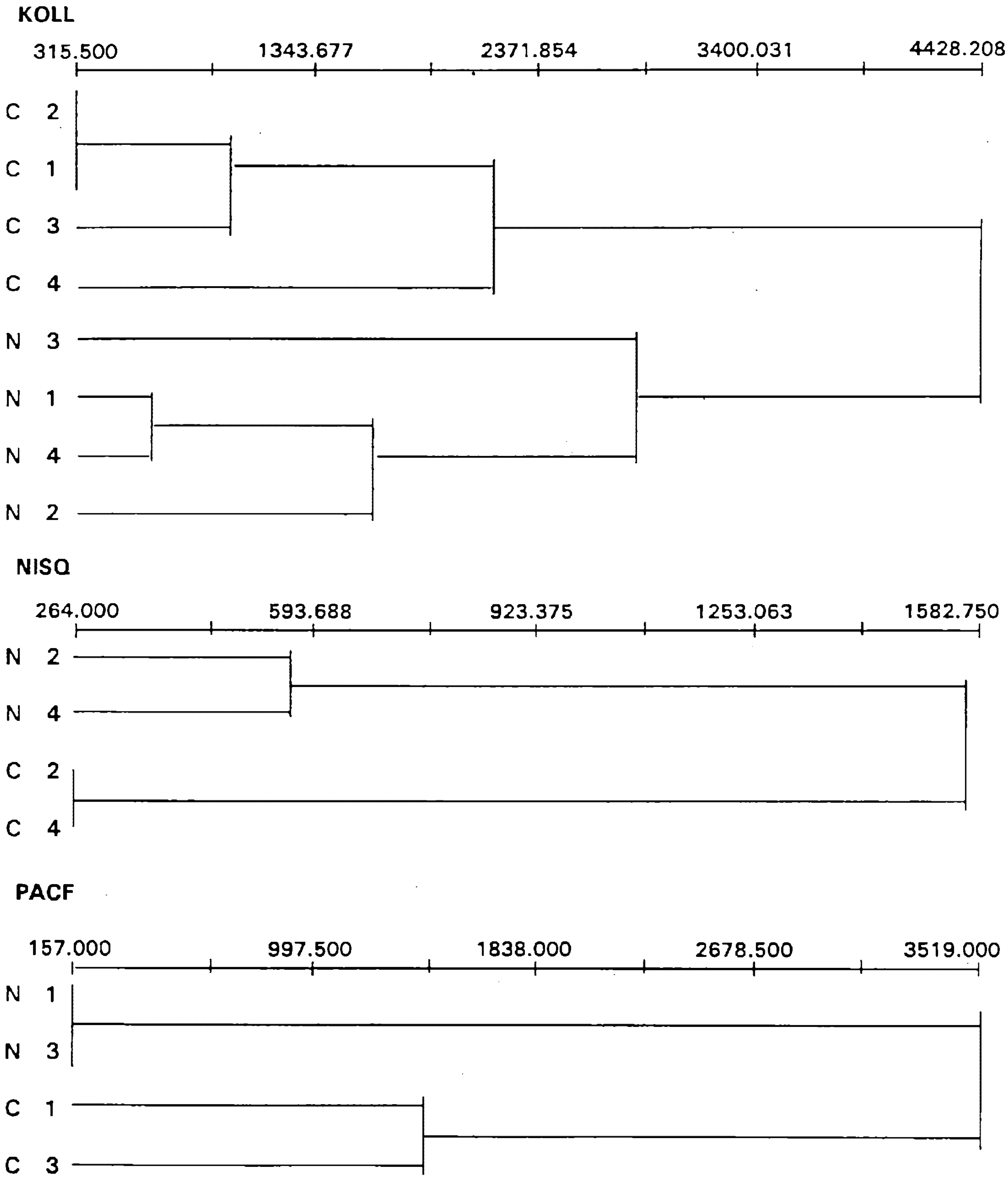

Figure 2. Dendrograms produced from vegetation data collected at the three pairs of freshwater wetlands. Dendrograms indicated that team differences were less than wetland differences because the teams clustered before the sites. C=Created wetland, N=Natural wetland; 1,2,3,4 are team numbers.

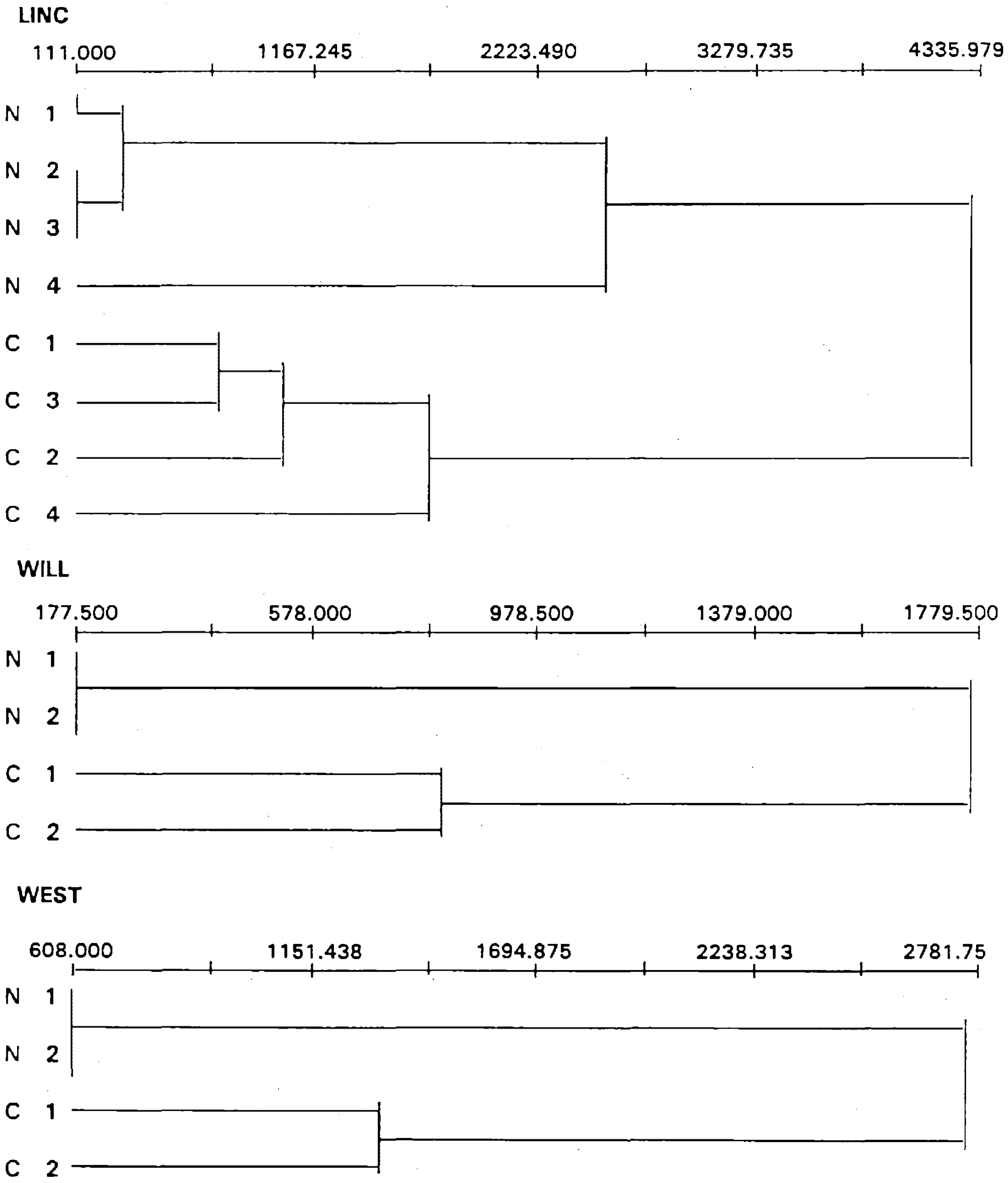

Figure 3. Dendrograms produced from vegetation data collected at the three pairs of salt marshes. Dendrograms indicated that team differences were less than wetland differences because the teams clustered before the sites. C=Created wetland; N=Natural wetland; 1,2,3,4 are team numbers.

However, they consistently agreed that the created and natural sites were different. The analyses determined that either the created and natural paired sites were not from the same parent population or that the plant communities on the created sites were not subsets of the communities on the natural sites.

WET

The total number of different ratings given by two teams at the same site was compared with the total number of different ratings given to the paired created and natural sites evaluated by the same team (Table 12). The total number of differences in the evaluations was 20 out of a possible 240 for both of the comparisons. Therefore, it appears that there was about as much difference in ratings between teams as there was difference in ratings between pairs of sites for the sites where just two teams visited.

Table 12. The number of differences in the Wetland Evaluation Technique (Adamus et al. 1987) evaluations for pairs of created and natural wetlands and for teams visiting the same wetland pair. C=created, N=natural.

SITE	TEAM	# OF DIFFERENCES IN EVALUATIONS	SITE	C/N	# OF DIFFERENCES IN EVALUATIONS
NISQ	2	0	NISQ	C	1
	4	2		N	1
PACF	1	2	PACF	C	1
	3	5		N	2
WEST	1	1	WEST	C	3
	2	0		N	4
WILL	1	2	WILL	C	2
	2	0		N	0
SEQU	3	2	SEQU	C	3
	4	6		N	3
TOTAL		20	TOTAL		20

SECTION 4

DISCUSSION

COMPARISON OF CREATED AND NATURAL WETLANDS

Freshwater wetlands

Different vegetation patterns were found at the three pairs of created and natural freshwater wetlands. Possible reasons include the elimination of species found only once within each site pair and the different number of teams sampling the sites. Seventy-six percent of all species found during sampling were used in the vegetation patterns analysis. By eliminating the less frequently found species, the results may have been biased. In addition, the NISQ and PACF sites were sampled by two teams and the KOLL site was sampled by four teams. Thus, the results were confounded and exact comparisons were not possible. However, dendrograms from the cluster analysis (Figure 2) showed that the teams consistently clustered before the created and natural sites, indicating that the differences between the teams were not as great as the differences between the sites.

Saltwater wetlands

The results indicated differences also existed between the three pairs of created and natural saltwater sites. As with the freshwater sites, possible explanations include the elimination of species found once within each site pair and different numbers of teams sampling each site. The LINC site was sampled by all four teams and the WEST and WILL sites were sampled by two teams each. The LINC site also had a large proportion of unidentified plant species which may have affected the results. Dendrograms for the pairs of saltwater sites (Figure 3) showed a similar pattern as was found for the freshwater sites. The teams clustered before the created and natural sites, indicating that the differences between the teams were not as great as the differences between the sites.

COMPARISON OF TEAMS

In contrast to the above findings, the results from WET, the Pielou method, and the site description data indicate that differences found between the teams were about as prevalent as differences found between the created and natural wetlands. The amount of heterogeneity on a site could have influenced the results. Although criteria for transect placement were used, site heterogeneity would affect whether a team sampled similar vegetation. Other possible reasons to explain this finding include: insufficient training, differing amounts of botanical expertise among the teams, and subjective methods for data collection.

The teams would have benefitted from more complete field training before data collection began. A one week training class in the use of WET, and the Army Corps of Engineers' (COE) and EPA's wetland delineation methods was attended by all the team members. However, time spent practicing the other field techniques and ascertaining whether the teams understood the rationale for the methods and goals of the study (i.e., why the data were collected in a certain order) was limited due to the amount of information that had to be communicated during the course. A practice run in the field using all the techniques would have helped both the team members and instructors to identify potential problems and to promote open communication early in the study.

The team members also had varying levels of botanical experience. The different results found between the teams for the Pielou analysis could be partially attributed to the varying skill levels of the botanists. The team with the most qualified botanist provided the most detailed data sheets and plant specimens were carefully collected and identified. This type of detailed documentation would likely be more difficult for individuals with lesser botanical training.

Finally, all of the methods tested had a certain amount of inherent subjectivity which could explain why teams sampling the same sites sometimes had different responses. For example, the estimates given by different teams sampling the LINC natural wetland for the percent of the wetland that was disturbed ranged between 0 and 100%. Although, the range for the estimates was smaller for the slightly less subjective variable, percent of open water found on the wetland, it was still sizeable (60%).

UTILITY OF METHODS

Pielou

The placement of the transects and determination of the number of species to record, may have affected the results of the Pielou analysis. Each team determined transect placement, therefore, the teams had different starting points and directions for their transects. If the method is robust, then the transect placement should not significantly effect results. Very heterogeneous sites, however, could produce varying results. Also, the analysis calls for the determination of the number of species to record in each quadrat, k, and assumes that there are always at least k different species within two meters of each sampling point (Pielou 1986). However, the analysis can be adversely affected by choosing a value for k that is either too small or too large. If the number chosen is too small, then the method might underestimate the true diversity of the site. If the number chosen is too large, then difficulties finding k species in the plot might be encountered. In this case, the method suggests an alternative method for analysis which ultimately makes the quadrats more similar to each other and the site diversity lower.

The Pielou method organized the data so that comparisons were made of the most typical quadrat found at the sites. Although, this was done to make the statistical analysis valid, information was lost by collapsing the 40 by 40 matrix into one variable.

WET

WET did not distinguish between the saltwater sites for many of the functions and it did not distinguish between either the fresh- or saltwater sites for four of the twelve functions. Of course, there could have been few differences to distinguish between. However, over 88% of the WET evaluations had low ratings for groundwater recharge, nutrient removal/transformation, and wildlife d/a breeding, and all the evaluations were medium for production export. For the remaining functions, the evaluations were different for various reasons, e.g., different wetland types, different paired created and natural sites, and different teams at the same site.

WET was evaluated by the teams at the end of the study and during a quality assurance audit of the teams in the field. The evaluation of WET by the field crews was important to the study because the field crews could be considered typical users of the technique, i.e., they were members of government agencies who had some training in the technique. However, the following discussion is based solely on their opinions. No doubt other users would have different experiences and opinions about WET.

The teams felt that many of the questions were too complicated and time consuming, and that some of the questions were difficult to interpret or did not make sense (D. Coffey, ManTech Environmental Technology Inc., Corvallis, OR, pers. comm.). They also felt that there should have been an option which enabled them to avoid answering questions or evaluating functions that were not applicable to a given region or situation (K. Kunz, COE, Seattle, WA, pers. comm.).

The consensus of the teams was that the WET data were not sensitive enough to adequately assess the success, or lack thereof, of the creation projects. They felt that the probability of a wetland performing a function was not the same as determining if a created wetland was actually functioning (K. Kunz, COE, Seattle, WA, pers. comm.).

The teams felt that WET was not ready to be adopted as a national procedure. They questioned whether the interpretation of the literature which was used to develop the predictors could be extrapolated to the Pacific Northwest and whether generalized wetland questions could adequately characterize functions and values in extremely different wetland types (K. Kunz, COE, Seattle, WA, pers. comm.).

In a report prepared for the Federal Highway Administration, Normandeau Associates, Incorporated (NAI) provided a review and critique of WET (NAI 1990). NAI also found that certain questions were worded in such a way as to make them easy to misinterpret and that WET was difficult to use due to the obtuse wording of the predictor questions. They suggested that WET was too general for mitigation evaluation, primarily because it placed more importance on location than wetland features. NAI also found that for some of the functions (sediment/toxicant retention, nutrient removal/transformation, aquatic d/a and wildlife d/a breeding), the "recent alteration" factor was pivotal in determining the probability rating for a wetland and almost always lead to a low probability rating. The low rating did not reflect the stage of development or design features, but rather was strictly a function of time (NAI 1990). It does not appear that the "recent alteration" factor affected the data in this report because there were some high, medium and low ratings for the above listed functions for both the created and natural wetlands. Finally, NAI, the team members, and others (e.g., Odum et al. 1986, van der Valk 1989) have all expressed concerns about the use of WET in different regions.

RECOMMENDATIONS

The lessons learned from this study can be summarized into the following recommendations:

1. Reserve an adequate amount of time for training to increase the probability that comparable results are obtained by the teams. Strive to reduce the variability between teams by allowing them the opportunity to practice, to discuss any areas of difficulty or disagreement, and to practice again. Having one team do the sampling would eliminate the between team variability, but it would also eliminate any determination of the method's replicability.

2. Evaluate between team performance before beginning actual sampling.

3. Ensure that the directions for all procedures are clear and easy to follow.

4. Strive to reduce the varying levels of experience and expertise on the teams. Realize that if there are varying levels of experience and expertise, variable results might be encountered.

5. Make sure communication between team members and researchers is initiated early so that potential problems are discovered.

6. Ensure that problems with the procedures are documented in writing so that they can be corrected for future studies.

CONCLUSIONS

The goals of the study were difficult to evaluate due to differences in the results of teams visiting the same wetland. The heterogeneity within the sites could explain some of the differences. If the sites were heterogeneous, then team differences might be expected. However, it is difficult to determine whether differences found between teams at the same site were due to site heterogeneity or actual differences between the teams.

The performance of WET was also difficult to assess due to different team results at the same site. However, concerns were expressed about WET by the teams participating in this study and NAI (1990). Both felt that WET: included questions that were complex and difficult to interpret, did not address regional concerns, and was not sensitive enough to assess success of created wetlands. Therefore, the applicability of WET for comparing created and natural wetlands is not clear at this point.

Team differences also made determination of the applicability of the Pielou method (1986) difficult. Concerns about the Pielou method included choosing the value of k (the number of species to sample) and the potential loss of information during analysis.

Suggested improvements for sample design would be to have the same number of teams visit each site. This makes comparison among teams more straightforward. Also, comparing samples of wetlands is more meaningful than comparing paired wetlands because extrapolation to the population of interest is possible. However, use of the Pielou method requires paired sites, so one of the goals of this study, to test techniques, could not have been met with another sampling scheme.

The objectives of this study were to test the effectiveness of methods that could be used by agencies to evaluate created wetlands, to use these methods to compare the created and natural wetlands, and to evaluate the consistency of results observed by teams sampling the same site. The limitations of both WET and the method recommended by Pielou (1986) were identified and documented in a "real life" situation. Because agency personnel, given the constraints of their work situation, conducted the study, we feel that the results of this study will have some utility for regulators in wetland evaluation. Although what we can say about the similarities and differences between the created and natural sites is restricted, the information compiled on the sites should provide a baseline for future evaluations.

SECTION 5

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APPENDIX I

DESCRIPTIONS OF CREATED AND NATURAL WETLANDS USED IN THE WASHINGTON FIELD STUDY

The following information on the created wetlands was compiled from the Section 404 permit record (Kentula et. al submitted). The natural wetlands were selected and described by Michael Rylko and Kathy Kunz. Four letter codes (e.g., KOLL) are pseudonyms for the permit numbers and are used to preserve the anonymity of the sites.

FRESHWATER WETLANDS

KOLL

wetland type	palustrine emergent marsh
location	North Creek (Sammamish River)
area (acres)	5.3
permit issued	1984
age when sampled	9 months

The natural wetland was located 3 miles north west of the created wetland in a similar situation.

NISQ

wetland type	palustrine emergent marsh
location	Nisqually River, side channel
area (acres)	0.1
permit issued	1985
age when sampled	7 months

The natural wetland was located to the immediate north of the created site in a similar habitat.

PACF

wetland type	palustrine emergent marsh
location	Woodward Creek
area (acres)	0.1
permit issued	1985
age when sampled	9 months

The natural wetland was located to the immediate north of the created site in a similar habitat.

SALTWATER WETLANDS

LINC

wetland type	salt marsh
location	Puyallup River
area (acres)	3.8
permit issued	1984
age when sampled	13 months

The created wetland was located in a heavily urbanized section of the Puyallup River and there were no comparable natural sites in the immediate vicinity. The only natural wetland in a similar situation was located near Seattle in the Duwamish River Basin at Kellogg Island. Although the areas were some 30 miles apart, both were located in a heavily urbanized tidal river with similar species composition.

WEST

wetland type	salt marsh
location	Gray's Harbor
area (acres)	0.1
permit issued	1986
age when sampled	8 months

The natural wetland was located to the immediate north, east, and south of the created wetland in similar habitat.

WILL

wetland type	salt marsh
location	Willapa Bay
area (acres)	2.2
permit issued	1983
age when sampled	22 months

The natural wetland was located to the immediate north of the created site in a similar habitat.

SEQU

wetland type	eelgrass beds
location	Sequim Bay
area (acres)	2.0
permit issued	1983
age when sampled	27 months

The natural wetland was 1 mile north of the created wetland within the confines of Sequim Bay.

BLR1

wetland type	mudflat
location	Blair Waterway (Commencement Bay)
area (acres)	0.3
permit issued	1984
age when sampled	28 months

The natural wetland was located on the Hylebos Waterway in a very similar situation to the created wetland.

PIER

wetland type	mudflat
location	Shilshole Bay
area (acres)	0.5
permit issued	1986
age when sampled	8 months

The natural wetland was located offsite at Alki Point, West Seattle, approximately 10 miles from the created wetland.

APPENDIX II

SPECIES FOUND DURING THE WASHINGTON FIELD STUDY

The following is a list of plant species found in the Washington Field Study. The species are listed in phylogenetic order. Hitchcock and Cronquist (1981) was used to identify species found during sampling. Adjacent to the specie's names are the codes used in the analyses. The plant's indicator status and native/introduced determination were taken from The Regional List of Plant Species that Occur in Wetlands: Northwest (Region 9) (Reed, 1988). Codes are: "o"--obligate wetland species; "w"--facultative wetland species; "f"--facultative wetland species; "u"--facultative upland species; "p"--upland species; "a"--absent from the List of Species that Occur in Wetlands; "+"--upper end of category; "-"--lower end of category; "\"--intermediate within the category; "n"--native species; "i"--introduced species; ***--no information.

	Code	Vegetation Found
010000		Equisetaceae
010100	***	Equisetum sp.
010101	w\n	Equisetum arvense
010103	w\n	Equisetum telmateia
020000		Polypodiaceae
020101	f\n	Athyrium filix-femina
020200	***	Dryopteris sp.
020301	p\n	Polystichum munitum
020401	u\n	Pteridium aquilinum
040000		Cupressaceae
040101	f\n	Thuja plicata
050000		Pinaceae
050101	f\n	Picea sitchensis
050201	p\n	Pseudotsuga menziesii
050301	u-n	Tsuga heterophylla
060000		Salicaceae
060101	w\n	Populus balsamifera
060102	f+i	Populus tremuloides\Populus tremula tremuloides
060102	f+i	Populus tremuloides
060102	f+i	Populus tremula tremuloides
060103	w\n	Populus trichocarpa\Populus balsamifera trichocarpa
060103	w\n	Populus trichocarpa
060103	w\n	Populus balsamifera trichocarpa
060200	***	Salix sp.
060202	w+n	Salix geyeriana
060203	w-n	Salix hookeriana
060204	w+n	Salix lasiandra
060205	w\n	Salix piperi
060207	f\n	Salix scouleriana
060208	w\n	Salix sessilifolia
060210	w\n	Salix sitchensis

070000		Betulaceae
070101	f\n	Alnus rubra
080000		Urticaceae
080101	f+i	Urtica dioica
090000		Polygonaceae
090100	***	Polygonum sp.
090101	w-i	Polygonum aviculare
090102	o\n	Polygonum coccineum\Polygonum amphibium emersum
090102	o\n	Polygonum coccineum
090102	o\n	Polygonum amphibium emersum
090104	o\i	Polygonum hydropiper
090106	w+n	Polygonum lapathifolium
090107	wdi	Polygonum persicaria
090200	***	Rumex sp.
090201	u\i	Rumex acetosella
090202	w\i	Rumex conglomeratus
090203	w\i	Rumex crispus
090204	w+n	Rumex occidentalis
090205	w+n	Rumex maritimus
100000		Chenopodiaceae
100101	w\n	Atriplex patula
100204	p\i	Chenopodium foliosum
100205	w+n	Chenopodium rubrum
100301	o\n	Salicornia virginica
120000		Caryophyllaceae
120201	w\n	Spergularia canadensis
120202	odn	Spergularia marina
120301	w+n	Stellaria calycantha
120303	o\n	Stellaria humifusa
150000		Ranunculaceae
150102	w\i	Ranunculus repens
160000		Brassicaceae
160601	w+n	Rorippa curvisiliqua
160603	o\i	Rorippa nasturtium-aquaticum\Nasturtium officinale
160603	o\i	Rorippa nasturtium-aquaticum
160603	o\i	Nasturtium officinale
180000		Saxifragaceae
180100	***	Mitella sp.
180301	f-n	Tiarella trifoliata
180401	f\n	Tolmiea menziesii
190000		Grossulariaceae
190101	f+n	Ribes lacustre
200000		Rosaceae
200101	p\i	Crataegus monogyna
200301	w+n	Geum macrophyllum
200401	u\n	Oemleria cerasiformis
200501	f+n	Physocarpus capitatus
200601	o\n	Potentilla pacifica\Potentilla anserina
200601	o\n	Potentilla pacifica
200601	o\n	Potentilla anserina
200700	***	Prunus sp.
200801	p\i	Pyrus malus\Malus sylvestris

200801	p\i	Pyrus malus
200801	p\i	Malus sylvestris
200903	u\n	Rosa rugosa
201001	u-i	Rubus discolor
201002	u+i	Rubus laciniatus
201003	f\n	Rubus pubescens
201004	f\n	Rubus spectabilis
201005	u\n	Rubus ursinus
201101	p\i	Sorbus aucuparia
201201	w\n	Spiraea douglasii
210000		Fabaceae
210101	u\i	Cytisus scoparius
210301	f\i	Lotus corniculatus
210302	u\n	Lotus micranthus
210500	***	Trifolium sp.
210502	p\i	Trifolium dubium
210505	u+i	Trifolium repens
210507	w+n	Trifolium wormskjoldii
210603	u\n	Vicia gigantea
210604	p\i	Vicia hirsuta
210605	p\i	Vicia sativa
250000		Callitrichaceae
250100	***	Callitriche sp.
250102	o\n	Callitriche verna
260000		Aceraceae
260101	u+n	Acer circinatum
260102	u\n	Acer macrophyllum
280000		Rhamnaceae
280101	p\i	Rhamnus purshiana
300000		Hypericaceae
300101	o\n	Hypericum anagalloides
300103	p\i	Hypericum perforatum
320000		Onagraceae
320201	w\n	Circaea alpina
320300	***	Epilobium sp.
320301	u+n	Epilobium angustifolium
320304	w-n	Epilobium watsonii\Epilobium ciliatum watsonii
320304	w-n	Epilobium watsonii
320304	w-n	Epilobium ciliatum watsonii
340000		Araliaceae
340101	p\i	Hedera helix
350000		Apiaceae
350101	f\n	Angelica lucida
350301	o\n	Cicuta douglasii
350501	o\n	Lilaeopsis occidentalis
350601	o\i	Oenanthe sarmentosa
360000		Cornaceae
360101	w\n	Cornus stolonifera
370000		Primulaceae
370201	w+i	Glaux maritima
390000		Gentianaceae
390100	***	Centaurium sp.

390101	w\n	Centaurium muhlenbergii
410000		Cuscutaceae\Convolvulaceae
410000		Cuscutacea sp.
410000		Convolvulaceae sp.
410101	w\n	Cuscuta salina
430000		Boraginaceae
430102	o\n	Myosotis laxa
440000		Lamiaceae
440101	a\i	Galeopsis tetrahit
440201	u+i	Glecoma hederacea
440801	w\n	Stachys cooleyae\Stachys emersonii
440801	w\n	Stachys cooleyae
440801	w\n	Stachys emersonii
450000		Solanaceae
450101	u\i	Atropa belladonna
450201	f\i	Solanum dulcamara
460000		Scrophulariaceae
460702	w+n	Mimulus moschatus
460801	w+n	Orthocarpus castillejoides
460901	f-i	Parentucellia viscosa
461101	***	Veronica sp.
461101	o\n	Veronica americana
461102	odn	Veronica peregrina
461104	o\i	Veronica scutellata
470000		Plantaginaceae
470101	w\i	Plantago coronopus
470102	u+i	Plantago lanceolata
470103	f+i	Plantago major
470104	w+n	Plantago maritima
480000		Rubiaceae
480100	***	Galium sp.
480101	u\n	Galium aparine
480102	w+n	Galium trifidum
490000		Caprifoliaceae
490101	f\n	Lonicera involucrata
490201	u\n	Sambucus racemosa
490301	u\n	Symphoricarpos albus
510000		Campanulaceae
510101	p\n	Triodanis perfoliata
520000		Asteraceae
520101	u\n	Achillea millefolium
520201	u\i	Anthemis cotula
520401	w\n	Aster subspicatus
520501	w\n	Bidens cernua
520900	***	Cirsium sp.
520901	u+i	Cirsium arvense
520902	w-n	Cirsium edule
520903	u\i	Cirsium vulgare
521101	w+i	Cotula coronopifolia
521201	p\i	Crepis capillaris
521301	f+i	Gnaphalium chilense
521302	f+n	Gnaphalium palustre

521303	a\n	Gnaphalium microcephalum
521304	f+n	Gnaphalium uliginosum\Filaginella uliginosa
521304	f+n	Gnaphalium uliginosum
521304	f+n	Filaginella uliginosa
521401	w\n	Grindelia integrifolia
521501	p\i	Hypochaeris glabra
521502	p\i	Hypochaeris radicata
521701	f-n	Lactuca serriola
522301	p\i	Senecio jacobaea
522400	***	Solidago sp.
522401	u\n	Solidago canadensis
522501	f-i	Sonchus asper
522502	p\i	Sonchus oleraceus
522601	o\n	Jaumea carnosa
522701	u\i	Taraxacum officinale
530000		Alismataceae
530102	o\n	Alisma plantago-aquatica
530201	o\n	Sagittaria latifolia
540000		Hydrocharitaceae
540100	***	Elodea sp.
550000		Juncaginaceae
550101	o\n	Triglochin concinnum
550102	o\n	Triglochin maritimum
570000		Zosteraceae
570101	o\i	Zostera nana
580000		Juncaceae
58UN01	***	Juncaceae 1
58UN02	***	Juncaceae 2
580100	***	Juncus sp.
580102	o\n	Juncus articulatus
580103	o\n	Juncus balticus
580104	w+n	Juncus bufonius
580105	w+n	Juncus effusus
580106	w\n	Juncus ensifolius
580107	w\n	Juncus nevadensis
580108	w+n	Juncus oxymeris
580111	f\n	Juncus tenuis
590000		Cyperaceae
59UN01	***	Cyperaceae 1
590100	***	Carex sp.
590101	***	Carex sp. 1
590102	***	Carex sp. 2
590103	***	Carex sp. 3
590104	***	Carex sp. 4
590109	f+n	Carex deweyana
590114	o\n	Carex lyngbyei
590115	o\n	Carex obnupta
590118	o\n	Carex stipata
590300	***	Eleocharis sp.
590303	w\n	Eleocharis bolanderi
590304	o\n	Eleocharis ovata
590305	o\n	Eleocharis palustris

590306	o\n	Eleocharis parvula
590400	***	Scirpus sp.
590401	o\n	Scirpus acutus
590402	o\n	Scirpus americanus
590404	o\n	Scirpus maritimus
590405	o\n	Scirpus microcarpus
500406	o\n	Scirpus validus
600000		Poaceae
60UN01	***	Poaceae 1
60UN02	***	Poaceae 2
60UN03	***	Poaceae 3
600102	u\i	Agropyron repens
600200	***	Agrostis sp.
600201	w\i	Agrostis alba
600202	w\n	Agrostis exarata
600204	f\n	Agrostis scabra
600205	p\i	Agrostis tenuis
600402	w\i	Alopecurus pratensis
600501	u\i	Ammophila arenaria
600601	u\i	Anthoxanthum odoratum
600903	p\i	Bromus rigidus
601001	u\i	Dactylis glomerata
601201	w\n	Deschampsia cespitosa
601401	w\n	Distichlis spicata
601601	p\n	Elymus cinereus
601801	u-i	Festuca arundinacea
601803	fdi	Festuca myuros\Vulpia myuros
601803	fdi	Festuca myuros
601803	fdi	Vulpia myuros
601804	p\n	Festuca ovina
601805	f\n	Festuca rubra
601902	w+n	Glyceria elata
601903	o\i	Glyceria grandis\Glyceria maxima grandis
601903	o\i	Glyceria grandis
601903	o\i	Glyceria maxima grandis
601904	o\n	Glyceria leptostachya
602101	f\n	Holcus lanatus
602200	***	Hordeum sp.
602201	w\n	Hordeum brachyantherum
602401	u\i	Lolium multiflorum\Lolium perenne multiflorum
602401	u\i	Lolium multiflorum
602401	u\i	Lolium perenne multiflorum
602701	w\n	Phalaris arundinacea
602801	u\i	Phleum pratense
602900	***	Phragmites communis
603003	f\n	Poa palustris
603004	u+n	Poa pratensis
603005	w-i	Poa trivialis
620000		Typhaceae
620101	o\n	Typha latifolia
630000		Araceae
630101	o\n	Lysichitum americanum\Lysichiton americanus

630101	o\n	Lysichitum americanum
630101	o\n	Lysichiton americanus
664000		Lemnaceae
640101	o\n	Lemna minor
650000		Liliaceae
650301	f-n	Maianthemum dilatatum
650401	f-n	Smilacina stellata
660000		Iridaceae
660100	***	Iris sp.
660101	o\i	Iris pseudocorus
67UN00	***	Unknowns
67UN01	***	Unknown 1
67UN02	***	Unknown 2
67UN03	***	Unknown 3
67UN04	***	Unknown 4
67UN05	***	Unknown 5
67UN06	***	Unknown 6
68WC01	***	Unknown 7
68WC02	***	Unknown 8

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16. ABSTRACT

Nine created wetlands were paired with nine natural wetlands and compared for species composition, species diversity, wetland function and other site characteristics. Results from comparison of species composition and species diversity indicated that some differences existed between the created and natural sites. However, because differences also existed in the data collected from different teams sampling the same site, the created and natural site differences were confounded. In addition to the possible heterogeneity within the sites, low replicability between the teams may have been due to insufficient training prior to field work, different botanical skill levels, or the subjectivity of some of other data collection forms.

A comparison of species composition also found some similarities with respect to the native/introduced and indicator status of the species found at the created and natural sites. Generally, the species classified as obligate, facultative wetlands, and wetland were native to the Pacific Northwest, while those species classified as facultative upland and upland were introduced.

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