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Subject Information for your files, a letter hopefully will be sent from our RD today stating we still have significant concerns, will send as soon as it is available

(See attached file: Weinstein et al 1992.pdf)(See attached file: West et al 2000.pdf)(See attached file: WESTetal_2000_EcologicalEngineering.pdf)

link to Rulifson 1991 follows
http://www.springerlink.com/content/706114551l373521/

(See attached file: PCS October 31, 2001 Letter.pdf)(See attached file: PCS JAN 8, 2001 LETTER.pdf)(See attached file: PCS July 16, 2001 LETTER.pdf)(See attached file: PCSPhosphate.pdf)(See attached file: PCS DEIS 3b letter.pdf)(See attached file: PCS DEIS DEC 2006.pdf)

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Shell Disease and Metal Content of Blue Crabs, *Callinectes sapidus*, from the Albemarle-Pamlico Estuarine System, North Carolina

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Abstract. Concentrations of 13 elements were determined for three tissues (gill, hepatopancreas, muscle) in diseased crabs from a contaminated estuary (Pamlico River, NC), and in non-diseased crabs from both the contaminated estuary and a relatively uncontaminated area (Albemarle Sound, NC) during the fall 1989 and summer 1990. The diseased crabs had lesions which completely penetrated their dorsal integument, while the non-diseased crabs lacked lesions.

Sediments within the contaminated area showed enrichment of arsenic, cadmium, manganese, titanium and vanadium relative to the uncontaminated area. Levels of aluminum, arsenic, cobalt, manganese, nickel, titanium, vanadium and zinc were significantly higher in both gill and hepatopancreas in crabs from the contaminated area. Manganese was always highest in the diseased crabs in all tissues measured. The concentrations of the remaining elements were greater in the gills of diseased crabs, while highest values of these elements in the hepatopancreas varied among the diseased and non-diseased crabs from the polluted area. Conversely, copper levels were always highest in all tissues in crabs from the uncontaminated area, and typically lowest in the diseased crabs. Concentrations of aluminum and arsenic were also significantly greater in the muscle tissue of crabs from the contaminated area, but no distinct trend was evident with regard to diseased versus non-diseased crabs.

Arsenic was the only element accumulated by crabs in the contaminated area which has a known toxic affect on the tissue responsible for cuticle synthesis and repair (hypodermis) in crustaceans. Metals also accumulated could possibly act synergetically to compromise normal metabolism. The results suggest that metal and trace element accumulation plays a minor direct role in the local etiology of shell disease.

Shell disease in crustaceans is the progressive microbial degradation and necrosis of the cuticle (Rosen 1970). This disease is common and has been reported in several commercially important species including the American lobster (*Homarus americanus*) (Hess 1937; Young and Pearce 1975), the blue crab (*Callinectes sapidus*) (Rosen 1967; Cook and Lofton 1973), and penaeid shrimp (*Penaeus* spp.) (Cipriani *et al.* 1980).

Shell disease is initially manifested as small reddish brown depressions which later coalesce to form lesions with cracked and pitted necrotic areas (Rosen 1967; Baross *et al.* 1978). Molting normally eliminates the disease because superficial lesions are not transferred to the new cuticle (Rosen 1970). However, mortality may result in the event cuticular erosion is sufficient to permit invasion of the underlying soft tissue by pathogenic bacteria (Baross *et al.* 1978).

Although shell disease has been attributed to mechanical damage of the outermost cuticular layer (epicuticle) followed by the activities of chitinoclastic bacteria and fungi (Rosen 1970; Gopalan and Young 1975; Baross *et al.* 1978), laboratory experiments have demonstrated that long-term exposure to some heavy metals can result in the formation of cuticular lesions resembling those of shell disease. Nimmo *et al.* (1977) observed cuticular lesions in pink shrimp (*Penaeus duorarum*) exposed to 1.0 μg/L cadmium for 21 days. Similarly, Doughtie *et al.* (1983) induced cuticular lesions in grass shrimp (*Palaemonetes pugio*) exposed to 0.5 μg/L chromium for 28 days. Crabs (*Cancer irroratus*) and lobster (*Homarus americanus*) exposed to sediments contaminated with lead, copper, and chromium (2–37 μg/g) developed exoskeletal lesions within six weeks (Pearce 1972).

The incidence of shell disease is known to vary with habitat quality, being lowest (2.5%) in unstressed environments and highest (10.5%) in heavily polluted environments (Cipriani *et al.* 1980). High incidences of shell disease have been reported from sewage sludge and dredge spoils dumping ground of the New York Bight which contain high concentrations of heavy metals in the sediments (Young and Pearce 1975; Gopalan and Young 1975).

Since 1986, lesions have been observed on the carapace of approximately 10% (but regionally as high as 90%) of the blue crabs (*Callinectes sapidus*) harvested from the Pamlico River estuary, North Carolina (McKenna *et al.* 1990). In many cases, these lesions were frequently large (>2 cm diameter) and completely penetrated the integument (personal observation). Re-

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Table 1. Results of the analyses of National Institute of Standards and Technology (NIST) (formerly National Bureau of Standards) SRM-1566 oyster tissue during the Fall 1989 and Summer 1990 ICAPES analyses (all values in μg/g, unless otherwise noted)

Element	NIST Certificate Value	Measured Value Fall 1989 (N = 5)	Measured Value Summer 1990 (N = 13)[b]
Al	N/A[c]	76.35 ± 12.90	69.72 ± 6.13
As	13.4 ± 1.9	14.35 ± 0.54	13.07 ± 0.89
Cd	3.5 ± 0.4	3.27 ± 0.14	3.11 ± 0.17
Co	0.4[a]	0.31 ± 0.01	0.28 ± 0.03
Cr	0.69 ± 0.27	0.25 ± 0.02	0.13 ± 0.08
Cu	63.0 ± 3.5	65.05 ± 0.94	61.59 ± 2.16
Mn	17.5 ± 1.2	17.51 ± 0.45	16.85 ± 0.64
Mo	<0.2*	0.15 ± 0.02	0.15 ± 0.03
Ni	1.03 ± 0.19	0.69 ± 0.07	0.64 ± 0.09
Pb	0.48 ± 0.04	0.48 ± 0.15	0.54 ± 0.42
V	2.8[a]	2.23 ± 0.05	2.12 ± 0.07
Zn	852 ± 14	939.50 ± 28.74	810.07 ± 25.55

[a] Indicates Non-Certified Value
[b] Sample size for zinc was 12
[c] N/A = Not Available

cent sediment analyses have also revealed long term metal and trace element enrichment at several locations within the Pamlico River environs (Riggs *et al.* 1989).

The above evidence suggests a link between the occurrence of shell disease among Pamlico River blue crabs and exposure to sediments containing high levels of metals and trace elements. We tested this hypothesis by quantifying metal and trace element content in the tissues of three groups of crabs: (1) diseased crabs (*i.e.*, bearing cuticular lesions) from a contaminated area (Pamlico River); (2) non-diseased crabs (*i.e.*, without any overt indications of shell disease) from a contaminated area; and (3) non-diseased crabs from a relatively uncontaminated area (Albemarle Sound).

This study is the first to determine metal and trace element concentrations in crustaceans showing symptoms of shell disease. In addition, this study is unique with regard to the number of elements analyzed (cf. Engel and Brouwer 1984; Kneip and Hazen 1979; Sanders 1984). Element concentrations were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES). Our method and instrumentation permitted as many as 24 elements to be quantified simultaneously from a single sample. Typically, trace metal analyses of crustaceans are conducted by flame atomic absorption spectrometry (FAAS); FAAS limits measurements to one element at a time, although detection limits for some elements are lower than those determined by ICP-AES.

Materials and Methods

Element concentrations were determined in gill, hepatopancreas (digestive gland), and muscle (cheliped and fifth pereopod) in diseased and non-diseased crabs from a contaminated environment, and in non-diseased crabs from an uncontaminated area. Crabs were obtained from a crab dealer during October and November, 1989 and during May and June, 1990. All crabs were free of external sediment, and were kept frozen until tissue extraction. All tissue was removed by plastic forceps, and stored in 50 ml polystyrene centrifuge tubes at −20°C. Forty-eight crabs were used in each group in the Fall 1989 collection.

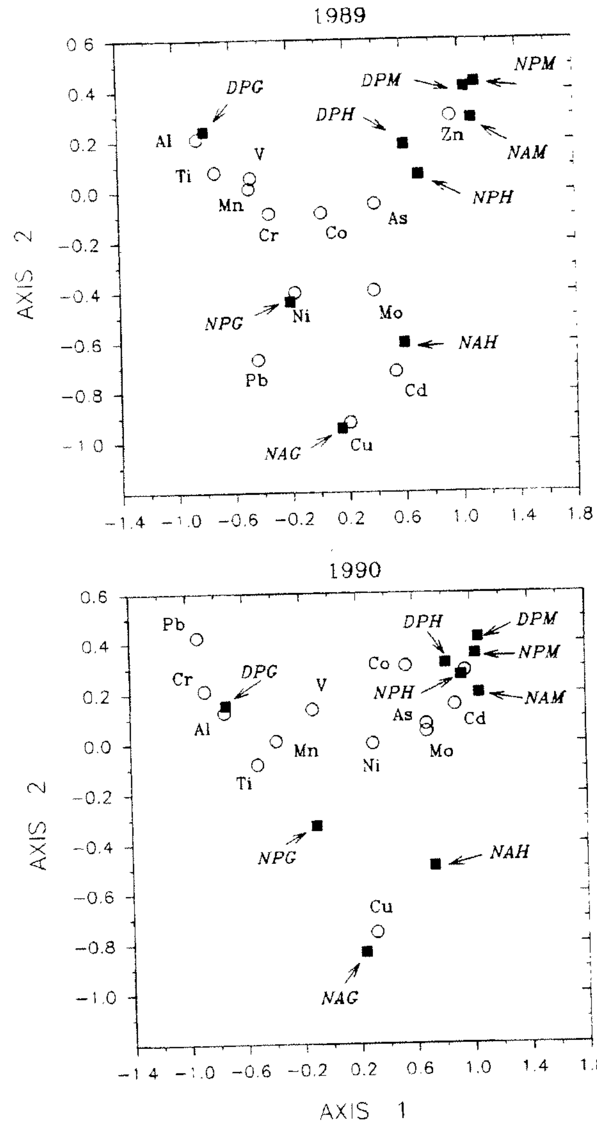

Fig. 1. Correspondence analysis ordination of metal and trace element burdens of tissues from diseased and non-diseased blue crabs collected during fall 1989 (upper graph), and summer 1990 (lower graph). Arrows point to combinations of crab group and tissue; open circles pertain to individual elements. DP = diseased Pamlico; NP = non-diseased Pamlico; NA = non-diseased Albemarle; G = gill; H = hepatopancreas; M = muscle

Within each group, tissue samples from three individuals were pooled to yield a sample size (n) of 16 per tissue type. Pooling was not done for crabs collected in 1990. Thirty crabs were used in each group, giving a sample size of 30 per tissue type.

All samples were lyophilized, using a Labconco Freeze-Dry System and subsequently homogenized with a plastic spatula. Samples were digested using a nitric acid-hydrogen peroxide digestion procedure.

Tissue burdens of elements were determined by ICP-AES using a Jarrell-Ash Plasma AtomComp (Mark II System) modified with the Ward Scientific, Ltd., and MDA (Multiple Data Acquisition and WICS) hardware and software upgrades. Analyses were made with a six-point exposure of all element profiles simultaneously in order to provide on-peak and off-peak (baseline) readings for each element. The system was calibrated with the appropriate matrix matched multi-element standards and corrections were made for potential spectral

Table 2. Student-Newman-Keuls comparisons of element content in gill tissue of blue crabs collected during 1989 and 1990. Underlined groups are not significantly different ($\alpha = 0.05$). DP = diseased Pamlico; NP = non-diseased Pamlico; NA = non-diseased Albemarle

Fall 1989 (N = 16)

Element	Mean	Crab Group (µg/g dry wt.)	
Al	DP	NP	NA
	1273.3	216.6	70.3
As	DP	NP	NA
	8.08	4.46	3.45
Cd	NA	DP	NP
	0.70	0.63	0.27
Co	DP	NP	NA
	0.92	0.36	0.21
Cr	DP	NP	NA
	1.25	0.64	0.11
Cu	NA	NP	DP
	302.48	207.92	102.26
Mn	DP	NP	NA
	435.65	87.34	76.21
Mo	DP	NP	NA
	0.43	0.30	0.27
Ni	NP	DP	NA
	1.32	0.89	0.22
Pb	NP	DP	NA[a]
	7.35	1.94	−0.33
Ti	DP	NP	NA
	15.71	3.76	1.56
V	DP	NP	NA
	2.85	0.91	0.20
Zn	DP	NA	NP
	110.56	100.80	96.54

Summer 1990 (N = 30)

Element	Mean	Crab Group (µg/g dry wt.)	
Al	DP	NP	NA
	1454.0	238.6	89.5
As	DP	NP	NA
	5.43	3.39	2.48
Cd	DP	NP	NA
	1.08	0.87	0.63
Co	DP	NP	NA
	1.18	0.67	0.19
Cr	DP	NP	NA
	1.34	0.15	0.04
Cu	NA	NP	DP
	227.25	178.49	131.17
Mn	DP	NP	NA
	281.24	79.17	35.84
Mo	DP	NP	NA
	0.45	0.31	0.21
Ni	DP	NP	NA
	0.96	0.52	0.35
Pb	DP	NP*	NA*
	1.11	−0.23	−0.29
Ti	DP	NP	NA
	23.59	3.27	2.05
V	DP	NP	NA
	2.19	0.43	0.27
Zn	NP	DP	NA
	107.33	94.02	85.79

[a] Mean concentration was below limit of detection

interferences involving Fe, Al, P, Zn, Ca, and Cu. Quantitative analysis was performed on twenty-four elements. Controls included acid digested blanks, National Institute of Standards and Technology (NIST) (formerly the National Bureau of Standards) Standard Reference Material (SRM-1566 Oyster Tissue), and several internally prepared reference standards.

Measurement of 24 elements in three tissues in three categories of crabs over a period of two years generates a large and complex data set. We have therefore limited our statistical analyses to 13 of the 24 elements examined in order to reduce the size and complexity of the data matrix, and in order to minimize difficulties in interpreting the data. The 13 elements included in the statistical analyses were some of those: (1) designated by the USEPA as toxic (arsenic, cadmium, chromium, copper, nickel, lead, and zinc); (2) occurring at high levels in the Pamlico River sediments (molybdenum, manganese, titanium, and vanadium) (Riggs *et al.* 1989), and (3) occurring at high concentrations within the phosphate ore being mined locally (nickel and cobalt) (Ellington 1984). Elements eliminated were the macronutrients and those trace elements for which the analytical quality may have been in question. A novel chemometric technique designed to enable statistical analysis of the 3-mode data array of all 24 elements is the subject of another report (Gemperline *et al.* 1992).

Statistical analyses consisted of an ordination technique (correspondence analysis) and standard analyses of variance and *a posteriori* contrasts (Student-Newman-Kuels). Correspondence analyses (COA) were carried out using mean values of each element. COA estimates similarities between sampling units, such as metal content and crab tissue type. Hence this technique can be used to delineate associations between specific metals and the tissues of diseased and non-diseased crabs. Similarity is denoted by the extent of proximity of two or more sampling units when these units are positioned relative to one or more coordinate axes.

Analyses of variance were carried out with log-transformed or inverse square root-transformed data. Data for cobalt were not normalized using these transformations, and were therefore analyzed using the non-parametric Kruskal-Wallis Analysis of Variance and Mann-Whitney U Test to characterize crab group effects for a specific metal and tissue type. All analyses other than the COA were done using both CSS:Statistica (Statsoft, Inc.), and SYSTAT software. COA were carried out using Anthropac software.

Control values of all elements except chromium and nickel were similar to the corresponding NIST Reference Standards (Table 1). The chromium and nickel controls were low compared to the NIST values in both the 1989 and 1990 analyses. The concentrations of these elements have not been corrected for these discrepancies because the primary objective of this study was to determine if relative differences in metal tissue burdens existed among the groups of crabs.

Results

Metal and trace element content of the crabs varied markedly as a function of tissue analyzed. The COA show clear separations between gill, hepatopancreas, and muscle tissues for all crabs collected in both 1989 and 1990 (Figure 1). Albemarle crabs were distinct from Pamlico crabs with regard to the metal content of their hepatopancreas, and all three groups of crabs

Table 3. Student-Newman-Keuls comparisons of element content in hepatopancreas tissue of blue crabs collected during 1989 and 1990. Underlined groups are not significantly different ($\alpha = 0.05$). DP = diseased Pamlico; NP = non-diseased Pamlico; NA = non-diseased Albemarle

Fall 1989 (N = 16)

Element	Mean	Crab Group (µg/g dry wt.)	
Al	DP 14.55	NP 5.07	NA 4.76
As	DP 6.40	NA 4.13	NP 4.10
Cd	NA 2.91	DP 1.16	NP 0.56
Cr	NP 0.19	NA 0.16	DP 0.13
Co	DP 0.48	NP 0.40	NA 0.21
Cu	NA 87.81	NP 43.80	DP 28.65
Mn	DP 47.34	NP 39.01	NA 16.99
Mo	NA 0.61	NP 0.57	DP 0.47
Ni	NP 0.29	DP 0.23	NA 0.15
Pb	DP[a] −0.49	NA[a] −0.55	NA[a] −0.62
Ti	DP 0.40	NP 0.34	NA 0.16
V	NP 0.38	DP 0.35	NA 0.17
Zn	NP 157.84	DP 151.12	NA 89.34

Summer 1990 (N = 30)

Element	Mean	Crab Group (µg/g dry wt.)	
Al	DP 20.65	NP 19.99	NA 9.67
As	NP 7.15	DP 6.33	NA 5.08
Cd	NP 4.81	DP 3.61	NA 2.33
Cr	NP[a] 0.00	DP[a] −0.09	NA[a] 1.66
Co	NP 1.75	DP 1.21	NA 0.27
Cu	NA 99.51	NP 52.86	DP 29.74
Mn	DP 25.17	NP 19.86	NA 14.21
Mo	NP 0.91	DP 0.72	NA 0.49
Ni	NP 0.72	DP 0.49	NA 0.21
Pb	NP[a] 0.38	NA[a] −0.31	DP[a] −0.31
Ti	NP 0.54	DP 0.65	NA 0.39
V	NP 0.69	DP 0.44	NA 0.21
Zn	NP 243.94	DP 166.00	NA 105.74

[a] Mean concentration was below limit of detection

showed marked differences in the metal content of their gill tissue. Comparatively minor differences in the metal content of the muscle tissue were observed among crab groups.

The correspondence analyses also link particular elements to tissue type and crab groups. Thus, gill tissue is distinguished by its levels of aluminum, titanium, manganese, vanadium, chromium, nickel, lead and copper. Furthermore, gill tissue from diseased Pamlico River crabs is particularly associated with the first four of these metals, while gill tissue of Albemarle crabs is associated with copper (Figure 1). Similarly, hepatopancreas is distinguished by its concentrations of cadmium, molybdenum, and arsenic. Hepatopancreas tissue from both diseased and healthy Pamlico crabs was strongly affiliated with arsenic in 1989, and with all three elements in 1990. Muscle tissue is distinguished by its zinc concentration, and the absence of any consistent linkage with a specific crab group.

Details of the relationships between particular elements, tissues, and crab groups are provided by the ANOVAs, and the *a posteriori* contrasts (Tables 2–4). Concentrations of all thirteen elements differed significantly among tissues and among crab groups. Interactions between tissues and groups were significant for all elements except copper, indicating that for these elements, relative differences in content among crab groups varied with the type of tissue (Figure 2).

Plots of tissue burdens as a function of crab group (=ANOVA interactions) show that elements associated with a specific tissue and crab group according to the COA are found in highest concentration in that tissue (aluminum and gill, cadmium and hepatopancreas, zinc and muscle), and crab group (aluminum and diseased Pamlico crabs, copper and Albemarle crabs) (Figure 2). Gills of diseased Pamlico crabs were denoted by levels of aluminum, cobalt, chromium, manganese, titanium and vanadium which were 6–16 times higher than those of Albemarle crabs, and a copper concentration approximately one half that of Albemarle crabs. Arsenic, lead, molybdenum and zinc were also significantly more concentrated in diseased crabs than in Albemarle crabs. Levels of metals in the gills of non-diseased Pamlico crabs were usually intermediate between these two extremes, and always significantly greater than those of the Albemarle crabs (Table 2). Lead was an exception to this trend; the concentration of lead in the gills of non-diseased Pamlico crabs in 1989 was at least three times higher than that in any other crab group during either 1989 or 1990.

Table 4. Student-Newman-Keuls comparisons of element content in muscle tissue of blue crabs collected during 1989 and 1990. Underlined groups are not significantly different ($\alpha = 0.05$). Cr, Mo, Ni, Pb, and V were omitted because their concentrations were below the limit of detection for both 1989 and 1990. DP = diseased Pamlico; NP = non-diseased Pamlico; NA = non-diseased Albemarle

FALL 1989 (N = 16)

Element	Mean	Crab Group (μg/g dry wt.)	
Al	DP 7.15	NP 2.92	NA 1.61
As	DP 3.54	NP 3.28	NA 1.86
Cd	NA[a] 0.07	DP[a] 0.06	NP[a] 0.05
Co	DP[a] 0.05	NP[a] 0.01	NA[a] 0.01
Cu	NA 52.78	DP 28.57	NP 23.60
Mn	DP 13.58	NP 3.87	NA 3.56
Ti	DP 0.14	NP[a] 0.10	NA[a] 0.06
Zn	NA 329.91	DP 301.91	NP 291.80

SUMMER 1990 (N = 30)

Element	Mean	Crab Group (μg/g dry wt.)	
Al	NP 8.16	DP 7.23	NA 5.47
As	NP 2.12	DP 1.94	NA 1.58
Cd	NP 0.15	NA 0.13	DP 0.11
Co	NP 0.13	DP 0.08	NA[a] 0.02
Cu	NA 46.54	NP 28.65	DP 22.37
Mn	NP 9.47	DP 9.23	NA 4.34
Ti	NP 0.12	NA 0.10	DP 0.09
Zn	NA 178.82	NP 169.07	DP 163.94

*Mean concentration was below limit of detection

Most of the elements found in high concentrations in the gills of diseased crabs were also present at high levels in the hepatopancreas of these crabs. Thus diseased crabs had significantly greater levels of aluminum, arsenic, cobalt, manganese, titanium, vanadium, and zinc in their hepatopancreas than did Albemarle crabs (Table 3). Non-diseased Pamlico crabs also showed significantly higher concentrations of cobalt, titanium, vanadium, and zinc than did Albemarle crabs. Levels of aluminum, arsenic and manganese in healthy Pamlico crabs typically exceeded those in Albemarle crabs, but the differences were not significant during either 1989 or 1990. Levels of copper in diseased Pamlico crabs, and non-diseased Pamlico crabs were again a fraction of those of Albemarle crabs (Table 3; Figures 2,3).

Metals which lacked this correspondence in concentration between gill and hepatopancreas tissue were chromium, lead, and molybdenum. Chromium concentrations in the hepatopancreas were similar in diseased crabs and Albemarle crabs in 1989, and were undetectable in all crab groups the following year (Table 3). Lead was undetectable in the hepatopancreas in all groups during both 1989 and 1990. Molybdenum content of the hepatopancreas was inconsistent between years, being highest in Albemarle crabs in 1989, and highest in healthy Pamlico crabs in 1990.

Differences in metal and trace element content of muscle between diseased crabs and Albemarle crabs were limited to the signficantly higher concentrations of manganese, and the significantly lower levels of copper, in the diseased crabs (Table 4). Aluminum and arsenic were significantly elevated in Pamlico crabs relative to Albemarle crabs, but the group of Pamlico crabs with the greatest levels of these elements varied between years. Levels of zinc fluctuated widely in all groups of crabs between 1989 and 1990. The remaining elements (cadmium, cobalt, molybdenum, and titanium), were below the limit of detection for all crabs in 1989, and occurred at the highest levels in the healthy Pamlico crabs the following year.

Discussion

The findings indicate that metal and trace element burdens of diseased blue crabs collected from a contaminated environment (Pamlico River) were substantially higher than those of nondiseased crabs collected from a relatively uncontaminated environment (Albemarle Sound). Tissue burdens of non-diseased crabs from the Pamlico River either fell between these two extremes, or were similar to those of diseased crabs.

Fewer differences in metal and trace element burdens between the two groups of Pamlico crabs occurred in the 1990 samples than in the 1989 samples. The 1990 samples were collected earlier in the year (June) than were the 1989 samples (November). Differences in collection time between 1989 and 1990 imply different residence times of the crabs in their respective habitats. Blue crabs enter estuaries as post-larvae ("megalopa" stage), and colonize the upper regions of estuaries as juveniles (Van Engel 1957; Epifanio 1988; McConaugha 1988). All crabs used in this study were obtained from upstream locations within the Albemarle-Pamlico Estuary. Hence annual variations in metal burdens may reflect differences in the length of time the crabs were exposed to contaminated sediments prior to the time of collection.

Diseased crabs were distinguished by highly elevated gill tissue burdens of aluminum, arsenic, cobalt, manganese, titanium and vanadium during both 1989 and 1990. These elements are found in high concentrations in the Pamlico River sediments (Harding and Brown 1976; Riggs *et al.* 1989). The disproportionately high levels of these elements in the gills of diseased crabs may have resulted in part from direct sediment

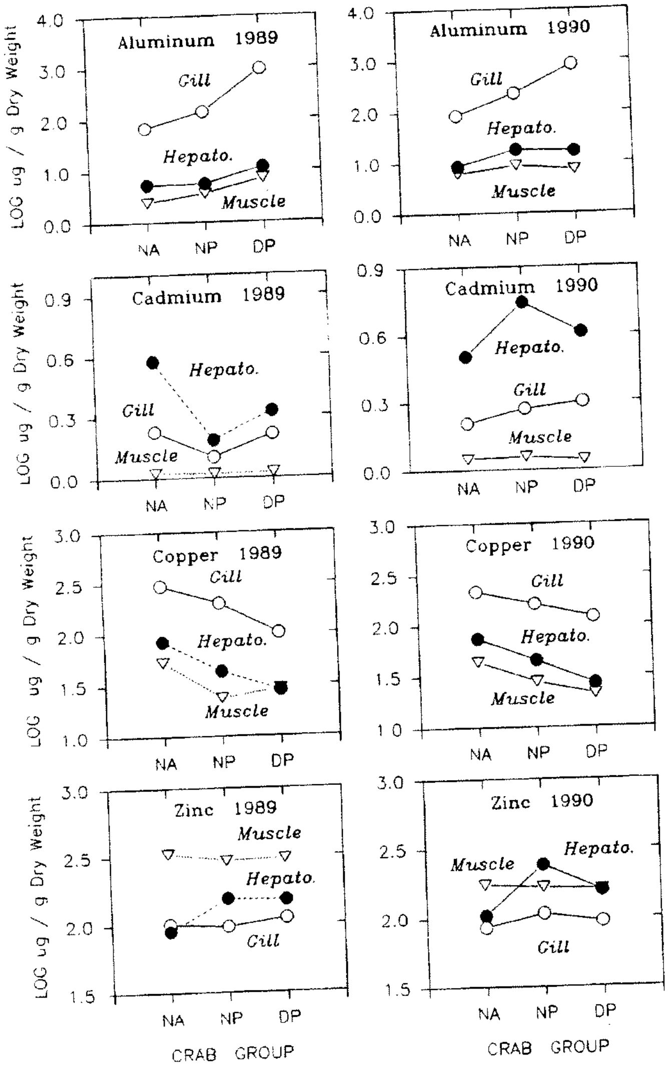

Fig. 2. Concentrations of selected elements in gill, hepatopancreas (hepato.), and muscle of diseased Pamlico crabs (DP), non-diseased Pamlico crabs (NP), and non-diseased Albemarle crabs (NA) during fall 1989 and summer 1990. Non-parallel lines between tissue types indicate an interaction between tissue type and crab group

Table 5. Estimated excessive amounts of muscle for human consumption from blue crabs obtained in the Pamlico River estuary. Mean muscle concentrations are the highest mean from either healthy or diseased crabs from the Summer 1990

Element	Adult (70 Kg) excessive daily intakes (μg/day)[a]	Summer 1990 Mean muscle conc. (μg/g dry weight)	Excessive consumption of muscle (g dry weight)
Cd	71[b]	0.15	473
As	not established[b]	2.12	—
Cr	200	−0.14[c]	—
Cu	5,000	28.65	174
Mn	10,000	9.47	1,055
Zn	15,000	169.07	89

[a] National Academy of Sciences-National Research Council, 1989
[b] World Health Organization, 1972
[c] Concentration below limit of detection

contamination, given that the diseased crabs sampled had lesions which often penetrated the entire integument, and were located over the gill chamber. However, the same elements were also present in substantial quantities in the gills of non-diseased crabs from the contaminated environment, and in the hepatopancreas of both groups of crabs from this environment. Thus the high concentration of these elements in crabs from an environment with high levels of metals and trace elements cannot be easily dismissed as an artifact of direct sediment contamination of tissues. Aluminum, arsenic and manganese were also found in significantly higher concentrations in the muscle of both groups of crabs from the contaminated environment compared to crabs from the uncontaminated environment.

Toxic levels of metals or trace elements could promote shell disease by causing physical degradation of the tissue (hypodermis) which secretes the cuticle, or by impairing either the synthesis of new cuticle or the process of wound repair. In this context, arsenic is potentially the most important trace element pollutant found in the tissues of Pamlico River crabs. Arsenic is toxic to freshwater fishes at concentrations as low as 1.3 μg/L (Salila and Segar 1979). Short term exposure (96 hours) to higher concentrations (17 μg/L) can produce degenerative changes to crab gill hypodermis and hepatopancreas tissue (Krishnaja *et al.* 1987).

Lead and cadmium have deleterious effects on the general body surface or gill epithelia of crustaceans (Couch 1977; Nimmo *et al.* 1977; Williams and Duke 1979; Krishnaja *et al.* 1987). Both of these metals represent anomalies within this study. High levels of lead were found just in the gills of non-diseased Pamlico crabs only in 1989. Elevated levels of cadmium were not consistently found in the tissues of diseased crabs, despite the fact that Pamlico River sediments are enriched with cadmium (Riggs *et al.* 1989). The causes of these anomalies are unclear. Nevertheless, there is no strong evidence of either lead or cadmium involvement with the local outbreak of shell disease.

Other elements accumulated by Pamlico River crabs could play an indirect role in the etiology of shell disease. The effects of aluminum on the crustacean hypodermis have not been well studied. However, in mammals, exposure to aluminum hydroxide can alter normal calcium metabolism, resulting in a loss of calcium from bone (Spencer *et al.* 1981). Interference with the normal process of calcification during formation of the cuticle in crabs could produce a structurally weakened shell more vulnerable to injury, and thus more susceptible to degradation by chitinoclastic fauna.

Levels of copper in both diseased and non-diseased crabs from the Pamlico River were ½ to ⅓ of that found in non-diseased Albemarle crabs for all tissues. Copper is a highly regulated metal in crustaceans; 50–60% of the total copper content is bound to the respiratory pigment hemocyanin, where it functions to reversibly bind oxygen (Engel 1987; Engel and Brouwer 1984; Depledge and Bjerregaard 1989). Hemocyanin content of blue crabs from the Pamlico River is approximately ½ that of crabs from uncontaminated areas in Core Sound, N.C. (Noga *et al.* 1990). Disturbances in normal copper metabolism could reduce overall health of the crabs by lowering hemocyanin levels and thereby impairing oxygen transport to the tissues. Other work has indicated that both diseased and non-diseased Pamlico crabs were clearly "unhealthy" compared to Albemarle crabs in terms of behavior, survival, hemocyte levels, and wound repair capability (Weinstein 1991). Hence, shell disease may be a manifestation of poor health due to impaired copper metabolism.

Zinc is also highly physiologically regulated in crustaceans (Rainbow 1985). It is an important constituent of enzymes involved in calcification (carbonic anhydrase) (Zatta 1984; Henry and Kormanick 1985), and plays a critical regulatory role in muscle contraction in crustaceans (Depledge 1989). Pamlico crabs had significantly higher zinc concentrations in the gills and hepatopancreas than did the Albemarle crabs. Nevertheless, these concentrations were within the range of normal concentrations reported by other workers (Hall *et al.* 1978; Engel and Brouwer 1984; Eisenberg and Topping 1984; Sanders 1984).

Nickel and vanadium are considered relatively non-toxic to marine invertebrates (Mance 1987). Toxicity and cellular effects of cobalt, manganese and titanium on crustaceans are largely unknown (Eisler 1981; Mance 1987).

The above inferences concerning metal burdens and shell disease are severely constrained given the paucity of information on toxicity levels, ionic form, route of entry, and pathological effects of most of these elements for aquatic invertebrates. Much work needs to be done to delineate their individual and synergistic effects in order to define their contribution to the occurrence of shell disease among the local blue crab population.

None of the metals and trace elements found to be significantly enriched in the edible portion (muscle) of the Pamlico River blue crabs appear to constitute potential health risks to human consumers (Table 5). The excessive daily intakes listed in Table 5 are considered toxic only if maintained for long periods of time (National Academy of Sciences-National Research Council 1989). Acutely toxic levels of these elements are several times higher than those found in the crabs sampled. Cadmium is of particular interest because it can accumulate in seafood and become potentially toxic to humans. The "average" blue crab meal consists of the muscle from 6 adult crabs and weighs approximately 240 g wet weight (O'Conner 1983), or roughly 57 g dry weight. However, these results indicate that even three average crab meals per day would be below the excessive intake level of cadmium.

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Assessment of function in an oligohaline environment: Lessons learned by comparing created and natural habitats

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Abstract

Assessments of nursery area function were carried out over a 10-year period in a 3-ha oligohaline marsh and creek system ('Project Area 2') and four natural 'control' creeks (Drinkwater, Jacks, Jacobs, and Tooley) located in the Pamlico River estuary, North Carolina. Habitat function was assessed by comparing (1) growth and survival of fish; (2) long-term monitoring of water quality, sediment organic carbon, and the benthic infaunal community; and (3) measurement of benthic food availability. Growth (weight gain) and survival of the fish *Leiostomus xanthurus* held within enclosures were similar in both created and natural habitats. Species composition, total fauna density, and species richness of the infaunal community of the Project Area and the natural creeks were comparable within 3 years after construction of the Project Area. However, the sediments of the Project Area lacked the woody detrital cover, high peat content, and predominance of silt and clay characteristic of the natural creek sediments. There was no evidence of significant accretion of total organic carbon in the Project Area during the course of the study. This study has heuristically inspired four recommendations concerning assessment criteria of mitigation success. (1) Direct experimentation is needed to assess habitat function for motile species such as fish. (2) Studies of community structure need to be carried out long enough to permit testing of community stability, especially when working in areas exposed to stochastic abiotic and biotic stressors. (3) Measurements of nutritional content of the sediments should include estimates of overall organic quantity and nutritional quality. (4) Site design or restoration techniques should be included in the experimental design of each mitigation effort. Specifically, the lack of replication in these aspects of the mitigation process limits the inferential potential of the study, constrains the ability to make accurate predictions about the probability of success of future mitigation endeavors, and impedes our understanding of the critical mechanisms governing successful habitat creation, restoration, and enhancement.

Keywords: Mitigation; Oligohaline; Fish; Benthic infauna; Sediment; Organic carbon; Biological protein

1. Introduction

Increasing development of wetlands and coastal areas in the United States during the past 20 years

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has fueled concerns about the ecological consequences of the reduction of biodiversity and loss of critical habitats. Coincident with this increasing development has been a growth in the knowledge of, and applied efforts toward, restoring damaged or altered habitats, and creating new habitats to compensate for those lost to human activities (Zedler, 1988; Race and Fonseca, 1996).

Efforts to remediate habitat alteration or loss have met with mixed results with 'failures' and inconclusive efforts greatly outnumbering 'successes'. The lack of success in mitigation has resulted from (1) improper construction or implementation of mitigation efforts; (2) non-compliance with permitting goals, objectives, and guidelines; (3) insufficient time frame for monitoring; (4) inadequate knowledge of forces structuring natural communities; and (5) inadequate knowledge of local ecosystem function (Zedler, 1988, 1996; Mitsch and Wilson, 1996; Race and Fonseca, 1996).

Such 'failures' have taught that criteria for determining 'success' of habitat remediation may focus on inadequate measures of the salient ecological processes that drive spatial and temporal change in the natural communities. Success is generally viewed in terms of a system's biological viability and sustainability. Indices of success commonly include species lists and measures of abundance, biomass or percent cover over time, sedimentary features (e.g. concentrations of organic carbon and nitrogen, porosity, chlorophyll, grain size), and measures of relevant abiotic variables (temperature, dissolved oxygen, salinity for aquatic systems). These indices have been favored because they are simple and relatively inexpensive to carry out, but they have been subject to criticism because the sampling may have been occasional, of short overall duration, and with little evidence of prior knowledge of the most ecologically suitable timing; moreover, the indices themselves may not be sufficient tests of ecosystem function (Mitsch and Wilson, 1996).

In this paper, we present both experimental and correlative work that (1) links traditional success criteria of (a) patterns of species abundance and (b) sedimentary organic carbon levels with habitat function; and (2) evaluates the importance of time as an element of mitigation research. All work was carried out during 1985–1995 in four natural and one created non-tidal oligohaline subtributaries of the Pamlico River estuary, North Carolina, USA. We link patterns of faunal abundance with habitat function by comparing the capability of natural and created habitats to support the growth of fish (*Leiostomus xanthurus* Lacepede) that prey on resident benthic invertebrate infauna (Tenore, 1972a; West and Ambrose, 1992). We evaluate the utility of sedimentary organic carbon as a predictor of habitat viability by comparing infaunal abundance and two separate measures of putative food availability; total organic carbon and nitrogen, and 'biologically available protein' (BAP). We assess the role of time by delineating the influence of 'predictable' periodic stressors (salinity) and novel stressors (invasion by the vascular plants *Myriophyllum spicatum* L. [Eurasian watermilfoil], and *Ruppia maritima* L. [widgeon grass]) on infaunal community structure.

2. Methods

2.1. Site description

All work was carried out in a single created 3-ha oligohaline marsh ('Project Area 2') and four adjacent natural oligohaline creeks (Drinkwater, Jacks, Jacobs, and Tooley) located in the Pamlico River estuary, North Carolina (Fig. 1). Project Area 2 is about half to one-fourth the area of the natural creeks (Table 1, North Carolina Phosphate Corporation, 1982). The land converted to the Project Area was originally a lowland forest of mixed hardwoods identical to those that border the undeveloped subtributaries of the Pamlico River estuary. The Project Area was constructed during 1980–1981 by North Carolina Phosphate Corporation. Four species of emergent vascular plants (*Juncus roemarianus* Scheele, *Spartina patens* (Aiton) Muhl., *Spartina cynosuroides* (L.) Roth, and *Spartina alterniflora* Loisel) were planted during 1981. In 1983, the earthen dam

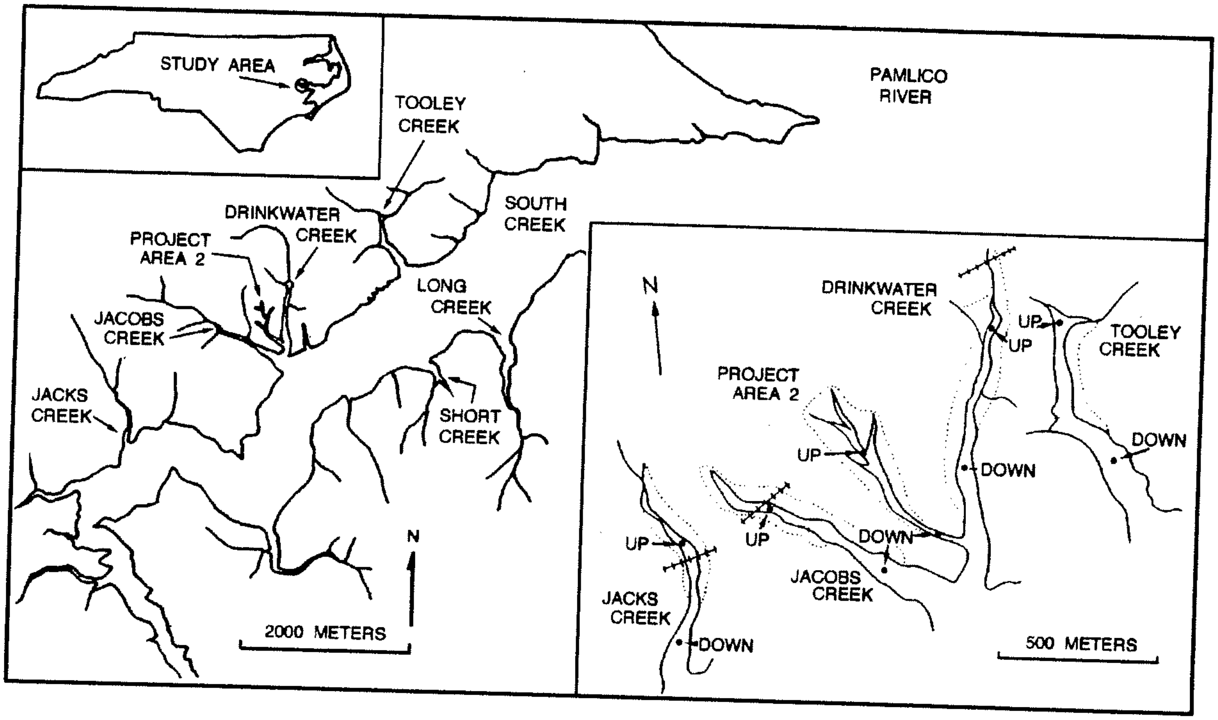

Fig. 1. Location of the sampling stations (upstream, downstream), Project Area 2, and the natural 'control' creeks (Tooley, Drinkwater, Jacobs, Jacks) in the Pamlico River estuary, North Carolina.

was removed that separated the Project Area from the confluence of Drinkwater and Jacobs creeks.

2.2. Water quality

Bottom temperature, salinity, and dissolved oxygen were measured with Yellow Springs Instruments recorders. Water quality measurements were taken at approximately monthly intervals throughout the study period. Water depths ranged from 0.3 to 1.8 m depending upon sampling station (upstream is shallower) and prevailing winds (southwesterlies produce high water levels; Pietrafesa et al., 1986). Continuous recording water quality meters were installed at the downstream sites of the Project Area and Drinkwater creek for a 7-day period in April and May 1995. Temperature, conductivity, and dissolved oxygen were measured at 15-min intervals during this 7-day period using a Yellow Springs Instruments PC6000 submersible environmental monitor.

2.3. Collection of invertebrates

Subtidal benthic samples (0.02 m^2) were taken using an Ekman or Ponar grab from upstream and downstream locations in Tooley creek, Drinkwater creek, and Jacks creek, and in Project Area 2 (Fig. 1). During 1985–1988, three samples were collected from a single site at each upstream and downstream location; during 1989–1995,

Table 1
Areal comparisons of Project Area 2 and the natural creeks involved in this study[a]

Creek	Open water	Marsh surface	Total
Jacks	2.63	2.88	5.51
Jacobs	6.78	5.61	12.39
Drinkwater	5.12	4.17	9.29
Tooley	4.98	4.99	9.97
Project Area 2	0.81	2.23	3.04

[a] All listed values are in hectares and are taken from North Carolina Phosphate Corporation (1982).

three samples were collected from each of two sites at both upstream and downstream locations. The sampling sites were located near the middle of the creek within each location, and sampling depths ranged from 0.3 to 2.5 m. Sampling was done quarterly (January, April, July, October) beginning in July 1985 and ending in July 1995. Samples were sieved in the field through a 0.5 mm mesh, and the residue was preserved in 10% formalin containing 0.1 g/l of Rose Bengal stain. Infauna were separated, counted, and identified to the lowest practical taxon in the laboratory, and subsequently stored in 70% *iso*-propanol.

2.4. Fish growth experiments

Fish growth experiments were carried out in May (29 May–13 June) and July (24 July–9 August), 1985. Juvenile *L. xanthurus* ('spot') were collected in 30–60 s trawls using a 3.9 m two seam otter trawl of 6.3 mm bar mesh equipped with a cod-end bag of 3.1 mm mesh. Collected fish were held overnight in an enclosure to allow for expression of latent mortality associated with the stress of capture. During an experiment, fish were contained within circular enclosures (0.9 or 1.9 m diameter) constructed of black plastic netting (Vexar; 6 mm bar mesh), supported on a frame of stainless steel and concrete reinforcing bar. Each enclosure was 1.2 m high and covered with a Vexar top.

Five pairs of cages (one large and one small) were placed in the downstream regions of Project Area 2, Drinkwater creek, and Jacobs creek. The cages were placed in water 0.4–1.0 m deep, and were forced about 20–30 cm into the sediment to prevent fish from escaping and to deter entry of unwanted predators. The cages were initially seined to remove fish inadvertently captured during installation. Eight fish were added to each large cage and two fish were added to each small cage. Thus, each enclosure contained the same number of fish per unit bottom surface area. Each fish had previously been individually marked by fin clipping and weighed while immersed in water (West, 1990a). The order of addition of fish to the cages was randomly determined. The cages were censused by seining after 16 days. Surviving fish were placed in 10% formalin and later weighed in the laboratory. Growth (weight gain) of wild *L. xanthurus* was estimated by taking 90 s trawls in Drinkwater creek at approximately 14 day intervals between March and October.

2.5. Measurement of sediment features

Grain size determinations were made on intact 4 cm (diameter) × 10 cm (depth) cores according the procedures of Folk (1968). Samples were sieved wet using mesh sizes of 2.0 mm (detrital fraction), 0.84 mm (sand fraction), and 0.074 mm (silt and clay fraction). Data are presented as percentage of the total sample weight represented by each size fraction.

In 1995, three intact 6 cm (diameter) by 15 cm (depth) sediment cores were collected from the downstream station of Drinkwater creek and Project Area 2 during January and April. Cores were returned to the lab and immediately sectioned into five separate 1 cm intervals (0–1, 1–2, 2–3, 3–4, 4–5 cm below the sediment–water interface). Each interval was placed in a −20°C freezer until further analysis (within 6 months of sampling). Samples were thawed, dried to a constant mass at 60°C, and ground and homogenized using a mortar and pestle. TOC and nitrogen were then determined using a Control Corporation model 440 elemental analyzer. Acetanilide was used as a standard for all samples. Possible inclusion of inorganic carbon was assessed for each sample interval using the gasometric technique of Schink et al. (1979). No inorganic carbon was found in any of the samples.

Biologically available protein was assessed for surface (0–1 cm interval) and deep (4–5 cm interval) sediment at each site during January and April 1995 according to the technique described by Mayer et al. (1986). This technique determines the content of the smaller, more labile components of the protein pool following a sequence of acidic digestion, enzymatic degradation, serial protein addition, and final analysis of an extensive set of replicates using spectrophotometric detection of Coomassie Blue dye. All data represent the means of three cores, each of which was subsampled four times.

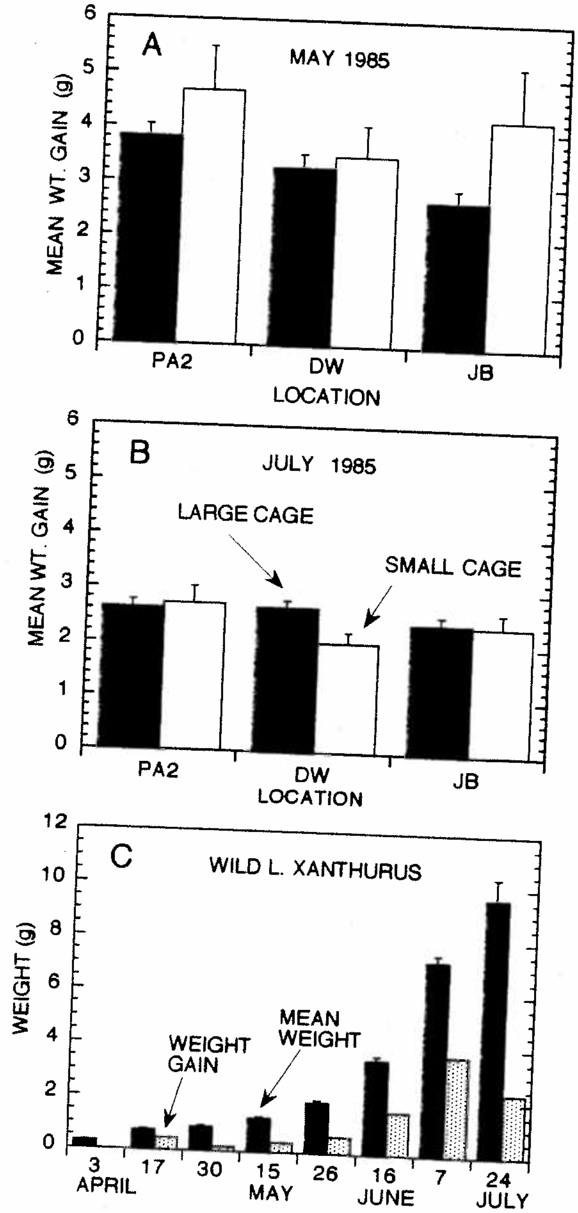

Fig. 2. Weight gain (g) of caged and wild *L. xanthurus* in Project Area 2 (PA 2), Drinkwater creek (DW), and Jacobs creek (JB). (A) May 1985 caging experiment. (B) July 1985 caging experiment. (C) Weight gain and mean weight (g) of *L. xanthurus* trawled at approximately 2-week intervals in Drinkwater creek during 1986. Columns represent mean values + 1 S.E.

Subsequent analyses (West and Clough, in prep.) have shown that wet volume and dry weight of sediment are both required for accurate analysis of sedimentary food concentration. Porosity of the sediment was not determined concurrently with the results being discussed. Instead, corrections for differences in porosity and dry sediment density were made using data obtained at each site during January and April 1997. Porosity was calculated using the wet and dry weights of a known volume of sediment.

2.6. Data analyses

Randomized block analyses of variance (ANOVA's) were carried out to test for creek and cage effects on weight gain and survival of *L. xanthurus*. Survival data were arcsin transformed prior to the ANOVA's. A series of three-way ANOVA's was carried on the infaunal density and species richness data to test for differences due to season (winter, spring, summer, fall), creek (natural vs. created), and location (upstream vs. downstream). Each three-way ANOVA analyzed the data for a single calendar year. A canonical analysis was carried out to test for correlations between infaunal species densities and salinity, and cluster analyses were used to discern temporal and spatial patterns in infaunal community structure. All multi-level ANOVA's and multivariate analyses were done on log $(x+1)$ transformed data. The canonical analyses were done using STATSTICA (StatSoft, Inc. Tulsa, OK); all other data analyses were carried out using DataDesk (Data Description, Inc. Ithaca, NY).

3. Results

3.1. Growth and survival of *L. xanthurus*

Mean weight gain of *L. xanthurus* during May (3–5 g/16 days) was approximately twice as high as that during July (Fig. 2A and B). Weight gain was significantly lower in Jacobs creek than in the Project Area during the May experiment, but differences in weight gain among creeks were not significant during the July experiment. Cage effects were limited to the May experiment, when significantly more growth occurred in the smaller cages in Jacobs creek (Fig. 2A). Weight gain of caged *L. xanthurus* equaled or exceeded that estimated for the ambient wild *L. xanthurus* population during similar time periods and months of the year (Fig. 2A vs. C).

Mean survival was similar among creeks during both experiments, with May values slightly lower than July values. Cage effects on survival were not significant. Mean survival values ranged from 50 to 100%.

3.2. Temporal and spatial patterns of benthic infauna

Data for each of the three natural creeks were pooled in all analyses comparing faunal abundance, diversity, and community structure in created and natural creeks. Data were pooled because (1) the primary issue of this study was whether the abiotic and biotic features of the created creek would fall within the normal range of values exhibited by nearby natural creeks, and not whether it was going to develop to resemble a particular, predesignated creek; and (2) to remain consistent with the symposium theme of assessment of success criteria for habitat restoration. The dynamics of the infaunal communities have been detailed in part in earlier reports (West, 1990b; Ambrose, 1992; Ambrose and Renaud, 1996) and will be dealt with more comprehensively in a future paper.

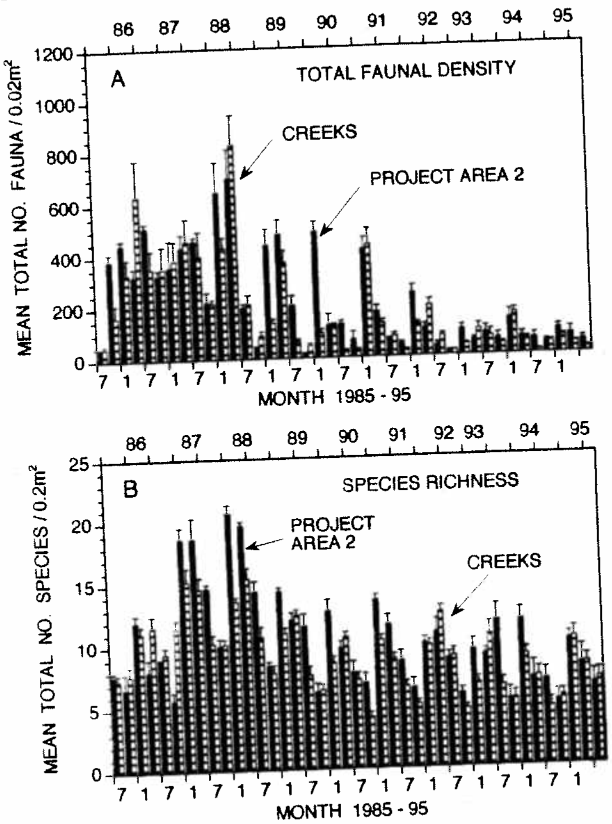

Fig. 3. Temporal variation in mean total faunal density (average total number of infauna/0.02 m^2 sample) and species richness (average total number of infaunal taxa/0.02 m^2 sample) at the downstream locations in Project Area 2 and the natural creeks between July 1985 and July 1995. Columns represent mean values + 1 S.E.

Total faunal density (mean total number of animals/unit area) varied markedly within and between years (Fig. 3A) in both the created and natural creeks. Within a given year, density peaked in the winter, declined sharply between spring and summer, and rose again during the late fall. Winter and spring values showed highly significant differences in all but 1 of the 10-year study (Table 2).

Annual differences in total faunal density were also pronounced. Winter and spring density values generally increased during 1986–1988, varied erratically between 1989 and 1991, and subsequently declined to values one-third to one-sixth of the 1986–1988 values. Summer and fall densities were similarly affected, with densities of individual species diminishing to near zero values in the summer months since 1992 (Fig. 3A).

The temporal and spatial patterns in total numbers of fauna described above were observed in both the Project Area 2 and the natural creeks (Fig. 3A). Summer and fall densities were occasionally significantly lower in the Project Area between 1985 and 1988. However, total densities of the Project Area have equaled or exceeded those of the natural creeks since 1988 (Fig. 3A; Table 2).

Similar annual and seasonal patterns in total faunal density occurred at the upstream and downstream stations in both the Project Area and the natural creeks. Within a single year, densities

Table 2
Selected significant ($P<0.015$) main effects and interactions of the three-way ANOVA's carried out on total faunal density and species richness in Project Area 2 (PA 2) and the natural creeks[a]

Year	Fauna	M	C	M × C × L
1986	Density	1 4 7 10	n.s.	n.s.
1986	Richness	1 4 7 10	n.s.	n.s.
1987	Density	2 4 7 10	n.s.	n.s.
1987	Richness	2 4 7 10	n.s.	n.s.
1988	Density	1 5 7 10	P>N	n.s.
1988	Richness	1 5 7 10	n.s.	n.s.
1989	Density	1 4 7 10	n.s.	n.s.
1989	Richness	1 4 7 10	P>N	n.s.
1990	Density	1 5 7 10	P>N	1 P Dn >1 N Dn
1990	Richness	1 5 7 10	n.s.	n.s.
1991	Density	1 4 7 10	P>N	n.s.
1991	Richness	1 4 7 10	P>N	n.s.
1992	Density	1 4 7 10	n.s.	n.s.
1992	Richness	1 4 7 10	n.s.	n.s.
1993	Density	1 4 7 10	P>N	n.s.
1993	Richness	1 4 7 10	n.s.	n.s.
1994	Density	1 4 7 10	P>N	4 P Up >4 N Up
1994	Richness	1 4 7 10	P>N	4 P Up >4 N Up
1995	Density	1 4 7 10	P>N	4 M Up >4 N UP
1995	Richness	1 4 7 10	n.s.	n.s.

[a] Month (M) numbers underlined are not significantly different. Creek (C) differences are listed as an inequality (P, PA2; N, natural creeks). Significant three-way interactions are limited to those pertaining to the winter (1, 2) or spring (4, 5) months. L, station location; DN, downstream station; Up, upstream location; n.s., not significant.

were typically greater at the downstream stations in each creek.

Species richness (mean total number of species/unit area) showed the same within-year temporal and spatial patterns as described above for total faunal densities. Numbers of species were highest in the winter and fall, and lowest during the summer (Fig. 3B), and fewer species occurred upstream than downstream. However, the pattern of annual variation in species richness differed from that of total density. Species richness attained highest values during 1988 and 1989, but in the succeeding years did not show either the variability or the precipitous decline noted for faunal densities (Fig. 3B vs. A).

Numbers of species in the Project Area were initially lower than the natural creeks, particularly during the summer. However, species richness in both created and natural creeks has remained similar since 1988.

3.3. Community structure

Approximately 50 taxa comprise the infaunal communities of the created and natural creeks (Fig. 4). However, 10 of the 50 taxa accounted for 95% or more of all individuals collected during any year, season, creek, or location within a creek. These taxa consisted of, oligochaetes; the polychaetes *Mediomastus* sp.; *Hobsonia florida* Hartmann; *Laeonereis culveri* Webster; *Capitella* sp.; and *Streblospio benedicti* Webster; chironomid insect larvae; and the amphipod crustaceans *Corophium lacustre* Vanhoffen; *Gammarus tigrinus* Sexton; and *Leptocheirus plumulosus* Shoem. The bivalve *Macoma balthica* L. and the gastropod *Hydrobia* sp. occasionally occurred in high densities in the natural creeks and Project Area 2, respectively. Consequently, differences in community structure among the creeks were derived primarily from temporal and spatial differences in the relative abundance of these species, and not from the absence of particular species.

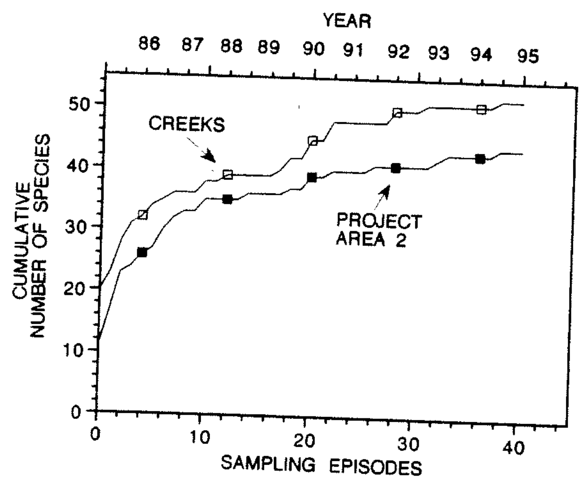

Fig. 4. Cumulative number of taxa collected in Project Area 2 vs. the pooled cumulative number of taxa of the natural creeks during the seasonal sampling schedule ('sampling episodes') between July 1985 and July 1995.

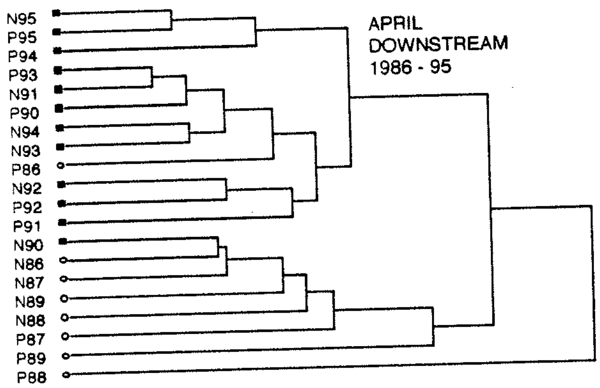

Fig. 5. Cluster analyses of spring infaunal communities of Project Area 2 and the natural creeks between April 1986 and April 1995. Codes indicate creek (*P*, Project Area; N, natural creeks) and year (open symbols, 1986–1989; closed symbols, 1990–1995).

Eight rare taxa were found only in the natural creeks. These taxa were insect larvae (three taxa of unidentified Coleoptera, Diptera), two unidentified crustacean taxa (Isopoda and Cumacea), the crab *Rhithropanopeus harrisii* Gould, and the polychaetes *Glycera dibranchiata* Ehlers and *Neanthes succinea* Frey and Leuckart. These taxa accounted for about 0.06% of the total faunal density for the natural creek fauna.

Cluster analyses of communities during seasons of highest faunal densities and species richness (winter and spring) show strong separation into a 1986–1989 group, and a 1990–1995 group (Fig. 5). This separation reflects the widespread reduction in species densities that occurred between these two time periods, and concomitant changes in the relative abundances of the numerically dominant species. The taxa showing large increases or decreases in relative abundance were virtually the same in the Project Area and the natural creeks. Chironomids, the amphipod *C. lacustre*, and the polychaetes *H. florida* and *S. benedicti* showed large gains in relative abundance, while oligochaetes, the amphipod *L. plumulosus*, and the polychaetes *Mediomastus* sp., and *S. benedicti* showed large declines in relative abundance (Table 3).

3.4. Abiotic variation

Salinity, temperature, and dissolved oxygen (DO) each evinced characteristic seasonal patterns. These patterns were the same in the Project Area and the natural creeks. Salinity usually fell sharply during the spring and rose during the summer to peak in the late fall or early winter (Fig. 6). Temperature was unimodal with a peak in July; values ranged from 6 to > 30°C. Dissolved oxygen varied inversely with temperature, with typical July values falling well below 25% saturation (West, 1990b; West and Ambrose, 1992).

Salinity also varied greatly among years. Three major episodes of salinity change occurred during the course of the study, resulting in fall–winter salinities exceeding 14 ppt during 1985–1986, 1988–1989, and 1994–1995 (Fig. 6). Late fall and early winter represent peak recruitment times for the infauna in the Project Area and natural Creeks (Ambrose, 1992). Canonical analyses were carried out on the relationship between salinity and infaunal density and species richness. The results did not reveal any important correlations and are therefore not presented here.

3.5. Colonization by aquatic vascular plants

M. spicatum (Eurasian watermilfoil) and *R. maritima* (widgeon grass) were first observed in the Project Area during 1989 and were abundant throughout the Pamlico estuary by 1990. Aboveground biomass of both species rose each spring, crested in June and July, and may have completely disappeared by the early fall (Fig. 7A and B). Biomass of both species was similar in the Drinkwater creek, but *M. spicatum* dominated in Project Area 2 (Fig. 7A vs. B).

Abnormally low DO readings (< 1–2 mg/l) became increasingly common during the spring and summer months following the invasion by the submersed aquatic plants, suggesting that the plants were influencing the DO levels. Continuous water quality recorders placed in Drinkwater creek and Project Area 2 during April and May 1995 showed a clear diurnal rhythm in DO concentration (Fig. 7C and D). Concentrations were lowest in the early morning (04:00–09:00) and rose steadily to the highest levels in the evening (17:00–21:00). The magnitude of the oscillation in oxygen content and the variance in diurnal highs and lows were greater during the May series of recordings, particularly in the Project Area (Fig. 7D vs. C). The relatively larger oscillations in DO in the Project Area during May coincided with a two-fold greater increase vascular plant biomass at this site (Fig. 7B vs. A). No diurnal pattern of variability was evident in specific conductivity during the same April and May time periods.

3.6. Features of the benthic sediments

Nearly 70% (by weight) of natural creek sediments consisted of silts and clays (< 0.074 mm), and approximately 30% consisted of sand-sized particles (0.074–0.84 mm; Table 4) in samples collected in 1992. This ratio was nearly reversed in the Project Area, where sand-sized particles accounted for about 60% of the sediment. Comparable particle size distributions were found in samples of natural creek and Project Area 2 sediments collected in 1984 (Craft et al., 1986; Table

Table 3
Changes in the relative abundances of the 12 numerically dominant taxa before (1985–1989) and after (1990–1995) colonization by *Myriophyllum spicatum* and *Ruppia maritima*

Project Area 2	1985–1989	Project Area 2	1990–1995
Taxon	Relative percent	Taxon	Relative percent
Mediomastus sp.	22.6	*Chironomida*	26.9
Hobsonia florida	13.2	*Hobsonia florida*	19.4
Chironomida	10.0	*Capitella* sp.	12.4
Hydrobia sp.	9.9	*Corophium lacustre*	11.3
Oligochaeta	9.4	*Laeonereis culveri*	7.0
Capitella sp.	8.7	*Mediomastus* sp.	4.9
Streblospio benedicti	5.6	*Gammarus tigrinus*	4.6
Laeonereis culveri	5.2	*Oligochaeta*	4.5
Corophium lacustre	3.5	*Polydora ligni*	2.1
Leptocheirus plumulosus	2.5	*Streblospio benedicti*	1.9
Polydora ligni	2.1	*Leptocheirus plumulosus*	1.1
Macoma balthica	2.1	*Macoma balthica*	0.7
Cumulative percent	94.8	Cumulative percent	96.9
Total number of fauna	39 713	Total number of fauna	34 530
Natural creeks	1985–1989	Natural creeks	1990–1995
Taxon	Relative percent	Taxon	Relative percent
Mediomastus sp.	22.8	*Chironomida*	28.3
Oligochaeta	22.6	*Mediomastus* sp.	12.4
Leptocheirus plumulosus	11.3	*Hobsonia florida*	12.2
Capitella sp.	9.6	*Corophium lacustre*	8.2
Hobsonia florida	8.9	*Gammarus tigrinus*	7.0
Chironomida	6.8	*Oligochaeta*	6.9
Streblospio benedicti	6.1	*Capitella* sp.	4.9
Laeonereis culveri	2.9	*Leptocheirus plumulosus*	4.2
Corophium lacustre	1.6	*Laeonereis culveri*	3.3
Macoma balthica	1.4	*Streblospio benedicti*	3.0
Polydora ligni	1.4	*Macoma balthica*	2.7
Macoma phenax	0.7	*Polydora ligni*	1.5
Cumulative percent	96.1	Cumulative percent	94.6
Total number of fauna	88 617	Total number of fauna	56 820

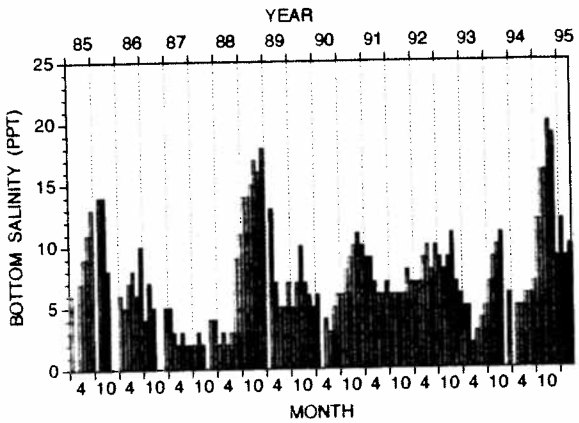

Fig. 6. Temporal variation in bottom salinity of the natural creeks. Samples were taken at approximately monthly intervals between July 1985 and July 1995.

4). Natural sediments also contained large amounts of peat and woody detritus, both of which were absent from the Project Area sediments.

Organic carbon normalized to per g dry weight of sediment was always at least an order of magnitude higher in natural sediments relative to the Project Area sediments (e.g. for the 0–1 cm interval, 13.94% C from Drinkwater creek vs. 0.93% C from Project Area 2 during January 1995; Fig. 8A and C). Samples collected intermittently between 1985 and 1992 showed similar differences in organic carbon levels among the natural creeks and Project Area 2, and the absence of any clear trend of increasing organic carbon content over time for the Project Area sediments (Fig. 9).

Drinkwater creek also contained approximately an order of magnitude more nitrogen than did Project Area 2 (e.g. for the 0–1 cm interval,

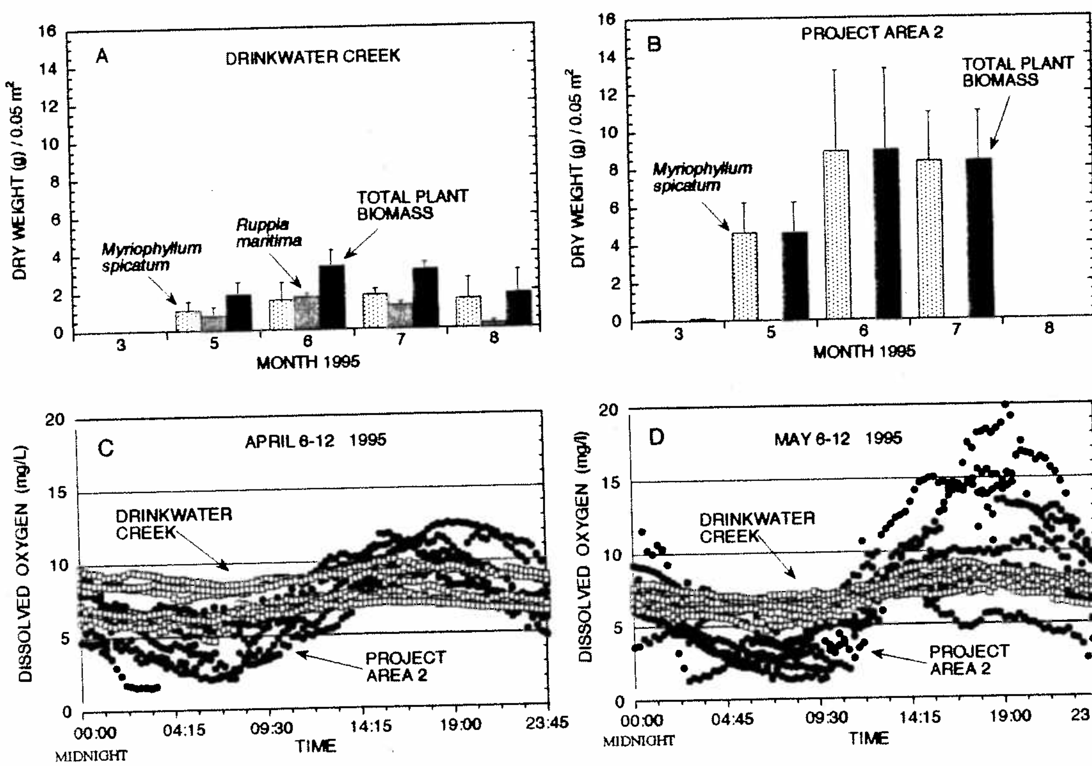

Fig. 7. Seasonal change in biomass of aquatic vascular plants, and diurnal variation in DO concentration, in Project Area 2 and Drinkwater creek. (A) and (B). Individual and combined mean biomass (+1 S.E.) of *Ruppia maritima* and *Myriophyllum spicatum* in Drinkwater creek (A) and Project Area 2 (B) during 1995. (C) and (D). Diurnal change in DO during April 1995 (C) and May 1995 (D).

Table 4
Relative percentage (by weight) of grain sizes of the subtidal sediments of Project Area 2 and the natural creeks

Year	Size class (mm)	Upstream creeks	Upstream PA 2	Reference
1984	>0.5 <2.0	5.85	0.48	Craft et al., 1986
	>0.05 <0.5	33.03	72.38	
	<0.05	60.62	27.12	
1992	>2.00	1.3	0.0	This study
	>0.84 <2.00	0.6	0.0	
	>0.074 <0.84	27.0	63.2	
	<0.074	71.8	35.9	
Year	**Size class (mm)**	**Downstream creeks**	**Downstream PA 2**	**Reference**
1992	>2.00	1.4	0.0	This study
	>0.84 <2.00	0.8	0.0	
	>0.074 <0.84	24.2	59.6	
	<0.074	73.2	41.0	

1.20% N in Drinkwater creek vs. 0.12% in Project Area 2 during January 1995; Fig. 8B and D). Project Area sediment showed the expected downcore decreases in both organic carbon and nitrogen, while organic carbon tended to increase with depth below the sediment–water interface in Drinkwater creek (Fig. 8A and D).

Sediment porosity and dry density also varied between the two locations. Average porosity of the Drinkwater sediments during January 1997 was 0.886, or approximately 90% water (by volume), while the coincident porosity of the Project Area sediments was only 0.673, or approximately 70% water (by volume). In addition, the natural sediments were less dense than the Project Area sediments (1.13 vs. 2.27 g/ml). Thus, in each ml of wet Project Area sediment there were many more particles than there were in each ml of wet Drinkwater sediment.

Normalizing organic carbon and nitrogen values to per g wet sediment has the effect of reducing the magnitude of differences in carbon and nitrogen levels between Drinkwater creek and Project Area 2 sediments relative to the percent dry weight values (Fig. 8E–H). For example, Drinkwater creek sediment contained only about three times the amount of organic carbon of Project Area sediment when normalized to wet volume (e.g. for the 0–1 cm interval, 17.95 vs. 6.87 mgC/ml during January of 1995; Fig. 8E vs. G). Relative differences in organic nitrogen decrease as well (e.g. for the 0–1 cm interval, 1.54 mg/ml for Drinkwater creek vs. 0.89 mg/ml in Project Area 2; Fig. 8F vs. H).

BAP was assessed to provide a better estimate of food quality than total organic carbon and nitrogen, given the large quantities of refractory material (e.g. peat) present in the natural creek sediments. BAP concentration normalized to per g dry sediment in Drinkwater creek was two times greater than in Project Area 2 (1.30 sediment vs. 0.60 mg BAP per g dry; Fig. 10A and B), reinforcing the patterns observed for organic carbon and nitrogen. However, Project Area 2 BAP values normalized to per wet ml of sediment equaled or exceeded those of Drinkwater (1.08 mg BAP per ml wet in Project Area 2 vs. 0.78 mg BAP per ml wet in Drinkwater creek; Fig. 10C and D). Both sites also showed the expected downcore decreases in BAP (Fig. 10).

4. Discussion and conclusions

4.1. *Fish growth and survival experiments*

The fundamental objective of this work was to determine whether created marshes could be a viable solution to the alteration of wetland and subtidal habitat by phosphate mining operations. A critical test in this regard concerned the capacity of the created habitat to emulate the nursery area functions of the ambient natural oligohaline creeks (Weinstein and Brooks, 1983; Miller et al., 1984; Ross and Epperly, 1985). We have presented two lines of evidence that argue for functional equivalence among the Project Area and the natural creeks. First, Project Area 2 developed an infaunal community of abundance and diversity rivaling that of the natural creeks. Second, growth and survival of spot were similar in the Project Area and the natural creeks.

Evidence of persistence of an infaunal community through time indicates utilization of the habitat in several dimensions, i.e. a place sufficient to permit survival, growth, and reproduction. The same cannot be said for motile fauna such as fish that use the habitat when conditions are favorable, but migrate elsewhere as conditions decline. Some form of direct assessment in addition to population surveys is therefore needed to evaluate utilization by the fish community, and we suggest experimentation is needed to accurately assess

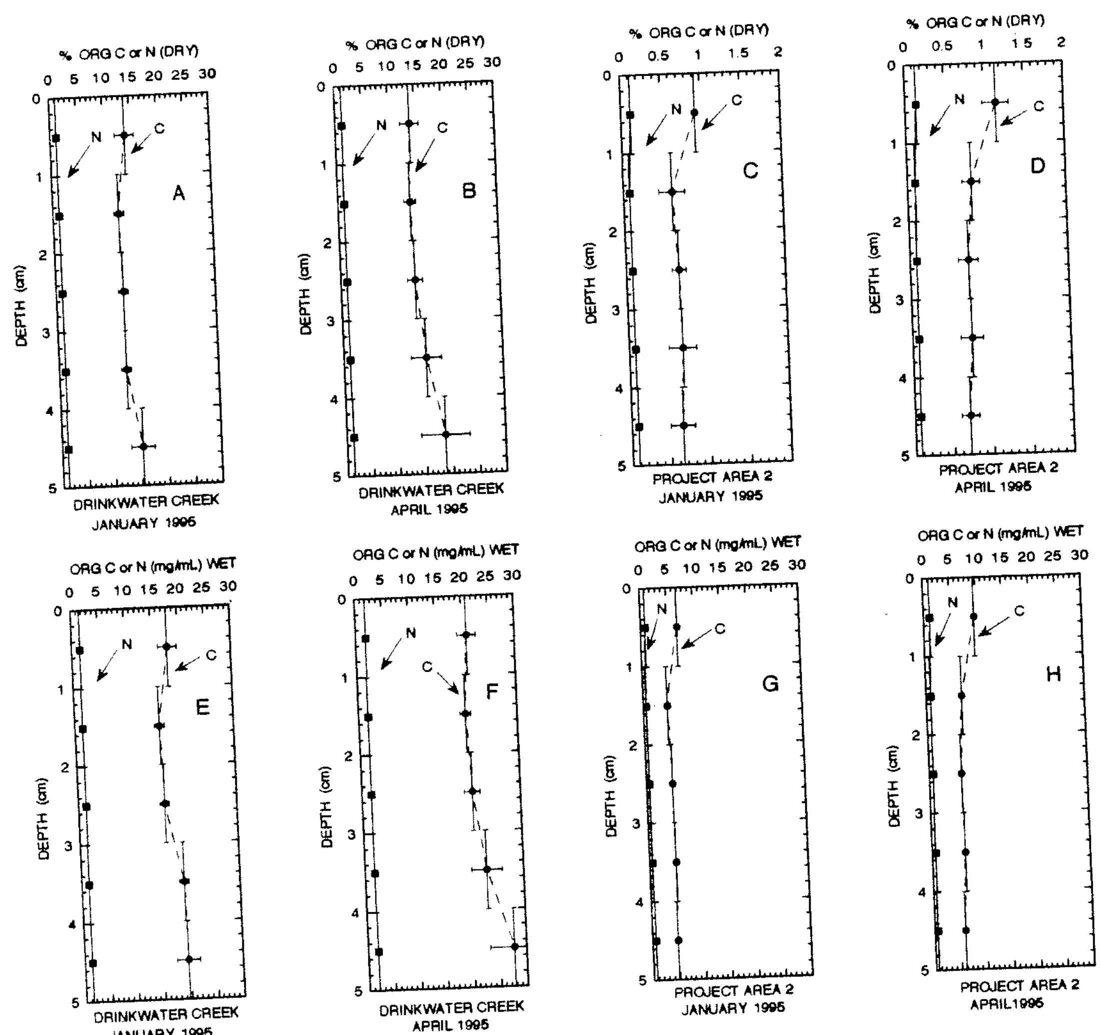

Fig. 8. Downcore distributions of organic carbon and total nitrogen. (A)–(D). Downcore concentrations expressed on a percent dry weight basis. Note order of magnitude differences in values for Drinkwater creek (A and B) and Project Area 2 (C and D). (E)–(H). Downcore concentrations of organic carbon and total nitrogen expressed as mg/ml wet weight sediment. Note that all values are on the same scale. Horizontal bars are +/− 1 S.D., vertical error bars indicate sampling depth interval.

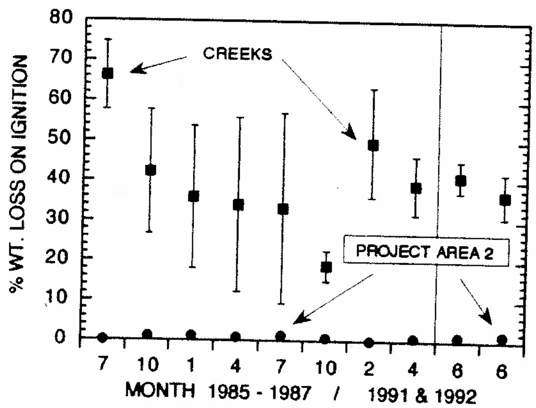

Fig. 9. Loss on ignition estimates of total organic carbon content of downstream sediments from Project Area 2 and the natural creeks. Values are mean + 1 S.D.

function from the perspective of this motile community.

Our fish growth experiments utilized enclosures to retain marked fish that could later be censused for measurements of growth. However, the presence of an enclosure can also alter the physical environment by reducing current flow and trapping sediment (Virnstein, 1977), acting as an attachment site for fouling organisms, and serving as a refuge for small crustacean predators (Peterson, 1979). These particular artifacts should be sensitive to some aspect of cage size (e.g. bottom surface area enclosed, cage surface area or volume), and we accordingly used enclosures of different diameter in an attempt to control for these artifacts. We found that a cage effect was important in fish growth but not survival. The effect was limited to the May experiment and was largely the result of an outlier in one of the small cages in Jacobs creek; therefore, it does not significantly detract from basic inference that all of

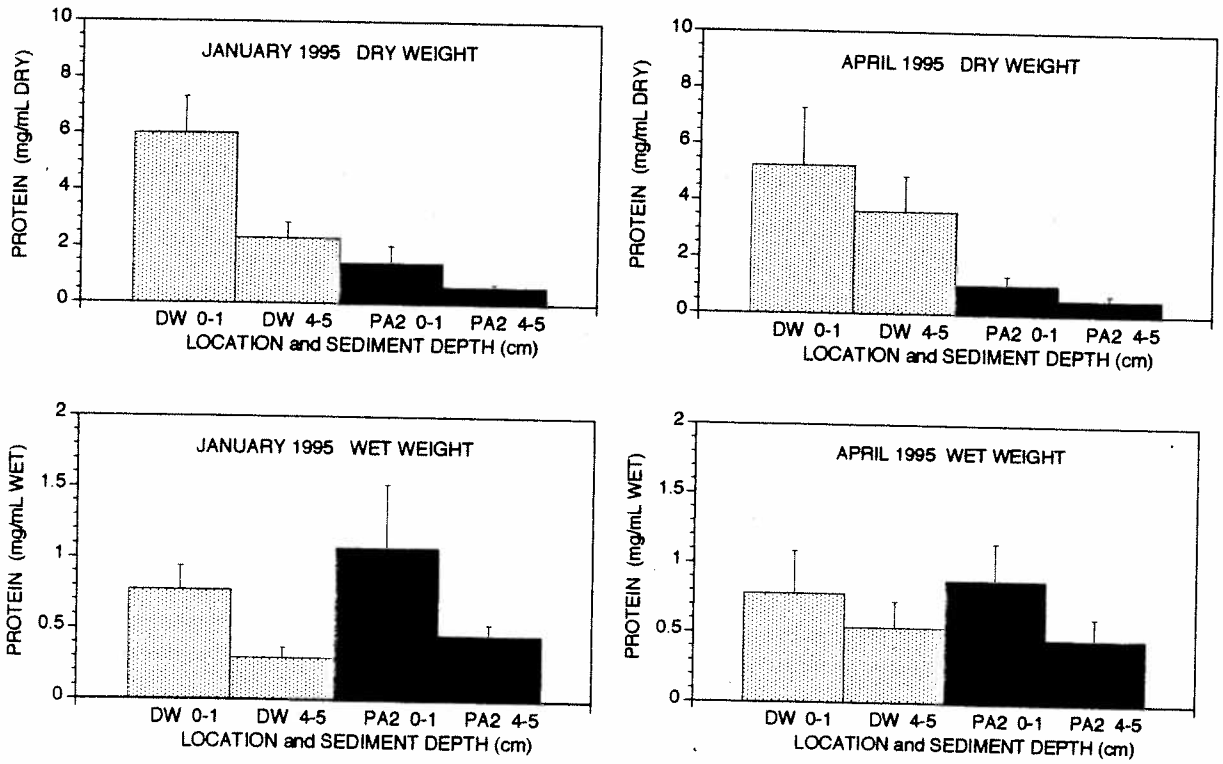

Fig. 10. Concentration of BAP in the surface interval (0–1 cm depth) and bottom interval (4–5 cm depth) of sediment cores taken from Project Area 2 and Drinkwater creek. (A)–(B). Concentrations of BAP expressed as mg/g dry weight. (C)–(D). Concentrations of BAP expressed as mg/ml wet sediment.

the creeks demonstrated a similar capacity to support the growth of *L. xanthurus*.

Enclosures may not accurately mimic normal competitive and predatory pressures encountered in the natural environment. We had no direct control for this kind of artifact. Growth of caged *L. xanthurus* equaled or exceeded that estimated for wild *L. xanthurus* trawled at comparable time intervals during the same months of the year. Our estimates of growth of wild *L. xanthurs* may not reflect true growth rates if foraging success and survival of juvenile *L. xanthurus* are size-dependent. However, the density of fish in the enclosures was within the range of natural densities (Rulifson, 1991), and there is no evidence of food limitation of juvenile spot in the Pamlico River estuary (Currin et al., 1984). We conclude that the use of the enclosures permitted a valid estimate of the relative ability of the created site and the natural creeks to support the growth of *L. xanthurus*.

4.2. Importance of time

The current work represents one of the longest continuous monitoring programs of a created or restored estuarine habitat (Zedler, 1988; Simenstad and Thom, 1996). The duration of the study is important in developing an accurate portrait of the faunal community. Numerically dominant species characteristic of the oligohaline environment were evident within the first 3 years of the study, and the continued increase in the species pools with time reflected the addition of rare species.

A more salient feature of time is the necessity to have a study duration be sufficient for the site to be exposed to a representative range of stochastic biotic and abiotic events characteristic of the local ecosystem, particularly those that constitute a potential stress to the biota. The long duration of this research has provided us with the opportunity to assess the response of the Project Area to both abiotic (salinity) and biotic (colonization by *M. spicatum* and *R. maritima*) stressors.

The magnitude of annual variation in salinity occurring during this work equaled that observed in the Pamlico River estuary during the past 20 years (Stanley, 1988). While it is evident that both the Project Area and the natural creeks responded similarly to salinity change, our understanding of the impact of salinity on community structure remains incomplete. Multivariate analyses of salinity and infaunal species did not explain more than 30% of the variation in abundance of any species, due to the persistent high variability in species densities. Similar results were also obtained for the relationship between salinity and abundance of ichthyofauna in other subtributaries of the Pamlico River estuary (West and Ambrose, 1992).

In contrast, the invasion by *M. spicatum* and *R. maritima* was accompanied by large and persistent reductions in faunal densities, and to a lesser extent, in species richness. The magnitude and character of these changes were similar in the Project Area and the natural creeks. The nature of the relationship between these plants and the infaunal community is unclear. It is possible that the plants affect the infauna indirectly by influencing water quality. Seasonal increases in plant biomass were accompanied by increasing diurnal variation in DO levels, and this phenomenon was most pronounced in the creek with the greatest plant biomass (Project Area 2). The smaller water volume of the Project Area, and the absence of significant water movement between it and south creek (as indicated by static water depth) may also have contributed to the more extreme fluctuations in DO observed at the Project Area.

Mortality of infauna could have resulted directly from exposure to hypoxia or to supersaturated levels of dissolved gases (see Au-Spearde, 1991), or indirectly from increased susceptibility to predation as infauna moved to the sediment surface in response to the low oxygen levels (Pihl et al., 1991, 1992). This interaction between the creek flora, water quality, and infauna could account for the low faunal densities in the summer, but not for the lowered densities during the winter when plant biomass is negligible.

4.3. Features of the benthic sediments

The sediments of the Project Area lacked the woody detrital covering, large peat component, and the predominance of silt and clay that characterized the natural creek sediments. Furthermore, there was no evidence of a trend in accretion of these materials in the Project Area during the 10 years of the study.

The persistent similarity of the species composition of the infaunal communities in the Project Area and the natural creeks suggests that gross features of the sediments such as grain size distribution, surface topography, and total organic carbon levels do not play key roles in the distribution of the species that dominate oligohaline sediments. Most of these species are widely distributed and are among the first to colonize new habitat (Tenore, 1972b; Santos and Simon, 1980; Marsh and Tenore, 1990). They are also prone to dramatic fluctuations in population size (Boesch et al., 1976), associated with sediments of high organic carbon content (Snelgrove and Butman, 1994), and occur in high densities in eutrophic and other stressed environments (Tenore, 1972b; Snelgrove and Butman, 1994; Grall and Glemarec, 1997).

The association of oligohaline fauna with organic-rich sediments and the order of magnitude greater concentrations of carbon and nitrogen in Drinkwater creek versus Project Area 2 might have led us to predict greater infaunal densities in the natural creek. However, faunal densities have proven to be consistently similar, not different. This apparent paradox suggests that (1) food is not limiting in either environment, or (2) measurements of total organic carbon and nitrogen do not accurately represent what actually constitutes food for the infauna.

At the present time, we cannot distinguish between these two hypotheses. In support of the first, a concentration of 1% organic carbon is certainly high compared with other regions of the world's oceans that are known to support infaunal populations (e.g. Lopez and Levinton, 1987). Direct manipulation of organic carbon concentration is needed to assess if and when food limitation occurs. In support of the second, we argue that the data obtained for BAP (but not organic C or N) negates the apparent paradox when considered on a per wet volume basis.

Inclusion of additional estimates of labile food quantities such as microbial and algal biomass will help to further refine our hypothesis that organic carbon does not accurately predict infaunal success in created oligohaline habitats. One possible solution is to use total organic carbon and nitrogen measurements as estimates of gross food quantity (i.e. if carbon contents are > 1% infaunal populations should not be food limited), and more specific estimates of labile food sources such as BAP as estimates of food quality.

We emphasize the utility of collecting porosity data and food evaluations simultaneously. Normalizing to wet volume instead of dry weight allowed the observation that BAP concentration is actually higher in the restored habitat. This result was obtained because the sediments in the created and natural creeks were physically dissimilar. Currently the decision to normalize to wet volume or dry weight varies arbitrarily in accordance with the particular technique used to measure food quantity. For example, pigment concentrations are traditionally reported on a per wet volume basis, while organic carbon and nitrogen data are reported on a per dry weight basis. This problem is compounded because comparisons between these different data sets are routinely made as a part of habitat assessments. We accordingly recommend including porosity in all investigations of sedimentary food quality, enabling each investigator to normalize to either wet volume or dry weight as appropriate.

In view of the similarities in community structure between Project Area 2 and the natural creeks, we argue that the BAP normalized to per volume wet sediment more accurately represents true food availability in created and natural systems than does total carbon or nitrogen. We are currently investigating this hypothesis in both oligohaline and polyhaline habitats.

4.4. Functional equivalency and limitations of the study

Evidence accumulated to date for Project Area 2 on wetland vascular plant productivity (Broome et al., 1986; Broome, 1989), ichthyofauna (Rulifson, 1991), and benthic infauna (this study) contends that it supports nursery area functions and responds to local ecological processes in a manner similar to the natural creeks. These findings contrast with most of the other restoration work carried out in estuarine systems (Moy and Levin, 1991; Sacco et al., 1994; Simenstad and Thom, 1996).

The 'success' of the Project Area may be linked to four aspects of its location. First, the created habitat is surrounded by the aquatic environs it was intended to mimic, thereby providing proximity to sources of infaunal recruits (Cammen, 1976; Christensen, et al., 1996). Second, the Project Area and the adjacent natural creeks are part of a large expanse of undeveloped habitat (South creek) and therefore are remote from municipal (but not agricultural) anthropogenic influences known to impede restoration efforts (Zedler, 1988; Simenstad and Thom, 1996). Third, it is a non-tidal habitat and therefore not as subject to sedimentary erosional forces as are restored intertidal projects (Simenstad and Thom, 1996).

Finally, and perhaps most importantly, the oligohaline ecosystem of which the Project Area is a part is characterized by intensely variable abiotic factors (temperature, salinity, DO). This variability evidently limits faunal diversity to a small subset of resilient eurytolerant estuarine taxa (Boesch et al., 1976). The number of taxa collected in the Project Area and natural creeks is half to one-tenth that reported for polyhaline areas of North Carolina estuaries (Cammen, 1976; Chester et al., 1983; Summerson and Peterson, 1984; West, 1985, 1990b) and of other Atlantic coast estuaries (Watling, 1975; Virnstein, 1977). Population dynamics of this oligohaline system appear to be driven primarily by these abiotic factors, especially hypoxia or anoxia (Tenore, 1972b; West and Ambrose, 1992), and the majority of the taxa are short-lived, prolific, deposit-feeding opportunists that rapidly invade new or disturbed habitats (Grall and Glemarec, 1997; Sheridan, 1997). As a result, these oligohaline infaunal communities probably never reach a stable state before a seasonal disturbance initiates a new round of recruitment. Therefore, from the perspective of infaunal community structure, mitigation is likely to be more successful in oligohaline areas than in areas of more constant and benign abiotic factors, because the organisms in oligohaline regions are more tolerant of the disturbance inherent in the process of habitat creation and restoration.

A caveat to inferences of functional equivalency discussed above for the Project Area 2 is the limitation imposed by reliance on that single site as the primary basis for our comparisons of structural and functional attributes of local created and natural oligohaline creeks. A second site exists (Project Area 1), but was not included in the analyses because the data for Project Area 1 are limited to descriptions of the infaunal community, and are confined to a relatively small time period (1991–1994) beginning about 10 years after the site was created.

The lack of replication of created or restored habitats is a general feature of mitigation research, and has several causes. First, space for a mitigation site may be limited due to a history of extensive development, such as urban areas and properties with waterfront access (Clark, 1989; Willard and Hiller, 1989). Mitigation efforts at these sites may encounter an additional difficulty if development has proceeded to the point where no undisturbed reference habitats remain, and the original ecological functions of these habitats are not fully understood (Zedler, 1996). Second, experimental design concerns such as site replication may not be required to be addressed in the planning and permitting procedures. Mitigation planning has often been poorly organized, ad hoc, and lacking in appropriate, standardized guidelines for construction and assessment (Clark, 1989; Garbisch, 1989). State agencies need to develop a strategic vision of environmental protection, and the administrative means to implement it. Third, replication is not included in the project design because mitigation efforts can be costly. The cost can be high because the permitting process is time consuming, land is expensive, construction is labor intensive, and planning, monitoring, and assessment require special skills. Estimates of the cost of constructing and monitoring Project Area 2 exceed one million dollars (NCPC staff, pers. commun.).

Finally, mitigation plans have had the objective of building a site in such a way as to maximize its potential for success. Thus, there has been reluctance to systematically vary physical or biological features of a site in order to determine their respective importance in the outcome of the mitigation process (e.g. size of watershed; ratio of marsh surface to water surface area; amount and character of detrital cover) (e.g. Pacific Estuarine Research Laboratory, 1990). Similarly, reliance on single mitigation sites does not permit assessment of site performance relative to known key abiotic and biotic variables that vary in kind and intensity along a spatial gradient (e.g. Brinson and Rheinhardt, 1996). All of these concerns combine to complicate the interpretation of the results, limit the ability to make accurate predictions about the probability of success (or failure) of future mitigation efforts, and impede our understanding of the critical mechanisms governing successful habitat creation, restoration, and enhancement. We accordingly emphasize the importance of including appropriate experimental design in the all phases of the mitigation process.

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Assessment of function in an oligohaline environment: Lessons learned by comparing created and natural habitats

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Abstract

Assessments of nursery area function were carried out over a 10-year period in a 3-ha oligohaline marsh and creek system ('Project Area 2') and four natural 'control' creeks (Drinkwater, Jacks, Jacobs, and Tooley) located in the Pamlico River estuary, North Carolina. Habitat function was assessed by comparing (1) growth and survival of fish; (2) long-term monitoring of water quality, sediment organic carbon, and the benthic infaunal community; and (3) measurement of benthic food availability. Growth (weight gain) and survival of the fish *Leiostomus xanthurus* held within enclosures were similar in both created and natural habitats. Species composition, total fauna density, and species richness of the infaunal community of the Project Area and the natural creeks were comparable within 3 years after construction of the Project Area. However, the sediments of the Project Area lacked the woody detrital cover, high peat content, and predominance of silt and clay characteristic of the natural creek sediments. There was no evidence of significant accretion of total organic carbon in the Project Area during the course of the study. This study has heuristically inspired four recommendations concerning assessment criteria of mitigation success. (1) Direct experimentation is needed to assess habitat function for motile species such as fish. (2) Studies of community structure need to be carried out long enough to permit testing of community stability, especially when working in areas exposed to stochastic abiotic and biotic stressors. (3) Measurements of nutritional content of the sediments should include estimates of overall organic quantity and nutritional quality. (4) Site design or restoration techniques should be included in the experimental design of each mitigation effort. Specifically, the lack of replication in these aspects of the mitigation process limits the inferential potential of the study, constrains the ability to make accurate predictions about the probability of success of future mitigation endeavors, and impedes our understanding of the critical mechanisms governing successful habitat creation, restoration, and enhancement.

Keywords: Mitigation; Oligohaline; Fish; Benthic infauna; Sediment; Organic carbon; Biological protein

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1. Introduction

Increasing development of wetlands and coastal areas in the United States during the past 20 years has fueled concerns about the ecological consequences of the reduction of biodiversity and loss of critical habitats. Coincident with this increasing development has been a growth in the knowledge of, and applied efforts toward, restoring damaged or altered habitats, and creating new habitats to compensate for those lost to human activities (Zedler, 1988; Race and Fonseca, 1996).

Efforts to remediate habitat alteration or loss have met with mixed results with 'failures' and inconclusive efforts greatly outnumbering 'successes'. The lack of success in mitigation has resulted from (1) improper construction or implementation of mitigation efforts; (2) non-compliance with permitting goals, objectives, and guidelines; (3) insufficient time frame for monitoring; (4) inadequate knowledge of forces structuring natural communities; and (5) inadequate knowledge of local ecosystem function (Zedler, 1988, 1996; Mitsch and Wilson, 1996; Race and Fonseca, 1996).

Such 'failures' have taught that criteria for determining 'success' of habitat remediation may focus on inadequate measures of the salient ecological processes that drive spatial and temporal change in the natural communities. Success is generally viewed in terms of a system's biological viability and sustainability. Indices of success commonly include species lists and measures of abundance, biomass or percent cover over time, sedimentary features (e.g. concentrations of organic carbon and nitrogen, porosity, chlorophyll, grain size), and measures of relevant abiotic variables (temperature, dissolved oxygen, salinity for aquatic systems). These indices have been favored because they are simple and relatively inexpensive to carry out, but they have been subject to criticism because the sampling may have been occasional, of short overall duration, and with little evidence of prior knowledge of the most ecologically suitable timing; moreover, the indices themselves may not be sufficient tests of ecosystem function (Mitsch and Wilson, 1996).

In this paper, we present both experimental and correlative work that (1) links traditional success criteria of (a) patterns of species abundance and (b) sedimentary organic carbon levels with habitat function; and (2) evaluates the importance of time as an element of mitigation research. All work was carried out during 1985–1995 in four natural and one created non-tidal oligohaline subtributaries of the Pamlico River estuary, North Carolina, USA. We link patterns of faunal abundance with habitat function by comparing the capability of natural and created habitats to support the growth of fish (*Leiostomus xanthurus* Lacepede) that prey on resident benthic invertebrate infauna (Tenore, 1972a; West and Ambrose, 1992). We evaluate the utility of sedimentary organic carbon as a predictor of habitat viability by comparing infaunal abundance and two separate measures of putative food availability; total organic carbon and nitrogen, and 'biologically available protein' (BAP). We assess the role of time by delineating the influence of 'predictable' periodic stressors (salinity) and novel stressors (invasion by the vascular plants *Myriophyllum spicatum* L. [Eurasian watermilfoil], and *Ruppia maritima* L. [widgeon grass]) on infaunal community structure.

2. Methods

2.1. Site description

All work was carried out in a single created 3-ha oligohaline marsh ('Project Area 2') and four adjacent natural oligohaline creeks (Drinkwater, Jacks, Jacobs, and Tooley) located in the Pamlico River estuary, North Carolina (Fig. 1). Project Area 2 is about half to one-fourth the area of the natural creeks (Table 1, North Carolina Phosphate Corporation, 1982). The land converted to the Project Area was originally a lowland forest of mixed hardwoods identical to those that border the undeveloped subtributaries of the Pamlico River estuary. The Project Area was constructed during 1980–1981 by North Carolina Phosphate Corporation. Four species of emergent vascular plants (*Juncus roemarianus* Scheele, *Spartina patens* (Aiton) Muhl., *Spartina cynosuroides* (L.) Roth, and *Spartina alterniflora* Loisel) were planted during 1981. In 1983, the earthen dam

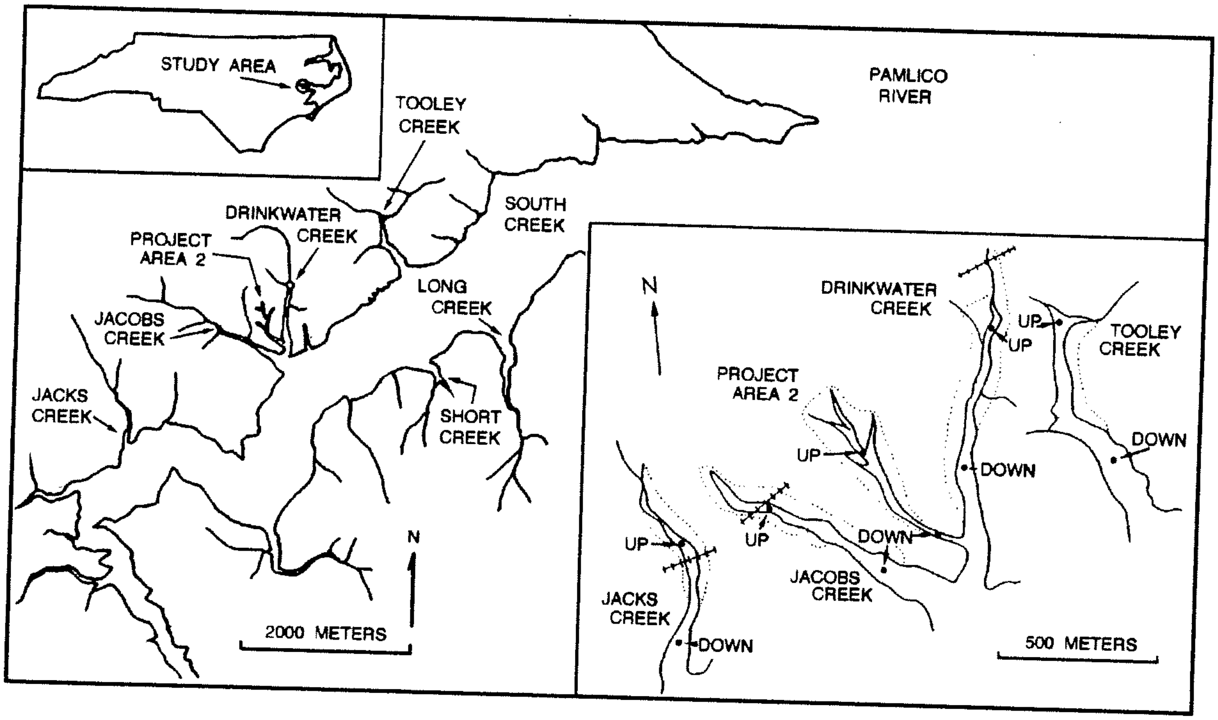

Fig. 1. Location of the sampling stations (upstream, downstream), Project Area 2, and the natural 'control' creeks (Tooley, Drinkwater, Jacobs, Jacks) in the Pamlico River estuary, North Carolina.

was removed that separated the Project Area from the confluence of Drinkwater and Jacobs creeks.

2.2. Water quality

Bottom temperature, salinity, and dissolved oxygen were measured with Yellow Springs Instruments recorders. Water quality measurements were taken at approximately monthly intervals throughout the study period. Water depths ranged from 0.3 to 1.8 m depending upon sampling station (upstream is shallower) and prevailing winds (southwesterlies produce high water levels; Pietrafesa et al., 1986). Continuous recording water quality meters were installed at the downstream sites of the Project Area and Drinkwater creek for a 7-day period in April and May 1995. Temperature, conductivity, and dissolved oxygen were measured at 15-min intervals during this 7-day period using a Yellow Springs Instruments PC6000 submersible environmental monitor.

2.3. Collection of invertebrates

Subtidal benthic samples (0.02 m^2) were taken using an Ekman or Ponar grab from upstream and downstream locations in Tooley creek, Drinkwater creek, and Jacks creek, and in Project Area 2 (Fig. 1). During 1985–1988, three samples were collected from a single site at each upstream and downstream location; during 1989–1995,

Table 1
Areal comparisons of Project Area 2 and the natural creeks involved in this study[a]

Creek	Open water	Marsh surface	Total
Jacks	2.63	2.88	5.51
Jacobs	6.78	5.61	12.39
Drinkwater	5.12	4.17	9.29
Tooley	4.98	4.99	9.97
Project Area 2	0.81	2.23	3.04

[a] All listed values are in hectares and are taken from North Carolina Phosphate Corporation (1982).

three samples were collected from each of two sites at both upstream and downstream locations. The sampling sites were located near the middle of the creek within each location, and sampling depths ranged from 0.3 to 2.5 m. Sampling was done quarterly (January, April, July, October) beginning in July 1985 and ending in July 1995. Samples were sieved in the field through a 0.5 mm mesh, and the residue was preserved in 10% formalin containing 0.1 g/l of Rose Bengal stain. Infauna were separated, counted, and identified to the lowest practical taxon in the laboratory, and subsequently stored in 70% *iso*-propanol.

2.4. Fish growth experiments

Fish growth experiments were carried out in May (29 May–13 June) and July (24 July–9 August), 1985. Juvenile *L. xanthurus* ('spot') were collected in 30–60 s trawls using a 3.9 m two seam otter trawl of 6.3 mm bar mesh equipped with a cod-end bag of 3.1 mm mesh. Collected fish were held overnight in an enclosure to allow for expression of latent mortality associated with the stress of capture. During an experiment, fish were contained within circular enclosures (0.9 or 1.9 m diameter) constructed of black plastic netting (Vexar; 6 mm bar mesh), supported on a frame of stainless steel and concrete reinforcing bar. Each enclosure was 1.2 m high and covered with a Vexar top.

Five pairs of cages (one large and one small) were placed in the downstream regions of Project Area 2, Drinkwater creek, and Jacobs creek. The cages were placed in water 0.4–1.0 m deep, and were forced about 20–30 cm into the sediment to prevent fish from escaping and to deter entry of unwanted predators. The cages were initially seined to remove fish inadvertently captured during installation. Eight fish were added to each large cage and two fish were added to each small cage. Thus, each enclosure contained the same number of fish per unit bottom surface area. Each fish had previously been individually marked by fin clipping and weighed while immersed in water (West, 1990a). The order of addition of fish to the cages was randomly determined. The cages were censused by seining after 16 days. Surviving fish were placed in 10% formalin and later weighed in the laboratory. Growth (weight gain) of wild *L. xanthurus* was estimated by taking 90 s trawls in Drinkwater creek at approximately 14 day intervals between March and October.

2.5. Measurement of sediment features

Grain size determinations were made on intact 4 cm (diameter) × 10 cm (depth) cores according the procedures of Folk (1968). Samples were sieved wet using mesh sizes of 2.0 mm (detrital fraction), 0.84 mm (sand fraction), and 0.074 mm (silt and clay fraction). Data are presented as percentage of the total sample weight represented by each size fraction.

In 1995, three intact 6 cm (diameter) by 15 cm (depth) sediment cores were collected from the downstream station of Drinkwater creek and Project Area 2 during January and April. Cores were returned to the lab and immediately sectioned into five separate 1 cm intervals (0–1, 1–2, 2–3, 3–4, 4–5 cm below the sediment–water interface). Each interval was placed in a −20°C freezer until further analysis (within 6 months of sampling). Samples were thawed, dried to a constant mass at 60°C, and ground and homogenized using a mortar and pestle. TOC and nitrogen were then determined using a Control Corporation model 440 elemental analyzer. Acetanilide was used as a standard for all samples. Possible inclusion of inorganic carbon was assessed for each sample interval using the gasometric technique of Schink et al. (1979). No inorganic carbon was found in any of the samples.

Biologically available protein was assessed for surface (0–1 cm interval) and deep (4–5 cm interval) sediment at each site during January and April 1995 according to the technique described by Mayer et al. (1986). This technique determines the content of the smaller, more labile components of the protein pool following a sequence of acidic digestion, enzymatic degradation, serial protein addition, and final analysis of an extensive set of replicates using spectrophotometric detection of Coomassie Blue dye. All data represent the means of three cores, each of which was subsampled four times.

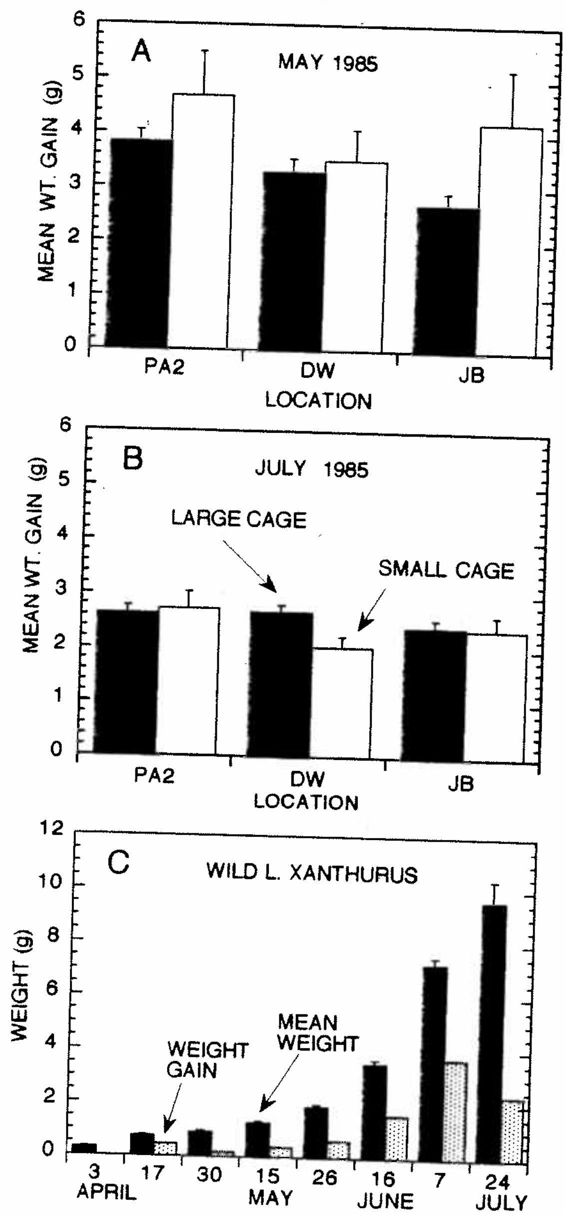

Fig. 2. Weight gain (g) of caged and wild *L. xanthurus* in Project Area 2 (PA 2), Drinkwater creek (DW), and Jacobs creek (JB). (A) May 1985 caging experiment. (B) July 1985 caging experiment. (C) Weight gain and mean weight (g) of *L. xanthurus* trawled at approximately 2-week intervals in Drinkwater creek during 1986. Columns represent mean values + 1 S.E.

Subsequent analyses (West and Clough, in prep.) have shown that wet volume and dry weight of sediment are both required for accurate analysis of sedimentary food concentration. Porosity of the sediment was not determined concurrently with the results being discussed. Instead, corrections for differences in porosity and dry sediment density were made using data obtained at each site during January and April 1997. Porosity was calculated using the wet and dry weights of a known volume of sediment.

2.6. Data analyses

Randomized block analyses of variance (ANOVA's) were carried out to test for creek and cage effects on weight gain and survival of *L. xanthurus*. Survival data were arcsin transformed prior to the ANOVA's. A series of three-way ANOVA's was carried on the infaunal density and species richness data to test for differences due to season (winter, spring, summer, fall), creek (natural vs. created), and location (upstream vs. downstream). Each three-way ANOVA analyzed the data for a single calendar year. A canonical analysis was carried out to test for correlations between infaunal species densities and salinity, and cluster analyses were used to discern temporal and spatial patterns in infaunal community structure. All multi-level ANOVA's and multivariate analyses were done on log $(x + 1)$ transformed data. The canonical analyses were done using STATSTICA (StatSoft, Inc. Tulsa, OK); all other data analyses were carried out using DataDesk (Data Description, Inc. Ithaca, NY).

3. Results

3.1. Growth and survival of *L. xanthurus*

Mean weight gain of *L. xanthurus* during May (3–5 g/16 days) was approximately twice as high as that during July (Fig. 2A and B). Weight gain was significantly lower in Jacobs creek than in the Project Area during the May experiment, but differences in weight gain among creeks were not significant during the July experiment. Cage effects were limited to the May experiment, when significantly more growth occurred in the smaller cages in Jacobs creek (Fig. 2A). Weight gain of caged *L. xanthurus* equaled or exceeded that estimated for the ambient wild *L. xanthurus* population during similar time periods and months of the year (Fig. 2A vs. C).

Mean survival was similar among creeks during both experiments, with May values slightly lower than July values. Cage effects on survival were not significant. Mean survival values ranged from 50 to 100%.

3.2. Temporal and spatial patterns of benthic infauna

Data for each of the three natural creeks were pooled in all analyses comparing faunal abundance, diversity, and community structure in created and natural creeks. Data were pooled because (1) the primary issue of this study was whether the abiotic and biotic features of the created creek would fall within the normal range of values exhibited by nearby natural creeks, and not whether it was going to develop to resemble a particular, predesignated creek; and (2) to remain consistent with the symposium theme of assessment of success criteria for habitat restoration. The dynamics of the infaunal communities have been detailed in part in earlier reports (West, 1990b; Ambrose, 1992; Ambrose and Renaud, 1996) and will be dealt with more comprehensively in a future paper.

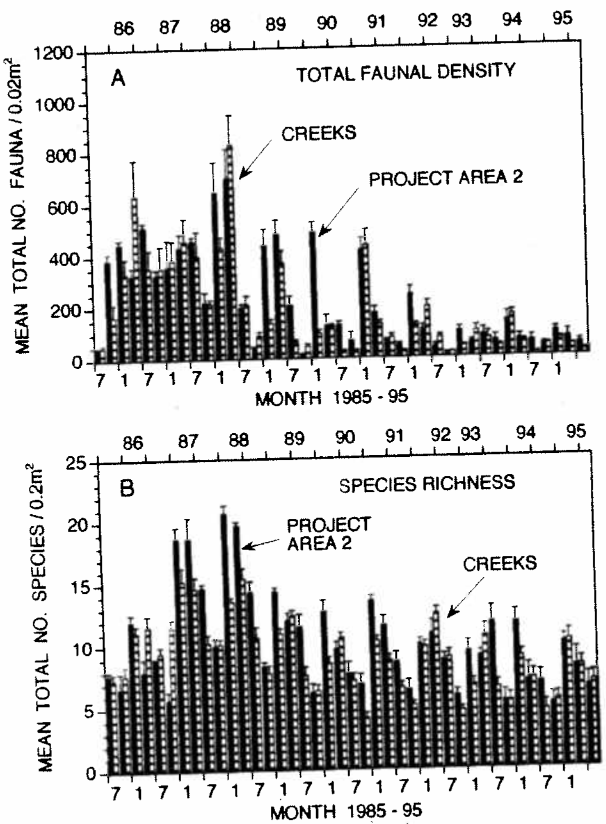

Fig. 3. Temporal variation in mean total faunal density (average total number of infauna/0.02 m^2 sample) and species richness (average total number of infaunal taxa/0.02 m^2 sample) at the downstream locations in Project Area 2 and the natural creeks between July 1985 and July 1995. Columns represent mean values + 1 S.E.

Total faunal density (mean total number of animals/unit area) varied markedly within and between years (Fig. 3A) in both the created and natural creeks. Within a given year, density peaked in the winter, declined sharply between spring and summer, and rose again during the late fall. Winter and spring values showed highly significant differences in all but 1 of the 10-year study (Table 2).

Annual differences in total faunal density were also pronounced. Winter and spring density values generally increased during 1986–1988, varied erratically between 1989 and 1991, and subsequently declined to values one-third to one-sixth of the 1986–1988 values. Summer and fall densities were similarly affected, with densities of individual species diminishing to near zero values in the summer months since 1992 (Fig. 3A).

The temporal and spatial patterns in total numbers of fauna described above were observed in both the Project Area 2 and the natural creeks (Fig. 3A). Summer and fall densities were occasionally significantly lower in the Project Area between 1985 and 1988. However, total densities of the Project Area have equaled or exceeded those of the natural creeks since 1988 (Fig. 3A; Table 2).

Similar annual and seasonal patterns in total faunal density occurred at the upstream and downstream stations in both the Project Area and the natural creeks. Within a single year, densities

Table 2
Selected significant ($P<0.015$) main effects and interactions of the three-way ANOVA's carried out on total faunal density and species richness in Project Area 2 (PA 2) and the natural creeks[a]

Year	Fauna	M	C	M × C × L
1986	Density	1 4 7 10	n.s.	n.s.
1986	Richness	1 4 7 10	n.s.	n.s.
1987	Density	2 4 7 10	n.s.	n.s.
1987	Richness	2 4 7 10	n.s.	n.s.
1988	Density	1 5 7 10	P>N	n.s.
1988	Richness	1 5 7 10	n.s.	n.s.
1989	Density	1 4 7 10	n.s.	n.s.
1989	Richness	1 4 7 10	P>N	n.s.
1990	Density	1 5 7 10	P>N	1 P Dn >1 N Dn
1990	Richness	1 5 7 10	n.s.	n.s.
1991	Density	1 4 7 10	P>N	n.s.
1991	Richness	1 4 7 10	P>N	n.s.
1992	Density	1 4 7 10	n.s.	n.s.
1992	Richness	1 4 7 10	n.s.	n.s.
1993	Density	1 4 7 10	P>N	n.s.
1993	Richness	1 4 7 10	n.s.	n.s.
1994	Density	1 4 7 10	P>N	4 P Up >4 N Up
1994	Richness	1 4 7 10	P>N	4 P Up >4 N Up
1995	Density	1 4 7 10	P>N	4 M Up >4 N UP
1995	Richness	1 4 7 10	n.s.	n.s.

[a] Month (M) numbers underlined are not significantly different. Creek (C) differences are listed as an inequality (P, PA2; N, natural creeks). Significant three-way interactions are limited to those pertaining to the winter (1, 2) or spring (4, 5) months. L, station location; DN, downstream station; Up, upstream location; n.s., not significant.

were typically greater at the downstream stations in each creek.

Species richness (mean total number of species/unit area) showed the same within-year temporal and spatial patterns as described above for total faunal densities. Numbers of species were highest in the winter and fall, and lowest during the summer (Fig. 3B), and fewer species occurred upstream than downstream. However, the pattern of annual variation in species richness differed from that of total density. Species richness attained highest values during 1988 and 1989, but in the succeeding years did not show either the variability or the precipitous decline noted for faunal densities (Fig. 3B vs. A).

Numbers of species in the Project Area were initially lower than the natural creeks, particularly during the summer. However, species richness in both created and natural creeks has remained similar since 1988.

3.3. Community structure

Approximately 50 taxa comprise the infaunal communities of the created and natural creeks (Fig. 4). However, 10 of the 50 taxa accounted for 95% or more of all individuals collected during any year, season, creek, or location within a creek. These taxa consisted of, oligochaetes; the polychaetes *Mediomastus* sp.; *Hobsonia florida* Hartmann; *Laeonereis culveri* Webster; *Capitella* sp.; and *Streblospio benedicti* Webster; chironomid insect larvae; and the amphipod crustaceans *Corophium lacustre* Vanhoffen; *Gammarus tigrinus* Sexton; and *Leptocheirus plumulosus* Shoem. The bivalve *Macoma balthica* L. and the gastropod *Hydrobia* sp. occasionally occurred in high densities in the natural creeks and Project Area 2, respectively. Consequently, differences in community structure among the creeks were derived primarily from temporal and spatial differences in the relative abundance of these species, and not from the absence of particular species.

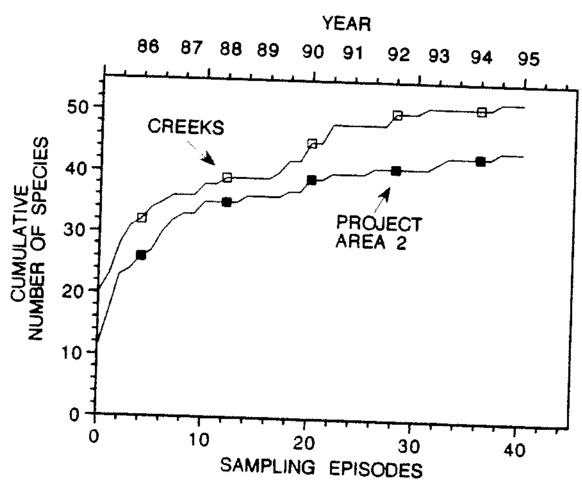

Fig. 4. Cumulative number of taxa collected in Project Area 2 vs. the pooled cumulative number of taxa of the natural creeks during the seasonal sampling schedule ('sampling episodes') between July 1985 and July 1995.

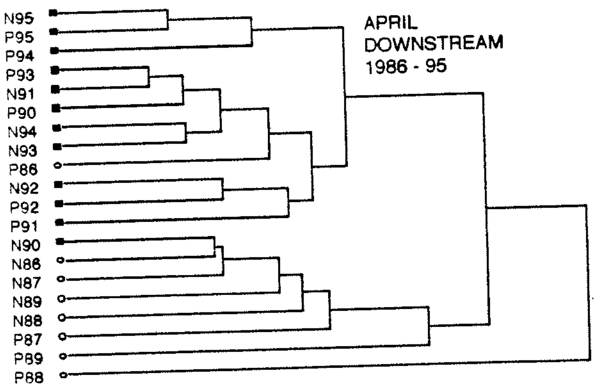

Fig. 5. Cluster analyses of spring infaunal communities of Project Area 2 and the natural creeks between April 1986 and April 1995. Codes indicate creek (*P*, Project Area; N, natural creeks) and year (open symbols, 1986–1989; closed symbols, 1990–1995).

Eight rare taxa were found only in the natural creeks. These taxa were insect larvae (three taxa of unidentified Coleoptera, Diptera), two unidentified crustacean taxa (Isopoda and Cumacea), the crab *Rhithropanopeus harrisii* Gould, and the polychaetes *Glycera dibranchiata* Ehlers and *Neanthes succinea* Frey and Leuckart. These taxa accounted for about 0.06% of the total faunal density for the natural creek fauna.

Cluster analyses of communities during seasons of highest faunal densities and species richness (winter and spring) show strong separation into a 1986–1989 group, and a 1990–1995 group (Fig. 5). This separation reflects the widespread reduction in species densities that occurred between these two time periods, and concomitant changes in the relative abundances of the numerically dominant species. The taxa showing large increases or decreases in relative abundance were virtually the same in the Project Area and the natural creeks. Chironomids, the amphipod *C. lacustre*, and the polychaetes *H. florida* and *S. benedicti* showed large gains in relative abundance, while oligochaetes, the amphipod *L. plumulosus*, and the polychaetes *Mediomastus* sp., and *S. benedicti* showed large declines in relative abundance (Table 3).

3.4. Abiotic variation

Salinity, temperature, and dissolved oxygen (DO) each evinced characteristic seasonal patterns. These patterns were the same in the Project Area and the natural creeks. Salinity usually fell sharply during the spring and rose during the summer to peak in the late fall or early winter (Fig. 6). Temperature was unimodal with a peak in July; values ranged from 6 to > 30°C. Dissolved oxygen varied inversely with temperature, with typical July values falling well below 25% saturation (West, 1990b; West and Ambrose, 1992).

Salinity also varied greatly among years. Three major episodes of salinity change occurred during the course of the study, resulting in fall–winter salinities exceeding 14 ppt during 1985–1986, 1988–1989, and 1994–1995 (Fig. 6). Late fall and early winter represent peak recruitment times for the infauna in the Project Area and natural Creeks (Ambrose, 1992). Canonical analyses were carried out on the relationship between salinity and infaunal density and species richness. The results did not reveal any important correlations and are therefore not presented here.

3.5. Colonization by aquatic vascular plants

M. spicatum (Eurasian watermilfoil) and *R. maritima* (widgeon grass) were first observed in the Project Area during 1989 and were abundant throughout the Pamlico estuary by 1990. Aboveground biomass of both species rose each spring, crested in June and July, and may have completely disappeared by the early fall (Fig. 7A and B). Biomass of both species was similar in the Drinkwater creek, but *M. spicatum* dominated in Project Area 2 (Fig. 7A vs. B).

Abnormally low DO readings (< 1–2 mg/l) became increasingly common during the spring and summer months following the invasion by the submersed aquatic plants, suggesting that the plants were influencing the DO levels. Continuous water quality recorders placed in Drinkwater creek and Project Area 2 during April and May 1995 showed a clear diurnal rhythm in DO concentration (Fig. 7C and D). Concentrations were lowest in the early morning (04:00–09:00) and rose steadily to the highest levels in the evening (17:00–21:00). The magnitude of the oscillation in oxygen content and the variance in diurnal highs and lows were greater during the May series of recordings, particularly in the Project Area (Fig. 7D vs. C). The relatively larger oscillations in DO in the Project Area during May coincided with a two-fold greater increase vascular plant biomass at this site (Fig. 7B vs. A). No diurnal pattern of variability was evident in specific conductivity during the same April and May time periods.

3.6. Features of the benthic sediments

Nearly 70% (by weight) of natural creek sediments consisted of silts and clays (< 0.074 mm), and approximately 30% consisted of sand-sized particles (0.074–0.84 mm; Table 4) in samples collected in 1992. This ratio was nearly reversed in the Project Area, where sand-sized particles accounted for about 60% of the sediment. Comparable particle size distributions were found in samples of natural creek and Project Area 2 sediments collected in 1984 (Craft et al., 1986; Table

Table 3
Changes in the relative abundances of the 12 numerically dominant taxa before (1985–1989) and after (1990–1995) colonization by *Myriophyllum spicatum* and *Ruppia maritima*

Project Area 2	1985–1989	Project Area 2	1990–1995
Taxon	Relative percent	Taxon	Relative percent
Mediomastus sp.	22.6	*Chironomida*	26.9
Hobsonia florida	13.2	*Hobsonia florida*	19.4
Chironomida	10.0	*Capitella* sp.	12.4
Hydrobia sp.	9.9	*Corophium lacustre*	11.3
Oligochaeta	9.4	*Laeonereis culveri*	7.0
Capitella sp.	8.7	*Mediomastus* sp.	4.9
Streblospio benedicti	5.6	*Gammarus tigrinus*	4.6
Laeonereis culveri	5.2	*Oligochaeta*	4.5
Corophium lacustre	3.5	*Polydora ligni*	2.1
Leptocheirus plumulosus	2.5	*Streblospio benedicti*	1.9
Polydora ligni	2.1	*Leptocheirus plumulosus*	1.1
Macoma balthica	2.1	*Macoma balthica*	0.7
Cumulative percent	94.8	Cumulative percent	96.9
Total number of fauna	39 713	Total number of fauna	34 530
Natural creeks	**1985–1989**	**Natural creeks**	**1990–1995**
Taxon	Relative percent	Taxon	Relative percent
Mediomastus sp.	22.8	*Chironomida*	28.3
Oligochaeta	22.6	*Mediomastus* sp.	12.4
Leptocheirus plumulosus	11.3	*Hobsonia florida*	12.2
Capitella sp.	9.6	*Corophium lacustre*	8.2
Hobsonia florida	8.9	*Gammarus tigrinus*	7.0
Chironomida	6.8	*Oligochaeta*	6.9
Streblospio benedicti	6.1	*Capitella* sp.	4.9
Laeonereis culveri	2.9	*Leptocheirus plumulosus*	4.2
Corophium lacustre	1.6	*Laeonereis culveri*	3.3
Macoma balthica	1.4	*Streblospio benedicti*	3.0
Polydora ligni	1.4	*Macoma balthica*	2.7
Macoma phenax	0.7	*Polydora ligni*	1.5
Cumulative percent	96.1	Cumulative percent	94.6
Total number of fauna	88 617	Total number of fauna	56 820

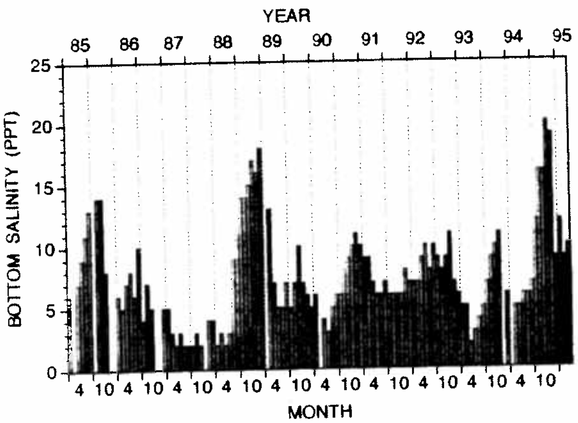

Fig. 6. Temporal variation in bottom salinity of the natural creeks. Samples were taken at approximately monthly intervals between July 1985 and July 1995.

4). Natural sediments also contained large amounts of peat and woody detritus, both of which were absent from the Project Area sediments.

Organic carbon normalized to per g dry weight of sediment was always at least an order of magnitude higher in natural sediments relative to the Project Area sediments (e.g. for the 0–1 cm interval, 13.94% C from Drinkwater creek vs. 0.93% C from Project Area 2 during January 1995; Fig. 8A and C). Samples collected intermittently between 1985 and 1992 showed similar differences in organic carbon levels among the natural creeks and Project Area 2, and the absence of any clear trend of increasing organic carbon content over time for the Project Area sediments (Fig. 9).

Drinkwater creek also contained approximately an order of magnitude more nitrogen than did Project Area 2 (e.g. for the 0–1 cm interval,

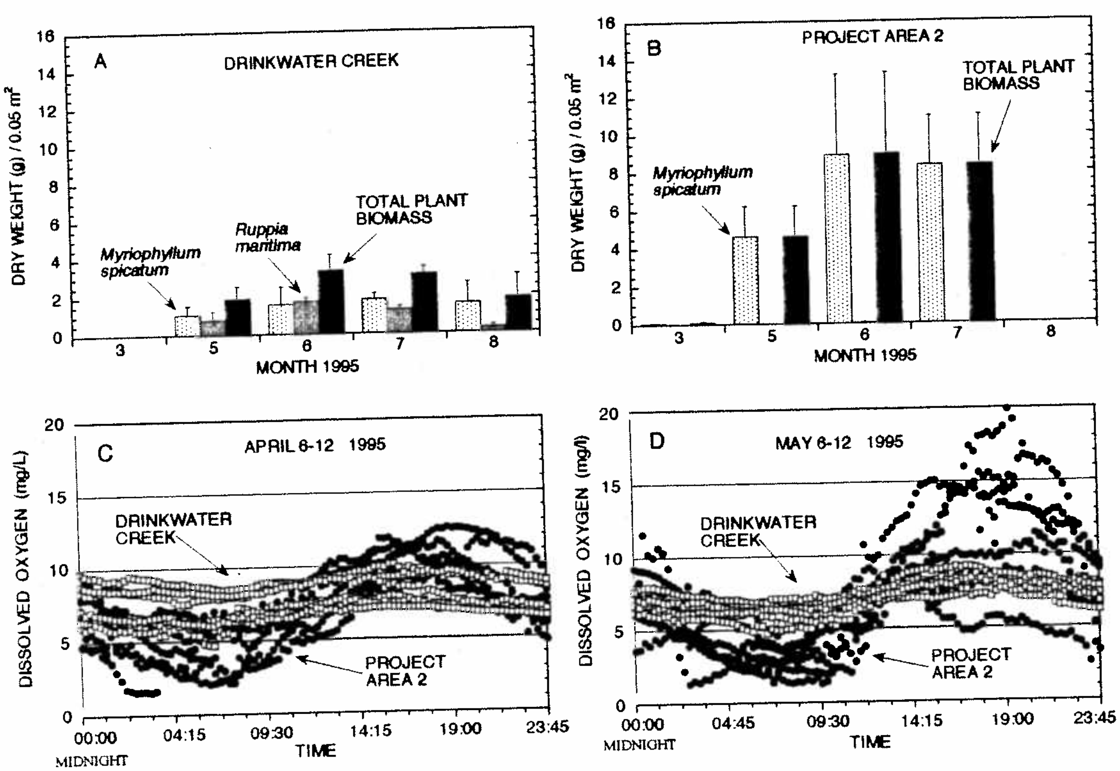

Fig. 7. Seasonal change in biomass of aquatic vascular plants, and diurnal variation in DO concentration, in Project Area 2 and Drinkwater creek. (A) and (B). Individual and combined mean biomass (+1 S.E.) of *Ruppia maritima* and *Myriophyllum spicatum* in Drinkwater creek (A) and Project Area 2 (B) during 1995. (C) and (D). Diurnal change in DO during April 1995 (C) and May 1995 (D).

Table 4
Relative percentage (by weight) of grain sizes of the subtidal sediments of Project Area 2 and the natural creeks

Year	Size class (mm)	Upstream creeks	Upstream PA 2	Reference
1984	>0.5 <2.0	5.85	0.48	Craft et al., 1986
	>0.05 <0.5	33.03	72.38	
	<0.05	60.62	27.12	
1992	>2.00	1.3	0.0	This study
	>0.84 <2.00	0.6	0.0	
	>0.074 <0.84	27.0	63.2	
	<0.074	71.8	35.9	
Year	**Size class (mm)**	**Downstream creeks**	**Downstream PA 2**	**Reference**
1992	>2.00	1.4	0.0	This study
	>0.84 <2.00	0.8	0.0	
	>0.074 <0.84	24.2	59.6	
	<0.074	73.2	41.0	

1.20% N in Drinkwater creek vs. 0.12% in Project Area 2 during January 1995; Fig. 8B and D). Project Area sediment showed the expected downcore decreases in both organic carbon and nitrogen, while organic carbon tended to increase with depth below the sediment–water interface in Drinkwater creek (Fig. 8A and D).

Sediment porosity and dry density also varied between the two locations. Average porosity of the Drinkwater sediments during January 1997 was 0.886, or approximately 90% water (by volume), while the coincident porosity of the Project Area sediments was only 0.673, or approximately 70% water (by volume). In addition, the natural sediments were less dense than the Project Area sediments (1.13 vs. 2.27 g/ml). Thus, in each ml of wet Project Area sediment there were many more particles than there were in each ml of wet Drinkwater sediment.

Normalizing organic carbon and nitrogen values to per g wet sediment has the effect of reducing the magnitude of differences in carbon and nitrogen levels between Drinkwater creek and Project Area 2 sediments relative to the percent dry weight values (Fig. 8E–H). For example, Drinkwater creek sediment contained only about three times the amount of organic carbon of Project Area sediment when normalized to wet volume (e.g. for the 0–1 cm interval, 17.95 vs. 6.87 mgC/ml during January of 1995; Fig. 8E vs. G). Relative differences in organic nitrogen decrease as well (e.g. for the 0–1 cm interval, 1.54 mg/ml for Drinkwater creek vs. 0.89 mg/ml in Project Area 2; Fig. 8F vs. H).

BAP was assessed to provide a better estimate of food quality than total organic carbon and nitrogen, given the large quantities of refractory material (e.g. peat) present in the natural creek sediments. BAP concentration normalized to per g dry sediment in Drinkwater creek was two times greater than in Project Area 2 (1.30 sediment vs. 0.60 mg BAP per g dry; Fig. 10A and B), reinforcing the patterns observed for organic carbon and nitrogen. However, Project Area 2 BAP values normalized to per wet ml of sediment equaled or exceeded those of Drinkwater (1.08 mg BAP per ml wet in Project Area 2 vs. 0.78 mg BAP per ml wet in Drinkwater creek; Fig. 10C and D). Both sites also showed the expected downcore decreases in BAP (Fig. 10).

4. Discussion and conclusions

4.1. Fish growth and survival experiments

The fundamental objective of this work was to determine whether created marshes could be a viable solution to the alteration of wetland and subtidal habitat by phosphate mining operations. A critical test in this regard concerned the capacity of the created habitat to emulate the nursery area functions of the ambient natural oligohaline creeks (Weinstein and Brooks, 1983; Miller et al., 1984; Ross and Epperly, 1985). We have presented two lines of evidence that argue for functional equivalence among the Project Area and the natural creeks. First, Project Area 2 developed an infaunal community of abundance and diversity rivaling that of the natural creeks. Second, growth and survival of spot were similar in the Project Area and the natural creeks.

Evidence of persistence of an infaunal community through time indicates utilization of the habitat in several dimensions, i.e. a place sufficient to permit survival, growth, and reproduction. The same cannot be said for motile fauna such as fish that use the habitat when conditions are favorable, but migrate elsewhere as conditions decline. Some form of direct assessment in addition to population surveys is therefore needed to evaluate utilization by the fish community, and we suggest experimentation is needed to accurately assess

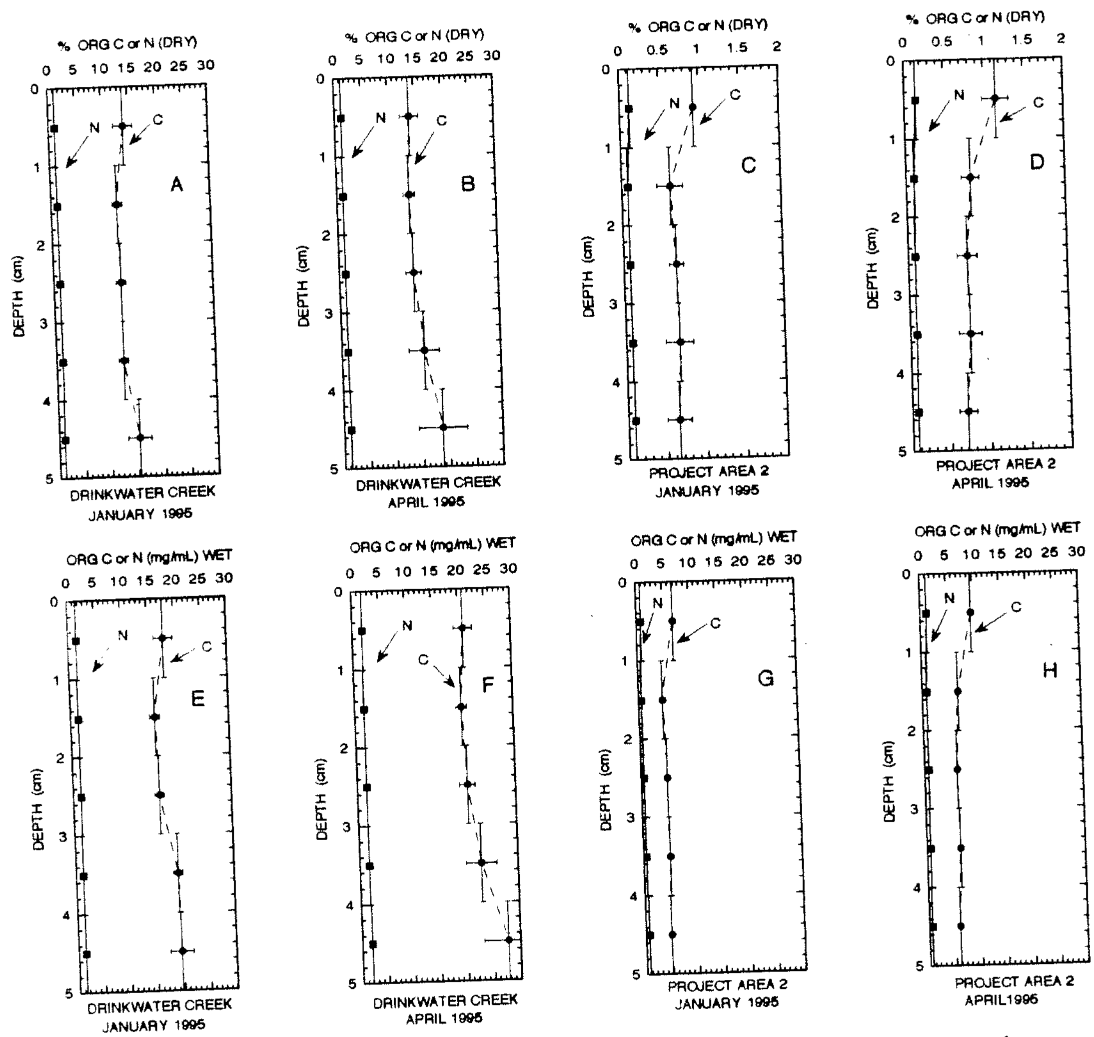

Fig. 8. Downcore distributions of organic carbon and total nitrogen. (A)–(D). Downcore concentrations expressed on a percent dry weight basis. Note order of magnitude differences in values for Drinkwater creek (A and B) and Project Area 2 (C and D). (E)–(H). Downcore concentrations of organic carbon and total nitrogen expressed as mg/ml wet weight sediment. Note that all values are on the same scale. Horizontal bars are +/− 1 S.D., vertical error bars indicate sampling depth interval.

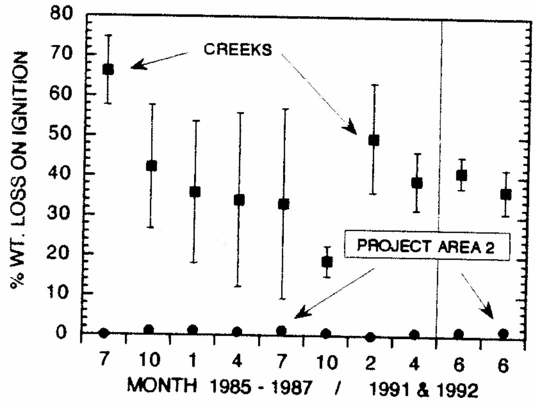

Fig. 9. Loss on ignition estimates of total organic carbon content of downstream sediments from Project Area 2 and the natural creeks. Values are mean +1 S.D.

function from the perspective of this motile community.

Our fish growth experiments utilized enclosures to retain marked fish that could later be censused for measurements of growth. However, the presence of an enclosure can also alter the physical environment by reducing current flow and trapping sediment (Virnstein, 1977), acting as an attachment site for fouling organisms, and serving as a refuge for small crustacean predators (Peterson, 1979). These particular artifacts should be sensitive to some aspect of cage size (e.g. bottom surface area enclosed, cage surface area or volume), and we accordingly used enclosures of different diameter in an attempt to control for these artifacts. We found that a cage effect was important in fish growth but not survival. The effect was limited to the May experiment and was largely the result of an outlier in one of the small cages in Jacobs creek; therefore, it does not significantly detract from basic inference that all of

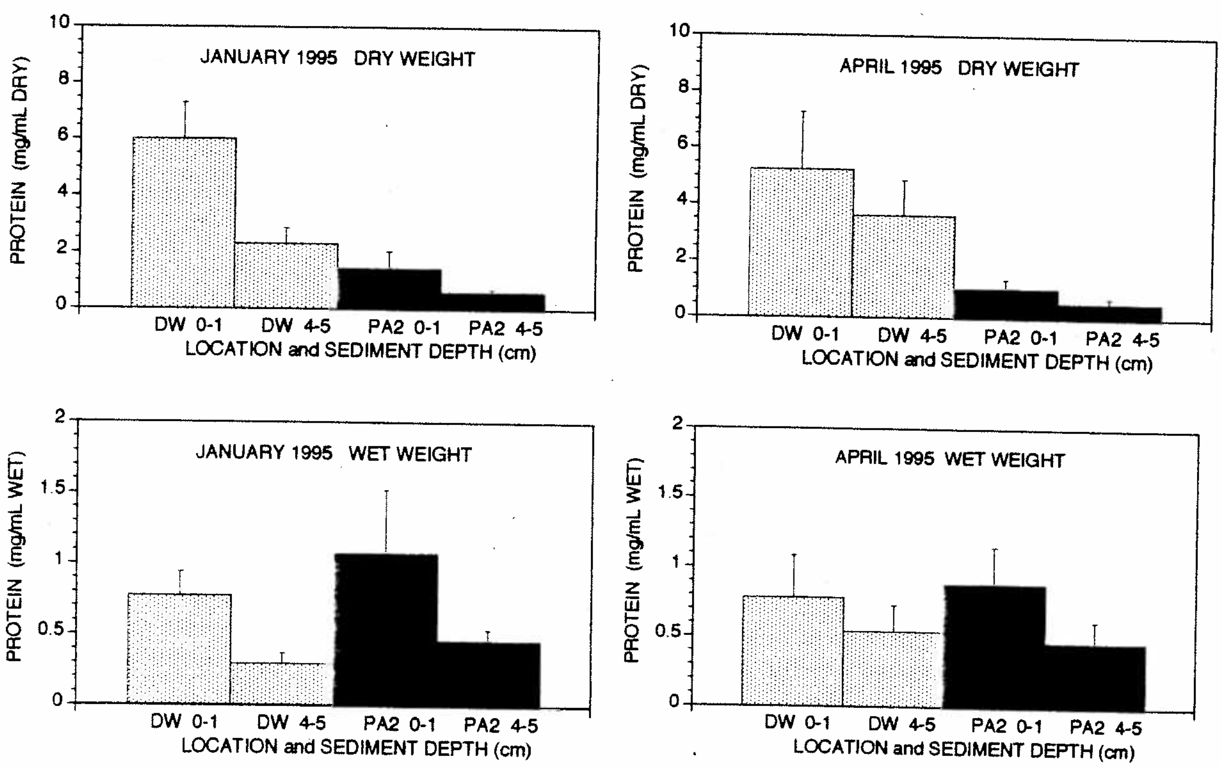

Fig. 10. Concentration of BAP in the surface interval (0–1 cm depth) and bottom interval (4–5 cm depth) of sediment cores taken from Project Area 2 and Drinkwater creek. (A)–(B). Concentrations of BAP expressed as mg/g dry weight. (C)–(D). Concentrations of BAP expressed as mg/ml wet sediment.

the creeks demonstrated a similar capacity to support the growth of *L. xanthurus*.

Enclosures may not accurately mimic normal competitive and predatory pressures encountered in the natural environment. We had no direct control for this kind of artifact. Growth of caged *L. xanthurus* equaled or exceeded that estimated for wild *L. xanthurus* trawled at comparable time intervals during the same months of the year. Our estimates of growth of wild *L. xanthurs* may not reflect true growth rates if foraging success and survival of juvenile *L. xanthurus* are size-dependent. However, the density of fish in the enclosures was within the range of natural densities (Rulifson, 1991), and there is no evidence of food limitation of juvenile spot in the Pamlico River estuary (Currin et al., 1984). We conclude that the use of the enclosures permitted a valid estimate of the relative ability of the created site and the natural creeks to support the growth of *L. xanthurus*.

4.2. Importance of time

The current work represents one of the longest continuous monitoring programs of a created or restored estuarine habitat (Zedler, 1988; Simenstad and Thom, 1996). The duration of the study is important in developing an accurate portrait of the faunal community. Numerically dominant species characteristic of the oligohaline environment were evident within the first 3 years of the study, and the continued increase in the species pools with time reflected the addition of rare species.

A more salient feature of time is the necessity to have a study duration be sufficient for the site to be exposed to a representative range of stochastic biotic and abiotic events characteristic of the local ecosystem, particularly those that constitute a potential stress to the biota. The long duration of this research has provided us with the opportunity to assess the response of the Project Area to both abiotic (salinity) and biotic (colonization by *M. spicatum* and *R. maritima*) stressors.

The magnitude of annual variation in salinity occurring during this work equaled that observed in the Pamlico River estuary during the past 20 years (Stanley, 1988). While it is evident that both the Project Area and the natural creeks responded similarly to salinity change, our understanding of the impact of salinity on community structure remains incomplete. Multivariate analyses of salinity and infaunal species did not explain more than 30% of the variation in abundance of any species, due to the persistent high variability in species densities. Similar results were also obtained for the relationship between salinity and abundance of ichthyofauna in other subtributaries of the Pamlico River estuary (West and Ambrose, 1992).

In contrast, the invasion by *M. spicatum* and *R. maritima* was accompanied by large and persistent reductions in faunal densities, and to a lesser extent, in species richness. The magnitude and character of these changes were similar in the Project Area and the natural creeks. The nature of the relationship between these plants and the infaunal community is unclear. It is possible that the plants affect the infauna indirectly by influencing water quality. Seasonal increases in plant biomass were accompanied by increasing diurnal variation in DO levels, and this phenomenon was most pronounced in the creek with the greatest plant biomass (Project Area 2). The smaller water volume of the Project Area, and the absence of significant water movement between it and south creek (as indicated by static water depth) may also have contributed to the more extreme fluctuations in DO observed at the Project Area.

Mortality of infauna could have resulted directly from exposure to hypoxia or to supersaturated levels of dissolved gases (see Au-Spearde, 1991), or indirectly from increased susceptibility to predation as infauna moved to the sediment surface in response to the low oxygen levels (Pihl et al., 1991, 1992). This interaction between the creek flora, water quality, and infauna could account for the low faunal densities in the summer, but not for the lowered densities during the winter when plant biomass is negligible.

4.3. Features of the benthic sediments

The sediments of the Project Area lacked the woody detrital covering, large peat component, and the predominance of silt and clay that characterized the natural creek sediments. Furthermore, there was no evidence of a trend in accretion of these materials in the Project Area during the 10 years of the study.

The persistent similarity of the species composition of the infaunal communities in the Project Area and the natural creeks suggests that gross features of the sediments such as grain size distribution, surface topography, and total organic carbon levels do not play key roles in the distribution of the species that dominate oligohaline sediments. Most of these species are widely distributed and are among the first to colonize new habitat (Tenore, 1972b; Santos and Simon, 1980; Marsh and Tenore, 1990). They are also prone to dramatic fluctuations in population size (Boesch et al., 1976), associated with sediments of high organic carbon content (Snelgrove and Butman, 1994), and occur in high densities in eutrophic and other stressed environments (Tenore, 1972b; Snelgrove and Butman, 1994; Grall and Glemarec, 1997).

The association of oligohaline fauna with organic-rich sediments and the order of magnitude greater concentrations of carbon and nitrogen in Drinkwater creek versus Project Area 2 might have led us to predict greater infaunal densities in the natural creek. However, faunal densities have proven to be consistently similar, not different. This apparent paradox suggests that (1) food is not limiting in either environment, or (2) measurements of total organic carbon and nitrogen do not accurately represent what actually constitutes food for the infauna.

At the present time, we cannot distinguish between these two hypotheses. In support of the first, a concentration of 1% organic carbon is certainly high compared with other regions of the world's oceans that are known to support infaunal populations (e.g. Lopez and Levinton, 1987). Direct manipulation of organic carbon concentration is needed to assess if and when food limitation occurs. In support of the second, we argue that the data obtained for BAP (but not organic C or N) negates the apparent paradox when considered on a per wet volume basis.

Inclusion of additional estimates of labile food quantities such as microbial and algal biomass will help to further refine our hypothesis that organic carbon does not accurately predict infaunal success in created oligohaline habitats. One possible solution is to use total organic carbon and nitrogen measurements as estimates of gross food quantity (i.e. if carbon contents are $> 1\%$ infaunal populations should not be food limited), and more specific estimates of labile food sources such as BAP as estimates of food quality.

We emphasize the utility of collecting porosity data and food evaluations simultaneously. Normalizing to wet volume instead of dry weight allowed the observation that BAP concentration is actually higher in the restored habitat. This result was obtained because the sediments in the created and natural creeks were physically dissimilar. Currently the decision to normalize to wet volume or dry weight varies arbitrarily in accordance with the particular technique used to measure food quantity. For example, pigment concentrations are traditionally reported on a per wet volume basis, while organic carbon and nitrogen data are reported on a per dry weight basis. This problem is compounded because comparisons between these different data sets are routinely made as a part of habitat assessments. We accordingly recommend including porosity in all investigations of sedimentary food quality, enabling each investigator to normalize to either wet volume or dry weight as appropriate.

In view of the similarities in community structure between Project Area 2 and the natural creeks, we argue that the BAP normalized to per volume wet sediment more accurately represents true food availability in created and natural systems than does total carbon or nitrogen. We are currently investigating this hypothesis in both oligohaline and polyhaline habitats.

4.4. Functional equivalency and limitations of the study

Evidence accumulated to date for Project Area 2 on wetland vascular plant productivity (Broome et al., 1986; Broome, 1989), ichthyofauna (Rulifson, 1991), and benthic infauna (this study) contends that it supports nursery area functions and responds to local ecological processes in a manner similar to the natural creeks. These findings contrast with most of the other restoration work carried out in estuarine systems (Moy and Levin, 1991; Sacco et al., 1994; Simenstad and Thom, 1996).

The 'success' of the Project Area may be linked to four aspects of its location. First, the created habitat is surrounded by the aquatic environs it was intended to mimic, thereby providing proximity to sources of infaunal recruits (Cammen, 1976; Christensen, et al., 1996). Second, the Project Area and the adjacent natural creeks are part of a large expanse of undeveloped habitat (South creek) and therefore are remote from municipal (but not agricultural) anthropogenic influences known to impede restoration efforts (Zedler, 1988; Simenstad and Thom, 1996). Third, it is a non-tidal habitat and therefore not as subject to sedimentary erosional forces as are restored intertidal projects (Simenstad and Thom, 1996).

Finally, and perhaps most importantly, the oligohaline ecosystem of which the Project Area is a part is characterized by intensely variable abiotic factors (temperature, salinity, DO). This variability evidently limits faunal diversity to a small subset of resilient eurytolerant estuarine taxa (Boesch et al., 1976). The number of taxa collected in the Project Area and natural creeks is half to one-tenth that reported for polyhaline areas of North Carolina estuaries (Cammen, 1976; Chester et al., 1983; Summerson and Peterson, 1984; West, 1985, 1990b) and of other Atlantic coast estuaries (Watling, 1975; Virnstein, 1977). Population dynamics of this oligohaline system appear to be driven primarily by these abiotic factors, especially hypoxia or anoxia (Tenore, 1972b; West and Ambrose, 1992), and the majority of the taxa are short-lived, prolific, deposit-feeding opportunists that rapidly invade new or disturbed habitats (Grall and Glemarec, 1997; Sheridan, 1997). As a result, these oligohaline infaunal communities probably never reach a stable state before a seasonal disturbance initiates a new round of recruitment. Therefore, from the perspective of infaunal community structure, mitigation is likely to be more successful in oligohaline areas than in areas of more constant and benign abiotic factors, because the organisms in oligohaline regions are more tolerant of the disturbance inherent in the process of habitat creation and restoration.

A caveat to inferences of functional equivalency discussed above for the Project Area 2 is the limitation imposed by reliance on that single site as the primary basis for our comparisons of structural and functional attributes of local created and natural oligohaline creeks. A second site exists (Project Area 1), but was not included in the analyses because the data for Project Area 1 are limited to descriptions of the infaunal community, and are confined to a relatively small time period (1991–1994) beginning about 10 years after the site was created.

The lack of replication of created or restored habitats is a general feature of mitigation research, and has several causes. First, space for a mitigation site may be limited due to a history of extensive development, such as urban areas and properties with waterfront access (Clark, 1989; Willard and Hiller, 1989). Mitigation efforts at these sites may encounter an additional difficulty if development has proceeded to the point where no undisturbed reference habitats remain, and the original ecological functions of these habitats are not fully understood (Zedler, 1996). Second, experimental design concerns such as site replication may not be required to be addressed in the planning and permitting procedures. Mitigation planning has often been poorly organized, ad hoc, and lacking in appropriate, standardized guidelines for construction and assessment (Clark, 1989; Garbisch, 1989). State agencies need to develop a strategic vision of environmental protection, and the administrative means to implement it. Third, replication is not included in the project design because mitigation efforts can be costly. The cost can be high because the permitting process is time consuming, land is expensive, construction is labor intensive, and planning, monitoring, and assessment require special skills. Estimates of the cost of constructing and monitoring Project Area 2 exceed one million dollars (NCPC staff, pers. commun.).

Finally, mitigation plans have had the objective of building a site in such a way as to maximize its potential for success. Thus, there has been reluctance to systematically vary physical or biological features of a site in order to determine their respective importance in the outcome of the mitigation process (e.g. size of watershed; ratio of marsh surface to water surface area; amount and character of detrital cover) (e.g. Pacific Estuarine Research Laboratory, 1990). Similarly, reliance on single mitigation sites does not permit assessment of site performance relative to known key abiotic and biotic variables that vary in kind and intensity along a spatial gradient (e.g. Brinson and Rheinhardt, 1996). All of these concerns combine to complicate the interpretation of the results, limit the ability to make accurate predictions about the probability of success (or failure) of future mitigation efforts, and impede our understanding of the critical mechanisms governing successful habitat creation, restoration, and enhancement. We accordingly emphasize the importance of including appropriate experimental design in the all phases of the mitigation process.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

October 31, 2001

Colonel James W. Delony
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Attention: Mr. Scott McLendon

Dear Colonel DeLony:

The U.S. Fish and Wildlife Service (Service) has reviewed Public Notice Action ID#200110096, dated October 4, 2001. The applicant, Potash Corp of Saskatchewan (PCS) Phosphate Company, has applied for a Department of the Army permit to impact 2,394 acres of waters of the United States (shown in the following table), including navigable waters, to continue its phosphate mining operation on Hickory Point, near NC Highway 306, adjacent to the Pamlico River, South Creek and its tributaries, north of Aurora, Beaufort County, North Carolina.

The proposed project wetland impacts are extensive in terms of wetland acreage and wetland diversity:

1. Creeks/Open Water	4 acres
2. Brackish Marsh Complex	35 acres
3. Bottomland Hardwood Forest	120 acres
4. Disturbed-Herbaceous Assemblage	207 acres
5. Disturbed Scrub-Shrub Assemblage	581 acres
6. Pine Plantation	745 acres
7. Hardwood Forest	209 acres
8. Mixed Pine-Hardwood Forest	314 acres
9. Pine Forest	100 acres
10. Ponds	19 acres
11."47 % wetland" area	60 acres
Total	2394 acres

In addition, 1,028 acres of upland habitat are included in the mine continuation for a total of 4,422 acres of disturbance.

The project will impact 4 acres of open waters, the majority of which are located in Huddles Cut, Tooleys Creek, and the unnamed tributary near Pamlico Aquaculture Center. In addition, Project Area II (marsh creation area) would be impacted by the proposed mine. Navigable waters of Jacks Creek, Jacobs Creek, and Tooleys Creek would be impacted by the proposed project. Impacts to submerged aquatic vegetation (SAV) including widgeon grass (Ruppia maritima), Eurasian water milfoil (Myriophyllum spicatum), horned pondweed (Zannichellia palustris), and hornwort, (Ceratophyllim demersum) will occur under the proposed action.

The coastal wetlands mentioned above as being impacted are important regulators of fresh water, suspended solids, nutrients, and contaminants. Ninety percent of the State's commercial fisheries harvest is composed of estuarine dependent species. The year 2000 value of North Carolina's commercial fishery was 108 million dollars and the recreational fishery is valued around one billion dollars annually. These values would be substantially higher except for environmental problems. The Service is very familiar with the lands being impacted and believes the type and scale of these losses will result in an unacceptable loss of fish and wildlife habitat and watershed function to the Albemarle-Pamlico Estuary. The Albemarle-Pamlico Estuary is the second largest estuary in the United States (only Chesapeake Bay is larger). A multi-agency study (Albemarle-Pamlico Estuary Study) led by the State of North Carolina and the US Environmental Protection Agency, and on which the Service and the US Army Corps of Engineers participated, reported the following in the Comprehensive Conservation and Management Plan:

- Eight percent of the freshwater rivers and streams in the Albemarle-Pamlico region are unfit for fish propagation or recreation. An additional 34 percent are only partially supporting these uses; 32 percent are threatened.
- 21,611 acres of prime shellfish habitat are closed because of pollution.
- Disease epidemics have been reported in finfish, blue crabs and oysters.
- Throughout the region, draining and filling of wetlands has contributed to the destruction of vital fish, plant, and wildlife habitats.

From this multi-agency study, it is apparent that water quality and natural resource management concerns in the watershed are will documented. It is also known that wetland losses of the magnitude proposed by this permit contribute significantly to water quality impairment. Clearly, wetland losses of this magnitude are of high concern.

The Service recommends that the district engineer not issue a permit for the project as proposed. In accordance with the procedural requirements of the 1992 404(q) Memorandum of Agreement, Part IV.3 (a), between our agencies, we are advising you that the proposed work may result in substantial and unacceptable impacts to aquatic resources of national importance. It is our opinion that the applicant has not satisfied the Environmental Protection Agency's 404(b)(1) guidelines especially in regards to avoidance and minimization of impacts, nor the 40 CFR § 230.10(c) guidelines.

Section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), requires that all federal agencies, in consultation with the Service, insure that any action authorized, funded , or carried out by such agency is not likely to jeopardize the continued existence of any federally-listed threatened or endangered species. The Service is concerned about the impacts associated with the proposed action for the following reasons:

1. We cannot accurately assess the impacts of the proposed action on federally-protected species because surveys for species with known occurrences are not included in the application package.

2. We are concerned about the loss of foraging habitat for the federally-endangered red-cockaded woodpecker (Picoides borealis) which has known populations on adjacent properties and are also concerned about potential for genetic isolation of these known populations by the removal of such large areas that may naturally serve as migrational corridors.

The Service has been an active participant of the permit review team for the project since its inception, and is hopeful that, ultimately, a solution that satisfies federal and state legal requirements and industry needs on Hickory Point can be found. Sending this permit application back to the applicant will underscore the seriousness of the issues being dealt with and, hopefully, set the stage for meaningful dialog.

We provide these comments in a constructive manner and are willing to provide substantial support to the permit review team if the stage can be set for serious discussion. We appreciate the opportunity to provide comments. If you have any questions please contact Mike Wicker at (919) 856-4520, extension 22.

Sincerely,

for Tom Augspurger

Garland B. Pardue, Ph.D.
Ecological Services Supervisor

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

January 8, 2001

Colonel James W. DeLony
District Engineer, Wilmington District
U.S. Army Corps of Engineers
Post Office Box 1890
Wilmington, North Carolina 28402-1890

Attention: David Lekson

Dear Colonel DeLony:

The U.S. Fish and Wildlife Service (Service) has reviewed correspondence dated December 6, 2000, referencing PCS Phosphate Company's application for a Department of the Army individual permit to continue its surface mining operations on a 3,604 acre tract of land located on the Hickory Point peninsula, adjacent to the Pamlico River, South Creek and associated tributaries, north of Aurora, in Beaufort County, North Carolina. The following comments are submitted pursuant to, and in accordance with, provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.).

We recognize that this is only the beginning of the process which must include the preparation of an Environmental Impact Statement but we offer the following points for your consideration.

- The Service will strongly oppose mining in tidal creeks or their buffer areas or activities that will damage area submerged aquatic vegetation.

- The Service has previously expressed concerns with high levels of cadmium in soils of reclaimed mined lands at PCS, concerns which remain relevant to the new permit application. We have worked successfully with the applicant, U.S. Army Corps of Engineers, and others to get data on the significance of this issue, and we anticipate working through the results of those studies and their land management implications soon.

- Many of the impacts in this request are estuarine and the Service believes that the area to be evaluated for potential mitigation should be commensurate in scale with the affected aquatic community. Because the estuarine community is composed of fish, shellfish and migratory birds that migrate on a large scale during their life cycle, we believe the area considered acceptable for mitigation should be larger than it would, if the impacts were more terrestrial in nature. Also, since this project is so large and invasive, mitigation should be very substantive. For example, for this project, the applicant should consider a tract such as Open Grounds Farm for mitigation after being purchased from a willing seller. A site such as Open Grounds Farm is farther from the site than might normally be considered; however, restoration on such a site would benefit the same assemblage of estuarine animals that are effected on this site, and the scale of that type of mitigation is commensurate with this type of impact.

- The Service considers this process very important and looks forward to being actively involved.

- The Service would like the U.S. Army Corps of Engineers to convene a meeting of the environmental agencies and organizations to discuss environmental concerns. Although this meeting would be a gathering of government agencies, PCS Phosphate can also attend, if desired. However, in an effort to provide an atmosphere which will allow free discussion, the environmental agencies/groups should convene a meeting *prior to* scheduling a meeting to include PCS Phosphate. That meeting would be a more efficient venue for discussing Service scoping comments on a project of this magnitude (e.g., wetland impact avoidance, minimization, compensation, endangered species section 7 consultation issues, etc.). We will be pleased to provide written scoping comments as a follow-up to such a meeting for the Corps' files on this project.

If you have any questions or comments, please contact Mike Wicker at (919) 856-4520 (Ext. 22) or via email at mike_wicker@fws.gov. Mike will have the lead for the office regarding this permit application.

Sincerely,

Garland B. Pardue
Ecological Services Supervisor

cc:	Mr. William T. Cooper	Mr. Terry Moore
	Mr. William L. Cox	Mr. Rob Perks
	Mr. John Dorney	Mr. Ross Smith
	Mr. Jeffrey C. Furness	Mrs. William Wescott
	Mr. Larry Hardy	Mrs Katy West
	Mr. Doug Huggett	Mr. Floyd Williams

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

July 16, 2001

Mr. Scott McLendon
Regulatory Project Manager
Department of the Army
Wilmington District, Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Dear Mr. McLendon:

Thank you for your June 20, 2001, request for comments on the capping of cadmium enriched PCS Phosphate mine reclamation lands near Aurora, Beaufort County, North Carolina. The U.S. Fish and Wildlife Service (Service) greatly appreciates PCS Phosphate's interest in eliminating exposure of fish and wildlife to cadmium. Specifically the following comments address the type of material that is used, thickness of the cap, and establishment of grades and elevations.

- The cap should be topsoil, recognizing that in order to be practically accomplished with conventional mining equipment the topsoil grab may contain some depth of material underlaying the topsoil. The capping soil should be able support reasonable growth of the type of tree species native to the area prior to mining or in the case of sandier soils longleaf pine stands with growth characteristic of that species on sandy soils. Based on the observed greater diversity of vegetation in topsoil-capped areas at the site, the topsoil cap allows for a faster and more complete restoration of mined areas. Spatial variation with some areas with pure or almost pure topsoil and others with sand are preferable to complete homogeneity.

- The soil cap should be a <u>minimum</u> of 1-3 feet deep.

- The reclaimed land should be contoured so that after reclamation surface drainage would enter natural streams and creeks similar to natural drainage patterns prior to mining. After topsoil capping, reforestation and natural contouring, the reclaimed watershed would ultimately return as an environmental asset instead of a liability.

- Based on the cadmium risk evaluation, topsoil capping should also be considered for reclamation areas R-1, 2 and 3 and the clay ponds. We understand that the U.S. Army Corps of Engineers cannot require this, but we hope that capping solutions on these sites can be developed that are acceptable to all parties involved.

The Service appreciates the opportunity to provide these comments and we look forward to continued involvement with this process. Questions or comments should be directed to Mike Wicker at 919-856-4520, extension 22, or by e-mail at **mike_wicker@fws.gov.**

Sincerely,

for Tom Augspurger

Dr. Garland B. Pardue
Ecological Services Supervisor

FWS/R4/MWicker/July 11, 2001/919-856-4520, ext 22/pcs cadmium capping.wpd

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

June 25, 2008

Tom Walker
U.S. Army Corps of Engineers
Project Manager, Wilmington Regulatory Division
Post Office Box 1890
Wilmington, NC 28402-1890

Reference: PCS Phosphate, Action ID # 200110096

Dear Mr. Walker:

This letter provides the comments from the United States Fish and Wildlife Service (Service) on the subject Public Notice dated May 22, 2008 under Corps Action ID #: 200110096 (review of the Final Environmental Impact Statement, FEIS, for the proposed Potash Corporation of Saskatchewan Mine Continuation near Aurora, Beaufort County, North Carolina). Service comments were sent previously on the Draft Environmental Impact Statement (DEIS) and the Supplement to the Draft Environmental Impact Statement (SDEIS). The Potash Corporation of Saskatchewan Phosphate Division, Aurora Operation (PCS) has applied for Department of the Army authorization pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act to advance its current mining operation. The proposed expansion (Alternative L) would impact 4,135 acres of waters of the United States including wetlands adjacent to the Pamlico River, South Creek and Durham Creek. These comments are submitted in accordance with the Fish and Wildlife Coordination Act (FWCA) (48 Stat. 401, as amended; 16 U.S.C. 661-667d). Comments related to the FWCA are to be used in your determination of compliance with 404(b)(1) guidelines (40 CFR 30) and in your public interest review (33 CFR 320.4) in relation to protection of fish and wildlife resources.

The PCS mine expansion is proposed adjacent to the Albemarle Pamlico Estuary Complex, the largest lagoonal estuary in the country and nationally significant estuarine resource. The fringe marshes, creeks, and beds of submerged aquatic vegetation in the Albemarle Pamlico Estuary Complex provide essential nursery habitat for most commercial and recreational fish and shellfish in the North Carolina coastal area (Street et al. 2005) and important habitat for waterfowl (http://www.fws.gov/birddata/databases/mwi/mwidb.html), shorebirds and other migratory birds. The importance of wetlands to coastal fish is not unique to North

Carolina. Over 95% of the finfish and shellfish species commercially harvested in the United States are wetland-dependent (Feierabend and Zelazny 1987). The estuary also provides important habitat for anadromous fish, including the endangered shortnose sturgeon (*Acipenser breviorostrum*). The Albemarle Pamlico Estuary Complex supports an important recreationally-based economy. According to the 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (U.S Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau 2006) fishing expenditures for 2006 in North Carolina totaled over 1.1 billion dollars. Given that the proposed expansion would result in impacts to more than 4100 acres of wetlands and over 5.5 miles of streams located directly adjacent to the Pamlico River, such large-scale impacts would likely have direct effects on the environmental quality of the Albemarle Pamlico Estuary Complex. We are especially concerned about the potential for mine expansion and operation to be detrimental to the food webs of the Albemarle Pamlico Estuary Complex. Consequently, as stated in our January 5, 2007 letter, the Service continues to believe that the proposed PCS mine expansion will result in substantial and unacceptable impacts to aquatic resources of the Albemarle Pamlico Estuary Complex. Our concerns regarding the FEIS revolve around three specific issues discussed below.

1. <u>Proposed mining operations will negatively impact estuarine trophic structure through disruption of substrate inputs crucial to primary producers; reduction of energy sources that fuel estuarine productivity; and degradation of the nutrient sequestration capacity of the estuarine system</u>. Estuary productivity is dependent on the complex interactions among the various components of the aquatic food web; with epiphytes (attached to wetland macrophytes) and submerged aquatic vegetation; (SAV) forming the foundation of the estuarine food web (Odum 1971; Mitsch and Gosselink 2000; Wetzel 2001). SAV populations have recently declined by as much as 50%, possibly because of anthropogenic impacts (North Carolina Division of Marine Fisheries 2005). As a result, detritus supplied by wetland macrophytes has become more important as an epiphytic substrate. While phytoplankton are also important for productivity, the role of wetland plants and SAV detritus is of greater importance to the overall stability of shallow aquatic food webs (Rich and Wetzel 1978). It is our opinion that the proposed mining operations will negatively impact both types of epiphytic substrates, and adequate mitigation is not proposed in the FEIS. However, adequate restoration is available if PCS focuses their expansion and other operations on lands south of Hwy 33.

   Also of importance to estuarine food webs is the gradual and episodic release of dissolved organic matter (DOM) from the contributing basins and wetlands immediately adjacent to the Albemarle Pamlico Estuary Complex. This energy source fuels bacterial communities that, through mineralization, provide inorganic nitrogen, phosphorous and carbon, supporting productivity. In addition, DOM supported bacteria are an important component of the "microbial loop" (Pomeroy 1974; Sherr and Sherr 1988). This part of aquatic food webs links DOM (of autochthonous and/or allochthonous origin) to higher trophic levels, via bacteria-protist-metazoan-zooplankton interactions. The impacts associated with the proposed alternative would decrease the quantity and quality of allochthonous DOM supplied to the estuary because of the close proximity of PCS's proposed mining operations.

Marsh systems provide additional functions that can influence estuarine food webs. For example, carbon of wetland origin is also exported from marsh systems in the guts of migratory feeding fish and birds or cycled through the marsh to the upper ends of tidal creeks and back to the marsh (Mitsch and Gosselink 2000). Also, marshes act to sequester and process inorganic nutrients from flood waters. The major tributaries to the Pamlico Sound, the Neuse and Tar Rivers, have been found to be excessively polluted with nutrients and are currently being managed to reduce nutrient loads. Nutrient enrichment, or eutrophication, has promoted increased algal productivity, which had resulted in hypoxia, anoxia, and fish kills in the lower estuary. Removal of wetlands in the Pamlico Sound system acts to exacerbate the impacts of this loading by removing the system's nutrient uptake capability.

Most of the wetlands that would be subjected to impacts are wet forests, including bottomland hardwood forests. These areas are subjected to repeated periods of inundation and desiccation. This is important from a biogeochemical perspective as it allows for the accumulation of particulate organic matter and its subsequent processing (dissolution and mineralization). This leads to episodic exports of dissolved organic materials to the estuary. It also retains nutrient loads carried by high flow events, which are later sequestered into forest biomass. Such systems are also important for denitrification. These areas also provide refugia and nursery habitat for aquatic organisms during high flow periods. Productivity is high in such wetlands with pulsing hydroperiods (Mitsch and Gosselink 2000).

2. <u>Mining will directly affect the rate at which water is routed through the watershed.</u> As the mine expansion progresses, there is an ever increasing trend of diverting surface water drainage which once promoted estuarine productivity into National Pollutant Discharge Elimination System (NPDES) channels, pipes and outfalls. This redirection of surface flows contributes to estuarine degradation because it removes natural watershed drainage patterns that 1) promote infiltration and trapping of sediments and other pollutants, and 2) provide a beneficial diffuse source of water to the estuary. This critical watershed function is reflected in the DEIS (paragraph 3, A-91) "Mr. Wicker stated that the … catchment basin is critically important for these streams, because rainfall is the stream's source of water. Dr. Skaggs replied that Mr. Wicker's summation was correct." In light of this concern, we are troubled that the rate of mine expansion far exceeds the rate of recovery completed. According to page 4-78 of the SDEIS between 1965 – 2005 a total of 7,729 acres were mined but only 1,101 were reclaimed. In short, reclamation (including vegetation and hydrology restoration) will allow the water quality benefits of natural drainage to return to the estuary over time; however,

the discrepancy in progress between mining and reclamation activities significantly limits the potential for system recovery.

Offsets to wetland plant community losses through the proposed mitigation schedule may not be adequate to maintain the wetland functions within the watershed. Replacing mature wetlands with immature restored or created wetlands will not provide the physical or chemical functions of existing wetland systems. Plant communities drive many physical and chemical processes within wetlands such as 1) sedimentation, and, because of adsorption, nutrient retention, 2) hydrological demand through transpiration, 3) nutrient (inorganic nitrogen and phosphorous) cycling, 4) soils for microbial communities responsible for denitrification and 5) flood mitigation because mature communities are stable sources of hydraulic roughness.

It is our opinion that the applicant should provide upfront mitigation for stream, riparian buffer and wetland impacts. By replacing mature watershed systems with restored wetlands, there will be significant lag time (several decades at least) before vegetation and soils can develop so they can adequately mitigate for the losses of DOM production and nutrient sequestration/processing provided by the present ecosystems. Given the estuary's designation as an aquatic resource of national importance, this large-scale loss of habitat quality for a period of decades is not acceptable. For these reasons, we suggest that the applicant mine in the area south of Hwy 33 because all of the other mining alternatives destroy large watersheds too close to the estuary to be adequately mitigated. In all areas other than south of Hwy 33, adequate compensatory mitigation was not proposed.

3. Given the potential for significant hydrological and trophic impacts to estuarine resources highlighted above (bullets # 1 & 2), and the lack of adequate mitigation, proposed expansion of PCS mining operations north of Hwy 33 cannot be supported. We note that the PCS plant facilities can operate independent of the mine (Section 2.6.2) and mining south of Hwy 33 could be supplemented with importation of phosphate rock to eliminate any shortfalls in supply. Therefore, the Service does not agree with the applicant's assertion of "purpose and need" requiring continued mining since the plant facilities can operate with importation of rock, thus avoiding degradation of the nationally significant Albemarle Pamlico Estuary Complex.

The Albemarle Pamlico Estuary Complex is a bar-built estuary (Odum 1971), enclosed by North Carolina's Outer Banks. These barrier islands create a lake-like, brackish water body with only small outlets connecting it to the Atlantic Ocean (Paerl et al. 2001). Such geomorphic character produces a relatively closed system with a hydrologic residence time of about one year (Giese et al. 1985). This means that the Albemarle Pamlico Estuary Complex is highly effective at retaining nutrients, sediments and organic matter conveyed by its freshwater sources. These sediments and organic materials have absorptive relationships with nutrients, heavy metals and other toxicants that may cause chronic ecosystem impacts during hydrologic events that resuspend benthic materials in the estuaries. Thus, the impacts represented by PCS Phosphate's mining expansion should be considered with considerable diligence, as such impacts are likely to produce a legacy of environmental effects that could last for years, affecting estuarine food webs.

The Service concludes that the proposed project will result in substantial and unacceptable adverse impacts to aquatic resources of national importance. Such large-scale wetland impacts located directly adjacent to the Pamlico River, as argued above, will act to exacerbate the impacts of eutrophication while altering local food web stability; both of which have important implications for estuarine productivity. Additionally, the proposed compensatory mitigation is insufficient to offset adverse impacts to the aquatic environment except in the area south of Hwy 33 (the applicant considers an alternative to only mine south of 33 as not practicable, Section 2.7.4). Further, the applicant has not demonstrated that adverse impacts have been avoided and minimized to the extent required by the Section 404(b)(1) Guidelines. Therefore, in accordance with our 1992 Interagency Memorandum of Agreement, the Service recommends that the request for a Department of the Army permit for this project be denied.

The Service appreciates the opportunity to provide comments on the FEIS. If you have any questions regarding this letter or previous Service correspondence relating to PCS Mine Continuation near Aurora, Beaufort County North Carolina under U.S. Army Corps of Engineers Action ID # 200110096 please contact Mike Wicker at 919-856-4520ext22 or by e-mail at mike_wicker@fws.gov.

Sincerely,

Pete Benjamin
Field Supervisor

References cited:

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Giese, G.L., H.B. Wilder and G.G. Parker. 1985. Hydrology of major estuaries and sounds of North Carolina. USGS water-supply paper 2221.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
1875 Century Boulevard
Atlanta, Georgia 30345

In Reply Refer To:
FWS/R4/ES

JAN 05 2007

Tom Walker
U.S. Army Corps of Engineers
Project Manager, Wilmington Regulatory Division
Post Office Box 1890
Wilmington, North Carolina 28402-1890

RE: Public Notice dated October 20, 2006, under Corps Action ID # 200110096 (review of the Draft Environmental Impact Statement, Potash Corporation of Saskatchewan Mine Continuation near Aurora, Beaufort County, North Carolina)

Dear Mr. Walker:

In accordance with the 1992 404(q) Memorandum of Agreement (MOA) between our agencies, the enclosed letter report provides the recommendations of the Department of the Interior in response to the above application for a Department of the Army Permit.

Pursuant to part IV.3(b) of the MOA, I have determined that the proposed work will have substantial and unacceptable impacts on aquatic resources of national importance if permitted as specified in the public notice, without incorporating our recommendations. I strongly encourage a mutual resolution of the identified wetland/wildlife concerns at the field level prior to your decision to issue the permit.

Sincerely yours,

Sam D. Hamilton
Regional Director

Enclosure

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Field Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

December 20, 2006

Tom Walker
U.S. Army Corps of Engineers
Project Manager, Wilmington Regulatory Division
Post Office Box 1890
Wilmington, NC 28402-1890

Reference: PCS Phosphate, Action ID # 200110096

Dear Mr. Walker:

This letter provides the comments from the United States Fish and Wildlife Service (Service) on the subject Public Notice dated October 20, 2006 under Corps Action ID #: 200110096 (review of the Draft Environmental Impact Statement, DEIS, for the proposed Potash Corporation of Saskatchewan Mine Continuation near Aurora, Beaufort County, North Carolina). The Potash Corporation of Saskatchewan Phosphate Division, Aurora Operation (PCS) has applied for Department of the Army authorization pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act to advance its current mining operation into a 3,608 acre area east of its current mining operation located north of Aurora. The proposed expansion would impact 2,408 acres of waters of the United States including wetlands adjacent to the Pamlico River and South Creek. These comments are submitted in accordance with the Fish and Wildlife Coordination Act (FWCA) (48 Stat. 401, as amended; 16 U.S.C. 661-667d). Comments related to the FWCA are to be used in your determination of compliance with 404(b)(1) guidelines (40 CFR 30) and in your public interest review (33 CFR 320.4) in relation to protection of fish and wildlife resources. Additional comments are provided regarding the District Engineer's determination of project impacts pursuant to section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531-1543).

The PCS mine expansion is proposed adjacent to the Albemarle Pamlico Estuary Complex, the largest lagoonal estuary in the country and nationally significant estuarine resource. The fringe marshes, creeks, and beds of submerged aquatic vegetation in the Albemarle Pamlico Estuary Complex provide essential nursery habitat for most commercial and recreational fish and shellfish in the North Carolina coastal area (Street et al. 2005) and important habitat for waterfowl (http://www.fws.gov/birddata/databases/mwi/mwidb.html), shorebirds and other migratory birds. The importance of wetlands to coastal fish is not unique to North Carolina. Over 95% of the finfish and shellfish species commercially harvested in the United States are wetland-dependent (Feierabend and Zelazny 1987). The estuary also provides important habitat for anadromous fish, including the endangered shortnose sturgeon (*Acipenser breviorostrum*). The Albemarle Pamlico Estuary Complex supports an important recreationally-based economy. According to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (http://www.census.gov/prod/2003pubs/01fhw/fhw01-nc.pdf, see page 9) fishing expenditures for 2001 in North Carolina totaled 1.1 billion dollars. Given that the Applicant's Preferred alternative (AP) would result in impacts to more than 2,400 acres of wetlands and 7 miles of streams located directly adjacent to the Pamlico River, such large-scale impacts would likely have direct effects on the environmental quality of the Albemarle Pamlico Estuary Complex. We are especially concerned about the potential for mine expansion and operation to be detrimental to the food webs of the Albemarle Pamlico Estuary Complex. Consequently, the Service believes that the PCS mine expansion may result in substantial and unacceptable impacts to aquatic resources of the Albemarle Pamlico Estuary Complex.

1. AP mining operations will negatively impact estuarine trophic structure through disruption of substrate inputs crucial to primary producers, 2) reduction of energy sources that fuel estuarine productivity, and 3) degradation of the nutrient sequestration capacity of the estuarine system. Estuary productivity is dependent on the complex interactions among the various components of the aquatic food web; with epiphytes (attached to wetland macrophytes) and submerged aquatic vegetation; (SAV) forming the foundation of the estuarine food web (Odum 1971; Mitsch and Gosselink 2000; Wetzel 2001). SAV populations have recently declined by as much as 50%, possibly because of anthropogenic impacts (North Carolina Division of Marine Fisheries 2005). As a result, detritus supplied by wetland macrophytes has become more important as an epiphytic substrate. While phytoplankton are also important for productivity, the role of wetland plants and SAV detritus is of greater importance to the overall stability of shallow aquatic food webs (Rich and Wetzel 1978). It is our opinion that the AP mining operations will negatively impact both types of epiphytic substrates, and adequate mitigation is not proposed in the DEIS. However, adequate restoration is available if PCS focuses their expansion and other operations on lands south of Hwy 33.

   Also of importance to estuarine food webs is the gradual and episodic release of dissolved organic matter (DOM) from the contributing basins and wetlands immediately adjacent to the Albemarle Pamlico Estuary Complex. This energy source fuels bacterial communities that, through mineralization, provide inorganic nitrogen, phosphorous and carbon, supporting productivity. In addition, DOM supported bacteria are an important component of the "microbial loop" (Pomeroy 1974; Sherr and Sherr 1988). This part of aquatic food webs links DOM (of autochthonous and/or allochthonous origin) to higher trophic levels, via bacteria-protist-metazoan-zooplankton interactions. The impacts associated with the AP would decrease the quantity and quality of allochthonous DOM supplied to the estuary because of the close proximity of PCS's proposed mining operations.

Marsh systems provide additional functions that can influence estuarine food webs. For example, carbon of wetland origin is also exported from marsh systems in the guts of migratory feeding fish and birds or cycled through the marsh to the upper ends of tidal creeks and back to the marsh (Mitsch and Gosselink 2000). Also, marshes act to sequester and process inorganic nutrients from flood waters. The major tributaries to the Pamlico Sound, the Neuse and Tar Rivers, have been found to be excessively polluted with nutrients and are currently being managed to reduce nutrient loads. Nutrient enrichment, or eutrophication, has promoted increased algal productivity, which had resulted in hypoxia, anoxia, and fish kills in the lower estuary. Removal of wetlands in the Pamlico Sound system acts to exacerbate the impacts of this loading by removing the system's nutrient uptake capability.

Most of the wetlands that would be subjected to impacts are wet forests, including bottomland hardwood forests. These areas are subjected to repeated periods of inundation and desiccation. This is important from a biogeochemical perspective as it allows for the accumulation of particulate organic matter and its subsequent processing (dissolution and mineralization). This leads to episodic exports of dissolved organic materials to the estuary. It also retains nutrient loads carried by high flow events, which are later sequestered into forest biomass. Such systems are also important for denitrification. These areas also provide refugia and nursery habitat for aquatic organisms during high flow periods. Productivity is high in such wetlands with pulsing hydroperiods (Mitsch and Gosselink 2000).

2. <u>Mining will directly affect the rate at which water is routed through the watershed.</u> As the mine expansion progresses, there is an ever increasing trend of diverting surface water drainage which once promoted estuarine productivity into National Pollutant Discharge Elimination System (NPDES) channels, pipes and outfalls. This redirection of surface flows contributes to estuarine degradation because it removes natural watershed drainage patterns that 1) promote infiltration and trapping of sediments and other pollutants, and 2) provide a beneficial diffuse source of water to the estuary. This critical watershed function is reflected in the DEIS (paragraph 3, A-91) "Mr. Wicker stated that the … catchment basin is critically important for these streams, because rainfall is the stream's source of water. Dr. Skaggs replied that Mr. Wicker's summation was correct." In light of this concern, we are troubled that the rate of mine expansion far exceeds the rate of recovery completed. According to page 4-78 of the DEIS, in the period between 1965 - 2005, a total of 7,729 acres were mined but only 1,101 were reclaimed. In short, reclamation (including vegetation and hydrology restoration) will allow the water quality benefits of natural drainage to return to the estuary over time; however, the discrepancy in progress between mining and reclamation activities significantly limits the potential for system recovery and should be addressed in the DEIS.

Offsets to wetland plant community losses through the proposed mitigation schedule may not be adequate to maintain the wetland functions within the watershed. Replacing mature wetlands with immature restored or created wetlands will not provide the physical or chemical functions of existing wetland systems. Plant communities drive many physical and chemical processes within wetlands such as 1) sedimentation, and, because of adsorption, nutrient retention, 2) hydrological demand through transpiration, 3) nutrient (inorganic nitrogen and phosphorous) cycling, 4) soils for microbial communities responsible for denitrification and 5) flood mitigation because mature communities are stable sources of hydraulic roughness.

It is our opinion that the applicant should provide upfront mitigation for stream, riparian buffer and wetland impacts. By replacing mature watershed systems with restored wetlands, there will be significant lag time (several decades at least) before vegetation and soils can develop so they can adequately mitigate for the losses of DOM production and nutrient sequestration/processing provided by the present ecosystems. Given the estuary's designation as an aquatic resource of national importance, this large-scale loss of habitat quality for a period of decades is not acceptable. For these reasons, we suggest that the applicant mine in the area south of Hwy 33 because all of the other mining alternatives destroy large watersheds too close to the estuary to be adequately mitigated. In all areas other than south of Hwy 33, adequate compensatory mitigation was not proposed.

3. <u>The Service has previously recommended that the applicant complete endangered species surveys.</u> We cannot concur with your endangered species determinations presented in the DEIS for bald eagle (*Haliaaetus leucocephalus*), or red-cockaded woodpecker (*Picoides borealis*) because both of these species occur in the area and no surveys have been completed within the last ten years. The Service also recommends surveys conducted on red wolf (*Canus rufus*) since it is also known to occur in the general area.

4. <u>The Service has been involved in reclamation soil quality issues described in subsection 4.1.3.1. While the four pages of text in this section present much useful information, four components are missing that are needed to capture the scope of the issues that should be considered for the DEIS;</u>

   - The subsection should be re-named Elemental Contaminant Issues and include a brief summary of other elements enriched in reclamation soils. For instance, average concentrations of arsenic at R2 were about 75-times background (maximum 110-times background), and concentrations in soils exceed some regulatory guidance values for polluted sites. Chromium concentrations at R2 also averaged about 75-times background (maximum 80-times background). Some additional summary statistics like this for the other elements evaluated by Drs. Trefry and Logan (e.g. specific constituents of concern other than Cd and As) would help readers see the scope of the elemental contaminant concerns in reclamation soils made from gypsum-clay waste blends.

- The Service draft report Significance of Cadmium in the Terrestrial Environment on and Adjacent to PCS Phosphate Mine Reclamation Lands (2001) is not referenced in this section and it should be summarized here. An appropriate place for inclusion would be just after the discussion of the earthworm bioaccumulation test (beginning on page 4-6 and ending at the top of page 4-7.

- The discussion of sources of elevated cadmium in South Creek and Pamlico River sediments is reasonable regarding historic inputs from a pipeline rupture and now-ceased wastewater discharges. The DEIS notes that these sources are gone. However, site run-off is also a plausible hypothesis for continued releases to these areas, and metals analyses of sediments collected recently would help clarify this issue. Most of the samples being discussed are over a decade old; if the historic spill and now eliminated discharge sources were the cause, then sediment metal concentrations should be lower now. We encourage some new sampling to address this issue.

- From the last paragraph on page 4-8 to the end of this section, the DEIS discusses the capping of reclamation soils. This section should include some information on the performance of the capping approach and whether PCS intends to continue with this approach based on their experience with capping thus far. We consider PCS's capping solution to be a very positive approach to ameliorating concerns with metals in reclamation soils, and we believe it should be continued. The effort is commendable, and if it is going well, PCS should let reviewers know the plan is working as anticipated. Because this section states several times that PCS may consider alternate approaches in the future, it would help readers if the performance of the existing approach was discussed along with the status of any studies on this or other options. Lastly, the section should be rephrased to note that any alternative to capping would need to be effective in addressing arsenic, chromium and other metals enriched in reclamation soils in addition to cadmium.

5. Given the potential for significant hydrological and trophic impacts to estuarine resources highlighted above (bullets # 1 & 2), and the lack of adequate mitigation, proposed expansion of PCS mining operations north of Hwy 33 cannot be supported. We note that the PCS plant facilities can operate independent of the mine (Section 2.6.2) and mining south of Hwy 33 could be supplemented with importation of phosphate rock to eliminate any shortfalls in supply. Therefore, the Service does not agree with the applicant's assertion of "purpose and need" requiring continued mining since the plant facilities can operate with importation of rock, thus avoiding degradation of the nationally significant Albemarle Pamlico Estuary Complex

The Albemarle Pamlico Estuary Complex is a bar-built estuary (Odum 1971), enclosed by North Carolina's Outer Banks. These barrier islands create a lake-like, brackish water body with only small outlets connecting it to the Atlantic Ocean (Paerl et al. 2001). Such geomorphic character produces a relatively closed system with a hydrologic residence time of about one year (Giese et al. 1985). This means that the Albemarle Pamlico Estuary Complex is highly effective at retaining nutrients, sediments and organic matter conveyed by its freshwater sources. These sediments and organic materials have absorptive relationships with nutrients, heavy metals and other toxicants that may cause chronic ecosystem impacts during hydrologic events that resuspend benthic materials in the estuaries. Thus, the impacts represented by PCS Phosphate's mining expansion should be considered with considerable diligence, as such impacts are likely to produce a legacy of environmental effects that could last for years, affecting estuarine food webs.

The Service concludes that the proposed project may result in substantial and unacceptable adverse impacts to aquatic resources of national importance. Such large-scale wetland impacts located directly adjacent to the Pamlico River, as argued above, will act to exacerbate the impacts of eutrophication while altering local food web stability; both of which have important implications for estuarine productivity. Additionally, the proposed compensatory mitigation is insufficient to offset adverse impacts to the aquatic environment except in the area south of Hwy 33 (the applicant considers an alternative to only mine south of 33 as not practicable, Section 2.7.4). Further, the applicant has not demonstrated that adverse impacts have been avoided and minimized to the extent required by the Section 404(b)(1) Guidelines. Therefore, in accordance with Part IV.3.a of our 1992 Interagency Memorandum of Agreement, the Service recommends that the request for a Department of the Army permit for this project be denied.

The Service appreciates the opportunity to provide comments on the DEIS. If you have any questions please contact Mike Wicker at 919-856-4520ext22 or by e-mail at mike_wicker@fws.gov.

Sincerely,

Pete Benjamin
Field Supervisor

References cited:

Feierabend, S.J. and J.M. Zelazny. 1987. Status report on our nation's wetlands. National Wildlife Federation, Washington, D.C., 50pp.

Giese, G.L., H.B. Wilder and G.G. Parker. 1985. Hydrology of major estuaries and sounds of North Carolina. USGS water-supply paper 2221.

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Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. N.C. Department of Environment and Natural Resources, Division of Marine Fisheries. Morehead City. 630 pp.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Washington, D.C. 20240

In Reply Refer To:
FWS/AFHC/HRC/DCN040619

The Honorable John Paul Woodley, Jr.
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Room 3E446
Washington, DC 20310-0108

Dear Mr. Woodley:

The Fish and Wildlife Service (FWS) notified the Wilmington District Commander on March 20, 2009, that we are pursuing review by the Assistant Secretary of the Army (Civil Works) of the proposed Clean Water Act (CWA) Section 404 permit to the Potash Corporation of Saskatchewan, Phosphate Division, Aurora Operation, to be issued by the Corps of Engineers Wilmington District. That request for elevation was made pursuant to Part IV, paragraph 3(d) (2), of the Memorandum of Agreement (MOA) between the Department of the Interior and the Department of the Army to supplement Section 404(q) of the CWA. The Wilmington District issued a Notice of Intent to Proceed on this permit under a letter dated March 2, 2009, and received by our regional office on March 5, 2009. We have been preparing to request our Acting Assistant Secretary for Fish and Wildlife and Parks to seek review of the permit decision document by the Assistant Secretary of the Army (Civil Works) pursuant to paragraph 3(f)(2) of the MOA. Under the standard MOA timeline, that request must be made by April 9, 2009.

However, on Friday, April 3, 2009, the Wilmington District provided our Raleigh Ecological Services Field Office (and EPA) approximately 80 pages of new material regarding the project, including the District's draft Record of Decision and supporting maps. It is not clear why this material was not included with the District's March 2, 2009 Notice of Intent to Proceed (NOI) to FWS. Since receipt of the NOI, FWS has noticed the stream impacts are different in the new material than were reported in the NOI. If the District had transmitted this information along with its NOI, FWS would have had a total of 35 days under the MOA to review this material. Since it was shared so late in the process, USFWS has effectively been denied an opportunity to review and respond to this material prior to initiating the elevation process. In order for FWS to be afforded an appropriate amount of time to review this new material, I request that you allow FWS an additional 20 days to review the new material and decide whether or not to continue the process under paragraph 3(f)(2).

I appreciate your prompt attention to this matter. Please feel free to contact me or Gary Frazer, Assistant Director for Fisheries and Habitat Conservation (202/208-6394) if you have questions or wish to discuss further.

Sincerely,

Acting DIRECTOR

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1875 Century Boulevard
Atlanta, Georgia 30345

In Reply Refer To
FWS/R4/ES

MAR 20 2009

Colonel Jefferson M. Ryscavage
District Engineer, Wilmington District
U.S. Army Corps of Engineers
69 Darlington Avenue
Wilmington, North Carolina 28403-1343

Subject: Recommendation to Request a Higher Level Review for Department of Army Permit AID 200110096, Potash Corporation of Saskatchewan Phosphate Division, Aurora Operation (PCS) Mine Continuation

Dear Colonel Ryscavage:

We have received your Notice of Intent to Proceed on the proposed Department of the Army Permit AID 200110096, The Aurora Operation (PCS) Mine Continuation, dated March 2nd and received at USFWS Region 4 on March 5, 2009. Pursuant to Paragraph 3(d)(2) of the Memorandum of Agreement (MOA) between the Department of the Interior and the Department of Army, under Clean Water Act Section 404 (q) Part IV, I am requesting a review of this permit by the Acting Assistant Secretary of Fish and Wildlife and Parks, Department of the Interior, and recommending that he request review of the permit by the Assistant Secretary of the Army for Civil Works. During this review, the permit should be held in abeyance pending completion of the review process pursuant to the MOA Part IV, Paragraph 3(e).

The USFWS remains concerned that the proposed project will result in unacceptable adverse impacts to aquatic resources of national importance, including direct and indirect impacts to waters of the U.S. which support the Albemarle Pamlico National Estuary Program area. The proposed project will have direct impacts to 3,953 acres of wetlands and 45,494 linear feet of stream, including a portion of a designated Significant Natural Heritage Area. The impacts also include a loss of approximately 70 percent of the watershed areas within the proposed project boundaries. The project will adversely affect the Albemarle Pamlico Complex and those effects have not yet been adequately addressed. In addition to the need to further avoid and minimize impacts to the site's high value aquatic resources, there are concerns regarding the adequacy of the proposed compensatory mitigation to offset any authorized impacts.

We recognize the desire for timely decision making on this permit. We have worked closely with your staff and have offered our comments throughout the Environmental Impact Statement and 404 permitting process, and we appreciate the efforts by both you and the applicant to address them. Still, critical issues about the impact of this project remain unresolved and based on the concerns cited above; we do not support issuance of the permit for the project as currently proposed. Therefore, pursuant to the procedures and timelines in the national 1992 Memorandum of Agreement with the Corps of Engineers, we are seeking review by Acting Assistant Secretary Fish and Wildlife and Parks, Department of the Interior and the Assistant Secretary for Civil Works.

Please contact Pete Benjamin, Field Supervisor, Raleigh Ecological Services, at (919) 856-4520, extension 11 for further information, and we look forward to continuing our dialogue as we move forward.

Sincerely Yours,

Linda A Kelsey

for / Sam D. Hamilton
Acting Regional Director

Mike_Wicker@fws.gov
04/16/2009 11:26 AM

To Rebecca Fox/R4/USEPA/US@EPA
cc
bcc
Subject USFWS will not be at onsite meeting

----- Forwarded by Mike Wicker/R4/FWS/DOI on 04/16/2009 11:24 AM -----

Mike Wicker/R4/FWS/DOI
04/16/2009 11:16 AM

To Jeff Weller/R4/FWS/DOI
cc Jack Arnold/R4/FWS/DOI, Pete Benjamin/R4/FWS/DOI@FWS
Subject Fw: PCS onsite visit

Jeff,

Here's the e-mail I had sent EPA earlier. Do not know where anyone got the impression I was going. Pete and I knew we were not invited.

I am off tommorrow and among other things plan on going fishing for American shad on the Neuse (one of my favorite things to do and the weekdays are best because on the weekends the best spots get competitive).

Have a nice weekend.

Thanks for all your help.

Mike

----- Forwarded by Mike Wicker/R4/FWS/DOI on 04/16/2009 11:06 AM -----

Mike Wicker/R4/FWS/DOI
04/15/2009 09:14 AM

To Fox.Rebecca@epamail.epa.gov
cc pace.wilber@noaa.gov, Pete Benjamin/R4/FWS/DOI@FWS
Subject Re: PCS onsite visit

Becky,

I talked with Pete. It was his understanding also that we we are not invited to attend the meeting since we did not get the elevation request in under the timeline. We will try to get our letter signed by the RD so that we can be there in proxy. Our absence at the meeting in no way reflects a lack of interest. It is a COE meeting and PCS is not public property so we can not go if we are not invited.

Mike
Fox.Rebecca@epamail.epa.gov

Fox.Rebecca@epamail.epa.gov

04/15/2009 07:49 AM

To pace.wilber@nmfs.gov, mike_wicker@fws.gov

cc

Subject PCS onsite visit

Pace/Mike,

Just checking to see if anyone from FWS or NMFS is planning to attend
the PCS onsite this Friday with the Army. Jennifer Derby is now going
to go so EPA will have someone there and now Army is saying this will be
EPA's one and only time to make our case to Army -- that there will be
no further discussions after this visit. It's all very strange since we
were told they could not make our onsite date and this was the only day
they could do it and we weren't even planning to have anyone there
except my management decided it would be a good idea if we were
represented and now that we are going to have someone there -- Army is
saying this is EPA's only chance to make our verbal case to them.
Didn't know what your agencies' plans were but I'm sure it would be
helpful for Jennifer to have some support if you all are planning to
attend...

Mike, Palmer and I have reviewed your 3f1 letter and think it looks good
-- just have a few small comments -- will get them to you later this
morning. Stay tuned... b

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531

Email: fox.rebecca@epa.gov

"Pace.Wilber" <Pace.Wilber@noaa.gov>

04/16/2009 02:29 PM

To Mike Wicker <Mike_Wicker@fws.gov>, Palmer Hough/DC/USEPA/US@EPA, Rebecca Fox/R4/USEPA/US@EPA

cc Ron Sechler <ron.sechler@noaa.gov>

bcc

Subject NMFS PCS letter

Hi everyone.

Attached is the draft letter that Ron and I prepared for the COE in response to the 3(c) letter sent us a few weeks ago. Our response is due tomorrow (April 17). As noted previously, we simply do not have the time to pursue this further. Hopefully in letting the COE know that, we are still supporting FWS and EPA. Any comments Ron and I get by 0830 tomorrow have a good chance of being added to the letter.

Thanks,
Pace

--

Pace Wilber, Ph.D.
Atlantic Branch Chief, Charleston (F/SER47)
Southeast Regional Office, NOAA Fisheries
PO Box 12559
Charleston, SC 29422-2559

843-953-7200
FAX 843-953-7205
pace.wilber@noaa.gov

http://sero.nmfs.noaa.gov/dhc/habitat.htm

Colonel Jefferson Ryscavage
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
Regulatory Division
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Tom Walker

Dear Colonel Ryscavage:

NOAA's National Marine Fisheries Service (NMFS) reviewed your letter dated March 30, 2009, which was received April 2, 2009, concerning the Wilmington District's Final Environmental Impact Statement (FEIS) *"Potash Company of Saskatchewan, Inc. (PCS) Phosphate Mine Continuation at Aurora in Beaufort County, North Carolina"* (Action ID No. 200110096). Your letter, which included a draft Record of Decision and draft permit conditions, indicates that you conclude that issuance of a permit for the modified Alternative L alignment would not result in substantial and unacceptable impacts to aquatic resources of national importance and, based on the compensatory mitigation that would be required by the permit, adverse impacts to essential fish habitat (EFH) would not occur from the project. The letter was provided to NMFS in accordance with Part IV, Section 3(c)(2) of the 1992 Memorandum of Agreement between the Departments of Commerce and Defense regarding Clean Water Act section 404(q) and in accordance with 50 CFR Part 600, which describes how federal agencies will coordinate to protect, conserve, and enhance EFH. Our comments below summarize our more important concerns, including where NMFS continues to differ with the Wilmington District regarding the impacts expected to result from the project, however, due to competing priorities for staff time, NMFS will not appeal your decision under the terms of the 1992 Memorandum of Agreement.

Previous letters from NMFS and the Wilmington District describe the project, list project authorities, review consultation history, and identify the expected impacts to EFH and fishery species. Throughout the review process, NMFS consistently focused on the project's likelihood of degrading the nationally significant fish and wildlife resources of the Albemarle-Pamlico Estuary Complex (APEC) within which the proposed mine expansion is located. In short, the Wilmington District concludes after examining at least 11 action alternatives that modified

Alternative L represents the least environmentally damaging practicable alternative (LEDPA) for PCS to expand its mine, and this alternative includes mining within three tracts referred to as NCPC, Bonnerton, and S33. Modified Alternative L would impact 11,909 acres, including approximately 3953 acres of jurisdictional wetlands and 25,727 feet of streams. In comparison to other alternatives, modified Alternative L would avoid direct impacts to 141 acres of EFH that includes wetlands associated with South Creek within the NCPC tract and Porter Creek within the Bonnerton tract. Our comments are divided into three sections: (1) identification of EFH, (2) sequential mitigation, and (3) monitoring and adaptive management.

Identification of EFH

The Bonnerton and NCPC tracts include tidally influenced forested wetlands, creeks, and salt marsh designated as EFH by the South Atlantic Fishery Management Council and Mid Atlantic Fishery Management Council for federally managed fishery species, including penaeid shrimp, gray snapper, summer flounder, and bluefish. A subset of the areas designated as EFH is recognized by the North Carolina Wildlife Resources Commission (NCWRC) as inland Primary Nursery Areas (PNAs), and this state designation also makes these areas a federally designated Habitat Area of Particular Concern (HAPC), the subset of EFH that warrants the highest protection under the Magnuson-Stevens Act. The PNAs within the project area are Porter Creek, Tooley Creek, Jacobs Creek, and Jacks Creek; the latter three creeks empty into South Creek, which is designated a Special Secondary Nursery Area by the State of North Carolina and also is an HAPC.

As acknowledged in past correspondence from both of our offices, the upper limits of PNAs has not been delineated in the field. In the absence of this delineation, the Wilmington District focuses on the North Carolina State Statute that defines PNAs, and the District concludes that the upper limit of the PNAs equates to the boundary between perennial and intermittent flows within the creeks named as PNAs. The modified Alternative L for the proposed mine expansion avoids direct impacts to PNAs under this definition. While NMFS believes that substantial ecological services are provided to fishery resources from the portions of the creeks that have intermittent flows and their headwater wetlands, we accept the Wilmington District's interpretation of the relevant North Carolina State Statute as reasonable and that as a result of close coordination between the applicant, resource agencies, and Wilmington District, direct impacts to HAPCs are no longer proposed.

Sequential Mitigation

Avoidance and Minimization of Impacts

The LEDPA must be identified before evaluating compensatory mitigation. The US Environmental Protection Agency (EPA) contends in its comments on the EIS and subsequently submitted materials that the S33 alternative is the LEDPA because it is least damaging to the environment. The Wilmington District contends that the S33 alternative is not practicable, and that Alternative L is the LEDPA. It is disconcerting that the EPA and the Wilmington District do not agree upon this point given its fundamental and critical importance to the review process. Both agencies maintain their economic analysis is thorough and appropriately peer reviewed within their respective agency. Given the large differences in the outcomes of these analyses and that the Wilmington District is proposing to authorize the largest wetland destruction within

North Carolina under the Clean Water Act, an external peer review is clearly needed to provide the public with assurance that the laws and programs put in place to protect public trust resources, such as APEC, were rigorously followed. We recommend the US Army Corps of Engineers pursue this review even if it is done after a final decision on the application from PCS is rendered because the different approaches that EPA and the Wilmington District took in their analysis will likely trigger substantive disagreements on future projects.

Relative to alternatives earlier promoted by the applicant, modified Alternative L reflects avoidance and minimization of direct impacts to wetlands that we believe represent the higher value to fishery species. While these steps are noteworthy, additional avoidance and minimization appear practicable. On March 30, EPA, NMFS, and the US Fish and Wildlife Service provided the Wilmington District and applicant with an alternative boundary for the mine. In addition to reducing impacts to habitats that support nursery areas, this alternative would provide opportunities for on-site compensatory mitigation to be pursued within PNAs, which NMFS believes would also benefit fishery resources within South Creek as well as the larger APEC. The applicant expressed a desire to review the new alternative and noted that its evaluation could take a month or longer. NMFS recommends the Wilmington District withhold its final determination on the application until the applicant's review is complete and vetted through resource agencies and stakeholders. At the very least, we continue to recommend exclusion from the mine seven areas that total approximately 50 acres and serve as headwaters of tidally influenced creeks that we believe are significant nursery areas for fishery species (aerial images with these seven exclusion areas were informally provided to the District in March, and GIS data can be provided upon request).

Functional Assessment of the Compensatory Mitigation
The mitigation plan (FEIS Appendix I) involves multiple sites and strategies to compensate for the ecosystem services lost over the life of the project. The proposed restoration efforts primarily focus on croplands and drained forested wetlands that are underlain by hydric soils and, therefore, expected to be good candidates for wetland restoration. The proposed mitigation would occur at sites south of the Pamlico River (primarily south, east, and west of the S33 tract) and at sites north of the Pamlico River. Under the plan, 7968, 756, and 2472 acres of wetlands would be restored, enhanced, and preserved, respectively. To guide their evaluation of the proposed compensatory mitigation, replacement to loss ratios used by Wilmington District are based on 2:1 for restoration, 3:1 for enhancement, and 8:1 to 10:1 for preservation. The replacement ratio used for examining stream replacement is 1.8:1. In this regard, it is important to note that 71 percent of the NCPC tract, 76 percent of the Bonnerton tract, and 20 percent of the S33 tract are wetlands. By 2011, the applicant plans to complete construction of all the compensatory mitigation projects needed to offset the losses from mining the NCPC and Bonnerton tracts. To implement this schedule, the applicant has expended considerable effort to identify, acquire, and develop off-site mitigation through restoration of previously impacted waters and wetlands.

The applicant's proposal to provide mitigation up front and on an ambitious schedule is commendable. While tallies summarizing the overall mitigation are persuasive, it is disconcerting that a quantitative, functional assessment, using a habitat equivalency analysis or a similar method, has not been performed. Decisions relying mostly upon best professional judgment are unavoidable for a project of this scale. While a formal, functional assessment would also rely upon best professional judgment, it would do so in a manner that greatly increases precision (in the sense of repeatability) and transparency, facilitates sensitivity analyses, includes benefits from reclamation, and identifies key milestones for focus in an adaptive management program that ultimately focuses on whether the compensatory mitigation yields ecological services to South Creek, Durham Creek, and Pamlico River on a scale comparable to the losses at Jack, Jacob, Tooley, Porter, and other creeks within the NCPC and Bonnerton tracts. A formal functional assessment would also bring into sharper focus that what has been achieved thus far the issue of whether wetlands within the subset of the Bonnerton tract that is a nationally significant Natural Heritage Area can be mitigated and, if so, at what relative cost.

Monitoring and Adaptive Management

Monitoring

NMFS remains concerned about the loss of headwater wetlands associated with PNAs under the modified Alternative L alignment. Based on input regarding the designation of these areas as HAPCs, PCS agreed to avoid direct impacts to these creeks. However, as noted by the Wilmington District, resource agencies, and NOAA's Center for Coastal Fisheries and Habitat Research (Beaufort Laboratory), substantial indirect impacts to PNAs and other tidal creeks would result from the proposed loss of headwater wetlands and intermittent streams on the NCPC and Bonnerton tracts. To address this concern, we recommended that prior to initiation of land clearing activities in the headwater wetlands of state designated nursery areas located along the NCPC shoreline of South Creek, PCS develop a plan of study to address the effects of a reduction in headwater wetlands on the utilization of these nursery areas by resident fish and invertebrates. In these systems, resident fish and invertebrate are important prey for estuarine dependent species that seasonally frequent estuarine creeks during sub-adult development stages. Monitoring changes in these populations should prove a reasonable indicator of the effect of losses of headwater wetland on changes in resident species that support the nursery area function of these creeks. NMFS is pleased to see that the draft permit conditions require within 6 months of permit issuance development of a detailed plan for such a monitoring program. We offer to continue to work with the Wilmington District, PCS, and other interested parties to further refine these conditions into a detailed plan.

Adaptive Management

The scales of the proposed mine and compensatory mitigation are large and the impacts and benefits that would actually accrue from these actions (as opposed to predicted to accrue) would be subject to variables that can only be generally forecasted at the time of a permit decision. Proper and timely execution of the monitoring programs followed by responsive adjustments of mining and mitigation plans would be essential to ensure expansion of the PCS mine under modified Alternative L is done in a manner that is in the public interest. Requiring the applicant to adhere to a process that allows the Wilmington District and resource agencies to substantively engage in the oversight of the project and in adjustments to project design is necessary for NMFS to have reasonable assurance that impacts to NOAA trust resources would be adequately compensated.

NMFS is pleased to see that the draft permit conditions require that the applicant establish an independent panel of scientists and engineers that would annually review the project and determine if direct and indirect impacts and benefits are accruing at the rates forecasted at the time of a project authorization. Data and reports should be placed in a publically accessible location, such as a website, and be freely available. The panel will also annually provide the Wilmington District and applicant with recommended changes to the mining and mitigation that are necessary to bring the project into alignment with expectations. We offer to continue to work with the Wilmington District, PCS, and other interested parties to further refine and implement the adaptive management plan, should a permit be issued.

Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald Sechler at our Beaufort Field Office, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, or at (252) 728-5090.

Robin Wiebler
<Robin.Wiebler@noaa.gov>
04/17/2009 04:30 PM

To: NCCOE Tom Walker <William.T.Walker@usace.army.mil>, Mike_Wicker@fws.gov, Rebecca Fox/R4/USEPA/US@EPA, SAFMC Roger Pugliese <roger.pugliese@safmc.net>, NC

cc:

bcc:

Subject: PCS response letter

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
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263 13th Avenue South
St. Petersburg, Florida 33701-5505
(727) 824-5317; FAX (727) 824-5300
http://sero.nmfs.noaa.gov/

F/SER4:RS/pw

APR 17 2009

Colonel Jefferson Ryscavage
District Engineer, Wilmington District
Department of the Army, Corps of Engineers
Regulatory Division
P. O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Tom Walker

Dear Colonel Ryscavage:

NOAA's National Marine Fisheries Service (NMFS) reviewed the letter dated March 30, 2009, from the Corps of Engineers, Wilmington District (COE) which NMFS received April 2, 2009, concerning the COE's Final Environmental Impact Statement (FEIS) "*Potash Company of Saskatchewan, Inc. (PCS) Phosphate Mine Continuation at Aurora in Beaufort County, North Carolina*" (Action ID No. 200110096). The COE's letter, which included a draft Record of Decision and draft permit conditions, indicates that the COE concludes that issuance of a permit for the modified Alternative L alignment would not result in substantial and unacceptable impacts to aquatic resources of national importance, and based on the compensatory mitigation that would be required by the permit, adverse impacts to essential fish habitat (EFH) would not occur from the project. The letter was provided to NMFS in accordance with Part IV, Section 3(c)(2) of the 1992 Memorandum of Agreement between the Departments of Commerce and Defense regarding Clean Water Act section 404(q) and in accordance with 50 CFR Part 600, which describes how federal agencies will coordinate to protect, conserve, and enhance EFH. The comments below summarize NMFS' principal concerns, including areas where NMFS continues to differ with the COE regarding the impacts expected to result from the project. However, in light of factors described below as well as constraints on staff time, NMFS will not appeal the COE's decision under the terms of the 1992 Memorandum of Agreement. This letter therefore constitutes NMFS' response to the COE in accordance with Part IV, Section 3(d)(1) of the Memorandum of Agreement that NMFS will not request higher level review.

Previous letters from NMFS and the Wilmington District describe the project, list project authorities, review consultation history, and identify the expected impacts to EFH and fishery species. Throughout the review process, NMFS consistently focused on the project's likelihood of degrading the nationally significant fish and wildlife resources of the Albemarle-Pamlico Estuary Complex (APEC) within which the proposed mine expansion is located. The review process identified at least 11 action alternatives for consideration; the COE has concluded that Modified Alternative L represents the least environmentally damaging practicable alternative (LEDPA) for PCS to expand its mine. This alternative includes mining within three tracts referred to as NCPC, Bonnerton, and S33. Modified Alternative L would impact 11,909 acres, including approximately 3953 acres of jurisdictional wetlands and 25,727 feet of streams. In comparison to other alternatives, Modified Alternative L would avoid direct impacts to 141 acres of EFH that includes wetlands associated with South Creek within the NCPC tract and Porter Creek within the Bonnerton tract. NMFS' comments are divided into three sections: (1) identification of EFH; (2) sequential mitigation; and (3) monitoring and adaptive management.

Identification of EFH

The Bonnerton and NCPC tracts include tidally influenced forested wetlands, creeks, and salt marsh designated as EFH by the South Atlantic Fishery Management Council and Mid Atlantic Fishery Management Council for federally managed fishery species, including penaeid shrimp, gray snapper, summer flounder, and bluefish. A subset of the areas designated as EFH is recognized by the North Carolina Wildlife Resources Commission (NCWRC) as inland Primary Nursery Areas (PNAs). Pursuant to the designations of EFH by the Councils, PNAs are also designated as Habitat Area of Particular Concern (HAPC), the subset of EFH that warrants the highest protection under the Magnuson-Stevens Act. The PNAs within the project area are Porter Creek, Tooley Creek, Jacobs Creek, and Jacks Creek. The latter three creeks empty into South Creek, which is designated a Special Secondary Nursery Area by the State of North Carolina and is also designated as an HAPC.

As acknowledged in past correspondence from both of our offices, the upper limits of PNAs has not been delineated in the field. In the absence of this delineation, the COE referenced the North Carolina state statute that defines PNAs, and the COE concluded the upper limit of the PNAs equates to the boundary between perennial and intermittent flows within the creeks named as PNAs. The Modified Alternative L for the proposed mine expansion avoids direct impacts to PNAs under this definition. While NMFS believes that substantial ecological services are provided to fishery resources from the portions of the creeks that have intermittent flows and from their headwater wetlands, NMFS accepts the COE's interpretation of the relevant North Carolina state statute as reasonable. As a result of close coordination among the applicant, resource agencies, and the COE, NMFS has determined direct impacts to HAPCs are no longer likely.

Sequential Mitigation

Avoidance and Minimization of Impacts

The LEDPA must be identified before evaluating compensatory mitigation. The US Environmental Protection Agency (EPA) contends in its comments on the EIS and subsequently submitted materials that Alternative L/Modified Alternative L is not the

LEDPA because there are less environmentally damaging alternatives. The COE contends that the less environmentally damaging alternatives are not practicable, and that Alternative L (according to the FEIS) and Modified Alternative L (according to the ROD) is the LEDPA. Both agencies maintain their economic analysis is thorough and appropriately peer reviewed within their respective agency. Given the significant differences in the outcomes of these analyses and that the COE is proposing to authorize the largest wetland destruction within North Carolina under the Clean Water Act, an external peer review is clearly needed to provide the public with assurance that the laws and programs put in place to protect public trust resources, such as APEC, were rigorously followed. NMFS recommends the COE conduct this review even if it is done after a final decision on the application from PCS is rendered, because the different approaches that EPA and the Wilmington District took in their respective analysis will likely trigger substantive disagreements on future projects.

Relative to alternatives earlier promoted by the applicant, Modified Alternative L reflects avoidance and minimization of direct impacts to wetlands that NMFS believes represent the higher value to fishery species. While these steps are noteworthy, additional avoidance and minimization appear practicable. On March 30, EPA, NMFS, and the US Fish and Wildlife Service proposed to the COE and applicant an alternative boundary for the mine. In addition to reducing impacts to habitats that support nursery areas, this alternative would provide opportunities for on-site compensatory mitigation to be pursued within PNAs. NMFS believes this alternative would benefit fishery resources within South Creek as well as the larger APEC. The applicant expressed a desire to review the new alternative and noted that its evaluation could take a month or longer. NMFS recommends the COE withhold its final determination on the application until the applicant's review is complete and vetted through resource agencies and stakeholders. At the very least, NMFS continues to recommend exclusion from the mine seven areas totaling approximately 50 acres that serve as headwaters of tidally influenced creeks which NMFS believes are significant nursery areas for fishery species.

Functional Assessment of the Compensatory Mitigation
The mitigation plan (FEIS Appendix I) involves multiple sites and strategies to compensate for the ecosystem services lost over the life of the project. The proposed restoration efforts primarily focus on croplands and drained forested wetlands underlain by hydric soils which, therefore, are expected to be good candidates for wetland restoration. The proposed mitigation would occur at sites south of the Pamlico River (primarily south, east, and west of the S33 tract) and at sites north of the Pamlico River. Under the plan, 7968, 756, and 2472 acres of wetlands would be restored, enhanced, and preserved, respectively. To guide their evaluation of the proposed compensatory mitigation, replacement-to-loss ratios used by the COE are 2:1 for restoration, 3:1 for enhancement, and 8:1 to 10:1 for preservation. The replacement ratio used for determining stream replacement is 1.8:1. In this regard, it is important to note that 71 percent of the NCPC tract, 76 percent of the Bonnerton tract, and 20 percent of the S33 tract are wetlands. By 2011, the applicant plans to complete construction of all the compensatory mitigation projects needed to offset the losses from mining the NCPC and Bonnerton tracts. To implement this schedule, the applicant has expended considerable

effort to identify, acquire, and develop off-site mitigation through restoration of previously impacted waters and wetlands.

The applicant's proposal to provide mitigation up front and on an ambitious schedule is commendable. While tallies summarizing the overall mitigation are persuasive, NMFS believes a quantitative, functional assessment, using a habitat equivalency analysis or a similar method, should be performed. Decisions relying mostly upon best professional judgment should be avoided for a project of this scale and significance of potential impacts. While a formal, functional assessment would also rely upon best professional judgment, it would do so in a manner that greatly increases precision (in the sense of repeatability) and transparency, identifies and quantifies uncertainties and assumptions, facilitates sensitivity analyses, includes benefits from reclamation, and establishes key milestones for use in an adaptive management program that ultimately focuses on whether the compensatory mitigation yields ecological services to South Creek, Durham Creek, and Pamlico River on a scale commensurate with the losses at Jack, Jacob, Tooley, Porter, and other creeks within the NCPC and Bonnerton tracts. A formal functional assessment would also clarify whether wetlands within the subset of the Bonnerton tract, which is a nationally significant Natural Heritage Area, can be mitigated and, if so, at what relative cost.

Monitoring and Adaptive Management

Monitoring

NMFS remains concerned about the loss of headwater wetlands associated with PNAs under the Modified Alternative L alignment. Based on input regarding the designation of these areas as HAPCs, PCS agreed to avoid direct impacts to these creeks. However, as noted by the COE, resource agencies, and NOAA's Center for Coastal Fisheries and Habitat Research (Beaufort Laboratory), substantial indirect impacts to PNAs and other tidal creeks would result from the proposed loss of headwater wetlands and intermittent streams on the NCPC and Bonnerton tracts. To address this concern, NMFS recommended that prior to initiation of land clearing activities in the headwater wetlands of state-designated nursery areas located along the NCPC shoreline of South Creek, PCS develop a plan of study to address the effects of a reduction in headwater wetlands on the utilization of these nursery areas by resident fish and invertebrates. In these systems, resident fish and invertebrates are important prey for estuarine-dependent species that seasonally frequent estuarine creeks during sub-adult development stages. Monitoring changes in these populations should prove a reasonable indicator of the effect of losses of headwater wetland on changes in resident species that support the nursery area function of these creeks. NMFS is pleased to see that the draft permit conditions require, within six months of permit issuance, development of a detailed plan for such a monitoring program. NMFS offers to continue to work with the COE, PCS, and other interested parties to further refine these conditions into a detailed plan.

Adaptive Management

The scales of the proposed mine and compensatory mitigation are large and the impacts and benefits that would actually accrue from these actions (as opposed to predicted to accrue) are subject to variables that can only generally be forecasted at the time of a permit decision. Proper and timely execution of the monitoring programs followed by responsive adjustments of mining and mitigation plans would be essential to ensure expansion of the PCS mine under Modified Alternative L is done in a manner that is in the public interest. Requiring the applicant to adhere to a process that allows the COE and resource agencies to substantively engage in the oversight of the project, and in adjustments to project design, is necessary for NMFS to have reasonable assurance that impacts to NOAA trust resources would be adequately compensated.

NMFS is pleased to see that the draft permit conditions require the applicant to establish an independent panel of scientists and engineers to annually review the project and determine if direct and indirect impacts and benefits are accruing at the rates forecasted at the time of a project authorization. Data and reports should be placed in a publicly accessible location, such as a website, and be freely available. The panel will also annually provide the COE and applicant with recommended changes to the mining and mitigation that are necessary to bring the project into alignment with expectations. NMFS offers to continue to work with the COE, PCS, and other interested parties to further refine and implement the adaptive management plan, should a permit be issued.

Thank you for the opportunity to provide these comments. Related questions or comments should be directed to the attention of Mr. Ronald Sechler at our Beaufort Field Office, 101 Pivers Island Road, Beaufort, North Carolina 28516-9722, or at (252) 728-5090.

Sincerely,

Roy E. Crabtree, Ph.D.
Regional Administrator

cc:

FWS, Mike_Wicker@usfws.gov
EPA, Becky.Fox@epa.gov
SAFMC, Roger.Pugliese@safmc.gov
NCDCM, Doug.Huggett@ncmail.net
NCDMF, Sara.Winslow@ncmail.net
F/SER4, Miles.Croom@noaa.gov
F/SER47, Ron.Sechler@noaa.gov, Pace.Wilber@noaa.gov

Jeff_Weller@fws.gov
04/18/2009 09:16 AM

To Palmer Hough/DC/USEPA/US@EPA, Mike_Wicker@fws.gov
cc "Pace.Wilber" <Pace.Wilber@noaa.gov>, Rebecca Fox/R4/USEPA/US@EPA, "Ron Sechler" <ron.sechler@noaa.gov>
bcc
Subject Re: USFWS PCS letter

Palmer - it was signed late Thursday, I was "out" Friday. I'll send you a copy 1st thing Monday morning.

J. Weller
(sent from my handheld wireless Blackberry)

----- Original Message -----
From: Hough.Palmer
Sent: 04/18/2009 09:05 AM AST
To: Mike Wicker
Cc: "Pace.Wilber" <Pace.Wilber@noaa.gov>; Fox.Rebecca@epamail.epa.gov; Ron Sechler <ron.sechler@noaa.gov>; Jeff Weller
Subject: Re: USFWS PCS letter

Mike:

Good letter. Please forward a signed copy ASAP. I would like to get this in the hands of the folks at Army/Corps HQ. They need to hear more about the limitations regarding the studies cited in the draft ROD.

Yesterday's site visit was very interesting. As expected without FWS, NMFS, and Becky it was a full court press from PCS and the District. Both were very well represented as was Army/Corps HQ. As I was the only one with some knowledge of the site and project history who was pushing for change the deck was clearly stacked against us. But I am still hopeful that we have opportunities to improve the project.

-Palmer

Palmer F. Hough
US Environmental Protection Agency
Wetlands Division
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E-mail: hough.palmer@epa.gov

Street/Courier Address
USEPA
Palmer Hough
EPA West -- Room 7231-L
Mail Code 4502T
1301 Constitution Avenue, NW

Washington, DC 20460

From: Mike_Wicker@fws.gov

To: Palmer Hough/DC/USEPA/US@EPA

Cc: Rebecca Fox/R4/USEPA/US@EPA, "Pace.Wilber" <Pace.Wilber@noaa.gov>, Ron Sechler <ron.sechler@noaa.gov>

Date: 04/16/2009 05:36 PM

Subject: Re: USFWS PCS letter

This is the latest draft that I saw of our letter. I think it has been or is being signed shortly. Copies will be sent of the final Monday.

(See attached file: 20090414_PCS_404qf1.doc) One date in error was changed although that is not evident in this file.
[attachment "20090414_PCS_404qf1.doc" deleted by Palmer Hough/DC/USEPA/US]

WCARY@brookspierce.com
04/20/2009 12:47 PM

To Brooke.Lamson@saw02.usace.army.mil, William.T.Walker@usace.army.mil, Palmer Hough/DC/USEPA/US@EPA, Stan
cc James Gregory <jim.gregory@wathydro.com>, RSmith@Pcsphosphate.com, GHOUSE@brookspierce.com, JFurness@Pcsphosphate.com
bcc
Subject PCS - 404 Permit; Gregory Summary

At the meeting in Aurora on 4/17/09, we distributed a summary of Dr. Gregory's findings. Dr. Gregory has informed me that in his haste to get his summary to us in time for our 4/17/09 meeting, he failed to catch an error in that summary (i.e., several references to swamp white oaks): the three indicator species used by NHP for NRWHF include swamp chestnut oak, not swamp white oak. His field observations and findings were based on application of the correct criteria, and his conclusions and opinions are therefore unaffected. His final report should be available later this week.
I do not have the e-mail addresses for the attendees, so if you receive this, please forward it as appropriate.
Bill Cary, Counsel to PCS Phosphate

Palmer Hough/DC/USEPA/US
04/20/2009 12:33 PM

To Wilber Pace <Pace.Wilber@noaa.gov>, Mike_Wicker <Mike_Wicker@fws.gov>, Jeff_Weller@fws.gov
cc Rebecca Fox/R4/USEPA/US@EPA
bcc
Subject Fw: PCS Phosphate 3(d) Letter

Information Redacted pursuant to
5 U.S.C. Section 552 (b)(5), Exemption 5,
Privileged Inter/Intra Agency Document
Specific Privilege: Deliberative Process Privilege

Palmer F. Hough
US Environmental Protection Agency
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Washington, DC 20460

----- Forwarded by Palmer Hough/DC/USEPA/US on 04/20/2009 12:30 PM -----

From: Palmer Hough/DC/USEPA/US
To: "Smith, Chip R Mr CIV USA ASA CW" <Chip.Smith@HQDA.Army.Mil>
Cc: "Schmauder, Craig R SES CIV USA OGC" <craig.schmauder@us.army.mil>, "Dorsey, Garrett L NWP" <Garrett.L.Dorsey@usace.army.mil>, "Moyer, Jennifer A HQ02" <Jennifer.A.Moyer@usace.army.mil>, "Hurley, John S LTC MIL USA ASA CW" <John.Hurley@us.army.mil>, "Wood, Lance D HQ02" <Lance.D.Wood@usace.army.mil>, Meg.E.Gaffney-Smith@usace.army.mil, "Pfenning, Michael F COL MIL USA ASA CW" <Michael.Pfenning@us.army.mil>, "Morris, Patricia A Ms CIV USA OGC" <Patricia.Morris@us.army.mil>, Robert Wood/DC/USEPA/US@EPA, "Salt, Terrence C SES CIV USA ASA CW" <rock.salt@us.army.mil>, "Chubb, Suzanne L Ms CIV USA ASA CW" <Suzanne.L.Chubb@us.army.mil>, William.L.James@usace.army.mil, Ann Campbell/DC/USEPA/US@EPA, Brian Frazer/DC/USEPA/US@EPA
Date: 04/20/2009 12:25 PM
Subject: Re: PCS Phosphate 3(d) Letter

Chip:

Thanks for sharing the NMFS letter. Like NMFS, EPA also believes that Mod Alt L avoids directly impacting wetlands that provide the highest value to fisheries resources (i.e., the tidal creeks). As NMFS, FWS and EPA have highlighted, we are concerned regarding the indirect impacts to these wetlands systems that would result when 70-85 % of the watersheds of these tidal creeks are impacted by mining. As NMFS, FWS and EPA have highlighted, studies cited in the FEIS and draft ROD do not allay these concerns and it is not clear that the proposed compensatory mitigation would reduce these indirect impacts down to an acceptable level. On this point, the NMFS letter notes that:

"While tallies summarizing the overall mitigation are persuasive, NMFS believes a quantitative, functional assessment, using a habitat equivalency analysis or a similar method, should be performed. Decisions relying mostly upon best professional judgment should be avoided for a project of this scale and significance of potential impacts."

Also, I have attached a 4-16-09 letter from USFWS stating its continued concerns regarding the proposed project. Although FWS will not be elevating, its letter echoes the concerns raised by EPA and NMFS. A full read of both the NMFS and FWS letters is very helpful for understanding their perspectives.

Thanks, Palmer

FWS_20090416_3f1_withdraw_no_attachments.pdf

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Street/Courier Address
USEPA
Palmer Hough
EPA West – Room 7231-L
Mail Code 4502T
1301 Constitution Avenue, NW
Washington, DC 20460

"Smith, Chip R Mr CIV USA ASA CW" Sir: Attached is an April 17,... 04/20/2009 11:38:32 AM

From: "Smith, Chip R Mr CIV USA ASA CW" <Chip.Smith@HQDA.Army.Mil>
To: "Salt, Terrence C SES CIV USA ASA CW" <rock.salt@us.army.mil>
Cc: "Schmauder, Craig R SES CIV USA OGC" <craig.schmauder@us.army.mil>, "Morris, Patricia A Ms CIV USA OGC" <Patricia.Morris@us.army.mil>, "Chubb, Suzanne L Ms CIV USA ASA CW" <Suzanne.L.Chubb@us.army.mil>, <Meg.E.Gaffney-Smith@usace.army.mil>, <William.L.James@usace.army.mil>, "Moyer, Jennifer A HQ02" <Jennifer.A.Moyer@usace.army.mil>, "Dorsey, Garrett L NWP" <Garrett.L.Dorsey@usace.army.mil>, Palmer Hough/DC/USEPA/US@EPA, Robert Wood/DC/USEPA/US@EPA, "Pfenning, Michael F COL MIL USA ASA CW" <Michael.Pfenning@us.army.mil>, "Hurley, John S LTC MIL USA ASA CW" <John.Hurley@us.army.mil>, "Wood, Lance D HQ02" <Lance.D.Wood@usace.army.mil>
Date: 04/20/2009 11:38 AM

Subject: PCS Phosphate 3(d) Letter

Sir:

Attached is an April 17, 2009, letter from NOAA/NMFS providing their final comments and informing the Corps that they will NOT request higher level review under the 404q MOA. NOAA/NMFS is the Federal government's expert on marine fisheries and fishery issues. I have summarized the main points of their letter below.

Primary Nursery Areas - NMFS concludes that "as a result of close coordination among the applicant, resource agencies, and the COE, NMFS has determined direct impacts to Habitat Areas of Particular Concern are no longer likely".

Sequential Mitigation - "Modified Alternative L reflects avoidance and minimization of direct impacts to wetlands that NMFS believes represent the higher value to fishery species". The letter goes on to encourage the Corps to continue to consider opportunities to further avoid and minimize impacts.

Functional Assessment of the Compensatory Mitigation - NMFS notes that "the applicant has expended considerable effort to identify, acquire, and develop off-site mitigation through restoration of previously impacted waters and wetlands". While NMFS would prefer a functional assessment, they accept the approach used by the applicant and Corps.

Monitoring and Adaptive Management - NMFS is pleased to see that draft permit conditions require, within six months of permit issuance, development of a detailed plan for such a monitoring program. NMFS offers to continue to work with the COE, PCS, and other interested parties to further refine these conditions into a detailed plan". "NMFS is pleased to see that the draft permit conditions require the applicant to establish an independent panel of scientists and engineers to annually review the project and determine if direct and indirect impacts and benefits are accruing at the rates forecasted at the time of project authorization".

Chip Smith
Office of the Assistant Secretary of the Army (Civil Works)
Assistant for Environment, Tribal and Regulatory Affairs
108 Army Pentagon 3E427
Washington, D.C. 20310-0108
703-693-3655 Voice
703-839-0389 Cell
703-697-8433 Fax

[attachment "PCSPhosphateCorp_200110096_3(d) NMFS.pdf" deleted by Palmer Hough/DC/USEPA/US]

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1875 Century Boulevard
Atlanta, Georgia 30345

In Reply Refer To:
FWS/R4/ES

APR 16 2009

Colonel Jefferson M. Ryscavage
District Engineer, Wilmington District
U.S. Army Corps of Engineers
69 Darlington Avenue
Wilmington, North Carolina 28403-1343

RE: Department of Army Permit AID 200110096, Potash Corporation of Saskatchewan Phosphate Division, Aurora Operation (PCS) Mine Continuation

Dear Colonel Ryscavage:

This letter is provided under Part IV, paragraph 3(f)(1), of the 1992 Memorandum of Agreement (MOA) between the Department of the Interior and the Department of Army, under Clean Water Act (CWA) Section 404(q). The Fish and Wildlife Service (Service) has decided not to seek higher level review of the proposed decision by the Army Corps of Engineers' Wilmington District to issue a CWA Section 404 permit to the Potash Corporation of Saskatchewan, Phosphate Division, Aurora Operation. Nonetheless, the Service has substantial unresolved concerns regarding the proposed project and our decision to not seek higher level review is not an indication that these concerns have been resolved. The Service fully concurs with and supports the concerns expressed by the U.S. Environmental Protection Agency in their letter to the Assistant Secretary of the Army (Civil Works)(ASA (CW)) dated April 3, 2009.

The Wilmington District (District) issued a Notice of Intent to Proceed letter regarding this permit under paragraph 3(c)(3) of the MOA on March 2, 2009; this letter was received by our Southeast Regional Office on March 5, 2009. The proposed project is an expansion of the mine's 1997 CWA permit. The expansion, as currently proposed, will impact 3,953 acres of wetlands and 25,727 linear feet of streams, including a portion of a Significant Natural Heritage Area designated as "nationally significant." In addition, the project is adjacent to the Pamlico River and will result in a loss of approximately 70 percent of the watersheds of the project area streams which drain to the Albemarle-Pamlico Estuary Complex.

The March 2, 2009, Notice of Intent to Proceed letter included some provisions intended to minimize impacts through project footprint reduction and increase compensatory mitigation. The Wilmington District concluded that these provisions would adequately address our concerns for the project. Both the Service's Raleigh, North Carolina Field Office and Southeast Regional Office staff carefully considered these measures, and responded on March 20, 2009, pursuant to

Part IV, paragraph 3(d)(2) of the 1992 MOA. That response stated that the Service does not concur that our concerns have been adequately addressed.

Pursuant to Part IV, paragraph 3(f) of the 1992 MOA, the Department of the Interior had until April 9, 2009, to notify the ASA (CW) that the Department of the Interior was requesting higher level review. On April 3, 2009, the District provided the Service with an 80-page draft Record of Decision containing information not previously reviewed by the Service. In response the Service requested, via a letter dated April 8, 2009, an extension of the MOA timeframe in order to allow a review of the new information. The Corps denied that request, and the Service was unable to complete its review within the timeframe prescribed by the MOA.

In our continuing effort to assist the Corps in making a timely decision in this matter, we have completed an expedited review of the draft Record of Decision. We note the draft Record of Decision contains the same flaws the Service previously noted in the Final Environmental Impact Statement (FEIS). Specifically, it is our opinion that the Corps has consistently drawn inappropriate conclusions from limited data that are contrary to, and not supported by, the vast body of knowledge regarding the functioning of estuarine systems.

The FEIS, the March 2, 2009, Notice of Intent to Proceed letter, and the draft Record of Decision rely heavily on monitoring data and studies of local estuaries to support the conclusion that project-related reductions of approximately 70 percent of the watersheds of project area streams would not substantially impair the functioning of those stream or their associated estuaries. The Service has consistently noted the limitations of these analyses.

To summarize, it has been pointed out by the Service and others that these studies are of insufficient scope, duration, and design to provide a basis for determining the effects of project-related drainage basin reduction on the creeks and estuaries of the project area. The Corps appears to acknowledge this in the FEIS with statements such as those appearing on page 4-14 of the FEIS: "...although a definitive conclusion cannot be made because the pre-drainage basin reduction monitoring data on flow and salinity for this creek covers less than a year." The FEIS further states (page 4-16) "it is difficult to draw any definite conclusions because there was no control site for Stanley's 1990 statistical study and there was only one year of baseline water quality and flow data for Jacks Creek." Also in Appendix J.II-7 of the FEIS it is stated in reference (in part) to a report by Entrix: "Although the Corps does not endorse or agree with all of the conclusions and statements found in either of these reports, both have been included in Appendix F in their entirety and the relevant information from these reports has been used as appropriate in the discussion of potential impacts found in Section 4.0 of the FEIS. Additionally, the Entrix report was supplied to the Review Team and their comments have been considered." We note that this is apparently in response (at least in part) to a critique of the Entrix study provided by NMFS following the February 12, 2008, interagency meeting (see enclosed). We concur completely with the NMFS comments, and note that although the Corps states that these comments were "considered" we can find no specific evidence of such consideration in the FEIS or draft Record of Decision.

Despite acknowledgement of the limitations of these studies, the Corps consistently overlooks these limitations and draws definitive conclusions that the project will not result in substantial adverse impacts to the Albemarle-Pamlico Estuary. We view this as an inappropriate use of the available information. We point again to the comments submitted throughout the process by the state and Federal agencies responsible for the management and conservation of the Albemarle-Pamlico Estuary including the Service, NMFS, EPA, NC Wildlife Resources Commission, and NC Division of Marine Fisheries (see enclosed comments of the NC WRC and NC DMF) that have noted the limitations of these studies, and drawing on their accumulated expertise and the vast body of available scientific information have concluded that one cannot deprive a waterbody of 70 percent of its watershed and expect it to function normally.

We remain committed to working with the Corps to effectively address our concerns. We are hopeful that a reasonable outcome can be achieved that satisfies the economic interests of the applicant while sustaining the ecologically and economically vital resources of the Albemarle-Pamlico Estuary.

Thank you for your consideration in this matter. Should you have any questions regarding these comments or wish to discuss this matter further, please contact Pete Benjamin, Supervisor of the Raleigh Field Office, at (919) 856-4520 extension 11.

Sincerely yours,

Sam D. Hamilton
Regional Director

Enclosures

"Schafale, Michael" <michael.schafale@ncdenr.gov>

04/23/2009 09:36 AM

To Rebecca Fox/R4/USEPA/US@EPA

cc

bcc

Subject RE: Draft Gregory assessment of SNHA

Hi Becky,

Here is my response, hopefully in time for your briefing. This is probably complete, but I will go over it again before calling it final.

-----Original Message-----
From: Fox.Rebecca@epamail.epa.gov [mailto:Fox.Rebecca@epamail.epa.gov]
Sent: Wednesday, April 22, 2009 7:47 PM
To: Schafale, Michael
Subject: RE: Draft Gregory assessment of SNHA

That's about the reaction I expected. I feel about the same. Pretty amazing... Sorry you have to endure this type of thing -- hopefully we will get some more avoidance out of it...

I will try to give you a call around 9 tomorrow -- have a briefing at 9:45. Will be here all afternoon, if we do not hook up earlier, you can give me a call.

If you are going to respond -- the sooner the better. Army is making their decision this week and hope to have an internal draft by Monday (4-27) so we would like to get them something before then -- not much time, eh? Thanks very much for your help in this Mike and once again I'm sorry it has gotten so dirty. bf

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531
Email: fox.rebecca@epa.gov

"Schafale, Michael" <michael.schafale@ncdenr.gov>

04/22/2009 06:35 PM

To Rebecca Fox/R4/USEPA/US@EPA

cc

Subject RE: Draft Gregory assessment of SNHA

Hi Becky,

I'll have to digest this report before I have anything really to say. My first reaction is incredulity, but I presume you need something more substantial.

I'll be doing some combination of working at home tomorrow and taking time off tomorrow. I may be hard to reach but you're welcome to try. The number is 919-567-1098. The earlier morning is the most likely time for me to be there - after 7:00 till 9:00 or 10:00, though it's worth a try if you can't try till later. Or, if you want to tell me a time range you're available, I'll try to call some time during it. I'll be back in the office Friday, at 919-715-8689, but will be in a meeting at 10:00 and maybe one at 3:00.

From: Fox.Rebecca@epamail.epa.gov [Fox.Rebecca@epamail.epa.gov]
Sent: Tuesday, April 21, 2009 2:41 PM
To: Schafale, Michael
Subject: Fw: Draft Gregory assessment of SNHA

Hi Mike,

Just wanted to share with you this report on Bonnerton SNHA prepared for PCS by Jim Gregory. Your thoughts on this would be greatly appreciated. Also, would you send me your phone # again. I would like to have it so I can call and talk to you about another aspect of this. PCS is claiming that DWQ had total buy in by NHP that is was ok to go ahead and mine the NW part of SNHA -- I know you and John talked about this but to hear it from them you were there at the table negotiating -- that may be true but just wanted to clarify. They are hitting us with -- why does EPA think this area is so important when NHP themselves said it was ok to mine... Thanks! bf See Gregory report attached below.

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531
Email: fox.rebecca@epa.gov

----- Forwarded by Rebecca Fox/R4/USEPA/US on 04/21/2009 02:33 PM -----

Palmer Hough/DC/USEPA/US	To	Rebecca Fox/R4/USEPA/US@EPA
04/20/2009 11:04 AM	cc	
	Subject	Draft Gregory assessment of SNHA

Becky:

Here is the draft Gregory assessment of the SNHA. Would be interesting to get the NC NHP's perspective.

-Palmer

(See attached file: 4-16-09 draft forestry report-SNHA_Jim Gregory.pdf)

Palmer F. Hough
US Environmental Protection Agency
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EPA West -- Room 7231-L
Mail Code 4502T
1301 Constitution Avenue, NW
Washington, DC 20460

Response to Jim Gregory's letter of April 16, 2009, regarding the PCS Bonnerton Nonriverine Wet Hardwood Forest site.

Mike Schafale, North Carolina Natural Heritage Program
April 23, 2009

Dr. Gregory's primary assertion is that the area does not meet the definition of a Nonriverine Wet Hardwood Forest and that, because of past land use, it is not a significant example of a Nonriverine Wet Hardwood Forest.

As Dr. Gregory notes, Nonriverine Wet Hardwood Forest was first defined as a type by the Natural Heritage Program. The name was first used in the program's classification of natural communities, based on concepts that had been used previously by program contractors and likely earlier in the scientific community. Dr. Gregory refers to Schafale and Weakley (1990), the program's official classification of natural communities, and Schafale (2008), a recent manuscript on status and trends of Nonriverine Wet Hardwood Forests. However, neither of these documents define Nonriverine Wet Hardwood Forests as having to be dominated by swamp chestnut oak, cherrybark oak, and laurel oak. Schafale and Weakley (1990) describe them as being dominated by various hardwood trees, with these three species named first but with sweetgum, tulip poplar, red maple, and several other species also named. Many of the earliest qualitative descriptions of specific sites described them as dominated by these oaks, but later quantitative study of some of the same sites found that, while abundant, they did not dominate.

Schafale (2008) does not define Nonriverine Wet Hardwood Forest as having to be dominated by the three oak species. In fact, it specifically discusses the fact that, while the *presence* of wetland oaks is important, these species often do not dominate in the best remaining examples and that their dominance is not crucial to recognition of the type. Nowhere is there a suggestion that all three species must be present to recognize the type. Because swamp chestnut oak, cherrybark oak, and laurel oak are collectively the most frequent oak species in these communities, they are often emphasized in other descriptions of the type. Abundant presence of other wetland oaks would also potentially support recognition as Nonriverine Wet Hardwood Forest. However, a forest that had no oaks and consisted only of the other trees mentioned in descriptions would not be considered an extant example of the type, but would be either a degraded example or a successional forest of some other type.

The fact that the Bonnerton site shows evidence of human action and past land use does not disqualify it from being a significant example and from being regarded as a Significant Natural Heritage Area. Indeed, there could be no Significant Natural Heritage Areas at all under such a definition. The Natural Heritage Program seeks the least altered, closest-to-natural examples remaining for each community type, and those closest to this ideal are regarded as the most significant. While I noted the evidence of past logging that Dr. Gregory cites, such evidence is common even in our best natural areas. There are no Nonriverine Wet Hardwood Forests that have not been logged, and selective logging of the sort noted by Dr. Gregory is the least alteration we can expect to find in any remnants of these communities. The Bonnerton site is in better condition than most remaining examples despite these impacts. Its condition and relatively large size and condition are among the best examples of this community type known to remain.

I am not sure how relevant Dr. Gregory's other observations on hydrology and soils are. He notes that the soils have hydric indicators. Most of the site has wetland vegetation, though there are minor marginal upland inclusions. The southern red oaks he reported may have been in such upland inclusions, which are also marked by beech trees. I visited the site with a number of people experienced in delineating wetlands, and there was no dispute that the area was jurisdicational wetland. Standing water does not always occur in Nonriverine Wet Hardwood Forests, though sporadic ponded water, along with seasonal saturated soil and widespread hydric indicators, would be expected.

"Schafale, Michael" <michael.schafale@ncdenr.gov>

04/23/2009 10:26 AM

To Rebecca Fox/R4/USEPA/US@EPA

cc

bcc

Subject RE: Draft Gregory assessment of SNHA

History: This message has been forwarded.

Here is the final version. A few modifications since the draft I sent you.

-----Original Message-----
From: Fox.Rebecca@epamail.epa.gov [mailto:Fox.Rebecca@epamail.epa.gov]
Sent: Tuesday, April 21, 2009 2:41 PM
To: Schafale, Michael
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to mine... Thanks! bf See Gregory report attached below.

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531
Email: fox.rebecca@epa.gov

----- Forwarded by Rebecca Fox/R4/USEPA/US on 04/21/2009 02:33 PM -----

Palmer Hough/DC/USEPA/US

04/20/2009 11:04 AM

To Rebecca Fox/R4/USEPA/US@EPA

cc

Subject Draft Gregory assessment of SNHA

Becky:

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-Palmer

(See attached file: 4-16-09 draft forestry report-SNHA_Jim Gregory.pdf)

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Mike Schafale, North Carolina Natural Heritage Program
April 23, 2009

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The fact that the Bonnerton site shows evidence of human action and past land use does not disqualify it from being a significant example and from being regarded as a Significant Natural Heritage Area. Indeed, there could be no Significant Natural Heritage Areas at all under such a definition that required no human influence. The Natural Heritage Program seeks the least altered, closest-to-natural examples remaining for each community type, and those closest to this ideal are regarded as the most significant. While we have not formalized definitions for mature forests, in our experience, any hardwood forest that has most trees 12 inches dbh or over and has some many trees 18-20 inches is unusually mature. While forestry books may suggest trees should be 20 inches to be considered mature, this does not appear to match the practice in that field, as most stands are harvested well before trees reach that size. While I noted the evidence of past logging that Dr. Gregory cites, such evidence is common even in our best natural areas. There are no Nonriverine Wet Hardwood Forests that have not been logged, and selective logging of the sort noted by Dr. Gregory is the least alteration we can expect to find in any remnants of these communities. The Bonnerton site is in better condition than most remaining examples despite these impacts. Its condition and relatively large size place it among the best examples of this community type known to remain.

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"Schafale, Michael" <michael.schafale@ncdenr.gov>
04/23/2009 12:21 PM

To: Rebecca Fox/R4/USEPA/US@EPA
cc: "Dorney, John" <john.dorney@ncdenr.gov>
bcc:
Subject: RE: PCS - 404 Permit; Gregory Summary

Oh. I should have figured there was more coming. This will take longer to work through. I won't get it done today, and tomorrow is questionable too. Sorry.

-----Original Message-----
From: Fox.Rebecca@epamail.epa.gov [mailto:Fox.Rebecca@epamail.epa.gov]
Sent: Thursday, April 23, 2009 11:20 AM
To: Schafale, Michael
Subject: Fw: PCS - 404 Permit; Gregory Summary

Mike,

Just received a final copy of Gregory report. Earlier version I sent you was a draft. Haven't had a chance to review yet but wanted to forward on to you -- not sure how it is changed. Let me know if you want to revise the information you sent me earlier. Thanks! b

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531
Email: fox.rebecca@epa.gov

----- Forwarded by Rebecca Fox/R4/USEPA/US on 04/23/2009 11:17 AM -----

WCARY@brookspierce.com
04/23/2009 10:10 AM

To: Brooke.Lamson@saw02.usace.army.mil, William.T.Walker@usace.army.mil, Palmer Hough/DC/USEPA/US@EPA, Stan Meiburg/R4/USEPA/US@EPA, Jim Giattina/R4/USEPA/US@EPA, Tom Welborn/R4/USEPA/US@EPA, Jennifer Derby/R4/USEPA/US@EPA, Gregory Peck/DC/USEPA/US@EPA, Suzanne Schwartz/DC/USEPA/US@EPA, David Evans/DC/USEPA/US@EPA, Brian Frazer/DC/USEPA/US@EPA, Rebecca Fox/R4/USEPA/US@EPA

cc: James Gregory <jim.gregory@wathydro.com>, RSmith@Pcsphosphate.com, GHOUSE@brookspierce.com, JFurness@Pcsphosphate.com, RTINSLEY@brookspierce.com

Subject: PCS - 404 Permit; Gregory Summary

Attached is Dr. Gregory's report on his initial assessment of the portion of the Bonnerton tract listed by NHP along with the two maps referenced in that report. Please review the list of recipients and forward this to anyone in your agency who should have received it (these are the only addresses I have).

6-19-08 map
1-6-09 Biotic Communities

(See attached file: Gregory report NRWH stands 4-22-09.pdf)(See attached file: 20090422220441160.pdf)(See attached file: 20090422220446795.pdf)

Rebecca Fox/R4/USEPA/US
04/24/2009 01:36 PM

To: mike_wicker@fws.gov, pete_benjamin@fws.gov, pace.wilber@noaa.gov, ron.sechler@noaa.gov
cc:
bcc:
Subject: Fw: PCS Phosphate mine permit elevation - Permit AID 200110096

here is SELC letter. enjoy... b

Becky Fox
Wetland Regulatory Section
USEPA
Phone: 828-497-3531
Email: fox.rebecca@epa.gov

----- Forwarded by Rebecca Fox/R4/USEPA/US on 04/24/2009 01:31 PM -----

Geoff Gisler
<ggisler@selcnc.org>
04/24/2009 12:40 PM

To: "'rock.salt@us.army.mil'" <rock.salt@us.army.mil>, Mike Shapiro/DC/USEPA/US@EPA
cc: "'Chip.Smith@HQDA.Army.Mil'" <Chip.Smith@HQDA.Army.Mil>, "'craig.schmauder@us.army.mil'" <craig.schmauder@us.army.mil>, "'Patricia.Morris@us.army.mil'" <Patricia.Morris@us.army.mil>, "'Suzanne.L.Chubb@us.army.mil'" <Suzanne.L.Chubb@us.army.mil>, "'Meg.E.Gaffney-Smith@usace.army.mil'" <Meg.E.Gaffney-Smith@usace.army.mil>, "'William.L.James@usace.army.mil.'" <William.L.James@usace.army.mil>, "'Jennifer.A.Moyer@usace.army.mil'" <Jennifer.A.Moyer@usace.army.mil>, "'Garrett.L.Dorsey@usace.army.mil'" <Garrett.L.Dorsey@usace.army.mil>, "'Michael.Pfenning@us.army.mil'" <Michael.Pfenning@us.army.mil>, "'John.Hurley@us.army.mil'" <John.Hurley@us.army.mil>, "'Lance.D.Wood@usace.army.mil'" <Lance.D.Wood@usace.army.mil>, Stan Meiburg/R4/USEPA/US@EPA, Jim Giattina/R4/USEPA/US@EPA, Gregory Peck/DC/USEPA/US@EPA, Suzanne Schwartz/DC/USEPA/US@EPA, Palmer Hough/DC/USEPA/US@EPA, Tom Welborn/R4/USEPA/US@EPA, David Evans/DC/USEPA/US@EPA, Robert Wood/DC/USEPA/US@EPA, Dawn Messier/DC/USEPA/US@EPA, Jennifer Derby/R4/USEPA/US@EPA, Rebecca Fox/R4/USEPA/US@EPA, Derb Carter <derbc@selcnc.org>
Subject: PCS Phosphate mine permit elevation - Permit AID 200110096

Mr. Salt and Mr. Shapiro,
Please accept the attached letter providing comments on the PCS Phosphate's permit

application requesting authorization to expand its phosphate mine near Aurora, North Carolina (Permit AID 20010096). In sum, the letter identifies substantial information within the administrative record that demonstrates that:

- EPA has properly elevated the permit decision;
- EPA's proposed alternative is practicable;
- The Wilmington District's modifications to the practicability analysis in the FEIS are arbitrary;
- Alternative L would result in unacceptable adverse effects on aquatic resources of national importance; and
- PCS's proposed mitigation will not offset the proposed impacts.

We appreciate the opportunity to submit this information for your consideration.

Sincerely,

Geoff Gisler
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April 24, 2009

Terrence C. "Rock" Salt
Principal Deputy Assistant Secretary of the Army
108 Army Pentagon
Room 3E446
Washington, D.C. 20310-0108

Michael H. Shapiro
Acting Assistant Administrator
U.S. Environmental Protection Agency
Office of Water (4101M)
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Re: Region 4 Environmental Protection Agency elevation of Wilmington District, COE permit decision on PCS Phosphate Mine in Beaufort County, North Carolina

Dear Mr. Salt and Mr. Shapiro:

Region 4 of the Environmental Protection Agency has elevated to EPA headquarters under the 404(q) MOA a decision by the Wilmington District of the U.S. Army Corps of Engineers to proceed with the issuance of a Section 404 permit to PCS Phosphate, Inc. to mine 3,953 acres of wetlands and approximately five miles of streams adjacent to the Pamlico River and estuary in coastal North Carolina. EPA has concluded that issuance of the permit would result in unacceptable adverse effects to aquatic resources of national importance. EPA is advocating for additional wetland avoidance to prevent significant degradation of aquatic resources and an improved mitigation plan for unavoidable wetland impacts. EPA's proposal would allow uninterrupted mining for at least 29 years. PCS Phosphate has responded to the elevation of the permit decision and to EPA's proposal.

This letter is submitted on behalf of the Pamlico-Tar River Foundation, Environmental Defense Fund, North Carolina Coastal Federation, and Sierra Club in response to PCS's contentions that its proposed mining plan would not result in unacceptable adverse effects to aquatic resources, that additional avoidance of wetlands and streams is not practicable, and certain procedural issues. The response below includes appropriate reference to the permit administrative record, PCS Phosphate documents, and applicable laws and regulations.

In summary, it provides support for the following conclusions:

- **The EPA is not required to refer its objections to PCS's unacceptable environmental impacts to the Council on Environmental Quality under Clean Air Act Section 309.**
- **PCS has delayed the permitting process by insisting that the AP Alternative – an alternative that cannot be permitted under state law – was the only practicable alternative.**
- **EPA's Proposed Alternative Is Practicable Under the Wilmington District's Practicability Analysis in the DEIS, SDEIS, and FEIS.**
- **The Wilmington District's determination that all practicable alternatives must provide 15 years of mining north of highway 33 is arbitrary and indefensible.**
- **The Albemarle-Pamlico Sound estuary and associated wetlands are aquatic resources of national importance.**
- **PCS proposes to mine substantial parts of the watersheds of five fishery nursery areas and impair the functions of these vital, priority habitats and aquatic resources of national significance.**
- **PCS's proposed mitigation will not offset the unacceptable adverse impacts to aquatic resources of national importance.**

We appreciate the opportunity to submit this information for your consideration.

Sincerely,

Derb S. Carter, Jr.
Senior Attorney-NC/SC Office Director
Southern Environmental Law Center

Geoffrey R. Gisler
Staff Attorney
Southern Environmental Law Center

EPA PROPERLY ELEVATED PCS'S PERMIT APPLICATION

The EPA is not required to refer its objections to PCS's unacceptable environmental impacts to the Council on Environmental Quality under Clean Air Act Section 309.

- PCS's contention that EPA "has not complied with requirements to refer any 'unsatisfactory' environmental effects to CEQ" has no merit because the 309 referral process is not relevant to the Section 404 Clean Water Act permit application elevation.

- The Memorandum of Agreement between the EPA and Corps establishes the procedure for proceedings under Clean Water Act Section 404(q) and PCS does not contest that the EPA has not complied with that procedure.

- Section 309 of the Clean Air Act, 42 U.S.C. §7609, may impose requirements on EPA during review of Clean Air Act permits, but does not require the EPA to refer objections to Clean Water Act projects to the Council on Environmental Quality. Regulations promulgated under Clean Air Act Section 309, i.e. 40 C.F.R. § 1504.3, are irrelevant to the Section 404(q) process.

PCS has delayed the permitting process by insisting that the AP Alternative – an alternative that cannot be permitted under state law – was the only practicable alternative.

- PCS and the Wilmington District have consistently compared all potentially practicable alternatives to the AP Alternative, a 15-year alternative that would illegally mine salt marsh.

- The state announced early in the permitting process that it could not and would not issue a permit for the AP Alternative:
  - "Mr. Dorney [from the N.C. Division of Water Quality] stated that mining of the creeks will never be permitted, and that proposing such an action as a 'straw man' is a waste of time." Meeting Notes from 28 February 2001, DEIS Appx. A-5.

- PCS objected, insisting on pursuing the AP Alternative:
  - "Mr. Smith [PCS Environmental Affairs Manager] reminded the group that the current proposal is appropriate to PCS Phosphate's stakeholders, considering the high value of the ore body on the NCPC Tract." *Id.*

- Rather than altering the mine plan, PCS sued the State of North Carolina to defend the illegal mining. *See* Meeting Notes from 26 February 2003, DEIS Appx. A-72. That case did not settle until October 2006, delaying the permitting process for years.

- Even after the lawsuit, PCS continued to push for the AP Alternative in spite of the Division of Water Quality's refusal to issue a permit for it:
  - "[T]he applicant preferred alternative is not acceptable to DWQ since (as outlined in our September 14, 2006 letter to PCS Phosphate and repeated at several meetings with

the company), this alternative proposes to mine through about 34 acres of salt marsh." 31 January 2007 comments of North Carolina Division of Water Quality, FEIS J-IV.A.4.

  - "[W]e strongly urge the company to present an applicant preferred alternative which is permittable by the Division of Water Quality in order to move this important project forward." *Id.*

- The Wilmington District continued to ignore the state permitting agency's comments rejecting the AP Alternative as not permittable under state law, delaying the permitting process by postponing serious consideration of reasonable alternatives:
  - "[T]o the Corps' knowledge, neither the NCDWQ nor the NCDCM have formally refused to process or denied any permit or certification." Wilmington District's response to comments, FEIS J.II-22.
- PCS insisted that Alternative L was impracticable as recently as December 19, 2007, delaying consideration of reasonable alternatives to Alternative L. PCS comments on SDEIS, FEIS J-VII.B.1.
- PCS modified its permit application on April 25, 2008 – less than one year ago – to request the 37-year Alternative L as its preferred alternative in place of the 15-year AP Alternative that it insisted on, and sued to defend, for the first 7.5 years of the permitting process.
- Yet PCS still uses the clearly unlawful AP Alternative to compare its claimed "concessions" on reducing wetland impact.

EPA'S PROPOSED ALTERNATIVE IS PRACTICABLE

EPA's Proposed Alternative is Practicable Under the Wilmington District's Practicability Analysis in the DEIS, SDEIS, and FEIS.

- The DEIS and SDEIS found that the SCRB Alternative is practicable. DEIS 2-19, *see* SDEIS at 2-3 (stating no change in economic analysis).
- "The . . . SCRB . . . alternative[] provide[s] for approximately 15 years of mining at operating costs similar to the current national averages and PCS's historic mine operating costs." DEIS 2-19, *see* SDEIS at 2-3, FEIS at 2-30.
- The SCRB Alternative provides approximately 7.5 years of mining north of Hwy 33 before requiring relocation to the South of Hwy 33 ("S33") tract. FEIS Appendix D. The EPA Alternative provides 8 years of mining north of Hwy 33 before requiring relocation to the S33 tract.
- The EPA Alternative provides more mining north of Hwy 33 than SCRB and allows more expansive mining than SCRB in the S33 Tract. Therefore it is practicable under the DEIS and SDEIS economic practicability analysis.

- The Wilmington District stated in response to comments in the FEIS that "[t]he Corps has not altered the economic analysis." Wilmington District's response to comments, FEIS J-V.B.2(R71). To clarify, the Wilmington District confirmed that "[t]he Corps has continued to use the DEIS approach in the FEIS." *Id.*

- Thus, any alternative that was practicable in the DEIS and SDEIS must be practicable under the analysis in the FEIS since the "[t]he Corps has not altered the economic analysis." *Id.*

- Since the EPA Alternative is practicable under the DEIS analysis and is practicable under the SDEIS analysis and "the Corps' approach to determining practicability have remained consistent throughout the DEIS, the SDEIS and the FEIS," the EPA Alternative must be practicable under the FEIS's practicability analysis. Wilmington District's response to comments of Dr. Douglas Wakeman, FEIS J-V.B.2 Exh.F(R1).

The Wilmington District's determination that all practicable alternatives must provide 15 years of mining north of highway 33 is arbitrary and indefensible.

- As discussed above, based on the economic practicability analysis in the DEIS, SDEIS, and FEIS, the Wilmington District concluded that 7.5 years of mining north of NC Highway 33 during the initial 15 years of mining is practicable. In the FEIS, however, the Wilmington District introduced an arbitrary and indefensible requirement that alternatives must – in addition to providing 15 years of mining within PCS's historical operating cost – include at least 15 years of mining north of NC Highway 33 to be considered practicable. This requirement was not introduced or discussed in any of the discussions of the Review Team or in the DEIS or SDEIS.

- The decision to require 15 years of mining north of Hwy 33 is critical to the assessment of impacts on the aquatic ecosystem. Not only is the area north of Hwy 33 adjacent to the tidal creeks, primary nursery areas, a secondary nursery area, and the Pamlico River estuary, it includes more than 3,400 of the 3,953 acres of wetlands that PCS proposes to mine.

- The 15-year requirement added to the economic analysis in the FEIS is erroneously and arbitrarily based on the applicant's decision to initially apply for a 15 year permit.
    - The purpose and need only requires a long-term mine expansion, the Wilmington District has failed to explain why less than 15 years is not long-term.
    - The FEIS states that "the applicant demonstrated that . . . 15 years presents an adequate planning horizon," but does not demonstrate that less than 15 years is not an adequate planning horizon. FEIS 2-31.
    - PCS's current permit was issued in 1997 and the company has stated it will exhaust all ore under that plan in 2009. This conclusively demonstrates that the company can operate on a 12-year planning horizon.

- Alternative L is not the "least environmentally damaging practicable alternative" because the company can – at a minimum – operate on a 12-year planning horizon and has not demonstrated that less than 12 years is not sufficiently long term to meet the purpose and need.

- The 15-year requirement introduced in the FEIS is erroneously and arbitrarily based on the "cash cost model" that was specifically rejected by the Wilmington District in responses to comments in the FEIS.

  - Following the DEIS, PCS submitted a new "cash cost" model that "eliminates the amortization of [costs]" and posts those costs in "the actual years of expenditures." PCS comments on DEIS, FEIS J-VII.A.1.

  - The Wilmington District incorporated the "cash cost" model's findings into the FEIS's practicability analysis, adopting the applicant's contention that "an alternative must not involve the incurring of costs that are not recouped [within the first 15 years]." FEIS 2-30. To further clarify, the FEIS states "[t]he key factors that make AP practicable are that all costs associated with mining the 15-year period are recouped within the same 15 years and that the 15 years does not involve mining at unreasonable costs." FEIS 2-29.

  - The Wilmington District clearly used the "cash cost" model as the basis for Alternative L: "Alternative L was developed to . . . provide 15 years of mining with no substantial capital and/or development costs that was not recovered in the same period." Wilmington District's response to comments, FEIS J-V.B.2(R51).

  - In response to comments criticizing the "cash cost" model, the Wilmington District denounced the model as inappropriate and uninformative, but then admitted using it. The response states "the Corps determined that the [cash cost model] was not informative or appropriate; however, some information was relevant in the Corps approach to practicability . . . this information was used in the Corps approach to determining practicability." Wilmington District's response to comments, FEIS J-V.B.2(R71).

  - The Wilmington District repeatedly rejected the "cash cost" model that formed the basis for the 15-year requirement in the FEIS, stating:

    - "The Corps agrees that there is no rationale or benefit in adopting the 'Cash Cost' model." Wilmington District's response to comments J-V.B.3(R12).

    - "The Corps agrees that the 'cash cost' analysis further complicates the economic analysis of alternatives. The Corps has not used the cash cost analysis in its approach to determining alternative practicability." Wilmington District's response to comments, FEIS J-V.B.2(R50).

    - "After fully considering the appropriateness and relevance of the cash cost model data . . . the Corps finds that . . . the results are, at best uninformative in determining the practicability of alternatives." Wilmington District's response to comments of Dr. Douglas Wakeman, FEIS J-V.B.2 Exh.F(R1).

  - "The Corps finds the use of the "cash-cost" model data to be, at best, uninformative in determining alternative practicability." Wilmington District's response to comments of Dr. Douglas Wakeman, FEIS J-V.B.2 Exh.F(R5).

  - "The Corps has not used the cash cost analysis in its approach to determining alternative practicability therefore, we do not attempt to justify, clarify or defend its use." Wilmington District's response to comments of Dr. Douglas Wakeman, FEIS J-V.B.2 Exh.F(R1).

- The Wilmington District's FEIS analysis ultimately relies on an indefensible, arbitrary finding that "there is no rationale or benefit in adopting the 'Cash Cost' model" yet that "some information" from that model "was relevant" and "was used in the Corps approach to determining practicability." This internally contradictory treatment of the "cash cost" model cannot be supported.

- Further, the Wilmington District refused to respond to substantive comments on the economic practicability analysis used in the DEIS and SDEIS based on the premise that it had not altered the analysis:

  - "This comment letter contains several manipulations of cost data using cash cost and discounting techniques. The Corps has not used the cash cost analysis in its approach to determining alternative practicability therefore, we do not attempt to justify, clarify or defend its use. Comments relevant to the overall approach and NEPA/CWA are addressed." Wilmington District's response to comments of Dr. Douglas Wakeman, FEIS J-V.B.2 Exh.F(R1).

- The 15-year requirement introduced in the FEIS is erroneously and arbitrarily based on the Wilmington District's contradictory treatment of the practicability of mining in the S33 tract.

  - Mining in S33 was included in the development of alternatives because PCS contends that mining there will be practicable in the future.

    - "The applicant has also indicated that it believes the market will eventually become favorable [for mining in S33]; a reasonable position based on USGS information regarding the rate of depletion of domestic production capacity and the applicant's future shift to higher margin products. The Corps has determined that it is therefore appropriate to include [S33] in the evaluation." FEIS 2-26.

    - "The applicant has made clear its desire to mine the entire project area if suitable market conditions exist. The applicant has developed a master plan which details their preferred sequential progression for the accomplishment of this goal. The applicant has also made clear that, if granted a permit for the AP Alternative, it would then seek a permit to mine Bonnerton and S33." FEIS 2-9.

- The Wilmington District even added areas adjacent to S33 to alternatives because mining in S33 was presumed to be practicable: "The Corps, the Review Team and the applicant agreed that it was reasonable to include these areas since they were readily accessible from the S33 area and they increased the minable area without a significant increase in environmental or socioeconomic impact." FEIS 2-9.

- The Wilmington District's FEIS analysis rejects the very assumption that justified including mining in S33 in any alternative – that mining in S33 will be practicable – and arbitrarily concludes that future mining in S33 is impracticable. Although previously describing that assumption as "a reasonable" position – and relying on it to include S33 in Alternative L – the Wilmington District eliminated less environmentally damaging practicable alternatives based on an arbitrary, contradictory finding.

    - "[T]he lower cost depicted for the initial 6-7 years of mining in the S33 Tract are only realized if the entire alternative boundary within the S33 Tract is mined." FEIS 2-30. That finding should not limit the practicable alternatives analysis since the "applicant has also indicated" it will be able to mine the entire S33 Tract.

    - "The Corps finds that SCRA, SCRB, and SJAB are not practicable alternatives due to the required commitment to higher mining costs . . . without the expectation of fully recovering these development costs." FEIS 2-30.

    - "Alternatives that relocate into the S33 Tract within 15 years confront the applicant with a commitment to several years of mining at a cost not currently considered practicable. Therefore, alternatives that involve relocation to the S33 Tract within the initial 15 years are not practicable." FEIS 2-31.

- The Wilmington District arbitrarily contradicts itself in the practicability analysis, finding that mining in S33 is practicable for the purpose of including that tract in mine plans, but impracticable for purposes of the practicability determination. It is the same land, mined through the same process, during the same time period, thus its practicability must be the same throughout the analysis.

PCS'S PROPOSED MINE EXPANSION WOULD CAUSE UNACCEPTABLE ADVERSE HARM TO AQUATIC RESOURCES OF NATIONAL SIGNIFICANCE

The Albemarle-Pamlico Sound estuary and associated wetlands are aquatic resources of national importance.

- In the Water Quality Act of 1987, Congress directed that the Administrator of EPA give priority consideration to designation of Albemarle Sound as an estuary of national significance and to convene a management conference to develop a comprehensive management plan to recommend priority actions to restore and maintain water quality, fish and shellfish resources, wildlife, and recreational uses of the estuary. *33 U.S.C. 1330(a).*

- In October 1987, the State of North Carolina and Environmental Protection Agency designated Albemarle and Pamlico Sounds as an estuary of national significance and convened a management conference to assess trends in water quality and natural resources, determine the causes of changes, and develop a comprehensive management plan with recommendations for priority actions. *State/EPA Conference Agreement for National Estuary Program Designation Under the Water Quality Act of 1987 (NEP Designation).*

- Justifications for designation of Albemarle-Pamlico Sounds as an estuary of national significance include the following:

    - Declines in fisheries productivity including major declines in commercial fisheries. *NEP Designation at 5.*

    - Eutrophication from excessive nutrient inputs. *NEP Designation at 5-6..*

    - Habitat losses which "have greatly affected ecosystem functions of estuarine habitats and tightly-linked wetlands habitats. *NEP Designation at 6.*

- The Albemarle-Pamlico Sound management conference issued its comprehensive conservation and management plan in 1994. *Environmental and Economic Stewardship in the Albemarle-Pamlico Region – A Comprehensive Conservation and Management Plan 1994 (NEP Plan).* The Plan identifies goals and priority actions including the following:

    - Conserve and protect vital fish and wildlife habitats and maintain the natural heritage of the Albemarle-Pamlico Region. *NEP Plan at 23.* Identified vital habitats include rare natural communities, wetlands and primary nursery areas for fisheries. *NEP Plan at 24-25.* Protection rare natural communities "is vital to the survival of species and to the maintenance of the region's natural heritage. *NEP Plan at 24.* "North Carolina has lost more than 50 percent of its original 10 to 11 million wetland acres." *NEP Plan at 24.*

    - Promote the protection and conservation of valuable natural areas in the APES region. *NEP Plan at 28.*

    - Maintain, restore and enhance vital habitat functions to ensure the survival of wildlife and fisheries. *NEP Plan at 29.*

    - Enhance the ability of state and federal agencies to enforce existing wetlands regulations. *NEP Plan at 29.*

- Strengthen regulatory programs to protect vital fisheries habitats. *NEP Plan at 29.*

PCS proposes to mine substantial parts of the watersheds of five fishery nursery areas and impair the functions of these vital, priority habitats and aquatic resources of national significance.

- Primary fishery nursery areas "are of critical important to the propagation of over 75 species of fish and shellfish [in Albemarle-Pamlico Sound]. The functions of these nurseries can be impaired by freshwater drainage, land use changes, and excessive algal growth. Nursery areas are most threatened by nonpoint sources of pollution and by development on nearby lands." *NEP Plan at 25.*

- PCS proposes to mine substantial parts of the watersheds of four tidal creeks designated by the State of North Carolina as primary fishery nursery areas:

  - Porter Creek: 71% drainage basin reduction
  - Jacks Creek: 84% drainage basin reduction
  - Jacobs Creek: 75% drainage basin reduction
  - Tooleys Creek: 55% drainage basin reduction

- Primary nursery areas are "areas inhabited by embryonic, larval, or juvenile life stages of marine or estuarine fish or crustacean species due to favorable physical, chemical or biological factors." 15A NCAC 10C.0502.

- The EPA is not alone in determining that the proposed mine expansion will have unacceptable adverse effects on aquatic resources of national importance. State and federal agencies alike have opposed impacts like those proposed under Alternative L throughout the permitting process.

  - "Such large-scale wetland impacts located directly adjacent to the Pamlico River . . . will act to exacerbate the impacts of eutrophication while altering local food web stability; both of which have important implications for estuarine productivity." U.S. Fish and Wildlife Service comments on DEIS and SDEIS, FEIS J-III.A.4.

  - "Both Alternative L and Alternative M . . . would indirectly impact estuarine habitats associated with South Creek, Pamlico River, Durham Creek, and Porter Creek." Therefore, "[m]ining activities within the NCPC and Bonnerton tracts shall not be authorized." National Marine Fisheries Service comments on SDEIS, FEIS J-III.B.3.

  - "Overall, the Division of Coastal Management has serious concerns regarding the two new alternatives described in the SDEIS as well as the prior alternatives in the DEIS because of their significant adverse impacts to the environment." North Carolina Division of Coastal Management comments on SDEIS, FEIS J-IV.B.3.

- "All the examined alternatives [in the SDEIS] would have significant adverse impacts on water quality, estuarine resources, wetlands, and public trust waters." North Carolina Division of Marine Fisheries comments on SDEIS, FEIS J-IV.B.7.

- "[W]e recommend that neither the AP, EPA, SCR, or SJA alternatives be considered as appropriate mining options on the NCPC tract because of significant degradation of fish and wildlife resources and the inability to provide adequate compensatory mitigation." North Carolina Wildlife Resources Commission comments on DEIS, FEIS J-IV.A.10.

- "Losses of these non-coastal wetlands and waters will affect downstream coastal waters and public trust resources under the jurisdiction of the [Marine Fisheries Commission]. . . . The additional proposed loss of headwaters wetlands would add to the significance of habitat losses that affect coastal fisheries production." North Carolina Marine Fisheries Commission comments on DEIS, FEIS J-IV.A.11.

- PCS contends that a report by its consultant ENTRIX establishes that mining the headwaters and dramatically reducing the drainage basins of tidal creeks and primary nursery areas will have "no significant indirect effects" on the downstream waters and aquatic ecosystem. While generally attempting to diminish the importance of headwaters to downstream waters in advocating for mining these areas, PCS proposes to do all its proposed compensatory mitigation in headwaters areas of watersheds significantly inland from the estuary.

- The Pamlico-Tar River Foundation and other agencies have submitted comments to the Wilmington District explaining why the conclusions in the ENTRIX report are misplaced. Key shortcomings of the report include:

    - A fundamental shortcoming of the ENTRIX report is that is selects data from studies not designed to assess the effects of drainage basin reduction to draw conclusions about the effects of drainage basin reductions and support unsubstantiated claims that mining through headwaters of estuarine creeks will have no discernable effects on the function of those creeks as primary nursery areas. *See, e.g., Rulifson 1991 (study of finfish utilization of man-initiated and natural wetlands); West (2000) (study comparing created marshes to natural marshes).*

    - In assessing the potential impacts of drainage basin reductions, the ENTRIX report fails to examine or evaluate the full range of potential effects of substantial drainage basin reductions on downstream estuarine systems, including organic carbon export, fishery productivity, biogeochemical processes, and overall ecological integrity, which are important factors which must be assessed to determine significant degradation under the 404(b)(1) guidelines.

- The ENTRIX report's reliance on a created marsh system with a limited drainage basin to draw conclusions about the effects of substantial drainage basin reductions on a natural creek and marsh system is inappropriate. Moreover, this study postulated that a primary factor in the faunal characteristics of the created system was that it was surrounded by aquatic systems it was intended to mimic, thereby providing sources of infaunal recruits. There is no assessment of the cumulative effects of substantial drainage basin reductions of all the creeks and primary nursery areas on the western shore of South Creek, as proposed by PCS.

PCS proposes to mine 3,953 acres of wetlands adjacent and linked to primary fishery nursery areas and other waters of the Pamlico estuary, including nonriverine hardwood forests designated by the State of North Carolina to be of national ecological significance.

- The Albemarle-Pamlico Sound designation identifies loss of wetlands as a priority environmental concern and enhancing protection of remaining wetlands as a priority action. *NEP Designtion at 6 and NEP Plan at 29.*

- The PCS proposal to mine and destroy 3,953 acres of wetlands, if authorized, would constitute the largest permitted destruction of wetlands in the Albemarle-Pamlico watershed and in the State of North Carolina.

- PCS proposes to mine parts of the Bonnerton nonriverine wet hardwood forest.

- NatureServe ranks nonriverine wet hardwood forests as a G2 or globally imperiled natural community, meaning there are between only 5 and 20 viable sites remaining. *See www.NatureServe.org/Explorer* (Ecological System ID: CES203.304, *Quercus michauxii - Quercus pagoda / Clethra alnifolia - Leucothoe axillaris* Forest). The remaining nonriverine wet hardwood forests are among the most scarce and endangered wetland systems in the United States and an aquatic resource of national importance.

- The North Carolina Natural Heritage Program was established by the North Carolina General Assembly to "include classification of natural heritage resources, an inventory of their locations, and a data bank for that information." "Information from the natural heritage data bank may be made available to public agencies and private persons for environmental assessment and land management purposes." NCGS 113A-164.4.

- The North Carolina Natural Heritage Program has designated the Bonnerton nonriverine wet hardwood forests as a natural community of national significance as one of the five best remaining examples of this type of wetland in the world. *Schafale, Nonriverine Wet Hardwood Forests in North Carolina – Status and Trends, January 2008.*

- The North Carolina Division of Water Quality has designated the Bonnerton nonriverine wet hardwood forests as a wetland of state or national ecological significance under wetland water quality standards. *401 Certification; 15A NCAC 2H.0506(e).* Activities that would alter wetlands of state or national ecological significance may only be authorized if the activities are for a public purpose. *15A NCAC 2H.0506(e).*

- The primary conclusion of PCS's consultant Dr. James Gregory, in his "rapid forest assessment," is that Dr. Schafale's determination that the Bonnerton tract is a nonriverine wet hardwood forest is incorrect. Dr. Schafale conducted a detailed examination of the site. Dr. Schafale also co-authored the accepted scientific report defining the nonriverine wet hardwood forest natural community (cited by Dr. Gregory). *See Schafale and Weakley, Classification of the Natural Communities of North Carolina 1990.* In sum, Dr. Gregory, a watershed hydrology consultant, contends Dr. Schafale, the Plant Community Ecologist with the North Carolina Natural Heritage Program who wrote the accepted definition and description of a nonriverine wet hardwood forest, did not, after carefully examining the Bonnerton tract, correctly determine it is a nonriverine wet hardwood forest. Not only did Dr. Schafale correctly determine the tract is a nonriverine wet hardwood forest, he concluded it is one of the best five remaining examples of the imperiled natural community remaining.

- To support his contentions, Dr. Gregory cites the definition of nonriverine wet hardwood forest in the EPA/Corps guidance on silvicultural activities but overlooks, or fails to note, footnote 7 which clearly states that the definition used for this forest type in the guidance is "a subset of those described in Schafale and Weakley, 1990." There is no requirement in Schafale and Weakley that a nonriverine wet hardwood forest have a greater than 50% basal area per acre of oak species. *EPA and Corps, Application of Best Management Practices to Mechanical Silvicultural Site Preparation Activities for the Establishment of Pine Plantations in the Southeast 1995.*

PCS's proposed mitigation will not offset the unacceptable adverse impacts to aquatic resources of national importance.

- Unacceptable adverse effects means impact on an aquatic or wetland ecosystem which is likely to result in significant degradation of ... or significant loss of or damage to fisheries, shellfishing, or wildlife habitat or recreational areas. In evaluating the unacceptability of such impacts, consideration should be given to the relevant portions of the section 404(b)(1) guidelines. 40 C.F.R. § 231.2(e).

- Under the 404(b)(1) guidelines, compensatory mitigation is only appropriate for unavoidable wetland impacts. 40 C.F.R. § 230.10(a). Practicable alternatives exist that would avoid wetlands and impacts to primary nursery areas and Bonnerton nonriverine wet hardwood forests.

- Under the 404(b)(1) guidelines, even if no practicable alternative exists, no discharge of dredged or fill material shall be permitted which will cause or contribute to significant degradation of waters of the United States. 40 C.F.R. § 230.10(c). In addition, no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken which will minimize potential adverse impacts of the discharge on the aquatic ecosystem. 40 C.F.R. § 230.10(d).

- Significant adverse impacts to the tidal creeks and primary nursery areas include significantly adverse effects on fish, wildlife and special aquatic sites; significantly adverse effects on life stages of aquatic life and wildlife dependent on aquatic ecosystems; significantly adverse effects on aquatic ecosystem diversity, productivity and stability; and significantly adverse effects on recreational and economic values. 40 C.F.R. § 230.10(c).

- None of the proposed compensatory mitigation for any of the adverse effects to the tidal creeks and primary nursery areas will be conducted within the immediate watersheds of these tidal creeks and primary nursery areas, resulting in unmitigated significant degradation of these aquatic resources of national importance.

- PCS inappropriately relies on proposed compensatory mitigation in the headwaters far removed from the estuary to mitigate the significant adverse effects of its mining operations on the tidal creeks and primary nursery areas and connected wetlands in the immediate watersheds that will be destroyed and severely degraded by its proposed mine plan.

- Destruction of the Bonnerton nonriverine wet hardwood forest will result in significantly adverse effects on a special aquatic site; adverse effects on aquatic ecosystem diversity, productivity and stability; and unmitigated significant degradation of an aquatic resource of national importance.

- Federal and state agencies agree that PCS has not provided adequately detailed mitigation plans and the mitigation it has proposed will not offset the proposed impacts:

    - "[T]he proposed compensatory mitigation is insufficient to offset adverse impacts to the aquatic environment except in the area south of Hwy 33." U.S. Fish and Wildlife Service comments on DEIS, FEIS J-III.A.4.

    - "The applicant's historical performance to ensure that adequate mitigation occurs for past mining efforts precludes NMFS from having reasonable assurance at this time that impacts from mining the NCPC tract will be satisfactorily mitigated." National Marine Fisheries Service comments on DEIS, FEIS J-III.A.6

    - "[T]he applicant has not developed a compensatory mitigation plan and, instead, continues to offer only a general strategy . . . we do not believe that the applicant has demonstrated that sufficient mitigation will be provided in a timely manner for the proposed project." National Marine Fisheries Service Comments on SDEIS, FEIS J-III.B.3.

- "Detailed mitigation plans must be provided in the final EIS, with adequate opportunity for thorough review." North Carolina Division of Marine Fisheries comments on DEIS, FEIS J-IV.A.8
- "Detailed mitigation plans need[] to be provide[d] in the final EIS." North Carolina Division of Marine Fisheries comments on SDEIS, FEIS J-IV.B.7.
- "[W]e conclude adequate mitigation in NCPC and Bonnerton has not been proposed." North Carolina Wildlife Resources Commission comments on DEIS, FEIS J-IV.A.10.
- "A detailed mitigation plan for permittable impacts has not been addressed." North Carolina Wildlife Resources Commission comments on DEIS, FEIS J-IV.B.11.