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FOOD CHAIN PANEL

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INTRODUCTION

It is the unanimous view of this panel, after a detailed review of the FHWA wetland assessment method, that the portion of the assessment dealing with food chain support and nutrient cycling should not be used in its present form. The panel's conclusion is based on the fundamental fact that the current understanding of wetlands ecology is not adequate to support such a specific, quasiquantitative evaluation procedure. We do not agree that the literature cited in the FHWA report (Adamus 1983) adequately documents or justifies the assertions made regarding the relative values of wetlands for food chain support and nutrient cycling. However, the panel recognizes the fact that decisions regarding the relative values of wetlands will continue to be made. The uncomfortable and humbling truth is that, to the degree that these decisions are based on considerations of the food chain, nutrient cycling, and numerous other values, they are largely subjective impressions with little empirical support at this time. To obscure this fact by invoking a complex and seemingly sophisticated scientific assessment procedure will not serve either decisionmakers or the public. On the positive side, however, the exercise of attempting to develop such a procedure has emphasized the importance of considering many dimensions of wetlands ecology. It has documented the pressing importance of obtaining new kinds of information about wetlands. It is probably not productive to pursue the kind of assessment protocol for food chain support attempted in the FHWA study until new research initiatives, such as those set out below, begin to provide the needed information.

GENERAL OBSERVATIONS AND RECOMMENDATIONS

It is necessary to be aware of the assumptions or hypotheses on which the evaluation is based, in order to understand our critique. These assumptions are listed in detail in Volume II, pages 69 and 71, of the FHWA report (Adamus 1983). Briefly, these assumptions are:

1. Wetlands have significantly greater net primary productivity than terrestrial or aquatic ecosystems;

2. There is a greater transport of food from wetlands to aquatic consumers than from other ecosystems, and greater transport of food from those wetlands that have better downstream transport mechanisms (flushing) than those that lack flushing.

The mechanism for evaluating food chain support is to use predictors that appear to correlate with primary productivity (or to use primary productivity itself), flushing and transport of the organic matter and nutrients, and more and faster decomposition results in greater food chain support. The panel either disagrees with these assumptions or believes that there is not enough information to generalize about them for the purpose of ranking one wetland above or below another wetland.

Our acceptance of four of the predictors and suggested modification of nine of the predictors should not be interpreted as revisions that would lead to a valid assessment of food chain support. What the panel is recommending is a completely new effort, outlined below, that is a more lengthy and detailed endeavor than simply revising the present FHWA document. The food chain section of the present document is based on invalid assumptions and misinterpretations of existing information. Until these deficiencies are corrected with better information and scientifically sound assumptions, food chain support values of wetlands must be assessed by other procedures. These other procedures might take the form of indicators that food chain functions exist and be based on HEP or HES procedures or observations by experienced wildlife and fisheries ecologists. However, the panel did not formally discuss or evaluate alternate procedures for evaluating this wetland function. The fact that the FHWA document has been found to be an inadequate and unacceptable procedure for the evaluation of food chain support (i.e., starting from the base of the food chain) does not mean that wetlands are any less valuable for this function.

The panel has learned an important lesson from the evaluation of the food chain support section of the FWHA document. In our attempt to seek a wetland evaluation method, the FWHA attempt could be considered analogous to a hypothesis. The panel has rejected this "hypothesis". Therefore, it is incumbent on us to provide direction toward the development of an alternate hypothesis (or method) to be tested. It is the opinion of the panel that more progress is needed in understanding food chains before an alternate hypothesis can be adequately developed. Therefore, we recommend a three step program toward developing information on which an initiative on food chain evaluation can be based.

1. Literature synthesis: Rather than a literature "review", this synthesis should be a very selective and intentional effort to document what is and is not known about food chains. The synthesis should address hypotheses that have as their components the following:

   a. the relationship of primary productivity to fish and wildlife production;

   b. the nature of coupling between wetland and open water areas of a basin; and

   c. the quality of food available and its value in food chains.

   Auxiliary factors that may be important regulators or modifiers of the relationships hypothesized above should also be evaluated.

These include, but are not limited to, the importance of structural features, morphometric characteristics, flushing, and interspersion.

2. Peer review: The literature synthesis should receive a comprehensive review by peers who are compensated for their efforts. This should be followed by a workshop of researchers in the field of wetland food chain support with expertise with a variety of wetland types. The workshop attendees would formulate the hypotheses to be tested for applicability to a broad spectrum of wetland types.

3. Research effort: The focus of the research would be testing the hypotheses that resulted from the literature synthesis and workshop. This step is discussed in detail in the following section.

RESEARCH NEEDS

The research effort should have a strong experimental component that takes the form of manipulating the key variables that affect food chain support. Ecosystem evaluations, including this one, reflect the maturity and evolution of the related field science. Hypotheses, data, and information summarization develop from the application of available time, money, and expertise. Consequently, a "best effort" evaluation tool may at this time incorporate untested hypotheses, hidden assumptions, and little data in the rationale for a particular ranking. This is not to say that information is not available, but that critical experiments and logic are absent. The surfeit of assumptions and dearth of appropriate analyses are conspicuous throughout the FHWA document. It is commendable that this document clearly identifies and states the hypotheses for each predictor. The lack of documentation to support conclusions or to test hypotheses reflect a preoccupation with descriptive, rather than experimental, approaches; with examining ecosystem standing stocks rather than turnover; and with restrictive studies of wetland parts, especially of large consumers, rather than studies of how the system "works" to produce large, rare consumers. It is the nature of our young science that descriptive work must often preceed experimentation. The very expression of the hypotheses in the FHWA document reflects the need for more explicit experimentation in food chain dynamics. Few of the hypotheses mentioned have been directly tested. Instead, evidence is given by inference and reference to other related, but also unproven, assumptions.

The panel's recommendations for a better evaluation procedure are based on the belief that explicit testing of hypotheses is the best long term opportunity to improve the present analysis. The method selected to test the hypotheses is, perhaps, as important as selecting the questions to be addressed. The panel believes that the following attributes would contribute to meaningful progress in the research effort:

a. Team approach. The fields of expertise required to study wetlands includes hydrology, microbiology, nutrient cycling, succession, and many others. The economies of scale may mean that several hypotheses can be addressed simultaneously by a number of scientists representing several disciplines.

b. Long term research sampling. Experience with a variety of ecosystems has demonstrated the need for long term data collection efforts. For example, food chain dynamics are notorious for their susceptibility to climatic events. In addition, ecosystems are held together by a disjointed (in time and space) coupling of parts. The different responses by ecosystem parts over time are often out of phase with each other simply because of differences in growth rate, doubling rate, integration, timing, and other factors. Long term experience and monitoring are valuable, irreplacable requirements for addressing certain hypotheses about wetland functions.

c. Standardization. Methods vary with changing needs and perspectives. Given the general lack of data currently available, standardization of methods to the degree possible should be encouraged. A review of the methods commonly used and the development of agency awareness of problems with these methods should be developed by review panels to foster standardization where feasible and appropriate.

d. Comparative research. Determining the variation among and within wetland ecosystems is an implicit requirement if ranking is to be accomplished with precision and accuracy. Questions that need to be answered include: What is a typical wetland? Are the few wetlands studied representative? Are the results from one or two studies applicable to other wetlands with a similar community structure? A few simple comparisons of wetlands spread wisely over wetland types would be valuable.

Specific hypotheses to be tested should focus on the assumption that food chain support is primarily related to: (1) the level of primary production; (2) the quality and quantity of the detritus that is produced during decomposition; and (3) the degree of coupling between the wetland and the adjacent open water area. There are, of course, other important variables. The panel believes, however, that the additional variables cannot be adequately tested until the first of three basic assumptions are critically evaluated. We propose that research activities be directed to focus on three general research questions: (1) What is the relationship between the amount of primary production that occurs in a wetland and the amount of secondary production within the wetland and in the wetland basin?; (2) What is the relationship between the amount of primary production that occurs in a wetland and the quality and quantity of the organic matter that is available to support secondary producers within the wetland and in the wetland basin?; and (3) What are the food chain relationships between wetlands and adjoining (coupled) open water areas, and how does the coupling affect food chain relationships within the wetland basin?

ANALYSIS OF KEYS AND PREDICTORS

The Food Chain Panel discussed each predictor that was utilized specifically in the food chain key. These predictors are listed in Table 1, along with rankings from highest (1) to lowest (4). Because the panel

had serious reservations about the value of many of the predictors, no attempt was made to assess whether or not the results of a particular evaluation would be properly interpreted for overall ranking of function (high, moderate, or low) in the food chain key (Adamus 1983: Vol. II, pp. 69-72).

Thirty-one of the 75 predictors used in the FHWA system were used in the Food Chain Key. The panel rejected 18 of these 31 predictors because they were of insufficient value to justify their use in assessing or ranking food chain support. Nine other predictors require modification in order to be acceptable for use. The remaining four predictors were considered acceptable; however, as a group, they are of little value in food chain assessment.

The extent and quality of documentation and the uncertainty about the assumptions for predictions are the two fundamental reasons that predictors were either rejected or judged to require modification. In many cases, this is because there is a fundamental dearth of knowledge about how food chains function. Adamus admits that the Food Chain Key is probably the least reliable of the evaluation keys. Although nearly 90% of the predictors were rejected by the panel or required modification, this should not be interpreted as meaning that food chain support is a trivial or even questionable function of most wetlands. On the contrary, this is possibly one of the strongest and most attractive attributes of many wetlands. The fact that so little information is available to document the predictors of food chain support may be another indication of how poorly the relationship between primary and secondary productivity is understood.

The following major reasons, with examples, indicate why the panel either rejected or suggested modification of predictors. Specific comments on each predictor are included later in this discussion.

1. Inadequate documentation. Many of the references cited to support the rationale for the hypotheses are generic in nature, but applied to specific processes (e.g., Darnell et al. 1976). In addition, many of the references are inappropriately cited (e.g., Gucinski 1978 - Predictor 44; Chabreck 1981 - Predictor 2),and many are misquoted (e.g., Klopatek 1978, Predictor 22 - Vegetation Form under F, nutrient retention). Overall, the amount of misquoted literature and inappropriate literature citations appears to be sizable. In addition, the misspelling of names, incorrect dates, and uncited references make the references difficult to verify.

2. The validity of the assumptions. Questions about the validity of the assumptions was one of the primary reasons for rejecting or modifying so many predictors. Many of the assumptions were based on data for estuarine or freshwater

Table 1. Ranking of wetland characteristics by their hypothesized importance to food chains (After Adamus 1983: Vol. II)

Wetland characteristics	1 Highest	2	3	4 Lowest	No. of References[a]
1.Contiguity	outlet & inlet	outlet only	no outlet		1
2.Constriction of basin's outlet	not constricted	constricted			4
3.Shape of basin	smooth	irregular or sinuous			0
4.Fetch & exposure	sheltered	unsheltered			2
13.Gradient of basin	steep	gradual			0
15.Land cover of subwatershed:	cropland or grazed	forested scrub-scrub, ungrazed grassland ----------developed-------- ----------barren----------			0
22.Vegetation form	emergent aquatic bed	scrub-shrub	forested moss/lichen		2
23.Substrate type	----------organic-------- ------------mud----------		---rubble-sand/cobble-- ----bedrock, gravel---		2
24.Salinity and conductivity	fresh	mixosaline	eusaline	hypersaline	8
25.pH	circumneutral	not circumneutral			5

Table 1. Continued

Wetland characteristics	1 Highest	2	3	4 Lowest	No. of References[a]
26.Hydroperiod	regularly flooded tidal, seasonal flooded tidal	irregular exposed tidal, irregular flooded nontidal intermittently non-tidal	semi permanently flooded non-tidal, intermittently exposed non-tidal	permanently flooded nontidal saturated nontidal	8
	----------artificially flooded nontidal----------				
27.Flooding duration and extent	great	not great		See Predictor #26	
28.Artificial water level fluctuations	small, infrequent gradual	large, frequently sudden			1
29.Natural water level fluctuations	flashy	not flashy			1
30.Tidal range	great	slight			2
31.Scouring	moderate or unknown severe and known			See Predictor #32	
32.Flow velocity	moderate	slow or very rapid			8

Table 1. Continued.

Wetland characteristics	1 Highest	2	3	4 Lowest	No. of References[a]
33.Water depth maximum/minium	shallow	deep			0
36.Oxygenation of sediments	O_2 stress				0
41.Basin's vegetation density	neither sparse or extremely dense	very sparse or extremely dense			1
43.Sheet vs channel flow	sheet	channel			0
44.Wetland-water edge	irregu-larity shaped, good interspersion	smooth or poor interspersion		See Predictor #32	
45.Gradient of edge	steep	gentle			0
49.Plants form richness	diverse forms	monotypic			2
52.Plant productivity	high	low			0
53.Invertebrate density: freshwater/ tidal flat					

Table 1. Concluded.

Wetland characteristics	1 Highest	2	3	4 Lowest	No. of References[a]
57.Suspended solids	moderate	low	high		12
58.Alkalinity	high	low			1
59.Eutrophic condition	moderate or high	low			59
63.Bottom water temperature	warm	cold			7
67.Total suspended solids differential	inlet lower than outlet	inlet higher than outlet			0
68.Nutrient differential	inlet lower than outlet	inlet higher than outlet			0

[a] The actual number of supporting research studies cited in Adamus 1983; Vol. I, chap. III of FHWA Report

systems and were then applied uniformly across all wetland types. The panel's collective expertise concerning a variety of wetland types led us to conclude that the assumptions and hypotheses were invalid in many cases. For example, Predictor 15 (Landcover of Subwatershed) states that agricultural cropland or grazed pasture is best for food chain support, yet the predictor does not consider the problem of increased sedimentation (turbidity) and herbicide/pesticide runoff associated with such land use practices. Studies in Maryland have documented the deleterious consequences of agricultural practices in watersheds (Correll and Dixon 1980; Orth and Moore 1983).

The section on the ranking of wetland types (Adamus 1983: Vol. I, Chap. 3) presents the rationale for the comparative ranking of the wetland attributes used in the 75 predictors. It is clearly stated in this chapter, and elsewhere, that the 75 wetland attributes cannot vary independently of other attributes, except for the purpose of evaluation. A critical assumption of all rankings is that all other factors (predictors) are held equal (Adamus 1983: Vol. I, p. 48, emphasis by Adamus). The rationale for ranking is, therefore, often unclear (much-less tested) or not evident in peer-reviewed research results. This lack of data is not a reflection on the author. Although the assumption on holding all other factors equal is clearly stated in the FHWA report, the rationale for ranking is often not stated as though all of the other factors are held constant. Unproven or questionable assumptions about ecosystem functions are introduced to support rankings. These "hidden assumptions" are often related to the idea that higher primary production rates are desirable. It is probably true that more consumption occurs with more primary production; however, it is not sufficient to state that substrate type (mud, sand, or organic; p. 70), osmotic stress (p. 71), or pH (p. 72), for example, influence food uptake equally when all other factors (predictors) are held equal. For these three factors, as well as others, the highest rating is reserved for wetlands with the highest primary production, which is supported, presumably, by an assumed direct relationship between primary production rates and predictor and between predictor and the ranking. Flowing water may stimulate primary production, and higher rates of primary production may allow more consumption, but it does not follow that increased water flow stimulates consumption by the important consumers. Viewed in isolation from all other factors, the highest consumption rates (downstream within the ecosystem) may be within a rubble, rather than a mud, environment because the organic standing crop may be lower in the latter due to greater predation. This is one example of assumptions that are 'hidden' or unsupported.

A listing of the panel's recommendations concerning the predictors utilized in the food chain key follows:

Predictors Acceptable Without Modification

1. Contiguity. In addition to the rationale that transport of food is more probable and effective in "open" basins (with both an outlet and an inlet), it is also true that fish consumers have

more opportunity to move or migrate into or through the system to utilize food resources produced *in situ* and transported to the basin.

33 and 34. Water depth (maximum/minimum). In addition to the rationale given for the presence of aquatic beds (and, thus, food production) in shallow systems, it also may be applicable that shallow systems with a productivity similar to deep systems have higher plankton densities for fish to consume.

52. Plants: Productivity. It is difficult to disagree with the statement that systems with high primary productivity have the potential for greater food chain support. However, no studies have been conducted to specifically test this assumption. Literature reviews that indicate this general relationship have a large amount of uncertainty associated with them.

58. Alkalinity. The panel agreed with this ranking for freshwater ecosystems.

Predictors That Require Modification To Be Acceptable

22. Vegetation Form. With one exception, ranking is impossible among vegetation forms because the value of a vegetation form is very site specific. The exception is a low ranking for moss/lichen vegetation. However, see Schell (1983) for the incorporation of fossil peat carbon into freshwater Arctic Alaskan food webs.

24. Salinity and Conductivity. The panel recommends that ranking not be done for salinity and conductivity, except for hypersaline conditions, which can be ranked low. Although decomposition rates may, in some way, be correlated with food chain support, the studies cited do not permit resolution of value among salinity regimes. Decomposition rates are probably more dependent on the plant species involved, ambient temperature, and hydroperiod of the site than on salinity or conductivity.

25. pH. The only ranking on the basis of pH that is justifiable is a low ranking for acid bogs, in part due to their low pH. This, however, duplicates the rationale in Predictor 22, above (vegetation form).

27. Flooding Duration and Extent. This predictor is related less to the effect of flooding on productivity than to either the: (1) opportunity for fish to expand their food resources; or (2) export of organic matter to open water.

28. Artificial Water Level Fluctuations. Artificial manipulations of the water level are generally perceived as undesirable, and the more severe they are, the less desirable they are. Few artificial water level regimes are compatible with the adaptations of native species to the hydroperiod. The alternate hypothesis stated in the FHWA report should be omitted. The original papers by Lantz et al. (1967) and Quennerstadt (1958) should be consulted rather than citing a paper that interprets the results of these papers.

31. Scouring. This predictor should be modified to give a higher ranking to (1) "moderate or unknown" than to (2) "severe and known."

36. Oxygenation of Sediments. First, use of the predictor should be limited to nontidal systems (i.e., those without thermohaline stratification). Second, the predictor should apply to the water column rather than the sediments, because most sediments are notoriously poorly oxygenated. Finally, for the water column, frequency and duration of deoxygenation are factors that should be ranked, and only severe, anthropogenically induced conditions should be considered. This is because "productive" monomictic and dimictic lakes typically develop hypolimnetic anoxia.

53 and 54. Invertebrate Density. Freshwater and Tidal Flat. Invertebrate densities (benthic) are part of the food chain; therefore, it is obvious that they contribute to food chain support. However, none of the panel members are aware of the principal source that is cited to justify the ranking (i.e., Diaz 1982 as cited in Adamus 1983).

57. Suspended Solids. This predictor should not be applied to tidal systems. However, there is no justification for ranking low and moderate concentrations of suspended solids. Unnaturally high turbidity in freshwater systems may be undesirable for certain species of fish. In any case, the relationship of suspended solids to food chain support is unknown.

Predictors Unacceptable to the Panel

2. Constriction. The panel questions the validity of constriction as a predictor of food chain support. The hypothesized rankings are unacceptable for a variety of wetland situations personally known to panel members. Two of the supporting references are believed to be inappropriately interpreted (Heinle et al. 1973; Chabreck 1981).

3. Basin Shape. Consensus of the panel is that there are no data to support the hypothesized ranking, and, in fact, arguments can be made for reversing the ranking depending on whether in-basin or downstream transport is being considered.

4. Fetch and Exposure. The rationale for this predictor does not appear to follow or support the hypothesized ranking (perhaps there is an error in the wording and the rationale is backwards). There is a possible conflict between in-basin and downstream food chain support. For example, depositional areas that are sheltered may have greater primary productivity. The panel's collective experience indicates that the generalization implicit in this predictor can not be supported.

13. Gradient of Basin. This predictor relies on varying factors that cannot, in reality, be equal or unchanging as the assumption requires. Supporting references are limited to forested wetlands, and it is impossible to generalize this information to other

wetland types. The supporting references of Brown et al. (1979) and Day et al. (1980) are considered inappropriate. The alternative hypothesis is believed to be misleading; i.e., in general, plants growing in a particular location are adapted to the stresses existing there.

15. Land Cover of Subwatershed. The panel believes that the assumed link between the land cover of the subwatershed and food chain support is obscure at best and inappropriate as a predictor. The reason that Predictor 16 was not included in the key for the food chain support function is unclear because the land cover of the subwatershed was included. Rankings are believed to be erroneous for a variety of situations (e.g., the recent Chesapeake Bay Studies conducted by the U.S. Environmental Agency; see Kemp et al. 1983; Orth and Moore 1983). The use of Sutcliffe (1972) is considered inappropriate, and the extensive use of chemicals in rural areas (i.e., pesticides) make the rationale for "D" doubtful.

23. Substrate Type. This predictor was believed by the panel to be unusable because substrate type covaries with so many other variables. Also, the hypothesized rankings cannot be generalized to a variety of wetland situations and still be considered valid.

26. Hydroperiod. The consensus of the panel is that the hypothesized rankings cannot be justified because there is no good evidence that any particular hydroperiod is better for food chain support in general. Hypothesized rankings may have to be modified to fit each consumer species (i.e., is the interest in ducks or finfish?).

29. Natural Water Level Fluctuations. There is no evidence to suggest that the tendency for a basin to be flashy or not flashy is related to the food chain support function.

30. Tidal Range. This predictor is relevant to a limited set of wetland conditions. Documentation for the predictor is limited to a few wetland types (e.g., salt marshes) and species (Spartina spp.). The Steever et al. (1976) reference is misinterpreted (i.e., there was no difference on a marsh average basis). The supporting evidence that is cited deals with the relationship between tidal range and net primary productivity and in no way links the predictor to the food chain support function.

32. Flow Velocity. The conditions under which measurements are made (i.e., time, place, and frequency) are of critical importance to this predictor. The great amount of variation possible makes this predictor very complex and difficult to justify. Wetland specificity is a necessity. The support references (Heinle and Flemer 1976, Odum 1980) are not appropriate. No good evidence exists that connects flow velocity to primary productivity and subsequently to the food chain support function.

41 and 42. Basin and Wetland Vegetation Density, respectively. The panel agreed that there is a qualitative relationship between

vegetation density and primary productivity and food chain support: however, there is no justification for the percent coverage levels utilized in the key to determine the level of food chain support. Because the size of the basin is critical to the level of support assigned to a particular wetland, the subjectivity inherent in determining what constitutes the basin is a potential problem.

43. Sheet vs. Channel Flow. This predictor was not considered to be of value because most storm-related flooding is sheet flow.

44. Wetland-Water Edge. Edge effect cannot be related to primary productivity or any subsequent food chain support. The support reference (Gucinski 1978) is believed inappropriate in this context.

45. Gradient of Edge. The consensus of the panel was that this predictor is totally unrelated to the food chain support function.

49. Plants: Form Richness. There is a general agreement among the panel members that diversity may have value as a food chain support function predictor. However, several points are unclear or unacceptable. For example, are phytoplankton included? How can the categories (classes, subclasses, and species) be used simultaneously? Which category is appropriate under what circumstances, and how are the categories defined? The references are not believed to support the hypothesized rankings or the cutoff value of "3" used in the key.

59. Eutrophic Conditions. The hypothesized rankings are erroneous. Highly eutrophic conditions may lead to situations that are unfavorable for secondary production. This predictor also is affected by the covariance of factors in different situations.

63. Bottom Water Temperature. The panel did not believe that a relationship between bottom water temperature and decomposition or primary productivity could be justified or supported with the present data base.

67 and 68. Total Suspended Solids (TSS) and Nutrient Differential, respectively. It is extremely difficult to accurately measure these and other variables linked to the hydrology of the wetland (see Hydrology section). Therefore, any "quick and dirty" technique must be suspect. With respect to nutrient differential, it is not necessarily true that phytoplankton will make up a significant portion of TSS. The lack of literature supporting the hypothesized rankings makes these predictors of little value.

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