# FINAL REPORT

# Peer Review for Kissimmee Chain-of-Lakes Long-term Management Plan Conceptual Ecosystem Model Document

Provided to the South Florida Water Management District
August 23, 2005


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This report is the final deliverable in a work order between the South Florida Water Management District and the members of the peer review panel for review of the Conceptual Ecosystem Model for the Kissimmee Chain of Lakes Long-Term Management Plan.

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# 1. Summary of Panel Recommendations

This report summarizes recommendations from the "Peer Review Panel for Kissimmee Chain-of-Lakes (KCOL) Long-Term Management Plan Conceptual Ecosystem Model (CEM) Document." This panel was developed under a work order with the South Florida Water Management District (SFWMD), for the period from July 1 to September 1, 2005. The panel was comprised of seven experts in south Florida ecosystem science: Dr. Karl Havens (general limnology and water quality, Panel Chair), Dr. Mike Allen (freshwater fish), Dr. Mark Clark (wetland plants and biogeochemistry), Dr. Dale Gawlik (wading birds), Dr. James Gore (macro-invertebrates), Dr. Steve Johnson (amphibians and reptiles), and Dr. Wiley Kitchens (raptors and wetland ecology). The panel was asked to review documents provided by the SFWMD and Florida Fish and Wildlife Conservation Commission (FWC) dealing with a CEM for the KCOL system, candidate ecological performance measures for restoration planning and long-term assessment, and lists of candidate indicator species. Panel members were asked to focus their reviews on five questions:

- Does the CEM capture the critical drivers, stressors, ecological effects, attributes and linkages? Should anything be added or omitted?
- Of the attributes detailed in the report, which do you recommend for development as performance measures and which do you recommend deleting? Are there other attributes that we should consider?
- Have we missed important KCOL literature and/or datasets?
- Are there reference sites that can be used for performance measure development in lieu of KCOL historical data?
- Is there a preferred strategy for finalizing performance measures for multiple lakes within the area of the KCOL LTMP project?

On July 15-16, 2005, the panel members each gave 30 minute presentations in their areas of expertise, focused on these questions, as part of a two-day public workshop with the SFWMD, FWC, other agencies, stakeholders, and interested members of the general public (in Kissimmee, Florida). On the second day of the workshop, the Panel Chair gave a 30 minute summary of key points from the individual panel presentations. This summary presentation was developed by the panel as a whole and reflected their combined view regarding major recommendations, and was organized to address a request from the SFWMD at the end of day one of the workshop to focus on recommendations that can be implemented without additional research or data collection, and in a six month time frame.

In this summary chapter, the panel responses and recommendations regarding the five questions listed above are put into the context of 6 month, 12 month, and long-term actions considered necessary to achieve the goals of the KCOL program. Although the SFWMD is presently focused on a 6-month time window for project evaluation, we strongly and unanimously recommend that the agency take a more holistic view of the KCOL LTMP and recognize the risks associated with uncertain knowledge regarding key components of the system and how they might respond to changes in water level, nutrient loads, etc.

## 1.1 Does the CEM capture the critical drivers, stressors, ecological effects, attributes and linkages? Should anything be added or omitted?

*The following can be accomplished in the next six months.*

All panel members concluded that the existing CEM is too complex to be an effective tool for supporting a planning, evaluation, and assessment program. A highly complex model may be useful to scientists if and when they aim to develop a mechanistic model of the lake ecosystems, but as we understand it, this is not a goal of the program. The panel recommends a simpler model that can be readily understood by a wide audience of scientists, managers, stakeholders, and decision makers, which clearly indicates the main linkages between ecosystem stressors and attributes (values) of nature and society. The focus should be on stressors that are expected to be influenced by the KCOL project, and the attributes should be real end-points / goals of the program, rather than the conditions needed to achieve them. For example, a major goal of the program might be to maintain a good sport fishery in certain lakes of the KCOL. Thus, sport fish might be included as an attribute in the revised model. Substrate quality, on the other hand, should be moved from its present position as an attribute up into the ecological process portion of the CEM because it is one of the factors that determine whether or not there will be a good sport fishery – but it is not itself an attribute.

The panel also recommends that Aquatic Plant Management (APM) programs be included as a major external driver in the model. The APM programs of the Florida Department of Environmental Protection (FDEP) and FWC have a major effect on hydrology of the lakes because drawdowns are required in order to conduct herbicide treatments to control *Hydrilla* and to remove accumulated organic muck from around the lake shore. The physical disturbance that occurs during muck removal and the non-target effects of herbicides are major ecosystem stressors, especially now that *Hydrilla* has become resistant to fluridone in the KCOL. The panel concludes that successful management of the KCOL may not be possible unless there is careful coordination of hydrologic modification with the evolving APM program. In regard to *Hydrilla*, it is critical that the revised CEM make it clear that at high densities and cover, this plant may be a major ecosystem stressor, whereas at low to moderate density its values as a fish habitat may outweigh its negative effects. This situation exists because *Hydrilla* now is providing an alternative habitat in lakes where the natural shoreline vegetative zone has been lost due to development and water level stabilization. If the shoreline areas are largely restored then the relative benefits associated with low to moderate density *Hydrilla* may change.

The panel notes that the CEM breaks out into three rather distinct parts (from left to right in the model diagram, Figure 3-1), with major focus on open-water, littoral, and wetland zones of the lakes. Utility of the model might be enhanced if this division is explicitly indicated in the diagram, perhaps with vertical dashed lines. A simplified model could retain this structure.

*The following can be accomplished without additional research or data collection, but may take longer than six months to implement.*

The CEM can be viewed as a set of hypotheses linking stressors to attributes in the lake ecosystems. For example, it is hypothesized that stabilization of water levels has resulted in a loss of wetland / littoral plant diversity, and this in turn has affected certain species of fish and aquatic fauna. Thus, one might predict that a restoration of all or part of the natural variation in water levels could reverse this pattern and ultimately have a beneficial effect on fish, wading birds, and other biota. When the SFWMD uses the CEM and its associated performance measures to evaluate planning scenarios (and ultimately select a set of actions to implement), they are assuming that the hypotheses included in the model are largely correct. Given the almost complete lack of information regarding key components of the ecosystems (e.g., amphibians and reptiles) and lack of knowledge regarding key processes (e.g., the relationship between water level fluctuation and location / extent of shoreline berms), that assumption about correctness of the model is likely false. Likewise, there is insufficient information at this time to accurately predict how bass, amphibians and reptiles will respond to major changes in hydrologic regimes in the lakes, or how proposed new *Hydrilla* control measures will affect these subtropical ecosystems.

Given this situation, the panel recommends that the SFWMD and its partner agencies convene a group of experts to look carefully at the hypotheses embodied in the revised CEM. Each "arrow" should be discussed in regard to the certainty associated with the hypothesis that it represents. We anticipate that in this process, the SFWMD will find that certain hypotheses are supported by a large body of knowledge from the KCOL and other shallow subtropical lakes, whereas other hypotheses presently are based only on expert opinion. The end product of this review process would be a prioritization of future research – i.e., to focus that research on areas of greatest uncertainty in the model.

*The following recommendations require additional research and data collection.*

Research and data collection efforts should begin to address remaining uncertainties as quickly as possible, so that new information can be incorporated early into the process, before major projects are implemented with uncertain knowledge. The panel recognizes that funds may not presently be available to fund such research, but recommends that this not be a constraint to developing comprehensive plans – there may be innovative ways to obtain the necessary support for research, including partnerships between agencies, stakeholders, and Florida universities.

The panel recommends that the KCOL hydrologic modifications be conducted in an Adaptive Management framework, with data collection occurring before, during and after implementation, and the flexibility incorporated into projects so that operational changes can be made if results do not match with expectations. Recognizing that the hydrologic modifications may be relatively minimal due to constraints, there still may be the opportunity to conduct true experimentation / adaptive management that is impossible with single ecosystems like Lake Okeechobee or the Florida Everglades.

We also recommend that the revised CEM be used to develop a set of simple predictive models (see the example in Figure 2-3) that reflect current views regarding how stressors affect ecological processes and in turn, affect attributes. As data are collected in the long-term assessment program, the hypotheses embodied in these simple models can be tested. This process may lead to a refinement of both the hypotheses and the CEM. In other words, the CEM should be considered as a flexible tool that will evolve and improve over time.

### 1.2 Of the attributes detailed in the report, which do you recommend for development as performance measures and which do you recommend deleting? Are there other attributes that we should consider?

*The following can be accomplished in the next six months.*

The panel is concerned that the SFWMD has no clearly stated goals and objectives for ecological conditions, and no clear statements of what he constraints are for hydrologic conditions. These are essential pre-requisites for developing performance measures. Although none of the questions the panel was asked to address relate to goals and objectives per se, every panel member focused on this omission, which made it difficult to evaluate performance measures without knowing what the SFWMD envisioned in 'restored' KCOL systems. The use of terms like 'restore,' 'protect' and 'enhance' interchangeably in the text of the CEM document further clouded the issue.

We recommend that the SFWMD immediately meet with its partner agencies and stakeholders to identify a clear set of goals and constraints for the KCOL program, as they relate to modifying the ecological attributes of the various lakes. This is particularly important because the goals and constraints may be quite different for certain lakes or groups of lakes, which will point to different performance measures both for evaluation and long-term assessment. Unless this is done, time and money may be spent evaluating and monitoring attributes that are not linked with key goals, and information gaps may develop for important goals which have not been clearly identified.

In identifying constraints, especially where it concerns lake hydrology, we recommend close coordination with counties and other local entities that have control over land development near the shoreline of KCOL systems. No doubt there already are constraints on maximal water levels due to flooding concerns for existing development. It would be unwise to move forward with plans for hydrologic modification without a clear understanding of whether these constraints are expected to change – for example, due to further development in low lying areas now dominated by agriculture or wetlands, or permitted development closer to the shoreline of lakes.

In regard to evaluation performance measures, the panel recommends the following interim set, which should be expanded by additional research and data collection. Details are provided in the subsequent chapters of this report.

Interim ecological evaluation performance measures:

- Wading bird foraging HSI
- Snail kite nesting HSI
- Amphibian and reptile habitat HSI
- Alligator habitat HSI
- Largemouth bass habitat HSI
- Apple snail habitat HSI
- Vegetation diversity, based on between-year and within-year water level variation
- Algal bloom frequency (see below)

It is important to recognize that in the alternatives analysis, there may be a high degree of uncertainty associated with biological responses to water levels, given our lack of knowledge regarding the future of the APM and densities / cover of *Hydrilla*. A one meter fluctuation in lake level will have a very different effect on plant habitat and aquatic animals in lakes with low vs. high percent cover by this exotic plant. Likewise, the extent to which the FWC continues to conduct shoreline muck removal operations will have a large influence on outcomes.

The algal bloom measure can be predicted if the SFWMD has a simple model that relates nutrient loading to in-lake concentrations of total N and P. Phytoplankton chlorophyll *a* concentrations in the KCOL are highly correlated with these nutrients, and if a particular concentration of chlorophyll *a* can be associated with bloom conditions (e.g., 40 ug/L) a regression model can also be developed to link frequency of chlorophyll *a* > 40 with yearly mean concentration using the existing KCOL data.

*The following can be implemented in the next year and conducted over a longer time frame, and relate to establishment of a comprehensive assessment program.*

In order to document success of the program, or more importantly to determine if trajectories of attributes are in the direction of expectations, it is critical to have a long-term comprehensive assessment program. This should include key physical, chemical, and biological attributes, and importantly, include not only stressors and attributes, but also major ecological pathways. Havens discusses this concept in detail in Chapter 2 of this report. The key is to have enough information to generally understand why changes are not occurring as expected, so that appropriate adaptive decisions can be made. The example used in Chapter 2 is that of bass population not increasing as expected when tussock occurrence is reduced. If only those two things are assessed, it may be difficult to identify how to adapt the program. However, if there also are data on food resource quality and abundance and plant habitat structure, the reason for unexpected response may be readily identified.

The panel also recommends that assessment performance measures consider both lake-specific and landscape-scale aspects of the KCOL. For example, there may be lake-specific goals regarding largemouth bass for certain KCOL lakes, but a regional goal regarding spatial extent of new wet prairie habitat to support migratory ducks.

As noted above, the panel recommends additional research / data collection to establish the complete set of assessment performance measures (including things such as reptiles and amphibians, for which there presently are no data). In the interim, we recommend the following minimal set of ecological assessment measures.

- Largemouth bass recruitment and population modeling
- Wading bird nesting success
- Apple snail density and spatial distribution
- Aquatic vegetation community structure
- Algal bloom frequency and percent cyanobacteria
- Total N, total N, chlorophyll *a*, and Secchi transparency
- Wetland sediment accumulation, organics, and nutrient content
- Chironomid biomass and taxonomic composition
- Percent area covered and volume infested by *Hydrilla*
- Snail kite nesting success

Detailed information regarding the assessment of these measures is provided in the subsequent chapters of this report.

### 1.3. Have we missed important KCOL literature and / or datasets?

In each chapter of this report, panel members have identified key literature (and in some cases, datasets) that we recommend for use by the SFWMD as they refine the CEM and develop final sets of evaluation and assessment performance measures.

### 1.4 Are there reference sites that can be used for performance measure development in lieu of KCOL historical data?

The panel concludes that there are not good reference sites for this complex set of subtropical lakes. The only exception may be in regard to some basic water quality characteristics. The FDEP presently is using a reference site approach to establish numeric criteria for total N, total P, chlorophyll *a* and Secchi transparency for Florida lakes and rivers, and that process will result in criteria for the KCOL. We agree with SFWMD staff regarding their conclusion that the best approach for establishing reference (background) conditions is to use a combination of existing historical data, anecdotal reports, historical photographs, and paleolimnological information. Paleolimnology has great potential to provide precise information about the historical conditions for water quality, algal composition, invertebrates, and lake / watershed plants.

The question about reference conditions brings us back to the question of 'what are the goals of this project?' If the goal is to restore certain historical conditions in the lakes, then reference information is important to setting of quantitative targets for performance measures. For most attributes, however, the goal of restoration probably is not reasonable, given the major changes in land use that have occurred in the KCOL watershed and the constraints that likely exist in regard to water level fluctuation. Nevertheless, background information still may be valuable, if goals include moving certain attributes in the direction of those historical conditions.

An important issue regarding reference sites is that the concept should be used more broadly than to just define background conditions. Reference sites also play an important role in differentiating project impacts from changes due to regional climate cycles. Havens and Gore both provide more details and specific examples in Chapters 2 and 4 of this report. When reference lakes are used in this manner, one need not be as restrictive about their characteristics – it is not necessary that they be identical to the KCOL. The key is to find a group of lakes in a region where there will not be human disturbance during the period of project implementation and assessment. For the KCOL, a good candidate group of lakes is located in the Ordway Preserve in north-central Florida (details in Chapter 2). These lakes are on state land, access is restricted to researchers, they are sampled under the Florida LAKEWATCH program for water chemistry, and could have ecological assessment added at a relatively low cost to track trends in a handful of selected attributes in concert with the KCOL sampling.

### 1.5 Is there a preferred strategy for finalizing performance measures for multiple lakes within the area of the KCOL LTMP project?

*The following can be implemented immediately, without additional research or data collection.*

The panel recommends that the SFWMD not use a single CEM for the entire KCOL. At a minimum, we recommend that separate models be developed for the Kissimmee and Alligator Chains. They differ in regard to major societal values (sport fishing vs. contact recreation and wildlife habitat) and in extent of fluridone-resistant *Hydrilla* (not a major issue in the Alligator Chain). After a careful examination of stressors and attributes, as many as five distinct subsets of lakes may be found, as discussed at the workshop. We recommend that the SFWMD first revise the CEM, to address issues of complexity, missing sources (aquatic plant control), and erroneously placed attributes (sediment quality, vegetation mosaic). The next step should be a workshop using the CEM as an organizing tool for a simple exercise of making arrows thick and thin (important vs. non-important pathways) and boxes small vs. large (important vs. non-important stressors and attributes) for individual lakes or groups of lakes. This could be done one lake at a time, and the results used to identify subsets of lakes that can be represented by a common CEM, or with pre-determined subsets of lakes, if the SFWMD feels that adequate information exists to make that prior determination. The first approach is the most objective.

### 1.6 Conclusions

A. The CEM document developed by the SFWMD and the guild documents developed by the FWC represent excellent summaries of information regarding the KCOL ecosystems, and provide a good starting point for the evaluation and assessment. They are detailed, clearly written, and quite complete considering the wide body of literature that they summarize.

B. The CEM itself is overly complex. Substantially reducing this complexity, by focusing on attributes most likely to be affected by the project and key natural and societal attributes would make the model a more useful planning tool.

C. Development of a clear set of goals, objectives and constraints should occur immediately, before evaluation and assessment performance measures are finalized.

D. The Aquatic Plant Management program of the FWC and FDEP needs to be incorporated into the revised model as a source term (e.g., see Figure 2-2).

E. The model should be viewed as an organizing tool for adaptive management, with hypotheses (arrows) in the model developed into simple predictions that can be tested when assessment data are collected.

F. There is a critical need for long-term ecological data collection and focused research to address major uncertainties in the CEM.

G. The panel provided recommended interim evaluation and assessment performance measures, but stressed the need for development of a more comprehensive list, especially for assessment of project outcomes.

H. The panel agrees with the conclusion of SFWMD scientists that historical data from the KCOL and paleolimnogical information are most useful for establishing reference conditions, which could provide a context for project goals.

I. The panel also recommends use of some regional lakes as controls so that effects of climate cycles can be differentiated from responses to management actions.

J. The panel recommends that the program employ adaptive management, taking advantage of the many lakes that exist within the project boundary to fine-tune hydrologic, water quality and ecological goals to optimally meet the multiple uses of these regional water resources.

# 2. Limnology and Water Quality

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## 2.1 General comments on the KCOL conceptual ecosystem model

The Conceptual Ecosystem Model (CEM) for the KCOL is a diagram that illustrates how external drivers result in stressors on the lake ecosystems, and in turn, how those stressors affect ecological attributes (values of society and nature) by way of ecological pathways. The model framework is patterned after that used in the Comprehensive Everglades Restoration Program (CERP), and is an effective way to illustrate anthropogenic impacts on complex natural ecosystems. This KCOL model was developed using the pre-existing CEM for Lake Okeechobee (Havens and Gawlik 2005) as template. One result of that approach is that the KCOL CEM includes some ecological pathways (e.g., sediment resuspension) that are important in Lake Okeechobee but not as applicable in the smaller KCOL systems. Like the original model for Lake Okeechobee, the KCOL CEM is very complex, presumably including all ecological pathways identified by the District as occurring or potentially occurring in the lakes.

In response to the first question to the panel - "Does the CEM capture the critical drivers, stressors, effects, attributes, and linkages?" - I provide the following comments and suggestions for model enhancement.

A. In its present form, the model is overly complex – to the point that it is difficult to see clear connections between stressors and attributes. A model of this complexity may be useful as a starting point for constructing a detailed mechanistic model, but as a planning tool, the complexity overwhelms utility. I recommend a simpler that focuses on the key processes occurring in the lakes, which can be viewed as a set of clear hypotheses about how stressors affect values. At this point in the planning process, it is critical to recognize that the model will serve not only as a context for performance measures, but also as a tool in adaptive management. The District should pro-actively consider how the conceptual model can be translated into a set of simple empirical or intermediate scale predictive models (Figure 2-1).

B. Certain stressors in the CEM are too generalized (levels of nitrogen and class III chemicals) while others are too narrowly focused (levels of phosphorus) based on available information. These seem to be direct carryovers from the LOCEM. Unless there is some specific 'class III' stressor with a known effects pathway on an attribute, my recommendation is to omit them from the model. Unless there is hard science to support the concept that phosphorus is the main cause of algal blooms in these lakes, I recommend not being so specific with that stressor. My recommendation is to combine these two stressors into one called "increased nutrients," which can be linked above to a source called "intensified land uses." While earlier studies of nutrient-chlorophyll relationships in the KCOL have focused on phosphorus (e.g., Havens 2003), and have noted declines in phosphorus and chlorophyll following point-source nutrient abatement

(James et al. 1994), it is not possible to rule out the possibility that nitrogen, or a synergistic effect of nitrogen and phosphorus are responsible for algal blooms in these subtropical systems. Inputs of both nutrients were reduced when sewage diversion occurred on Lake Toho (James et al. 1994), and it is common knowledge that both phosphorus and nitrogen are highly correlated with algal chlorophyll in lakes, including those in Florida (e.g., Bachmann et al. 2003). At this time it is premature to focus solely on phosphorus as the nutrient stressor to these lakes. In fact, some lakes in the KCOL may not be adversely impacted by nutrients at this time. Certain lakes in the Alligator Chain are relatively nutrient poor, as is the case in East Lake Toho, where total phosphorus averages only 30 ug/L and chlorophyll a averages near 5 ug/L (Havens 2004). If the District develops CEM for particular lakes in the KCOL or groups of those lakes, some of the resulting models may not have nutrients as a stressor.

C. Certain attributes in the CEM are not endpoints: they are means to achieve some desired end. For example, "substrate" is an important factor controlling the biomass and composition of submerged aquatic plants (Gafny and Gasith 1999) and littoral emergent vegetation (Richardson and Hamouda 1995), and it also influences nesting activity by certain fish. Substrate that is covered with a dense layer of organic material may become anoxic, and this can affect the composition of macro-invertebrates (Warren et al. 1995), as well as other structural and functional features of an ecosystem. I recommend that substrate be removed from the list of attributes and moved up into the process region of the model. The same recommendation is made for "native vegetation mosaic" – move it up into the process region unless there is a clear value such as aesthetics that is recognized by the public as a desired goal for the lakeshore. Otherwise, it is just a means to the endpoints associated with fish and wildlife.

D. Avoid redundancies in the model structure. For example, the effects of water quality on biota are inherent in the model structure, because algal blooms and other aspects of impaired water quality are included in the ecological process region, and fish and wildlife are included as attributes. Therefore the attribute "water quality" could be more specific and focus on the one aspect that is not represented by any model pathways – the aesthetic properties of water, including clarity, absence of blue-green algae scum, and absence of unpleasant odor.

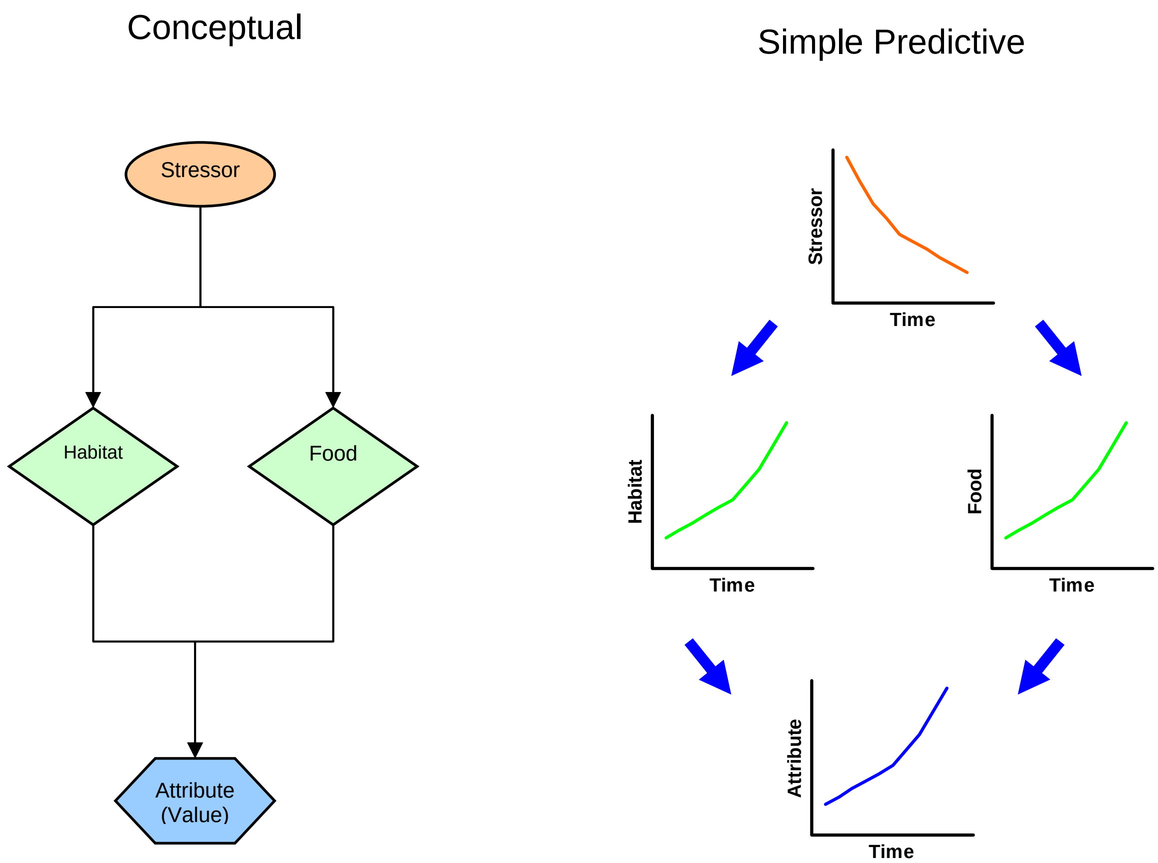


**Figure 2-1.** Illustration of how two pathways linking a stressor to an attribute in a conceptual ecosystem model can be transformed into a predictive model. In this example, the predictive model uses simple empirical relationships to show expectations regarding how processes change as a stressor is reduced, and how this will affect an attribute.

E. The Aquatic Plant Management programs of the Florida Department of Environmental Protection (FDEP) and Florida Fish and Wildlife Conservation Commission (FWC) represent a major ecosystem driver in the large lakes of the Kissimmee Chain. This should be clearly indicated in the revised model structure. Those management programs directly influence the hydrology of multiple lakes, by requiring draw-downs for herbicide application and/or muck removal. The herbicides applied in the programs may now impact non-target plant species, because high concentrations of fluridone are required to treat resistant strains of *Hydrilla*, and muck removal represents a major impact to he physical substrate and biota of treated lakes.

I have incorporated these recommended changes into a revised CEM diagram (Figure 2-2) that retains key ecological processes, but is more focused on stressors expected to be influenced by the project, and on attributes that are valued by society and integral to a healthy fish and wildlife assemblage.

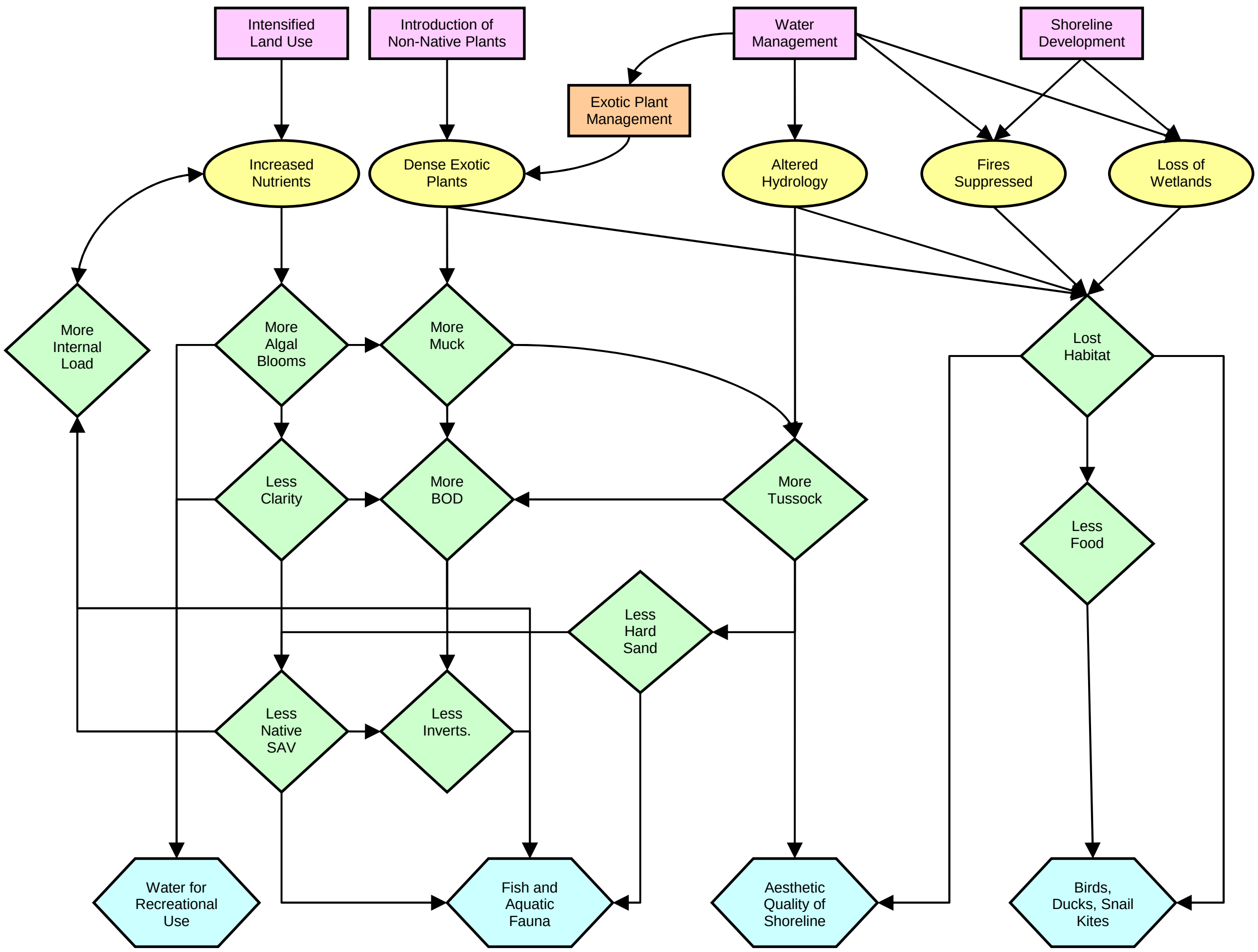


**Figure 2-2.** Simplified conceptual ecosystem model for the Kissimmee Chain of Lakes, as described in the text.

This revised model has a level of complexity similar to that presently included in the Lake Okeechobee chapter of the Monitoring and Assessment Plan for CERP, which as noted above, evolved from an originally complex CEM. There are at least three advantages to this simpler model, as a planning and assessment tool: (a) it will allow the connection between drivers, stressors, and attributes to be understood by a wider audience, including managers, decision makers, and the general public; (b) it will facilitate development of an economically feasible set of performance measures focused on the values of the natural system and society; (c) it will facilitate adaptive management. The last point will be discussed in greater detail below. Once again, it is important to note that scientists need not discard the more complex model. In fact they may use it as a starting point for an even more complex description of the ecosystem in support of particular focal areas of research or to develop mechanistic models.

## 2.2 Performance Measures

### *2.2.1 General Issues*

The second question asked of the panel was “of the attributes detailed in the report, which do you recommend for development, which are recommended for deletion, and are there any new attributes that should be considered?” The preceding text already recommended omitting certain attributes (substrate, native vegetation mosaic) and modifying others (quality of water for recreational use, aesthetic quality of the shoreline). Here I will address a closely related issue – the development of performance measures to provide a quantitative assessment of whether a project is on track towards its intended goals for those attributes.

After carefully examining the CEM document, the only goal that I encountered with any relation to ecology, was “improve, manage or sustain ecosystem health.” This is a very generic goal statement that does not identify any clear desired outcomes in regard to biological rehabilitation. During the peer review workshop, District staff pointed out that more focused goals exist in a companion document entitled “Proposed Scope for the Kissimmee Chain of Lakes Long-Term Management Plan” (March 2005, multiple agencies listed as authors). In that document, on page C-7, there is a list of general goals, including the following related specifically to ecological enhancement: (A) manage water levels for multiple uses, including aquatic habitat enhancement; (B) manage the lakes to preserve and enhance habitat, maintain or restore fish and wildlife resources, maintain healthy sport fish populations, and protect threatened and endangered species; (C) control aquatic plants to improve habitat and ecological integrity; and (D) achieve state water quality standards.

This list of goals should be incorporated into the CEM document, perhaps immediately following the description of the model structure, stressors, attributes and ecological processes. It definitely should be presented before any discussion of performance measures, because those measures will depend on the goals. Even then, there is concern about lack of specificity of the stated goals. Terms like “enhance,” “restore” and “protect” are used interchangeably, but have quite different meanings to most ecologists. To this reviewer, restore means take a system back to some pre-impact reference state; enhance means improve the quality of some attribute that is of value to society; and protect typically means prevent additional harm. The words need to be more carefully used after the District and its partners identify which attributes they aim to enhance, protect, or restore (the later being quite unlikely for most attributes given anticipated constraints).

The arrow in Figure 2-3 represents a continuum of stress that these lakes have experienced since the 1800s. The District and its partners must identify how far back along this gradient they intend to take the lakes in this program, and more specifically, develop quantitative targets for particular project goals (e.g., reduce spatial extent of *Hydrilla* by 80%, reduce the frequency of bloom level chlorophyll concentrations to <5% of the water samples collected in a given year, etc.). As noted, it seems quite unlikely that full restoration is a desired goal for any attribute, however, this is not stated in the existing CEM document.

The CEM document should explain the constraints to full ecological restoration. Presumably there is some maximal water level in each lake beyond which personal property is flooded. I presume this represents an upper constraint to full hydrologic restoration, but have no idea what those levels are. The March 2005 document noted above indicates that some of these lakes will have Minimum Flows and Levels (MFL) criteria established by the District at some future date. Will these result in constraints to restoration of the lower portion of lakes' historical hydrographs? This also needs to be described in the document, and in fact, it will logically precede the establishment of final goals (i.e., non-restricted ecological goals → constraints → feasible ecological goals → evaluation and assessment performance measures).

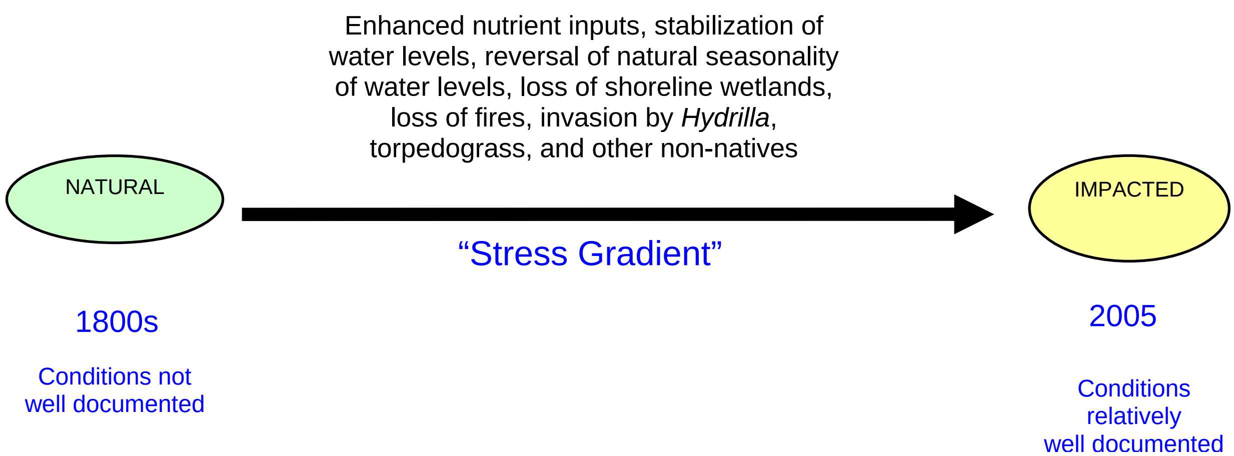


**Figure 2-3.** Simple illustration of a stress gradient experienced by the KCOL systems since the 1800s, recognizing that the solid arrow reflects trajectories along multiple gradients of environmental stressors. A critical issue for the program to resolve is how far back along these gradients the desired rehabilitation goals lie.

It also is important that performance measures be associated not only with stressors and attributes, but also with key ecological processes in the CEM. The inclusion of process-related measures becomes particularly important if the aim is to have an adaptive management process. Given uncertainties that exist regarding responses of a complex ecosystem to major perturbations, it is likely that some outcomes will not match expectations based on the CEM. If the model is well-focused and the program includes the monitoring of key pathways, it will be considerably more likely that appropriate actions can be taken upon observing the unexpected attribute responses. In a hypothetical example (Figure 2-4), bass are expected to increase when tussocks are reduced in a lake. If bass do not respond as expected and only the stressor and attribute are measured, managers have no guidance for adaptive management. In contrast, if there is information on two key factors that affect bass production (habitat and food resources), knowledge of which factor has failed to respond will allow for a targeted investigation by scientists and managers and a more rapid and appropriate adaptive response. Furthermore, the CEM itself should be viewed as an adaptive tool that is enhanced over time as data collection regarding stressors, ecological processes and attributes allows scientists to refine their understanding of the ecosystem. This in turn will help to adjust future management actions.

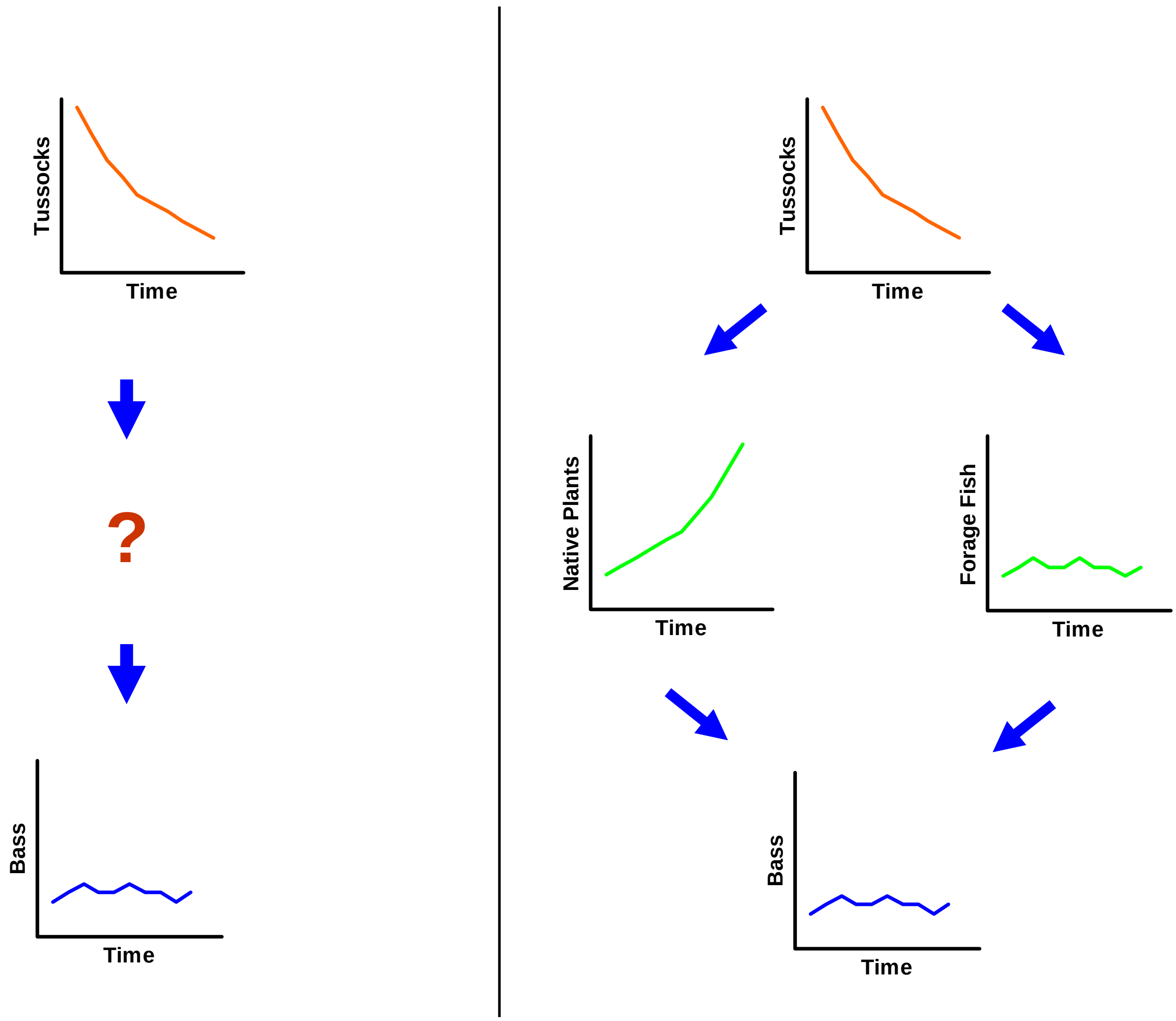


**Figure 2-4**. Hypothetical models supporting a program goal to reduce occurrence of tussocks and enhance biomass of largemouth bass in a lake. In the scenario on the left, bass biomass does not increase as expected when tussocks are reduced, but it is not possible to determine what action to take in response to this outcome because no other information exists. In the scenario on the right, native plants and forage fish also are monitored, and it is apparent that the lack of bass response is not due to poor recovery of native plants, but rather to a lack of forage fish. This allows scientists and managers to focus on that particular aspect of the ecosystem and achieve a more expedient solution to the problem.

### *2.2.2 Water Quality*

The lakes in the Kissimmee Chain vary considerably in their water chemistry, with a wide range in pH, dissolved color, total and soluble nitrogen and phosphorus, chlorophyll *a*, and Secchi disk transparency (Havens 2003). Chlorophyll *a* concentrations correlate significantly with both nitrogen and phosphorus, in a manner that is not distinguishable from the general pattern observed for North American lakes (Havens and Nurnberg 2004). These correlations exist in the majority of world-wide lakes, and reflect the fact that one is measuring three components of algae that correlate with their biomass. The correlations are not sufficient evidence, when taken alone, that nitrogen or phosphorus are limiting to the algae, and certainly not sufficient evidence that nutrients are stressors. There is evidence (James et al. 1994) that Lake Toho and other lakes in the Kissimmee Chain responded to reductions of point-source nutrient loading (sewage diversion) with significant declines in nitrogen, phosphorus, chlorophyll *a* and algal bloom frequency. This indicates that in the past the lakes were impacted by anthropogenic nutrient inputs. It also may be the case that some residual effect of those inputs remains in the form of elevated nutrient levels in the lake sediments and perhaps enhanced internal recycling (loading). It is less clear whether nitrogen or phosphorus continue to be stressors in all (or any) of these lakes. This issue could be reconciled by (A) identifying whether there are documented negative impacts to human uses or fish / wildlife from high nutrient and chlorophyll *a* levels; (B) comparing present rates of nutrient loading, concentrations, and algal composition to past values inferred from paleolimnological studies on the lakes; and/or (C) comparing nutrient and chlorophyll *a* concentrations in the KCOL with water quality 'reference conditions' identified by the FDEP for this particular lake ecoregion. Determination of whether nitrogen or phosphorus limits algal growth can be accomplished using standard whole-community bioassays (Aldridge et al. 1995) or surrogates such as the dissolved inorganic nitrogen to soluble reactive phosphorus ratio (DIN:SRP).

Basic water quality performance measures for the KCOL should include total phosphorus, total nitrogen, TN:TP ratio, DIN:SRP ratio, chlorophyll *a* and Secchi transparency. These are the standard measures of water quality in lakes as it relates to trophic state, and include indicators of nutrient limitation status (N:P ratios). Because organic color is a major contributor to light attenuation in these lakes, it also should be measured in the long-term assessment program, perhaps with a target of "no increase."

If there is good evidence that nutrient stressors are causing algal bloom problems (impaired aesthetics, odor, toxins or other impacts to fish and wildlife) in certain KCOL lakes, two additional performance measures should be included in the assessment program: <u>frequency of algal blooms</u> and <u>percent of algal biomass due to bloom-forming taxa of cyanobacteria</u> (e.g., *Microcystis*, *Anabaena*, *Aphanizomenon*, *Cylindrospermopsis*). These algae are most often responsible for toxic blooms when they are documented in eutrophic lakes (Paerl 1988), and they are the main ones associated with dense surface blooms in Lake Okeechobee (Havens et al. 1998), the Kissimmee River, and the KCOL (SFWMD, unpublished phytoplankton survey data from 2000 to 2005, recently provided to this author for inspection).

The first recommended performance measure, frequency of algal blooms, can be derived by following the procedure described in Havens and Walker (2002), and will require (A) a specified concentration of chlorophyll *a* that serves as a surrogate for indicting whether or not there is a bloom, and (B) a target frequency, which may be set by examining historical data from the lakes, data from FDEP reference lakes in this lake ecoregion, and/or paleolimnological survey results. This performance measure can be derived from data already available from the assessment described above, and it provides important information because extreme events like blooms have a more profound effect on public use of water and fish / aquatic fauna than do yearly averages (Walmsley 1984, Reckhow 1988, Havens 1994).

The second recommended performance measure, percent bloom-forming cyanobacteria, can be determined from data collected in an existing District sampling program on the KCOL. This presently is funded under the Lake Okeechobee Protection Program, and provides consistent sampling of phytoplankton in the KCOL, Kissimmee River and Lake Okeechobee. In the case of Lake Okeechobee, a target percentage was established from early 1970s phytoplankton data (Havens et al. 1996), and recently confirmed by analysis of algal pigment remains in historical sediment cores (Engstrom et al. 2005). For the KCOL, paleopigment analysis may be the best option for establishing targets for this performance measure.

### *2.2.3 Littoral Zone and Wetlands*

In the CEM document, there are separate sections dealing with the littoral zone and wetlands, but it never is explained how these are differentiated or where the boundary occurs (if indeed there exists a clear boundary). The shoreline of a lake represents an ecotone between aquatic and terrestrial systems, with a gradient of species from those adapted to deeper water to those adapted to periodic desiccation. Scientists have developed terms like littoral and wetland to describe this zone, and sometimes use them interchangeably. If the District has in mind some clear differentiation, I recommend a simple illustration of a lake in cross-section to show the readers of the CEM document where the boundary is thought to occur and what the differentiating characteristics are for these two zones.

The list of performance measures provided for littoral and wetland zones appears to be complete, in the sense that it includes the attributes one would typically assess (biomass, taxonomic composition, acreage, spatial pattern) to quantify an aquatic plant assemblage. However I do have three general comments about what is proposed in the CEM document.

First, it is suggested that the assessment of aquatic plants within the boundary of the lake proper can be done using results from ‘existing” sampling programs. Florida LAKEWATCH is mentioned as an example. It is important to recognize that while LAKEWATCH does periodically sample the aquatic vegetation of some lakes in the KCOL region, there is no systematic long-term project under LAKEWATCH for long-term sampling of multiple lakes in a manner that will support the KCOL program. Certainly it makes sense to consider the LAKEWATCH program as a cost-effective way to gather aquatic plant data, because that program already coordinates sampling of water quality on regional lakes and has established low-cost methods for sampling the aquatic plant communities. However, use of LAKEWATCH to conduct this part of the long-term assessment will require development of a specific scope of work that identifies a sampling regime necessary to support species-level plant assessment, and the necessary funding to support this program. Likewise, data collected by the FWC during their periodic habitat enhancement projects may be helpful in shaping expectations or providing background information, but since their sampling does not occur at regular intervals and is limited to a small number of lakes, it is not sufficient as a regional performance measure assessment program.

Second, the CEM document makes note of the FDEP Lake Vegetation Index (LVI) as a way to quantify the status of aquatic plants in the littoral zone of KCOL systems. As noted, this method has the advantage of being based on expert-derived value judgment, and as such, does not require an intensive data collection program. According to Fore (2005) the LVI is highly correlated with human disturbance in the watershed. I recommend caution in applying this method until it undergoes independent peer review (Fore 2005 is a FDEP report) and publication in a respected peer-reviewed scientific journal such as Wetlands or Aquatic Botany. Even when that occurs, I concur with the conclusion in the CEM document that rapid "field methods do not provide species level abundance data" that will be necessary to evaluate quality of the habitat for fish, aquatic biota, wading birds and other wildlife. I also agree with the conclusion in the CEM document that carefully planned "aerial photography, vegetation mapping and ground truthing" will be required for performance measure assessment at a level that can reasonably support adaptive management.

I agree with conclusions in the CEM document regarding periphyton assessment. Yes, periphyton can serve as sensitive indicators of a myriad of pollutants in lakes, ranging from heavy metals to persistent organics. However, in these lakes the main water quality stressors appear to be nutrients. It is very difficult to separate out periphyton responses to nutrient input from responses to changes in underwater irradiance, water temperature, wave energy, grazing, and various other factors. Periphyton taxonomic structure can be used to assess degree of nutrient stress in lakes, but it is expensive and time consuming. Use of artificial substrates and indicator taxa overcomes some of the logistical problems, but raises concerns about relevance of results obtained. Given these issues, I recommend investing the resources elsewhere in the assessment program.

I also agree with conclusions in the CEM regarding performance measures associated with phosphorus assimilation. Certainly this assimilation, by biological uptake and co-precipitation with calcium, is an important function of a lake's aquatic plant community (Havens et al. 2001). However, there are no specific goals in the CEM document regarding phosphorus assimilation in the KCOL. This reflects the fact that we have no idea how present rates compare with what occurred in the past, or whether present rates are lower than desired to allow other ecological objectives to be realized. In fact, a littoral / wetland community that has maximal phosphorus uptake capacity may not be compatible with high quality fish and wildlife habitat. I do not recommend performance measures focused on plant phosphorus assimilative capacity at this time.

I do recommend adding two hydrologic performance measures for alternatives evaluation and assessment, the within-year and between-year variation in water level. These measures can serve as simple surrogates for plant community diversity in the evaluation process. Keddy and Fraser (2000) documented that in North American lakes, maximal diversity of plants occurs at an intermediate level of hydrologic variation. Extremely high variation produces a system so unpredictable that no plants survive. Some large reservoirs fall into this category and cycle between conditions of deep water right up to tree line during fill periods vs. exposed sediment along the lake shore during draw down periods. In contrast, lakes such as Lake Istokpoga, which have lost nearly all of their natural variation in water levels, are characterized by monocultures of submerged and emergent plants because conditions are so predictable that superior competitors displace other plants from the landscape. Plants that do this include *Hydrilla*, *Typha* (cattail) and in some cases pickerelweed (*Pondaderia*). In the example shown in Figure 2-5, from Lake Istokpoga, the goal might be to move the lake back from its present condition, near the origin of the graph, towards the area encompassed by the green circle, which Keddy and Fraser (2000) identify as the zone of maximal diversity. In this case, the condition before water regulation (1936-63) fell inside that area of the graph and it is known that Lake Istokpoga had a diverse plant assemblage. Including these performance measures also provides a fundamental ecological underpinning for the program that, in my view, is critical.

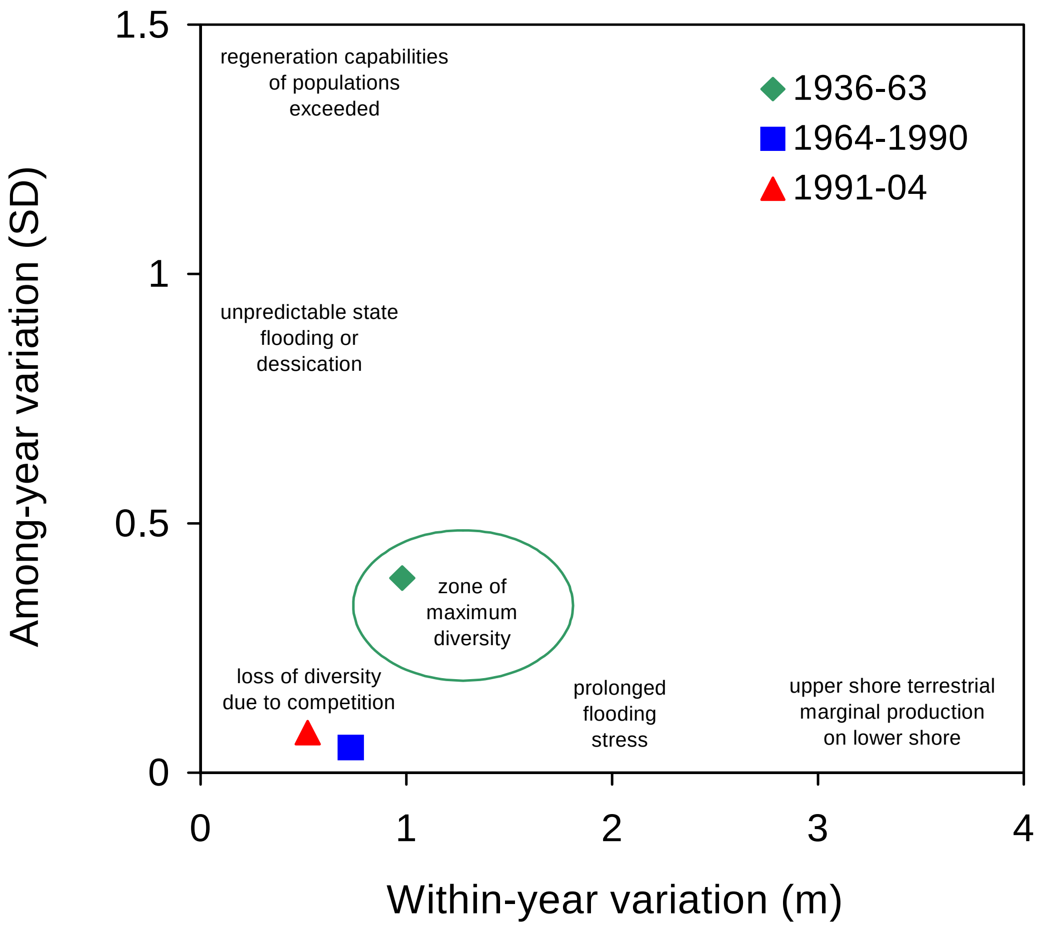


**Figure 2-5.** Conceptual diagram from Keddy and Fraser (2000) showing among-year and within-year variation in water level relates to conditions in the shoreline of lakes. Actual hydrologic conditions from Lake Istokpoga are plotted on this graph. The actual changes that occurred in Lake Istokpoga's plant assemblage when its water levels were stabilized match the predictions of this simple model.

## 2.3 Supporting Literature

The District asked the panel: "have we missed important literature and/or datasets?" In subsequent discussions, it became apparent that the District also was interested in whether important literature exists from other lakes that might be relevant to this program. Rather than addressing this question separately, I have provided citations to specific journal articles in the preceding and subsequent text dealing with the CEM, performance measures, and reference lakes, and noted above the availability of a comprehensive dataset dealing with the lake's phytoplankton assemblage.

## 2.4 Reference Sites

The District also asked the panel: "are there reference sites that can be used for performance measure development in lieu of KCOL historical data." With the possible exception of water quality reference conditions, which are under development by a technical advisory committee to the FDEP, I do not believe that there exists another set of lakes that could be used to indicate ecological background or pre-impact reference conditions for the KCOL. I agree with the conclusion in the CEM document that the best approach for identifying reference conditions is to examine existing historical data from the lakes, anecdotal reports of historical conditions, AND paleolimnological data. Although they are relatively expensive, paleolimnological studies of the lakes would provide a wealth of information on past conditions, including information on nutrient concentrations and ratios in the lake water, nutrient loads, phytoplankton taxonomic structure (including relative dominance of bloom-forming cyanobacteria), macro-invertebrates, zooplankton, as well as potential information regarding lake and watershed vegetation. The methods are well established and we know that they work in shallow Florida lakes (e.g., Engstrom et al. 2005, Schelske et al. 2005). Again, however, it is important to establish whether any of the reference conditions that are determined (e.g., levels of algal biomass, composition of phytoplankton) are program goals, or just a context that helps understand how targets for rehabilitation of the lakes compare against full restoration, which most likely is not feasible, desirable, or even possible.

My main recommendation regarding reference lakes is that they be considered more broadly, and be used as controls for the restoration program. This does not require finding lakes that are identical or even similar to the KCOL (see below). Given the high degree of year-to-year variation in certain attributes, especially those in the water quality category, and the long response time of certain biological attributes, it is expected that many years (decades) of data will be required to identify statistically significant trends that can be linked with projects. In that same time frame, south Florida will experience year-to-year changes in rainfall and runoff, as well as longer-term climate cycles associated with such things as the North Atlantic Multi-decadal Oscillation (Enfield et al. 2001). It is important to discern trends that are happening due to local projects from trends occurring more regionally in response to climate variability (Figure 2-6). The way this typically is addressed is by using reference lakes located somewhere in the general vicinity of the KCOL (i.e., central or north Florida), in a watershed that is undisturbed and not expected to undergo disturbance during the life of the project. Then trends happening in the KCOL can be compared with trends in the reference lakes to determine whether there is a local or regional cause. A classic example of this use of reference lakes is Schindler et al. (1985), where a whole lake was subjected to experimental acidification. Between 1974 and 1981, phytoplankton primary productivity increased nearly three-fold in the manipulated lake AND the same pattern occurred in a set of nearby non-treated reference lakes. The response was to a warming trend in the region. Had the reference lakes not been included in the design, the clear long-term trend would have led to an erroneous conclusion about the effects of acidification on primary production. Of course this same approach of using treatment and reference (control) lakes is now commonly seen in paired lake studies where data are analyzed with BACI (before after control intervention) analysis.

There may be numerous lakes that can provide the necessary controls for the KCOL program. One good candidate may be the 20+ lakes contained within the Ordway Preserve in north-central Florida. These lakes occur on public land, in watersheds with no human development, and they will be maintained in that state long-term because the land is owned and managed as a research and education preserve by the University of Florida. Like the KCOL, many of these lakes are highly colored and have relatively low pH. Several of the lakes have a long history of basic water quality sampling under the Florida LAKEWATCH program, making it cost effective to use those lakes by adding some biological attributes to that existing effort.

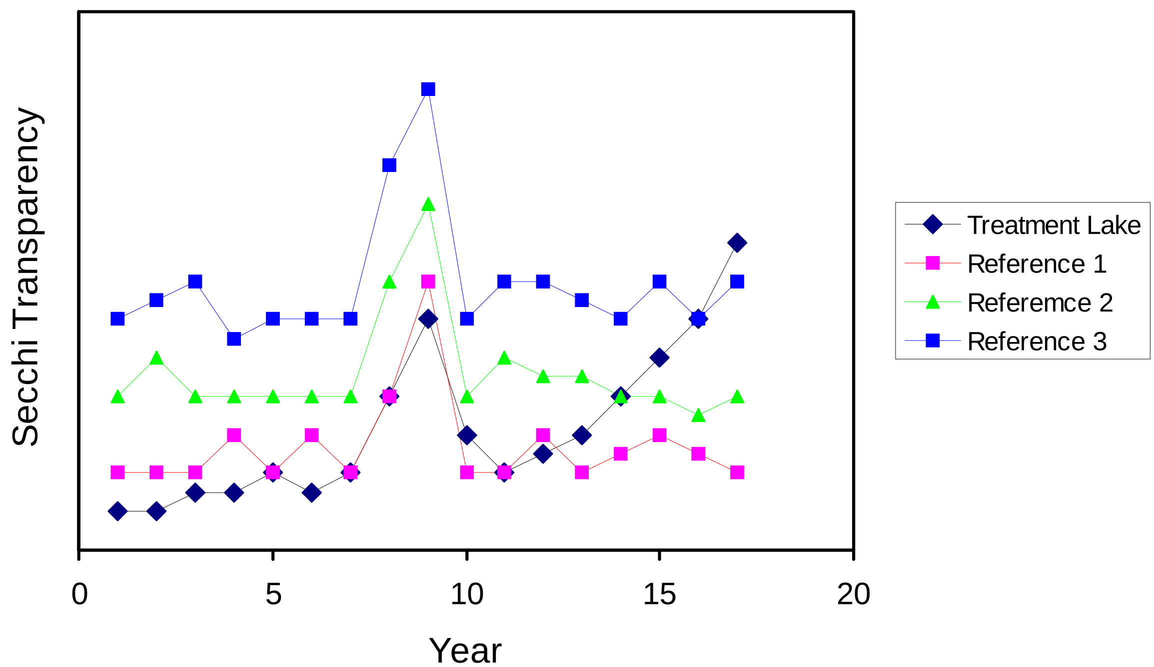


**Figure 2-6.** Hypothetical example of long-term assessment of Secchi disk transparency in a treatment lake and a group of reference (control) lakes. This dataset indicates that some regional phenomenon resulted in increased transparency in lakes between years 7 and 9, whereas a localized driver led to increased transparency in the treatment lake in years 10 to 17.

## 2.5 Multiple Lakes

The District asked the panel “is there a preferred strategy for finalizing performance measures for multiple lakes within the KCOL project?” I will address this at two levels -- (A) Is it necessary to develop lake-specific conceptual models and performance measures and how should this be accomplished? (B) Are there some clear advantages to having many lakes vs. just one lake to rehabilitate?

A. Based on available data on water quality, vegetation and human / wildlife uses, it appears that there must be at least two separate CEM – one for the Alligator Chain and another for the main Kissimmee Chain of Lakes. The Kissimmee Chain is heavily influenced by fluridone-resistant *Hydrilla*, programs to control *Hydrilla*, and large-scale shoreline habitat manipulation (muck removal), and the main societal value appears to be sport fishing. The Alligator Chain is not so influenced by *Hydrilla*, and includes lakes primarily valued for contact recreation and wildlife habitat. I recommend that the District and its partners / stakeholders derive separate conceptual ecosystem models for at least these two lake regions. In regard to an effective process, my suggestion is to use a simplified version (e.g., Figure 2-2) of the CEM as the organizing tool. Starting with this CEM, a group can begin with stressors and attributes, asking whether all of the boxes shown on the model diagram are important enough to retain in each regional model. If not, certain stressors and/or attributes can be removed, along with the pathways associated with them. This may be all the adjustment that is required to have lake region-specific models. However, it may also be of value to look at the arrows within the model structure (the ecological processes), and reach agreement on relative importance, perhaps illustrated by making the arrows thick (important) or thin (not important). That exercise could prove valuable in helping to determine which processes to include in the long-term assessment program. When doing this, however, the group should give explicit attention to the level of certainty associated with those process pathways, and not omit from consideration pathways considered non-important unless there also is a high degree of certainty about that part of the model structure.

B. Having multiple lakes in the program may be viewed as a challenge or an opportunity. In my view, it is the latter. In lake management projects there almost always are conflicting goals, reflecting the multiple values of water resources. Water that is rich in nutrients and algae supports a high biomass of sport fish, but is bad for swimming; dense plants around the shoreline provide habitat for ducks and wading birds, but restrict access to boat docks and locations to fish; frequent periods of low water are essential to maintaining a diverse community of aquatic plants, but when they occur, they negatively affect navigation and potentially affect water supply. In a single lake, a trade-off approach often is taken where no single value is significantly impacted, and thus no single value is significantly improved! In a single lake, there also is just one system to manipulate and no real opportunity to do adaptive management that compares different levels of manipulation. The multi-lake KCOL system may allow the District to break away from these traditional obstacles in two ways. First, it may be possible to achieve substantial enhancement of multiple values, as long as the KCOL can be viewed in a landscape concept, rather than expecting that each and every lake must support the full value suite. Some lakes may be managed to have an exceptional bass fishery, others may be managed to have clear water and contact recreation, and others may be managed to function largely as habitat for migratory ducks, wading birds and other wildlife. Second, it may be possible to conduct whole-lake tests of various actions to optimize the program in a relatively short time frame. For example, if a new herbicide is developed for treating *Hydrilla* and this plant is a problem in six particular lakes, then in the first year, treatment might be done at six different dosing levels in order to identify the optimal one for continued application in subsequent years. If there is uncertainty about how certain variation in water level influences the degree of berm (tussock) formation along the shoreline, and the aim is to reduce these features while having minimal effects on navigation, water levels might be managed differently in various lakes where tussocks occur to identify an optimal range (obviously this will only work in lakes that are not physically connected in an unrestricted chain).

### 2.6 Using the CEM to Prioritize Research

A well-designed CEM can support multiple aspects of a long-term ecosystem project. At this time, the District is focused on just two of those: (A) development of evaluation performance measures for alternatives analysis and (B) development of assessment performance measures for long-term assessment and adaptive management (the later being addressed in this review, but not explicitly mentioned by the District as an explicit part of their program). The CEM also can be used to prioritize future research on the lake ecosystems. Clearly if one examines the arrows (hypotheses) in the CEM, some are supported by a wealth of research on shallow lakes, and may require no additional research. The certainty associated with these hypotheses is high, and the expectations linked with such model components are sound. However, not all pathways have this level of certainty. As an example, the panel discussed the lack of information about the role of amphibians and reptiles in the lake food web, and incomplete knowledge about how variations in water level affect the location and extent of berm / tussock formation. I recommend that the District look carefully at the revised CEM that comes out of this review process, and with input from experts in lake ecology, identify which arrows in the model have high, moderate, and low certainty. If there exist arrows in a model with low certainty, and the expectations associated with those ecological pathways are important ones, then success of the program is potentially at risk. Spending funds to build certainty up front and make pro-active changes to plans, rather than reactive responses to unexpected consequences, would benefit the ecosystem and save time and money for the coordinating agencies.

# 3. Wetland and Littoral Plants

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## 3.1 Summary

Specific performance measures associated with wetland vegetation and soil development have not been recommended due to the lack of a target reference community or identification of specific KCOL management objectives. Instead, qualitative recommendations to improve the range of hydrologic fluctuation and provide for inter-annual variation in stage are proposed. Implementation of these hydrologic conditions should increase the breadth of vegetated communities along the shoreline and better mimic pre-regulation conditions. In addition, the accumulation of organic matter is often regulated by the frequency and duration of saturated or flooded soil conditions. Maintenance of suitable mineral soil habitats for some species and a suppression of conditions promoting floating wetland or tussock formation should also occur with greater hydrologic fluctuations.

Although specific performance measures are not presented, monitoring of vegetation as well as soil characteristics can provide a relatively simple and robust measure of the effects of alternative management conditions. Individual species, or species assemblage at a given elevation can provide a measure of change if evaluated before (baseline) and after management actions. If a reference conditions can be identified that relate to the objectives of the KCOL management alternatives then species assemblage and hydroperiod relationships can be developed for use in modeling various hydrologic management regimes and to determine likely species distributions that will result. In a similar manner soil organic matter content or other attributes can be used to monitor or predict successful changes in organic matter accretion rates or evaluate various hydrologic scenarios on soils development within the littoral zone.

Vegetative composition and soil characteristics are highly influenced by hydrologic conditions at a given elevation. With specific objectives for management, these relationships can be used to establish performance measures. In the absence of specific management goals, monitoring of littoral zone vegetative components can provide a relatively short-term measurable response to hydrologic manipulations.

## 3.2 Introduction

This review section focuses on wetlands and littoral plant communities and their possible use as Performance Measures, as well as an over all discussion related to the format and layout of the KCOL Conceptual Ecosystem Model. The charge to the overall review committee members was to review the draft KCOL LTMP Conceptual Ecosystem Model Document, and draft Florida Fish and Wildlife Conservation Commission Candidate Indicator Species Documents and specifically address the following questions:

- Does the conceptual ecosystem model capture the critical drivers, stressors, ecological effects, attributes, and linkages? Should anything be added or omitted?
- Of the attributes detailed in the report, which do you recommend for development as performance measures and which do you recommend deleting? Are there other attributes that we should consider?
- Have we missed important KCOL literature and/or datasets?
- Are there reference sites that can be used for performance measure development in lieu of KCOL historical data
- Is there a preferred strategy for finalizing performance measures (both evaluation and assessment) for multiple lakes within the area of the KCOL LTMP project?

### 3.3 Assessment of the KCOL conceptual ecosystem model

After an extended effort to become oriented with the CEM I felt that it was quite comprehensive in identifying most drivers, stressors and ecological processes/effects that are likely to exist within the KCOL. In fact, depending on the application of the model this comprehensiveness, or level of detail, may too cumbersome for use in certain audiences, such as to educate the public or policy makers. For this reason there may want to be some consideration for scaling of the model into a more general model with only the most prominent drivers and then other models that are more detailed, but nested within the main model. To this end, I thought there was a general partitioning of the model along landscape boundaries including pelagic zone, littoral zone and watershed wetlands. Figure 1 provides a general breakpoint for these partitions within the model. Linkages in the model across these boundaries are critical to maintain as it helps to assess not only the subject of a driver or stressor, but to some extent also its source within the landscape.

Another aspect of the model that came up during the workshop and in other discussions is the applicability and relative contributions of the various stressors within the model. Some consideration of weighting these stressors using size of ovals or text may be prudent. When evaluating these relative stressors in the system there may need to be additional consideration with regard to “does one model fit all”. That is, are all stressors the same in all lakes of the KCOL, or does the relative weighting of the model’s stressors need to change in response to different drivers and stressors among the lakes? This could be done by developing one model for each lake or classifying lakes into various classes or categories and applying a more generic model to each of the classes. For instance, Hydrilla was thought to be the most significant driver in some of the lakes, where as in other lakes hydrology or nutrients may be more significant factor to address. Identification of the relative stressors and driver within each lake will be very useful in public education efforts as well as the evaluation of various hydrologic modeling efforts that might resulting in improvement or exacerbating of existing conditions.

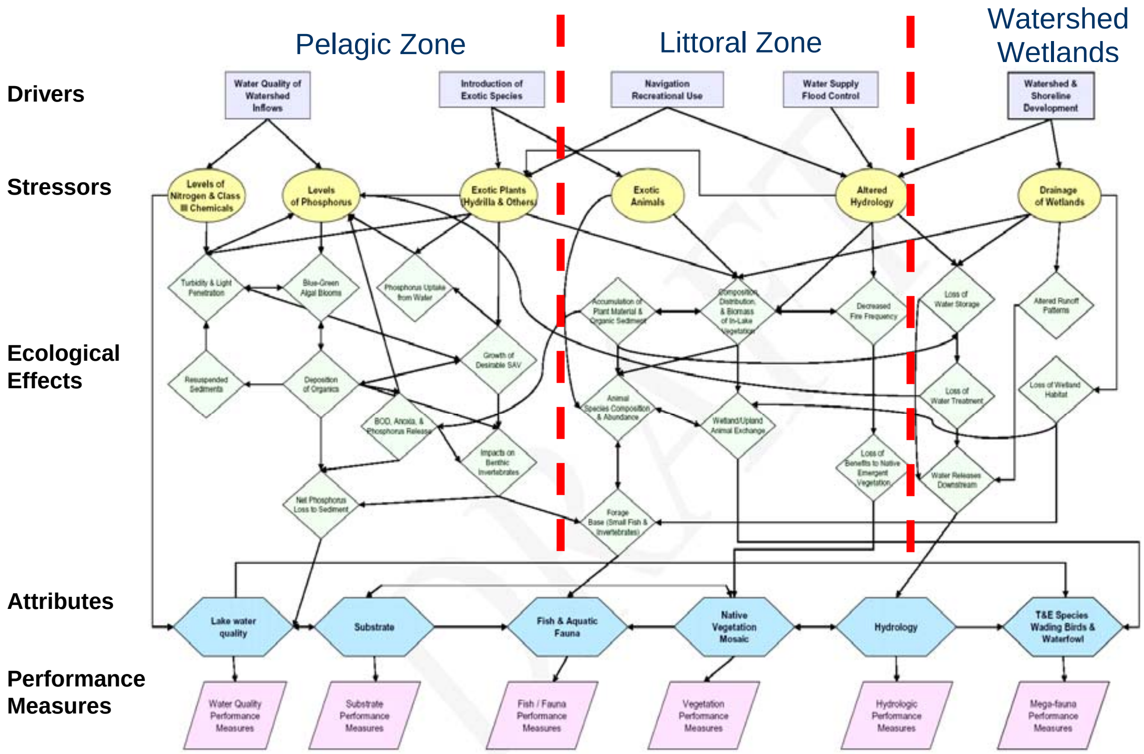


**Figure 3-1.** Conceptual Ecosystem Model with tentative landscape partitions (Pelagic Zone, Littoral Zone and Watershed Wetlands)

With regard to Attributes and Performance Measures of the model, these become difficult to assess unless there is a clear objective or goal for management. Attributes for the most part should be the physical characteristics associated with the goals, and performance measures are the modeling target and or post management assessment mechanism to determine success of outcomes. There was considerable discussion regarding attributes associated with the model where in some instances attributes provided in the model, such as substrate or soil quality, were not considered endpoints, but instead more of a means to an endpoint. However, the inclusion or placement of soil quality is very dependant on the goals. If for instance a sandy shoreline is in itself an attribute and not vegetative or wildlife habitat, then mineral soils, which would be a soil quality characteristic, could be a specific attribute. Therefore, until clear objectives and goals are identified it is somewhat difficult to assess the appropriateness of the attributes provided.

With regard to additions or deletions to the CEM, again it is somewhat dependant on the objectives, however, figure 2 outlines several state variables and ecological linkages that I believe should be included or at least considered in more complex models. Along with the existing stressors presented, "Physical Disturbance" is likely a stressor in all systems. The relative influence of this stressor may be minimal compared to others such as nutrients or hydrology; however, in localized areas the role of physical disturbance could be significant. Some of these aspects may be physical barriers between upland and wetland that decrease the frequency of fire (fuel managed landscapes, perimeter airboat trails acting as firebreaks), boat traffic resulting in shoreline erosion, as well as some aspects of aquatic plant management that might result in undesirable habitat impacts. Physical disturbances would be driven by navigation and recreational uses as well as watershed and shoreline development. Activates of the physical disturbance would effect severity and extent of fire frequency, as well as the composition, distribution and biomass in isolated areas of lake vegetation.

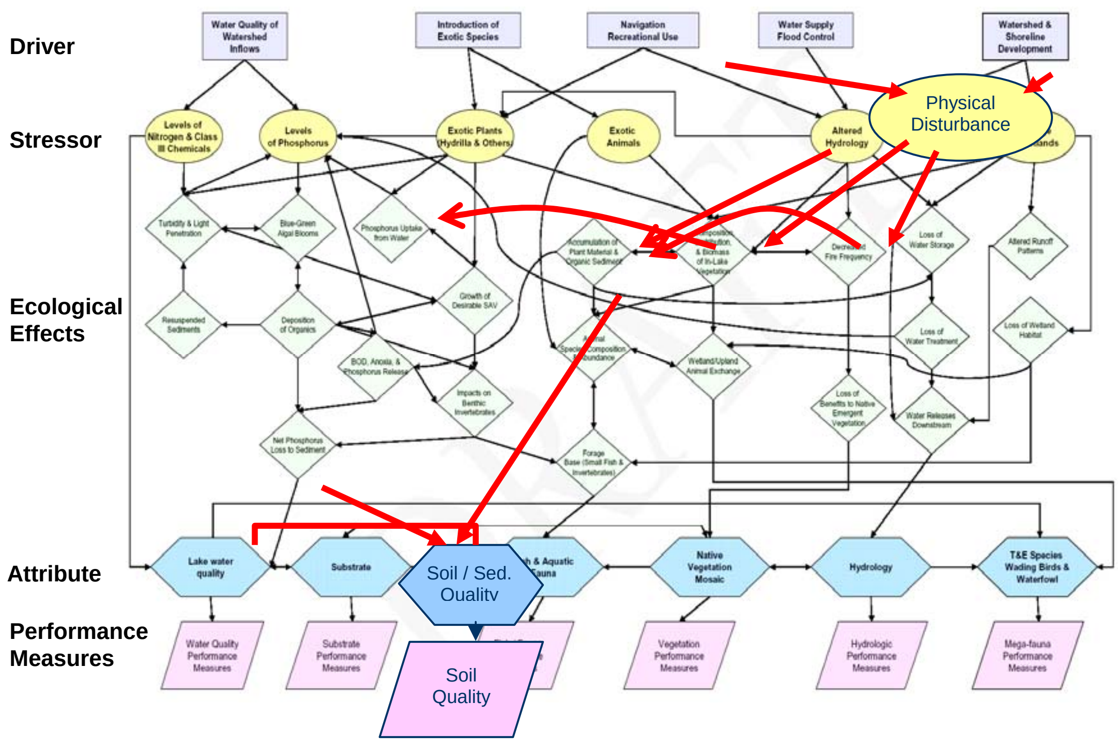


**Figure 3-2.** KCOL Conceptual Ecosystem Model with proposed stressor, ecological effects linkages and attribute additions.

Several linkages within the model that I thought were missing included internal ecological effects between altered hydrology and accumulation of plant material and organic sediments. Although this linkage may be implied laterally within the model in relation to fire, there is also a significant relationship between site hydrology and soil organic matter accretion or decomposition. In addition, the relationship between composition, distribution and biomass of in lake vegetation and phosphorous uptake from water should be added. Macrophyte vegetation provides some direct uptake and storage of nutrients, but it also provides a large substrate for other algal and ephiphytic organisms to become attached. These secondary colonizers provide a much more rapid uptake of water column nutrients than macrophytes and can have significant effects on nutrient assimilative rates in wetland environments (Vymazal 1995, Kadlec and Knight 1996).

I see only one possible attribute to add to the CEM and this one already exists under a different name. The proposed attribute includes Soil and or Sediment Quality. This attribute is synonymous with substrate, however may encompass a broader range of conditions. The term quality is inherently user defined and therefore the objectives of this soil or sediment condition would have to be defined. As mentioned above, if some specific soil characteristic was in itself an objective or goal and not just a means to another goal or objective then including soil and or sediment quality would be appropriate. One aspect that this attribute definition provides is a link across upland as well as lake and littoral zone conditions related to phosphorus loading and organic matter accumulation. Soil characteristics can be relatively easily measured and once Performance Measures are set, repeatable monitoring for performance measure assessment could be implemented.

In summary of discussion relative to the CEM, scaling of the CEM is one consideration that must be addressed relative to its application or audience. Secondly, evaluating the relative influence of stressors in the KCOL and modifying them on a lake by lake, or lake aggregate basis would likely increase the validity and applicability of the model. Lastly, determining more specifically what the attributes of the model should be based on goals and objectives will be necessary to determine whether or not some of the present attributes listed are indeed attributes or are they supporting conditions that lead to some other condition that is the true attribute desired.

## 3.4 Attributes and performance measures

Two metrics associated with wetlands and vegetation are proposed in the model these include a Wetland Metrics (3.1 CEM document) and a Littoral Zone Metrics (3.2). It was not clear to me whether the littoral zone was considered a subset of the wetland metric or if these two were considered two unique spatial areas. In most instances littoral zones would be considered wetlands and therefore would be a subset of the Wetland Metric, but in the document I felt that the Wetland Metric was focused more on wetlands within the watershed and not inclusive of wetlands directly associated or within the hydrologic fluctuation of the lakes. Conversely, the littoral zone (although wetlands) was that part of the landscape dominated by emergent macrophyte species that was within the direct influence of surface water fluctuations. Some clarification within the document between these two metrics would be helpful.

### *3.4.1 Wetland Metrics*

The CEM document proposes three sub metrics for possible development into performance measures –

- Distribution, land cover, and spatial extent of existing and drained wetlands
- Lost acre-feet of storage
- Lost phosphorus assimilation capacity

To the extent that wetlands within the watershed are identified as significant drivers or stressors to the KCOL, I would concur with the use of these sorts of metrics. However, setting specific performance measures other than qualitative ones will be difficult. The reality of existing development around the lake and establishment of hydrologic characteristics at much lower elevations than those of historic conditions limits the ability to reverse the loss of wetlands throughout the watershed or the distribution of these wetlands in the landscape. Assessing the extent of lost hydrologic storage or P assimilative capacity would provide quantitative targets of pre-disturbance hydrologic and nutrient loading rates which could be used to set performance measures very similar to a TMDL. In addition to direct loss of wetlands and changes in detention time of water within the landscape, the assimilative capacity of wetlands within the watershed is also likely impacted due to excessive loading.

Assimilative processes and long-term storage of phosphorus by wetlands is based on biological, physical and chemical processes (Reddy and D'Angelo 1994, Reddy et al 1999). The assimilative capacity of a wetland can be exceeded in part do to loading rates that are in excess of the biological uptake rate of the nutrient sorptive capacity of the soils. Over time, as sorption sites are satiated, the background phosphorus concentration in the wetland will increase. This is called the equilibrium phosphorus concentration or EPC. Although wetlands may still function and assimilate a high total load of phosphorus from the watershed, and therefore can be beneficial in overall watershed management of phosphorus loads, the accumulation of phosphorus on a relative fixed number of sorption sites can result in the wetland reaching capacity and then providing a decreased benefit. Second to this loss of assimilative capacity is the fact that the wetland can be come a significant source of phosphorus if phosphorus concentrations entering the wetland decrease after the wetland has been loaded.

Several useful measures to assess Phosphorus sorption capacity in upland soils include: the Degree of Phosphorus Saturation in mineral soils (DPS) (Nair et al 2004), the Equilibrium Phosphorus Concentration (EPC) (Reddy et al 1995) or the Maximum Sorption Capacity of the soils (Nair and Harris 2004). These measures could be used to evaluate the condition of the wetlands within the watershed to assimilate P over time.

Another aspect that is missing with regard to wetland assessment of indirect impacts is the change in structure and quality of habitat provided by remaining wetlands. In many instances wetlands within the watershed, but not directly associated with the lakes, may provide habitat for species that are also using the lake. For this reason assessment of the habitat quality, type of wetland community, and the location of the wetland within the watershed are likely critical to assess not only the % cover, but more importantly the functional value of these wetlands to improve water quality and habitat related attributes identified in the CEM.

Specific performance measures associated with these matrices are difficult to establish other than to state that no additional reduction in the cover, or functional capacity of wetlands within the watershed should occur, and enhancement where feasible should be promoted. Assessment of existing conditions to support management efforts as well as to establish a baseline condition would be advantageous. This assessment would be very helpful in determining the relative contributions of external vs. internal nutrient loads, habitat value of in lake vs. watershed wetlands, capacity of watershed wetlands to store additional stormwater if managed differently and the assimilative capacity of wetlands within the watershed to address likely additional loads as development of the KCOL watershed increases. Therefore, I would concur that specific performance measures associated with wetlands in the watershed are not prudent. However, incremental losses or gains of wetlands and more importantly losses or gains in wetland functions such as water storage, habitat and nutrient assimilative capacity could and should be monitored.

### *3.4.2 Littoral Zone Metrics*

Three littoral zone metrics are proposed in the CEM report. These metrics include:

- Littoral macrophyte abundance and distribution (including abundance or presence/absence of littoral plant species; species richness and diversity; abundance of emergent floating, and submergent aquatic vegetation; distribution and spatial extent of desirable and undesirable indicators plant species)
- Littoral burn frequencies
- Depth, spatial extent, and annual rate of organic deposition

### *3.4.3 Littoral Macrophyte Attributes*

I agree with the CEM document, and more specifically the KCOL LTMP Habitat Groups identification of various littoral macrophyte attributes and their usefulness in assessing lake condition and or use in analysis of change from baseline. Vegetative communities are integrators of environmental driving functions and therefore provide a relatively quick response to manipulation of drivers such as hydrology. The use and assessment of littoral macrophyte attributes can either provide a direct assessment of littoral vegetation characteristics such as plant species richness and plant diversity, or as an assessment of productivity, hydrologic range or habitat value. There are numerous relationships, both at the individual species as well as species assemblage level that appear in the literature indicating a stressor response relationship between vegetation composition and hydrologic or nutrient condition (Urban et al 1993, Portielje and Roijackers 1995, Dennison et al 1993, Craft and Richardson 1997). Baseline and later monitoring assessment of vegetation communities would be very useful tools to assess the implications of proposed or implemented management regimes.

With regard to use of these littoral macrophyte attributes providing a specific performance measure, I would suggest that unless a specific habitat type target or reference conditions is desired, setting particular performance measures based on vegetation type would be difficult. Instead a greater consideration to establishing a particular hydrologic regime that mimics as much as possible the pre-regulation conditions would result in a vegetative composition and diversity most similar that that of pre-regulation conditions. The full extent of this hydrologic condition can not be implemented in light of the limitations associated with increased development in the area. However increased range in stage, and increasing the frequency of inter-annual low and high water events should be facilitated.

Establishment of most wetland emergent species requires a drawdown events and exposure of soils to trigger seed germination. In the case of annual species this exposure would be required on an annual basis if a given species is desired annually at a particular elevation contour. In many instances wetland species have both vegetative as well as seed production strategies and therefore initial establishment by seed and then secondary propagation through vegetative reproductive allows a perennial or clonal species to persist at a location during non drawdown years. For this reason the maximum vegetative diversity can be promoted by an inter-annual staggering of stage conditions within the lake where during one particular year high water conditions promotes establishment of certain species at higher elevations, but stresses species at lower elevation contours. Conversely low water events in a staggered year will promote the germination of seeds at lower elevations and new recruitment or re-establishment opportunities for species.

The use of a Lake Vegetative Indices (LVI) could be useful if verified in the KCOL. In most instances these indices have been used to assess overall lake trophic conditions and been found to indicate a high degree of human disturbance (Fore 2005). The indices typically focus on species presence or absence and not abundance measures. However, LVI could be adapted to a more specific application within the KCOL to assess more than just trophic state or human disturbance indices. For instance an alternative weighting of the indices toward particular species or if abundance or density measures are included then relative abundances or diversities could also be used to evaluate certain fish habitats, and navigation as examples.

#### *3.4.4 Littoral Zone Burn Frequencies*

I highly support any attempts to integrate this stressor into the littoral landscape of the KCOL. There are three major influences resulting from fire, depending on severity. First, fire tends to suppress woody species that are non fire tolerant and if burns are frequent enough will tend to suppress all woody species. Because the movement of fire is often fuel dependant, certain species may facilitate fire better than others and therefore if native will tend to be more tolerant of fire conditions. Fire in less sever conditions is also often non uniform in its influence in the landscape often creating interdigitated areas of burn and non burned zones. These zones will of course give rise to a mosaic of vegetative characteristic either through different species or in some instances different stand densities, presence and absence of standing litter and overall height. Fire can also influence soil development. In many instances soils with sufficiently frequent hydroperiods will tend to accumulate organic matter, unlike upland conditions where organic matter is sufficiently rapidly oxidized such that long-term accumulation is less likely. As a result of organic matter accumulation, soil surface elevation increases resulting in an altered hydrologic regime. Changes in flooding frequency, depth, duration or annual timing can result in shifts of species composition. The term Hydrarch succession is often used to describe this process. Frequent, low intensity, burning of an area can reduce carbon loading rates and therefore decrease the rate of organic matter accretion. In the case of more sever fires, rapid oxidation of already organic matter accumulation is possible and a resultant change in elevation can occur. This has been termed retrograde succession and often is considered an infrequent, yet influential mechanism in peat based wetlands. However, the frequency of occurrence of these sorts of events sufficiently severe to oxidize peat soils in lakes may be beyond a realistic management window for the KCOL. Findings from peat stratigrapy surveys in Orange Lake in North Central Florida suggest that sever peat burns in that system only occur on the order of once every 140 year or so (Clark 2000) (Figure 3-3). Therefore, although likely influential on the development of the littoral shoreline vegetation and sediment characteristics, the historic frequency of occurrence is not a feasible performance measure. In addition, drought conditions necessary for sever peat fires to develop would be extreme and any managed burns during that time would likely be discouraged due to other risk factors.

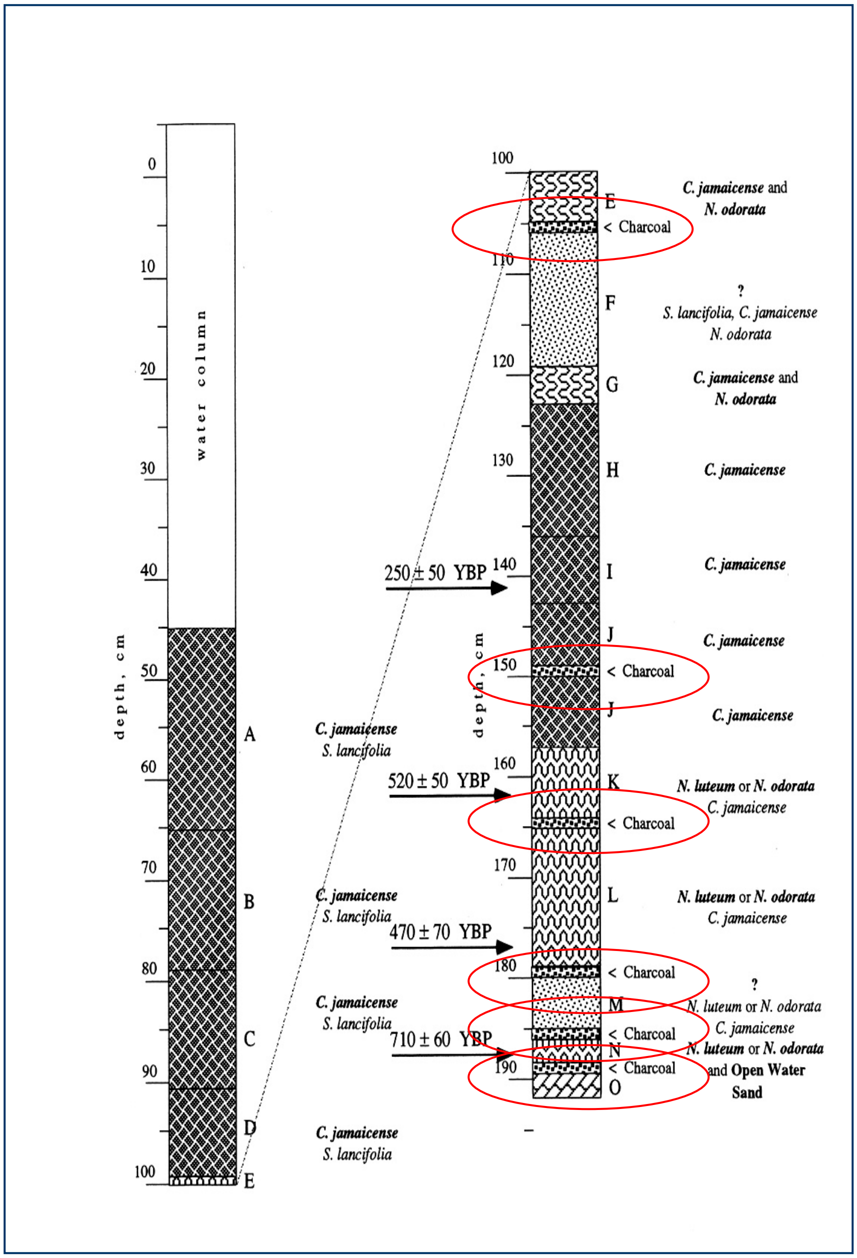


**Figure 3-3.** Charcoal layers in littoral zone soil core from Orange Lake in North Central Florida. Frequency of significant fire events and radiocarbon dates of soil horizons suggest a recurrence frequency of sever fires at this site approximately every 140 years. (Clark 2000)

A Performance Measure related to the frequency of less sever burns can be assessed and in conjunction with hydroperiod frequency could provide an effective management target. A study by Duever (1984) identified 13 dominant vegetative community types and distributed them along two environmental gradients (Figure 3-4). This sort of distribution could be used to support modeling and management decisions with regard to manipulation of hydrologic and fire drivers to promote or discourage various community types.

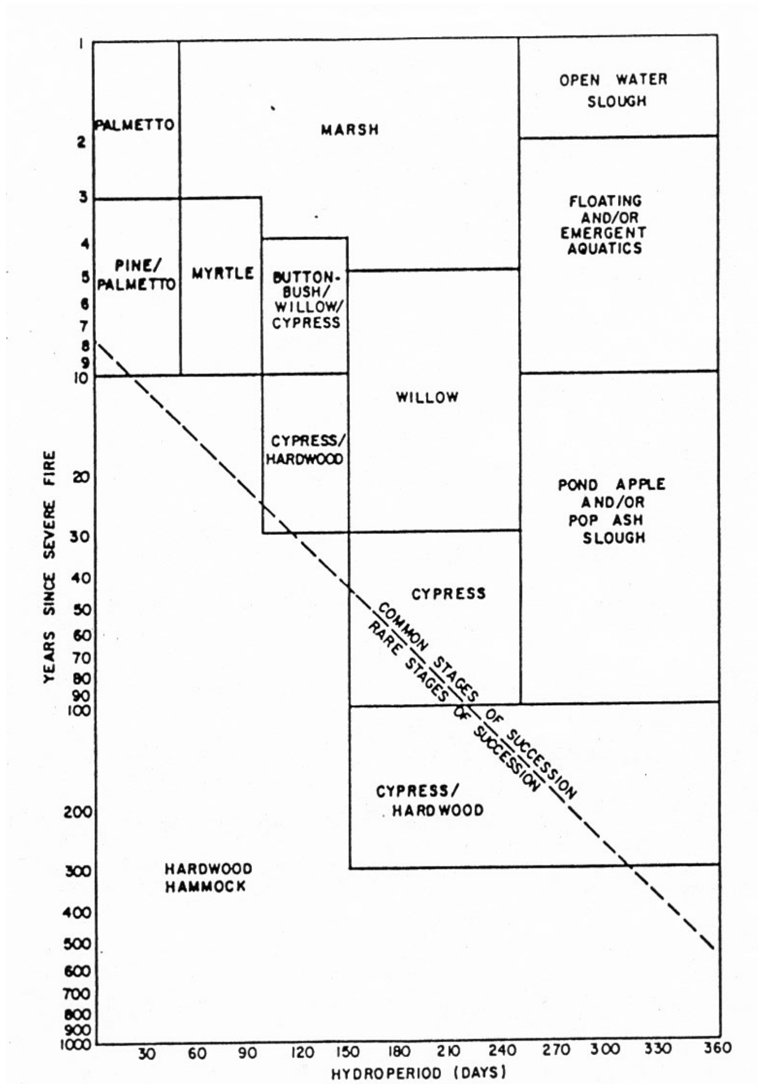


**Figure 3-4.** Graphic depicting the interactive effect of fire and hydropeirod on the development of vegetative communities in south Florida (Duever 1984).

### *3.4.5 Depth, Extent, and Annual Rate of Organic Deposition*

Soils within the littoral zone provide an integration of biotic and abiotic processes acting within this zone. When inputs of carbon in the form of litter are sufficient great and decomposition rates are sufficiently low there is a net accumulation of organic matter. Many factors influence the balance of carbon inputs and carbon decomposition rates such as trophic state (biomass production), litter quality (i.e. carbon to nitrogen ration and types of carbon compounds present), temperature, pH, and most importantly hydropattern, specifically frequency and duration of flooding. Because any one of these parameters may vary seasonally and internally, there is a dynamic equilibrium that develops along the shoreline leading to an uneven distribution of organic matter accretion. In figure 3-5, the relationship between zones of relative organic matter production (OM) and relative organic matter decomposition are provided along a theoretical elevation gradient. In the case of OM production, deep water conditions are often sufficiently stressful that emergent macrophyte species can not survive and therefore plant species with a high percentage of structural carbon do not contribute significantly to OM production. On the upper end of the elevation gradient, productivity may decline due to moisture or nutrient limitation. Therefore, the peak of OM production occurs at some optimum elevation between the two. In the case of relative OM decomposition rates, continuous flooded conditions at lower elevations will tend to reduce decomposition rates due to limitation of available oxygen for microbes. At some higher elevation, infrequent flooding will not limit oxygen availability and decomposition rates will tend to be at a maximum. Combining relative rates of OM production and OM decomposition, a zone of maximum/rapid OM accretion can form at some intermediary point along the littoral zone elevation gradient. As a result, OM content of soils along an elevation gradient will reflect this zonation of OM production and decomposition rates potentially influencing habitat for flora and fauna.

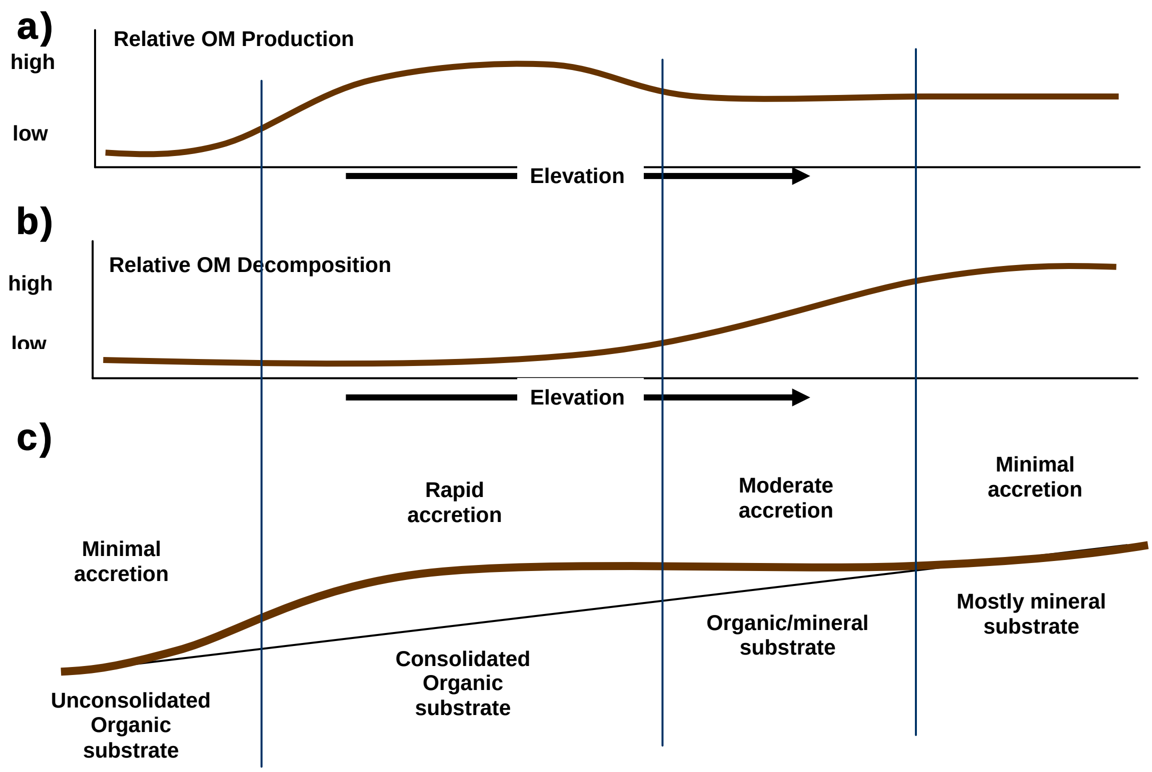


**Figure 3-5.** Three figures depicting, a) Relative OM Production rates along an elevation gradient, b) Relative OM decomposition rates along an elevation gradient, and c) combined effect of OM production and OM decomposition rates along an elevation gradient.

One of the frequent and recurrent problems in lakes with stabilized water levels and high macrophyte primary productivity rates is illustrated (in theory) in figure 3-6.

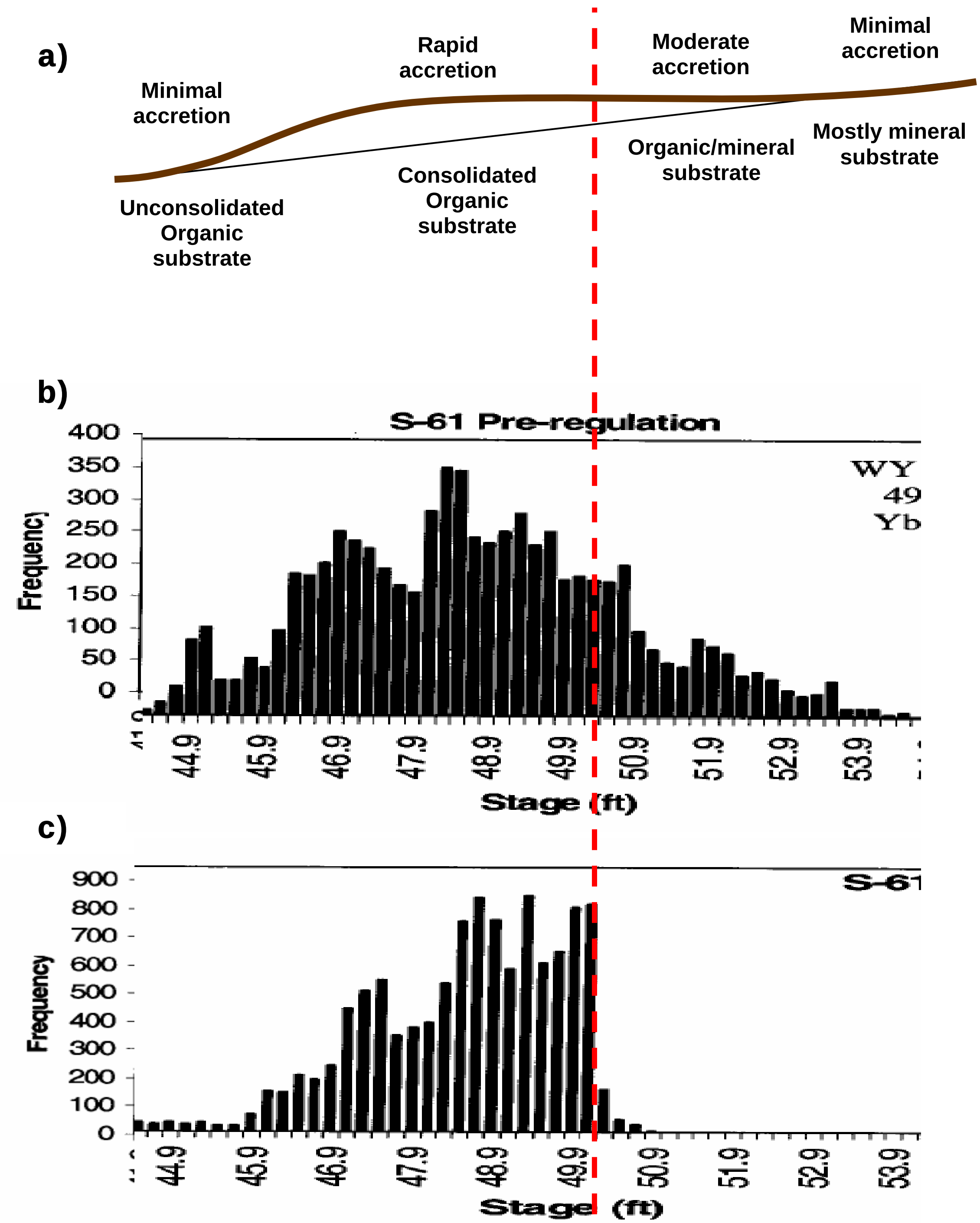


**Figure 3-6.** Extrapolation of a) theoretical shoreline depicting OM distribution relative to elevation and contrasting that with b) pre-regulated and c) post-regulated stage frequency graphs of Lake Tohopekaliga.

Under the pre regulated stage on Lake Tohopekaliga, sufficient flooding events occurred at stage 50 ft or above such that there was likely a gradient of organic matter deposition above this elevation, but in many areas mineral soils were present and sufficiently frequently flooded such that it may have provided suitable fish spawning habitat and or a much broader range of vegetative communities. Under regulated stage conditions it is clear that the frequency of hydrologic events above 50 ft and below 46 ft have decreased significantly. As a result, hydrologic conditions that would have provided for a gradient of OM content in the soils is no longer present, and although the specific relationship between hydrology and OM deposition rate is unknown, it is likely that the frequency and duration of post regulation hydrologic conditions at 50ft stage will tend to promote OM deposition and not a sandy soil. Therefore, OM accumulation directly adjacent to the shoreline and not at lower lake stages likely results. If OM content becomes sufficiently thick, decomposition gases in the sediment that can make the OM layer buoyant can result in the formation of floating vegetative mats or Tussocks.

Increasing the range and inter-annual variation in hydrologic extremes will tend to promote a gradient of OM accumulation along the shoreline and decrease the likelihood of tussock formation. This strategy is also compatible with efforts to broaden and diversify the zonation of wetland vegetation along the shoreline by increasing the range and inter-annual variability of hydroperiod. Because stage data is available on many of the KCOL lakes, it would be possible to develop relationships between shoreline soil OM content and hydroperiod. This assessment would be possible even in hydrologically stabilized lakes. Although the OM gradient may be significantly horizontally compressed, the same relationship between hydroperiod and OM matter content should exist.

### *3.4.6 Species Richness, Diversity and Biomass of Littoral Periphyton*

Periphyton communities can provide a relatively short term response variable to environmental stressors. These communities are typically an assemblage of algae and bacterial species and therefore often respond to changes in nutrient conditions. Periphyton as an indicator of water quality has been developed extensively in river and stream ecosystem as well as wetlands such as the Everglades. Application of periphyton indicators to KCOL would require calibration and evaluation to understand what relationships exist between periphyton community response and environmental drivers. Some of these relationships may require detailed analysis of species which may not be as easily quantified as the CEM document implies. There may be some merit in the development of gross indicators of trophic state that periphyton communities might provide. However, unlike stream communities, littoral zone vegetative communities are often more heterogeneous and correspondingly, periphyton communities may be equally heterogeneous responding to shading and decreased water circulation. Therefore, an increase in number and frequency of sampling may be required to detect a response in this parameter. On a positive note regarding use of a periphyton matrix, the Center for Wetlands at the University of Florida in coordination with the Florida Department of Environmental Protection have been working on algal/periphyton indicators for isolated wetland communities that might be transferable to littoral wetland habitat. This index has shown some promising results as a response variable to nutrient enrichment in non light limited wetlands.

### 3.5 Conclusions

In many respects I agree and support the positions and information provided in the CEM document and concur with much of the KCOL LTMP Habitat Group's assessment of suitable metrics and the applicability of these to establish Performance Measures. The lack of a clear objective or target makes establishing or recommending specific Performance Measures difficult. Many of the metrics suggested and discussed in this review provided appropriate monitoring parameters that are relatively straight forward, provided a habitat assessment tool and in some instances provided mechanisms to assess functional attributes of the landscape (soil sorptive indices). If a least impacted lake within the KCOL could be identified, then that particular lake might be used to develop a relationship between hydroperiod and soil OM content. In this same lake one could develop a multidimensional ordination of vegetation with particular emphasis on stage duration and frequency.

In the absence of specific performance measure recommendations, any efforts that increase the elevation range in stage frequency and provide more of a normal distribution in hydrologic stage frequency will bring the shoreline littoral zone to a condition more similar to pre-regulated conditions. In addition, efforts that promote inter-annual variation in water level with extreme highs and lows staggered at varying recurrence intervals would benefit vegetative recruitment and increase the distribution of soil characteristics. It is clear that present stage regulations do not provide for this inter-annual variation, and integration of this hydrologic dynamic will be useful to diversifying habitat and desired attributes of the KCOL chain.

# 4. Macroinvertebrates

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## 4.1 KCOL LTMP Conceptual Ecosystem Model (CEM)

The CEM is an impressive systems-type model which incorporates the primary functions and components that support the ecological integrity of most aquatic ecosystems. The CEM is tailored to depict the primary drives in the KCOL and, at a first glance, does, indeed, appear to model the system in a comprehensive manner. However, it must be noted that there are some uncertainties and complexities in the model that may make this system difficult to use. For example, although *Hydrilla* is listed as a potential stressor, the variety of mechanisms to control *Hydrilla* on an annual cycle (not likely to be altered) is not. Certainly there are very different changes in the system when one considers the various alternatives ranging from application of a broad-spectrum herbicide to mechanical harvesting. The actual management of *Hydrilla*, then, becomes a stressor itself.

In its current form, the model implies that all stressors have equal impact on the system and that all pathways are of equal impact or risk to the system. The model will be easier to communicate if the importance of the stressors is depicted by a series variously sized stressors and responses depending upon their perceived importance in the system. For example, altered hydrology is of considerable importance and impact to the KCOL. That set of pathways should receive greater emphasis in the model, with appropriately scaled objects and pathway arrows. This also helps future modelers, researchers and managers to prioritize efforts.

Although the model is certainly ecologically accurate, as a predictive tool it must ultimately be simplified. A number of metrics are being proposed as “response variables” or “performance measures”. This implies that a variable degree of treatment (management of various stressors) can be inserted into the model to evaluate the response of the model and the changes in the integrity of the system. If a true systems model is to be developed from this conceptual diagram, it will be necessary to consider the error that is hidden within all of the pathways associated with the model. Each object in the model represents a state variable (estimated by literature or field sampling with its accompanying variance). Each arrow connecting the object represents a rate of flux as determined by previous state variables; each flux rate having its associated variance. Thus, as the complexity of the model pathways increases, the error associated with measurable performance variables increases as a product of the error along any given pathway. At one point or another, it may be possible to attribute any level of metric response to the appropriate stressor and still be contained within the error limits of the model. To obtain a reasonable level of management options, it will be easier to simplify the system and concentrate on fewer pathways or more robust metrics to be observed.

Given the mandate that any suggested changes to the model must be able to be incorporated into the final version by the end of 2005, five months from the submission of this report, the model should be simplified to emphasize those state variables for which sufficient literature or historical information exist in order to reasonably estimate the current situation in the KCOL and to emphasize pathways that allow some effective prediction of changes in metrics where the correlations between the stressor and performance measure can provide a reasonably accurate flux rate. The model can be increased in complexity and predictive ability as future research in the LTMP process provides new information on state variables and accompanying flux rates to the various subordinate components.

## 4.2 Macroinvertebrate Performance Measures

Historically, macroinvertebrates have been used in biomonitoring since the early twentieth century (Rosenberg and Resh 1993). This application to determining the overall integrity of aquatic systems comes from a number of attributes in the macroinvertebrate community. They are ubiquitous; therefore, being affected by many different types of perturbations, physical and chemical. The large number of species (as community diversity) offers a spectrum of responses to a single disturbance, allowing an investigator or manager the opportunity to parse out specific pathways of impairment. Macroinvertebrates are basically sedentary and their response, then, can be used to measure the intensity and duration of many impairments. Finally, their relatively short life-cycles and responses can allow the analysis of temporal changes in impairment.

Although macroinvertebrates represent a critical link between primary production and the fish communities, the status of macroinvertebrate communities within the KCOL is essentially non-existent, as the conceptual model document indicates. This makes it very difficult to determine if the performance measures indicated are appropriate to the ability to predict response to the stressors or as appropriate indicator metrics.

The document provided to the review panel suggests four indicator species/assemblages to be used primarily by the Long-term Management Plan for the KCOL. The CEM document suggests the potential indicator taxa include the abundance and distribution of crayfish (*Procambarus* spp; number of species unknown), grass shrimp (*Paelomenetes paludosus*), freshwater mussels (community composition unknown), and the apple snail. With the possible exception of the apple snail, *Pomacea paludosa*, none of these indicators can provide metrics to improve the conceptual model or provide predictive value by the end of the year 2005. The response of the selected indicators to hydroperiod or changes in water quality, in its broadest sense, are too poorly known or variable to be of value to the CEM.

While it is true that the distribution of crayfish is strongly influenced by vegetative habitat and possibly by hydroperiod, the various species of *Procambarus* have the potential to respond in very different ways to the same type of impairment. Thus, it will be necessary to taxonomically differentiate between the varieties of species inhabiting the KCOL in order to determine the appropriate response. For example, burrowing *Procambarus* will likely respond differently to flux in hydroperiod than those which dwell exclusively in vegetations stands. Both types of habits are likely to occur in the KCOL, according to surveys of *Procambarus* in North America (Hobbs 1982). Thus, identification to the generic level could lead to errors in measuring the response variable. More importantly, the ability of *Procambarus* to predict changes in water quality and structural integrity seems to decline with the more southern species of this genus in

North America. For example, as indicators of ecological integrity, benthic macroinvertebrates have been used as biomonitors for many years. On a standard scale ranging from one (least tolerant of impairment) to ten (most tolerant of impairment), Hilsenhoff (1987), based upon his experience in the upper Midwest, rated *Procambarus* as intolerant of impairment (a Biotic Index value of 2). However, the North Carolina Biotic Index (Lenat 1993) lists *Procambarus* tolerance values up to a value of 4. Finally, moving further south, the Georgia Ecoregions Project (Gore *at al.* 2005) lists the tolerance values for the species of *Procambarus* to be 8; that is, extremely tolerant of impairment. This reflects the greater burrowing ability of southern species of *Procambarus*; essentially, their ability to follow groundwater with shifting hydroperiod. Thus, this genus may not be a good indicator of ecological integrity until more specific research is performed. It is unlikely that this can be accomplished by December 2005.

The grass shrimp (*Paelomenetes paludosus*) is an excellent indicator of response to change in hydroperiod as they are strongly dependent upon the habitat provided by submersed and emergent macrophyte beds. This species is generally considered to be intolerant of ecosystem impairment and are a critical diet item to many fish and wading bird species. However, since the status of the species (distribution and abundance) is unknown in the KCOL, the distribution and extent of the macrophyte beds may be an adequate surrogate of the response of *Paelomenetes paludosus* to hydrologic change. As such, this performance metric can be implemented in the model by December 2005.

Because they are the principal food item of snail kite, the apple snail (*Pomacea paludosa*) as well as the exotic apple snail (*P. canalicoulata*) must be included in the model. The response criteria necessary to make the CEM work can be obtained from various data sources in the custody of Dr. Wiley Kitchens, University of Florida, plus data from Turner (1996). These data could be used to create a relatively generic Habitat Suitability Index (HIS) for application in the CEM by December 2005. Turner's data also suggest that the distribution and extent of macrophyte beds may also be an adequate surrogate for apple snail responses if insufficient data are available to create an adequate HSI.

The CEM also suggests that the abundance and diversity of freshwater mussels be included as indicator species and performance metrics. Certainly, freshwater mussels have been noted as among the most sensitive species to habitat change, change in water quality, and change in hydrology in riverine systems. However, their status in standing water is less well known. Indeed, many standing water forms (*Anodonta*, for example) are extremely tolerant of low dissolved oxygen and organic loading and would, therefore, make a poor indicator of impairment (Barbour *et al.* 1999). Again, since the status of the diversity and distribution of native and non-native mussels (*Corbicula fluminea*, primarily) is unknown in the KCOL, it will be difficult to create a response metric that can be incorporated into the CEM by December 2005.

The non-biting midges (Diptera: Chironomidae) may provide an important hydrologic performance measure for the CEM. The diversity of Chironomidae in aquatic environments is quite high (often 100 species or more in a small wetland) and the range of tolerances to impairment (habitat change and water quality) is substantial (see, for example, Barbour *et al.* 1999). Indeed, Gore *et al.* (1997) have suggested a response measure that may be able to be incorporated into the CEM in a relatively short period of time. The response table shown below describes the ability of various species and tribes of Chironomidae to indicate habitat impairment. A shift in proportion of the various species assemblages could be used to indicate such a change.

**Table 4-1.** Proposed Response of Chironomidae to Changes in Hydroperiod (from Gore *et al.* 1997).

| Quasi-Permanent Water | Drawdown Tolerant | Desiccation Tolerant |
|---|---|---|
| *Beardius sp.* | *Monopelopia tillandsia* | *Ablabesmyia rhamphe (grp.)* |
| *Chironomus (Lobochironomus sp.)* | *Polypedilum trigonus* | *Krenopelopia sp.* |
| *Chironomus ochreatus* | *Tanytarsus sp. B (Epler 1992)* | *Polypedilum convictum* |
| *Goeldchironomus natans* | | *Tanytarsus sp. G (Epler 1992)* |
| *Monopelopia boliekae* | | *Tanytarsus sp. K (Epler 1992)* |
| *Tanytarsus sp. F (Epler 1992)* | | |
| *Zavreliella marmorata* | | |

Other data are contained within this report that can be used to enhance the CEM and to provide an adequate performance measure that can be used by December 2005.

The District should also consider examining the utility of a wealth of macroinvertebrate performance metrics that have been used in aquatic ecosystems (both lotic and lentic) for potential application to the CEM. The extensive literature references provided by Barbour *et al.* (1999) can provide qualitative, if not quantitative, response measures. The list of potential macroinvertebrate metrics is quite large and divided into various categories: richness, composition, tolerance, functional feeding group, and habit. The range of potential metrics is listed in the following tables:

**Table 4-2.** Candidate benthic metrics and predicted direction of metric response to increasing perturbation (adapted from Barbour *et al.* 1999, *Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers: Periphyton, benthic macroinvertebrates, and fish. 2nd Edition*)

| Category | Metric | Definition | Predicted response to increasing perturbation |
|---|---|---|---|
| **Richness measures** | Total No. taxa | Measures the overall variety of the macroinvertebrate assemblage | Decrease |
| | No. EPT taxa | Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) | Decrease |
| | No. Ephemeroptera Taxa | Number of mayfly taxa (usually genus or species level) | Decrease |
| | No. Plecoptera Taxa | Number of stonefly taxa (usually genus of species level) | Decrease |
| | No. Trichoptera Taxa | Number of caddisfly taxa (usually genus or species level) | Decrease |
| **Composition measures** | % EPT | Percent of the composite of mayfly, stonefly, and caddisfly larvae | Decrease |
| | % Ephemeroptera | Percent of mayfly nymphs | Decrease |
| **Tolerance/Intolerance measures** | No. of Intolerant Taxa | Taxa richness of those organisms considered to be sensitive to perturbation | Decrease |
| | % Tolerant Organisms | Percent of macrobenthos considered to be tolerant of various types of perturbation | Increase |
| | % Dominant Taxon | Measures the dominance of the single most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa. | Increase |
| **Feeding measures** | % Filterers | Percent of the macrobenthos that filter FPOM from either the water column or sediment | Variable |
| | % Grazers and Scrapers | Percent of the macrobenthos that scrape or graze upon periphyton | Decrease |
| **Habit measures** | Number of Clinger Taxa | Number of taxa of insects | Decrease |
| | % Clingers | Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water. | Decrease |

**Table 4-3.** Additional candidate benthic metrics and predicted direction of metric response to increasing perturbation (adapted from Barbour *et al.* 1999, *Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers: Periphyton, benthic macroinvertebrates, and fish. 2nd Edition*)

| Category | *Metric* | *Definition* | *Predicted Response* |
|---|---|---|---|
| ***Richness Measures*** | Number of *Pteronarcys* species | Presence/absence of a long-lived stonefly genus | Decrease |
| | No. Diptera taxa | Number of "true" fly taxa, which includes midges | Decrease |
| | No. Chironomidae taxa | Number of taxa of chironomid (midge) larvae | Decrease |
| **Composition Measures** | % Plecoptera | Percent of stonefly nymphs | Decrease |
| | % Trichotpera | Percent of caddisfly larvae | Decrease |
| | % Diptera | Percent of all "true" fly larvae | Increase |
| | % Chironomidae | Percent of midge larvae | Increase |
| | % Tribe Tanytarsini | Percent of Tanytarsinid midges to total fauna | Decrease |
| | % Other Diptera and noninsects | Composite of those organisms considered to be tolerant of a wide range of disturbances | Increase |
| | % *Corbicula* | Percent of the introduced Asiatic clam in the benthic community | Increase |
| | % Oligochaeta | Percent of aquatic worms | Variable |
| **Tolerance or Intolerance Measures** | No. Intolerant snail and mussel species | Number of species of molluscs generally thought to be pollution intolerant | Decrease |
| | % Sediment tolerant organisms | Percent of infauna tolerant of disturbance | Increase |
| | Hilsenhoff Biotic Index | Tolerance values to organic pollution to weight abundance in an estimate of overall stream health. | Increase |
| | Florida Index | Weighted sum of intolerant taxa, which are classified as 1 (least tolerant) or 2 (intolerant). FI = 2 x Class 1 taxa + Class 2 taxa | Decrease |
| | % Hydropsychidae to Trichoptera | Relative abundance of pollution tolerant caddisflies | Increase |
| **Feeding Measures** | % Omnivores and scavengers | Percent of generalists in feeding strategies | Increase |
| | % Ind. Gatherers and Filterers | Percent of collector feeders of CPOM and FPOM | Variable |
| | % Gatherers | Percent of macrobenthos that "gather" POM | Variable |
| | % Predators | Percent of predators, excluding omnivores | Variable |
| | % Shredders | Percent of macrobenthos that consumes leaf material (CPOM) | Decrease |
| **Life Cycle Measures** | % Multivoltine | Percent of organisms having short life cycle | Increase |
| | %Univoltine | Percent of organisms relatively long-lived (> 1 year to complete) | Decrease |

In general, a suite of metrics should be chosen in order that structural metrics do not dominate or overcompensate for functional metrics, the combination of these metrics has been successfully employed in the creation of a numerical classification system to assess the integrity of aquatic ecosystems in Georgia (Gore *et al.* 2006). Indeed, Gore *et al.* (2006) reported that various proportions of Chironomid tribes and species seem to display the best response to changes in ecological integrity in lowland and coastal plain habitats. This further supports the work performed in hydric pine flatwoods and isolated wetlands for the SFWMD in the 1990's (Gore *et al.* 1997).

### 4.3 KCOL Literature and Data Sets

It does not appear that any significant KCOL literature on benthic macroinvertebrates has been overlooked in the preparation of the CEM document. Indeed, there does not appear to have been any significant collection of macroinvertebrates within the system at any time. This is probably the greatest need in order to be able to create performance measures in the future. In order to create the performance measures for the CEM, the best document to review as a potential source of community composition and macroinvertebrate metrics will likely be those surveys of macroinvertebrates in Lake Okeechobee (Warren *et al.* 1995) or surveys of isolated wetlands (including wetlands adjacent to the KCOL) conducted for the SFWMD over a number of years in the late 1990's.

### 4.4 Reference Sites and Conditions

It does not appear that adequate data (nor best professional judgments) exist to suggest a reference lake system for the KCOL. Indeed, it appears that there may be three or four distinct lake groupings, each grouping having distinctive hydrographs, geomorphological and geological origins, and substantial differences in biotic and physical character to suggest a set of reference sites. It will be difficult to acquire analytical data to choose reference sites by December 2005. Ultimately, however, it will be possible to use geographic information systems (GIS) to create a reference condition adequate to assess impairment in the KCOL.

A *reference condition* differs from reference sites in that the *reference condition* describes a range of physical and chemical conditions which describe the least impaired water bodies in a given ecoregion (Hughes *et al.* 1986). A suite of biological metrics (periphyton, macroinvertebrate, fish [or other vertebrates]) is then chosen to reflect changes from the reference condition and the degree of impairment.

Gore *et al.* (2005) have described an unbiased method, using GIS, to choose reference conditions in all wadeable streams in Georgia's ecoregions and sub-ecoregions. The system describes the characteristics of unimpaired streams and then filters out those catchments that do not contain sufficient undisturbed elements to warrant inclusion in that suite of candidate reference sites. The most highly ranked reference sites are visited and a rapid assessment of physical, chemical, and biological conditions is created. This synoptic approach is relatively unbiased and creates a flexible system of assessment in which continual monitoring of impaired and unimpaired sites allows refinement of comparisons and numerical classification of relative degrees of impairment. Although this system has been primarily employed for running water systems and catchments, I suggest that it can be modified to lakes and associated wetlands with relatively simple modifications of GIS filters. The following table describes some of those modifications:

**Table 4-4.** Potential GIS Filters for use in choosing Candidate Lake Reference Sites and Conditions (adapted from Gore *et al.* 2005)

| Step | Criterion | Action | Evaluation |
|---|---|---|---|
| 1 | % Urban Land Use | Screen out sites with >15% | GIS |
| 2 | % Agriculture | Screen out sites with > 50% | GIS with MRLC data |
| 3 | Road Density | Select lowest density | DOT GIS data |
| 4 | Min. Riparian Zone | Screen out sites with < 15m width | GIS with MRLC data |
| 5 | Shoreline Alteration | Screen out sites with any alteration | Map/Aerial Photo |
| 6 | Regulating Structures | Select lowest density | USGS Lake data |
| 7 | Point Source Discharges | Screen out sites | EPA NPDES Permits |
| 8 | % Silviculture | Select Lowest Density | GIS with MRLC data |

The synoptic approach of determining the amount of cumulative impact was originally developed as a framework for comparing landscape units that quickly determines the relative amount of anthropogenic impact on a wetland (Abbruzzese and Leibowitz 1997). This approach is a compromise between the need for rigorous results and the need for timely information and is appropriate when little quantitative information is available, the cost of improving these data is high, there is an urgent need to make decisions, and the cost of a wrong answer is low. The steps to conduct a synoptic assessment are:

1. Define the goals and criteria of the assessment.
2. Define the synoptic indices to be used (i.e. types of impacts).
3. Select the landscape indicators that allow an assessment of the indices.
4. Conduct the assessment by analyzing maps and other spatial data.
5. Report the results of the analysis, usually in the form of a map.

Bolstad and Swank (1997) demonstrated how this approach could also be used to assess the cumulative impacts of NPS pollution on water quality in streams. Their results showed a consistent and cumulative decrease in water quality with increasing non-forest land use, principally building and road density and agricultural land use.

The synoptic approach to assessing the amount of anthropogenic disturbance to various water bodies is based on the idea that disturbance can be estimated by looking at the land use of the catchment that feeds into that water body. It has been argued that the conditions of the catchment influences or controls the conditions of the water body in the catchment (Richards and Host 1994), so it follows that the amount of disturbance in the catchment should predict the extent or intensity of disturbance in the water body, itself. With recent advances in remote sensing and geographic information system (GIS) technology, many studies have supported this inference. Anthropogenic land use affects water body communities both directly through changes in water chemistry by affecting the amount of metals and nutrients (Bolstad and Swank 1997), as well as through suspended sediment loading (Lenat and Crawford 1994; Johnson *et al*. 1997). The modification of habitat through the indirect effects of land use has also been documented (Richards *et al.* 1996). A clear, negative, correlation between the amount of urbanization in a catchment and a stream's biological integrity has been shown in several studies (Lenat and Crawford 1994; Wang *et al*. 1997; Kennen 1999; Roth *et al*. 1999) while a positive correlation has been shown with the proportion of the catchment that is forested (Roth *et al*. 1996; Wang *et al*. 1997; Rothrock *et al*. 1998; Kennen 1999; Roth *et al*. 1999).

The correlation between agricultural land use and water body integrity is much less clear. While some studies have shown that agriculturally dominated catchments have impaired biological integrity (Richards *et al*. 1996; Roth *et al*. 1996; Rothrock *et al*. 1998), Kennen (1999) did not. Lenat and Crawford (1994) found changes related to the amount of agricultural land use in benthic macroinvertebrates but not in fish communities. Roth *et al*. (1999) found a positive correlation between the fish Index of Biotic Integrity (IBI) and Hilsenhoff's Biotic Index and the amount of agriculture, but no correlation between their benthic IBI and the amount of agriculture. Lammert and Allen (1999) found a weak correlation between the amount of agriculture and fish IBI, benthic IBI, and four other common metrics, but only for land use within 100 m of the water body. Wang *et al*. (1997) found the impact on fish communities to be nonlinear, with the effects of agriculture only becoming apparent in catchments with more than 50% agriculture. Rothrock *et al*. (1998) also showed that both increasing road density and silviculture lead to lower biologic integrity. Schnackenberg and MacDonald (1998) also found a strong correlation between the number of road crossings and the percentage of fine particles in the substrate that would affect aquatic communities. They found a weaker correlation between fine particles and the amount of clear-cut forests.

Even though the relationship of water body condition to catchment condition seems clear enough, several factors make the relationship complicated. Several studies have shown other factors to have equal or greater impact than land use patterns on aquatic communities, including geology, topography, and geographical characteristics (catchment area, altitude, and length) (Richards *et al*. 1996; Johnson *et al*. 1997; Bailey *et al*. 1998). There are also interactions between these geologic or geographic features and land use that are difficult to separate. Most investigators have concluded that the catchment's land use has more impact on stream communities than the land use of the riparian buffer (Roth *et al*. 1996; Allen *et al*. 1997; Wang *et al*. 1997; Kennen 1999). However, Richards *et al*. (1997) found reach scale properties more predictive of species traits than catchment properties, although the catchments may have had an indirect effect on the reach scale properties. Lammert and Allen (1999) also found much more of the variance in stream communities explained by the type of land use within a 100-m riparian buffer than in the entire catchment. Since Lammert and Allen's results were opposite of those found by Roth *et al*. (1996) on the same stream, they suggested that the relative importance of buffer versus catchment might be a function of the scale of the investigation. Lammert and Allen proposed that larger scale, less spatially expansive, investigations are more sensitive to local changes in physical habitat than smaller scale investigations. The stronger relationship of catchment characteristics to the water body community structure found by others may also have been a function of the precision of the data used. The other studies described previously (Roth *et al*. 1996; Allen *et al*. 1997; Wang *et al.* 1997; Kennen 1999), used data with a minimum mapping unit greater than 2 ha and so were only able to examine the effect of 100-m buffers. A more fine grain data set would allow the analysis of smaller and perhaps more influential buffer zones.

If the amount of anthropogenic land use within a catchment is going to be used to predict the relative amount of water body impairment, then these geologic or geographic factors that also effect water body communities must be controlled during analysis. Using an a priori classification, by sub-ecoregion, and examining catchments within a single order of magnitude, variability in these geologic or geographic factors will by taken into account. Combining catchment-wide land use with measurements of direct impact on streams caused by road crossings and alterations within the riparian zone of streams, such as roads and agricultural land use should create a measure of the extent of impairment to a water body's ecosystems relative to other systems in the same sub-ecoregion.

The complete application of this system of reference condition creation is described by Gore *et al.* (2005) but involves the analysis of those sites which cluster in the upper-most quartile of distributions and constitute the "least impaired" sites, or reference condition. Obviously, it will be impossible to create a reference condition for each of the lake groupings by December 2005, but this system has the potential to provide a dynamic evaluation tool for the long-term management and monitoring goals in the KCOL.

## 4.5 Recommendations

With regard to macroinvertebrates, since little is known of the current status of species distributions or community composition, there is not much room to improve the CEM in the near-term. However, ultimately, long-term monitoring of macroinvertebrate communities must be accomplished in order to choose more appropriate metrics or suites of metrics that will improve the predictive ability of the CEM and future numerical models. Essential needs for macroinvertebrates are:

1. A more comprehensive survey of macroinvertebrate assemblages

2. Supplement current indicators with analysis of other potential indicator metrics – esp. Chironomidae and other Diptera

3. Verify the applicability of lentic mussel fauna as indicators of hydrological change and ecosystem integrity

4. Consideration of creation of a "Reference Condition" based upon physicochemical and biological surveys in the region – an unbiased GIS approach seems reasonable as a technique to approach this technique

5. Impact of the Atlantic Multidecadal Oscillation (AMO) on model and management options – wet tri-decades and dry tri-decades – Kelly (2004) has demonstrated that there is a significant relationship between the AMO (an approximate 1.5$^{o}$ C change in mid-Atlantic water temperatures, annual rainfall patterns, and hydrographs in the southeastern United States. These long-term oscillations (approximately every 30 years) have a significant influence upon management decisions made regarding minimum flow levels for rivers in Florida (see, for example, Kelly *et al.* 2005). I suggest that these relationships will be duplicated in the KCOL and will be one of the major weather-related (climate change) phenomena that will influence management decisions in the coming decades. It will be necessary to review lake levels, river hydrographs, and wetland hydroperiods in the region to determine if the AMO relationships demonstrated by Kelly can be observed in the KCOL and what impacts these might have on long-term research and management strategies.

## Amphibians and Reptiles

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### 5.1 Summary

Although historical data on amphibian and reptile species richness and population estimates are lacking for the KCOL, meaningful performance measures can and should be developed within the next six months for select species (e.g., salamanders, turtles, alligators) based on life-history information and published data. Hydrologic performance measures (PMs) for these groups will be limited to general predictions of nest success or failure from specific hydrological regimes. Longer-term PMs and assessment should take into account additional species. Using abundance as a metric to estimate during monitoring and assessment is not advised. A better metric is “Percent Area Occupied” with associated detection probabilities on a per species basis.

### 5.2 General comments on Conceptual Ecosystem Model

The conceptual model does a good job capturing the critical drivers, stressors, effects, attributes and linkages. An important stressor, DISEASE, is missing from this complex model. It is well known that diseases can have major impacts on plant and animal populations and this stressor should be considered in the model. For example, infectious diseases are a great concern to amphibian biologists and several diseases are emerging as significant stressors of amphibian populations (Green et al. 2002, Carey et al. 2003, Daszak et al. 2003). Specific examples include chytridiomycosis, which is caused by a primitive type of fungus and is affecting many frog populations; red-leg disease, which is caused by bacterial infection; disease caused by the organism *Anuraperkinsis*, which is a recently discovered pathogen that appears to be a protozoan-like organism; and there are numerous others. Well known diseases in birds (including waterfowl and wading birds) include: avian cholera, avian botulism, and West Nile virus. Disease has been implicated as a significant source of mortality in American Alligators as well (Schoeb et al. 2002, Jacobson et al. 2005). Diseases that may impact the KCOL ecosystem may be introduced via baitfish and/or exotic plants and animals that are inadvertently or intentionally released into the system (e.g., vegetation on boats, aquarium fish).

Although the model is quite complex, which reflects the complex interrelationships of the many biotic and abiotic components in the KCOL ecosystem, it should be simplified to better reflect the what are believed to be the most crucial drivers, stressors, effects, linkages, etc. The importance of disease as a stressor in the KCOL, as compared to other stressors, may be minor, but it should still be recognized and included in the complex model. In addition to effects on wildlife, some of the diseases they harbor are know to infect humans. Therefore, I feel that “DISEASE” should be incorporated into the CEM.

I suggest leaving the complex model in the CEM document to demonstrate the complexity of the system, but also to include a simplified model as mentioned above. To imply the importance of some components of the model over others (e.g., stressors) the size of the ovals, boxes, etc. should be adjusted accordingly. If disease is incorporated in the complex model, there are numerous linkages among the DISEASE stressor and other model attributes that should be recognized. These include links from the anthropogenic driver INTRODUCTION OF EXOTIC SPECIES TO DISEASE; links from the stressors EXOTIC PLANTS and EXOTIC ANIMALS to DISEASE, as well as links from DISEASE to the ecological effects ANIMAL SPECIES COMPOSITION, WETLAND/UPLAND ANIMAL EXCHANGE, FORAGE, and BENTHIC INVERTEBRATES.

### 5.3 Amphibian Performance Measures

Amphibians and more reptiles need to be added as additional performance measures. Amphibians and reptiles are two major taxonomic classes of vertebrates. They differ as much from each other in their morphology, physiology, and ecology as either of them does from mammals. The lumping of these two major groups under the heading of "herpetofauna" is merely an artifact of history. Numerous species of amphibians and reptiles are integral components of lake food webs and they need better representation as performance measures in the KCOL CEM.

Presently the only proposed performance measure proposed for reptiles and amphibians is a single reptile species—American Alligator. This is despite the fact that amphibians are touted in several places in the text as being important food sources for other indicator species, such as alligators, fish, and wading birds. Furthermore, amphibians have experienced major population declines and extinctions globally (Houlahan et al. 2000, Stuart et al. 2004, Beebee and Griffiths 2005) and they have been the source of a vast amount of media attention in the past decade. This has brought the amphibian decline issue to the attention of the public. Although I do not suggest removing alligators as a performance measure, I strongly encourage the addition of more herpetofauna.

Justification for excluding amphibians and reptiles as performance measures, exclusive of the alligator, is that no quantitative data are available for them in the KCOL. The CEM also states that coming up with a single performance measure for species richness, diversity, and relative abundance may be difficult because of variability among the lakes. I do not feel that either of these reasons is justification for precluding herpetofauna. Using the lack of baseline data and reference data from the KCOL is a weak argument to exclude amphibians and reptiles as performance measures. Baseline data and/or KCOL reference data are also lacking for most other taxa proposed as performance measures (e.g., fish, macroinvertebrates, wading birds). Many species or amphibians form crucial links in food webs, and two species of aquatic salamanders typical of lake ecosystems, *Amphiuma means* (Two-toed Amphiuma) and *Siren lacertina* (Greater Siren) are tertiary consumers in aquatic food chains. The same could be said for several species of lake-inhabiting reptiles (e.g., water snakes, soft-shelled turtles, snapping turtles). Furthermore, Pig Frogs and Florida Soft-shelled Turtles are harvested recreationally and commercially from some of the KCOLs.

Although there is not much published information available as reference data for amphibian and reptile species richness, relative abundance, and diversity in Florida lakes, meaningful performance measures may still be able to be developed. Several species of herpetofuana have the potential to be especially impacted by changes in lake stage and management actions in lake littoral zones. For example, *Amphiuma* and *Siren* inhabit heavily vegetated areas of lakes. When water levels decline significantly, they have the ability to burrow into the substrate and aestivate until water levels rise. Thus, they are particularly vulnerable to prolonged drawdown and mechanical treatments that remove organic deposits. There are numerous species of aquatic turtles that certainly inhabit the KCOL, with the exception of the Florida Red-bellied turtle, which nest in alligator nests, these turtles usually crawl significant distances into surround upland habitats to lay eggs. Therefore, the nests of all turtle species in the KCOL may be adversely affected by reversals in lake stage or increases in lake stage that occur during the nesting and incubation periods. The same is true for American Alligator nests.

I suggest development of amphibian and reptile performance measures as outlined below. Natural history information and data from reference sites should allow the development of hydrologic performance measures within the next six months. Responses of herpetofauna to various hydrological regimens are general and are related to success of failure of nests, similar to measures for wading birds and Snail Kites.

### *5.3.1 Perfomance measures for Siren and Amphiuma*

Both species of these aquatic salamanders inhabit littoral zones of lakes (Sorensen 2004, Johnson and Owen 2005) and certainly are present in the KCOL. Individuals burrow into muck to aestivate when water levels recede significantly. Mechanical removal of muck therefore has the potential to cause direct mortality. *Amphiuma* slither to moist locations up to up to 7 meters from water's edge and lay their eggs terrestrially and the nesting season appears to occur from May-Sep. in Florida (Johnson and Owen 2005). Rising water that inundates nests triggers hatching of embryos (Gunzburger 2003). Therefore, hydrologic conditions of a slow decline in lake stage during the spring and summer, followed by a reversal in the fall would most benefit *Amphiuma* nest success. However, mechanical treatment to remove muck following drawdown is predicted to cause reductions in *Amphiuma* and *Siren* populations. As long as muck removal does not occur across vast areas of a lake, the populations of these species should recover over time. Development of performance measures may be enhanced by referring to the thesis research of (Muench 2004), who was a graduate student of Dr. Wiley Kitchens and evaluated the impacts of littoral zone habitat modification on aquatic vertebrates in West Lake Toho.

Aestivating *Amphiuma means* individuals appear to have the ability to persist in desiccated habitats for up to 2 years (see review in Johnson and Owen 2005). Therefore, unless drawdowns persist for longer than this, at least some individuals are likely to survive.

### *5.3.2 Performance measures for aquatic turtles*

Numerous species of aquatic turtles inhabit lakes in Florida (see CEM document Table 4). Female aquatic turtles travel significant distances (hundreds of meters) from aquatic habitats in order to nest (Carr 1952, Ernst et al. 1994, Burke and Gibbons 1995). Real estate development in upland habitats, especially the construction of roads, has significant negative impacts on freshwater turtle populations and has been shown to influence turtle population structure (Aresco

2003, 2005, Marchand and Litvaitus 2004, Gibbs and Steen 2005). Therefore, wetland/upland animal exchange, as identified in the CEM, is a crucial ecological effect for aquatic turtles. Excessive development and road construction within several hundred meters of lake edges may have long-term deleterious effects on aquatic turtle populations via altered sex ratios and population declines resulting from mortality of adult females. Additionally, if human presence facilitates an increase in mammalian predators (e.g, raccoons, opossums, foxes), significant increases in mortality of turtle nests may result.

In addition to upland habitat modification and loss, lake stage can impact turtle nest success. If lake stage rises too much at the wrong time of year, turtles nests in upland sites and in alligator nests may be inundated, resulting in death of developing embryos. Nesting seasons of various species of freshwater turtles expected in the KCOL varies, but occurs primarily from March through July (Ernst et al. 1994, Table 5-1). Once eggs are laid, depending on temperatures in the nest, incubation takes approximately 2-3 months. Therefore, a hydrograph of lake stage in which there is a rapid, major increase in water level in late summer may negatively impact incubating nests. The most beneficial pattern of water level for incubating turtle nests would be stable or slowly declining levels in the spring and summer continuing into the fall. Reversal of lake stage that results in significant increase in water levels over a short period of time prior to September would likely drown some nests. However, because of variation in the elevation of nesting sites, all nests might not be lost. Impacts of altered hydrology resulting in poor recruitment of turtle hatchlings over an extended period are likely to have a measurable effect on turtle populations. Because turtles are slow to mature and long-lived they can tolerate periodic severe nest losses. Therefore variation in annual lake stages within the KCOL should benefit turtles. As indicated above, lake hydrology and upland habitat quality are likely to be the major stressors that impact turtle populations in the KCOL.

**Table 5-1.** Nesting seasons for lake-inhabiting turtles in Florida

| Species | Common name | Nesting season |
|---|---|---|
| *Pseudemys nelsoni* | Florida Red-bellied Cooter | Apr.-Sep. |
| *Pseudemys floridana* | Florida Cooter | Sep.-Apr. |
| Apalone ferox | Florida Soft-shelled Turtle | Mar.-Jul. |
| *Kinosternon bauri* | Striped Mud Turtle | Feb.-Apr. |
| *Sternotherus odoratus* | Stinkpot | Mar.-Jul. |
| *Chelydra serpentina osceola* | Florida Snapping Turtle | Mar.-Jun. |

### *5.3.3 Performance measures for American Alligators*

As identified in the FWC indicator species document, flooding of nests is a significant threat to alligator nests. Alligator nesting and incubation periods overlap considerably with most species of aquatic turtles expected in the KCOL. Thus, hydrologic performance measures developed for turtles should be very similar to PMs developed for alligators, and vice versa. Information to develop hydrologic PMs for alligators can be found in the FWC account.

Because of similarities in reproductive seasons and nesting sites between alligators and aquatic turtles, the littoral habitats used by large aquatic salamanders, and the nesting habits of

*Amphiuma means*, a simple model of drivers, stressors, etc. can be developed that should capture the important ecological parameters most likely to influence these aquatic vertebrates.

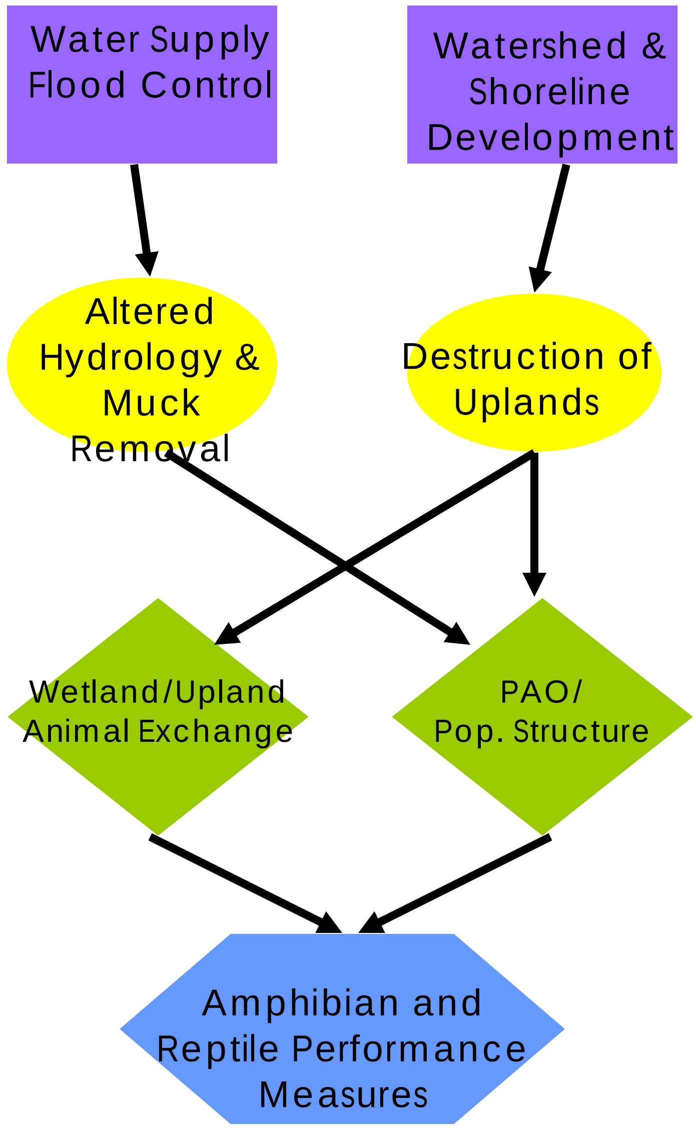


**Figure 5-1.** Simplified, hypothetical model for amphibians and reptiles in the KCOL. PAO refers to "Percent Area Occupied", which is used in lieu of abundance to track changes in herpetofauna populations. See MacKenzie et al. (2002) and other references referred to below for and explanation of this metric.

### *5.3.4 Long-term priority measures for amphibians and reptiles*

Because of the lack of historical data for herpetofauna of the KCOL, a species list needs to be developed based on other Florida lakes. Table 4 in the CEM document is a list of lake-inhabiting herpetofauna based on a landmark publication in 1940 by the late Archie Carr. This list forms a good basis for amphibians and reptiles in Florida lakes, but the list needs some significant modification in my opinion. Even though a comprehensive review of amphibians and reptiles of Florida's lakes does not exist as far as I know, we still have a relatively good understanding of which species to expect. Knowledge of herpetofauna in Florida lakes has certainly increased since Carr's publication, and I have included several citations that can provide useful information toward establishing herpetofauna performance measures (Goin 1943, Telford 1952, Duellman and Schwartz 1958, Bancroft et al. 1983, Franz 1995, Aresco 2003, Aresco and Gunzburger 2004, Sorensen 2004). Taking into account variation in geographic ranges of species, Florida lakes tend to have relatively similar species richness of amphibians and reptiles. Therefore, species richness should be consistent enough across the KCOLs to use this metric as a long-term assessment tool. I do not think that variation among lake stages in the Kissimmee Chain should preclude this, as suggested in the CEM text. I do not recommend using abundance as a performance measure, however. True abundance can be extremely labor and time intensive to estimate. CPUE (catch per unit effort) is a potentially useful metric, but it has problems too. Without species-specific estimates of detection probability, temporal variation in CPUE might not be very valuable from a monitoring perspective. A better measure for herpetofauna monitoring and assessment would be "Percent Area Occupied" (see section 5-5).

A modified list of amphibians and reptiles, based on Table 4 in the CEM, is a good starting point to develop a species richness list for use as a potential performance measure that should be developed for long term assessment in the KCOL. Below are my suggested modifications for the Table:

Characteristic Taxa

Additions to the list:

1) *Siren lacertina* (Greater siren)
2) *Amphiuma means* (Two-toed Amphiuma)
3) *Rana sphenocephala* (Southern Leopard Frog)
4) *Acris gryllus dorsalis* (Florida Cricket Frog)
5) *Chelydra serpentina osceola* (Florida Snapping Turtle)
6) *Sternotherus odoratus* (Stinkpot)
7) *Pseudemys nelsoni* (Florida Red-bellied Cooter)
8) *Kinosternon bauri* (Striped Mud Turtle)
9) *Alligator mississipiensis* (American Alligator)

Deletions from the list:

1) *Nerodia taxispilota* (Brown Watersnake)

Frequently Occurring Taxa

Additions to the list:

1) *Rana heckscheri* (River Frog)
2) *Notophthalmus viridescens piaropicola* (Peninsula newt)

Deletions from the list:

1) *Rana catesbeiana* (American Bullfrog)
2) *Deirochelys reticularia* (Chicken Turtle)
3) *Kinosternon subrubrum steindachneri* (Florida Mud Turtle)
4) *Kinosternon bauri* (Striped Mud Turtle)

Based on my modifications, there are 22 species of amphibians and reptiles that occur frequently in littoral zones of lakes in central Florida. There is some recent information from West Lake Toho (Muench 2004), and these data confirm the presence of many of the species listed in Table 4 of the CEM. Before long-term herpetofauna performance measures and assessment strategies are finalized (assuming they are added), I suggest the SFWMD conduct (or fund) a thorough review of lake-inhabiting herpetofauna in Florida.

In addition to using reference data from Florida lakes external to the KCOL, herpetofauna data collected along the Kissimmee River may also be useful for developing performance measures. I know the district has funded such studies and these data should be used. There may be useful data from Lake Okeechobee, which may be discovered during the suggested literature search. Long-term PMs and assessment based on herpetofauna species richness and diversity can be used to augment the PMs suggested above that can be developed within the next six months.

### 5.4 Important datasets

I am not aware of any important historical KCOL datasets or literature for amphibians and reptiles that were missed. I suggest trying to find if there are any landing statistics for Pig Frogs or turtles harvested from the KCOL. There is a recent Master of Science thesis that has valuable data in species richness and influence of littoral zone management in West Lake Toho (Muench 2004).

### 5.5 Reference sites

Unfortunately, the herpetofauna of Florida lakes have not been studied in great detail. I included some citations the District should consult to develop amphibian and reptile performance measures based on data from other lakes. One of the most appropriate references is the work by Bancroft et al. (1983) conducted on the Conway chain of lakes. Two other important references, although based largely on studies in the panhandle, are Aresco (2003, 2005) and Aresco and Gunzburger (2004). As mentioned in section 5-3, consult Muench (2004). As stated earlier, the District should consider conducting or funding a review of data for lake-inhabiting amphibians and reptiles in Florida. They should also consult data from the Kissimmee River restoration studies by Maureen Donnelly (Florida International University) and Joe Koebel (SFWMD) and try to find data from Lake Okeechobee.

### 5.6 Preferred strategy for performance measure development

Proceed with developing hydrologic PMs for amphibians and reptiles as outlined in section 5-2. Conduct a literature review to aid with development of long-term PMs for amphibians and reptiles. As far as assessment is concerned in the near and long-term future, I would caution against using “abundance” as a target to measure unless species-specific detection probabilities are estimated concurrently (see below).

When developing specific assessment techniques amphibians and reptiles (other groups too), the District should seriously consider NOT setting specific goals based on absolute numbers (i.e., abundance) of fish and wildlife unless this is justifiable. First, because historic and recent data are lacking for most species, performance measures will have to be based on reference data from other sites. The same data may be lacking for reference sites too. And if such data actually exist, it is going to be difficult to justify setting “target numbers” for the KCOL based on other lakes.  Second, estimating true abundance is inherently difficult and in many cases, the values people report as abundance are only counts or captures/observations per unit effort, and rarely do they include estimates of detection probability. Because abundance = count/detection probability, failing to account for variation in detection is a major problem (MacKenzie et al. 2002, MacKenzie et al. 2003, Gu and Swihart 2004, Schmidt 2004). It is crucial that detection probability be considered as monitoring and assessment plans are developed to track performance measures. Estimating “Percent Area Occupied” as the metric to me monitored through time is much preferred over “abundance.”

## 5.7 Additional comments

### *5.7.1 Adjacent Wetlands*

I suggest that some type of performance measure be developed for adjacent wetlands within the KCOL. These types of wetlands were severely impacted when canals and water-control structures were built among the KCOL. Such wetlands are extremely important habitat for fish and wildlife. I am not suggesting that water storage capacity of lost wetlands specifically be used as an indicator, but I support development of some type(s) of performance measure regarding adjacent swamps and marshes.

### *5.7.2 Fire Frequency*

Although I see the justification for not including fire frequency or some other metric of fire as a performance measure, I suggest the District continue to try to glean data on the historic role of fire in the KCOL ecosystem and incorporate this stressor in models.

### *5.7.3 FWC Documents*

Regarding the FWC documents: they vary considerably in their thoroughness and format. Specific recommendations for water-level management are listed for some groups/species but not others. There are discrepancies between the species suggested as performance measures by the FWC and those included in the KCOL CEM. Specifically for the American Alligator account, food habits of adults are neglected to a large extent and there is no mention of the influence of disease and endocrine disruptors.

### *5.7.4 Maximize sampling effort*

During assessment, it is advisable to maximize data collection effort. This can be accomplished through good communication among those entities conducting sampling. I suggest a coordination and planning meeting be convened early so that each group will understand the methods used by other teams and allow data to be shared. For example, a specific trapping technique for amphibians and reptiles also captures forage fish, and invertebrates (Johnson and Barichivich 2004).

# 6. Fisheries

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## 6.1 Summary

The KCOL Conceptual Model contains the important factors that will influence fish communities and fisheries in the system. The model could be improved in two ways: (1) by listing the relative importance of each stressor in the model, and (2) by including only high coverage (> 80%) of *Hydrilla* as a stressor, and recognize that low/moderate coverage of *Hydrilla* provides quality fish habitat. Individual fish species chosen as measures should be carefully considered, and largemouth bass may be the most appropriate species due to its need for aquatic plants as habitat in large Florida lakes. Population modeling of largemouth bass could be conducted to use long-term data from the KCOL to predict population responses to habitat change. Additionally, detailed fish and plant mapping activities would provide a good measure of factors influencing fish communities at the KCOL. Specific short-term and long-term recommendations are made in Section 6-7.

## 6-2 General comments on the KCOL Conceptual Model

From my perspective, the KCOL Conceptual Model contained the critical factors that will influence fish communities in the system. The documents did a very thorough job of discussing long-term data sets that may exist and potential approaches that could indicate change in the fish population/community in response to habitat changes. I commend the authors on a thorough literature review regarding fish measures in the KCOL document. I do feel that the model should be modified to reflect the relative importance of each stressor on the system. For example, altered hydrology is probably a more critical stressor on the KCOL system than nutrient loading, yet both stressors had equal emphasis in the model. In the sections below, I will discuss the potential use of individual species and fish community measures in the KCOL Conceptual Model. I will recommend some additional measures that should be included in efforts to identify factors influencing fish communities in the system.

## 6.3 Individual Fish Metrics

The model documents considered using individual fish species measures through time as fish metrics. Although this approach has promise, the fish species selected for trends through time should be carefully considered. Bluegill *Lepomis macrochirus*, redear *L. microlophus*, and black crappie *Pomoxis nigromaculatus* support very important recreational fisheries at the KCOL, but population abundance of these species may not respond to changes in littoral plant community composition. All three species are open-water zooplanktivores during early life (Mettee et al. 1996; Allen et al. 1998), and thus, we find high-quality populations of all three species in productive Florida lakes that have low coverage of aquatic plants. For example, the Harris Chain of Lakes in the upper Oklawaha River basin are highly eutrophic lakes (chlorophyll > 50 *ug*/L) with low coverage of macrophytes (Florida LAKEWATCH 2004), yet these lakes contain abundant populations of large bluegill, redear, and black crappie based on Florida Fish and Wildlife Conservation Commission FWC creel survey data. Thus, it is possible that large changes in the native plant mosaic in littoral areas of the KCOL could occur without a decline in the populations of bluegill, redear, and black crappie. Thus, these species may not indicate littoral habitat change.

Conversely, largemouth bass *Micropterus salmoides* also support very important fisheries at the KCOL, but population abundance of adult largemouth bass is influenced by littoral plant abundance and composition (Hoyer and Canfield 1996). Juvenile largemouth bass require complex habitats as refuge from predation, and recruitment (i.e., the number of fish that survive to age-1) is positively related to percent area covered by aquatic plants, particularly in large Florida lakes (Hoyer and Canfield 1996; Tate et al. 2003) such as those found in the KCOL. Thus, largemouth bass population abundance will likely be related to large-scale plant community changes in the KCOL. Because largemouth bass are also a top predator in the system and support world-renowned recreational fisheries at the KCOL, the species is an excellent candidate to use as an individual fish measure.

## 6.4 Modeling Largemouth Bass Population Response to Habitat Change at the KCOL

In addition to their importance in the system from both ecological and economic (fisheries) perspectives, the FWC has collected long-term data for largemouth bass at the KCOL, particularly at Lakes Kissimmee and Tohopekaliga. Over 20 years of fixed-station *electro-fishing* and creel survey data exist for both lakes. Thus, it is possible to use these data to monitor trends in largemouth bass abundance via *electro-fishing* catch per hour (CPH) and angler effort and catch rate through time.

A population model could be developed for largemouth bass at the KCOL. The model could be used to predict effects of changes in largemouth bass recruitment, via changes in littoral habitat through time, on largemouth bass abundance and angler catch rates. This approach would include three steps: 1) relate bass recruitment indices to changes in habitat/water levels through time, 2) construct a population model that mimics variation in largemouth bass recruitment through time at each lake, and 3) use the population model to predict how changes in largemouth bass recruitment through time would influence adult largemouth bass abundance and angler catch rate or harvest. This approach would provide a framework for predicting how changes in water level regimes and/or aquatic plant communities would influence the largemouth bass populations and fisheries at the KCOL.

Some of the analyses for step number 1 above have already been conducted. Bonvechio and Bonvechio (In revision) assessed factors related to *electro-fishing* CPH and angler catch rates at Lake Tohopekaliga over 20 years (1983-2002). They found that *electro-fishing* CPH of largemouth bass was positively related to *Hydrilla Hydrilla verticillata* coverage over the period (0-83%), and angler effort for largemouth bass increased greatly as *Hydrilla* coverage increased from 1983-2002 (Bonvechio and Bonvechio, In Revision). Conversely, Allen et al. (2003) assessed 18 years of *electro-fishing* and angler catch rates at Lake Kissimmee and found that age-1 largemouth bass CPH did not vary with *Hydrilla* coverage ranging from nil to 34%. The lack of a relationship between age-1 largemouth bass CPH and *Hydrilla* coverage at Lake

Kissimmee may have resulted from abundant native plant coverage at the lake and *Hydrilla* abundance that did not vary as widely through time (0-34%) compared to Lake Tohopekaliga (0-83%). *Hydrilla* as related to fish measures at the KCOL is discussed below in Section 6-5. In summary, some analyses for step #1 above have already been conducted for these lakes, and trends in largemouth bass recruitment exist that could be used for population modeling.

### *6.4.1 Example of Population Modeling*

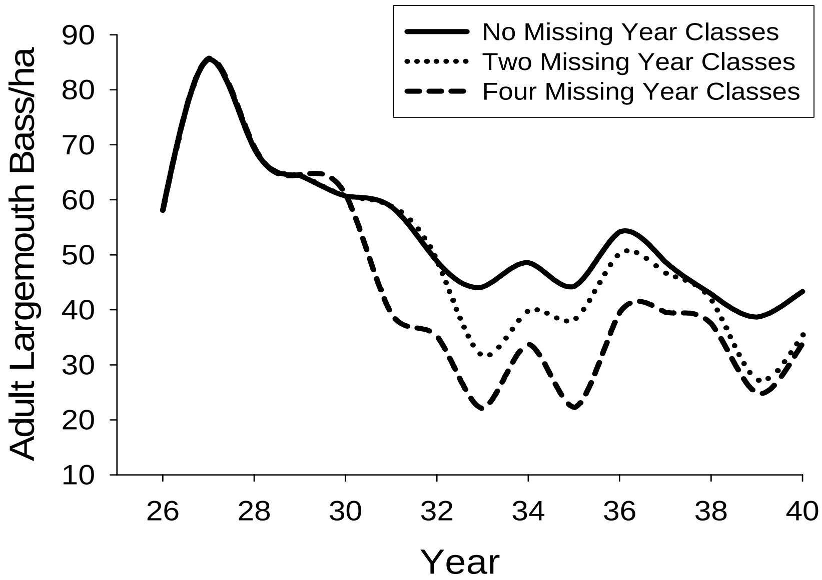
As a hypothetical example of how population modeling could be used to provide a measure for largemouth bass in the KCOL Conceptual Model, I conducted some simulations. I used an age-structured population model to assess how missing year classes (years with no recruitment) would influence adult largemouth bass abundance and angler harvest. The model uses age and gender-specific growth and mortality rates, and can be used to predict population responses to changes in habitat or harvest restrictions. The model has previously been used for several fish species including black crappie (Allen and Miranda 1998) and Florida largemouth bass (Allen et al. 2002).

I created a 50-year time series of recruitment to age-1 using a random number generator. Recruitment averaged 150 age-0 fish per hectare which was similar to Allen and Tugend (2002) at Lake Kissimmee. Recruitment was lognormally distributed across years to simulate variation in recruitment through time, which in practice would presumably be related to habitat measures from step #1 above. I used largemouth bass growth rates from from Lake Kissimmee (Allen, unpublished data), and mortality rates from Allen et al. (2002) for Florida largemouth bass populations. Fishing and natural mortalities were both 25% per year as per Allen et al. (2002).

I conducted three simulations. First, I simulated the population abundance through time using the random recruitment trends. To simulate how large changes in habitat quality could influence the simulated population, I introduced missing year classes at two and four randomly selected years within the 15-year period of years 26-40 of the 50-year time series. These simulations would indicate how year class failure, due to large changes in habitat, would influence population trends. Although I chose scenarios of periodic year class failure in this example, the model could also be used to assess how declining trends in largemouth bass recruitment through time would influence the population.

The simulations suggesting that year class failure in two and four of 15 years would substantially influence the largemouth bass population abundance and angler harvest. Under a scenario of two missing year classes in 15 years, abundance of largemouth bass declined from about 48 to 38 fish/ha in years 33 to 34 (Figure 6-1). If four missing year classes occurred, the population would be predicted to be about half of that found under random recruitment with no missing year classes (Figure 6-1). Angler harvest showed similar trends, where four missing year classes in 15 years would cause angler harvest to decline from about 2.5 fish/ha to about 1.5 fish/ha.

In summary, the hypothetical simulations showed how a population model could be used to predict how changes largemouth bass recruitment would influence the largemouth bass population and fishery characteristics through time.



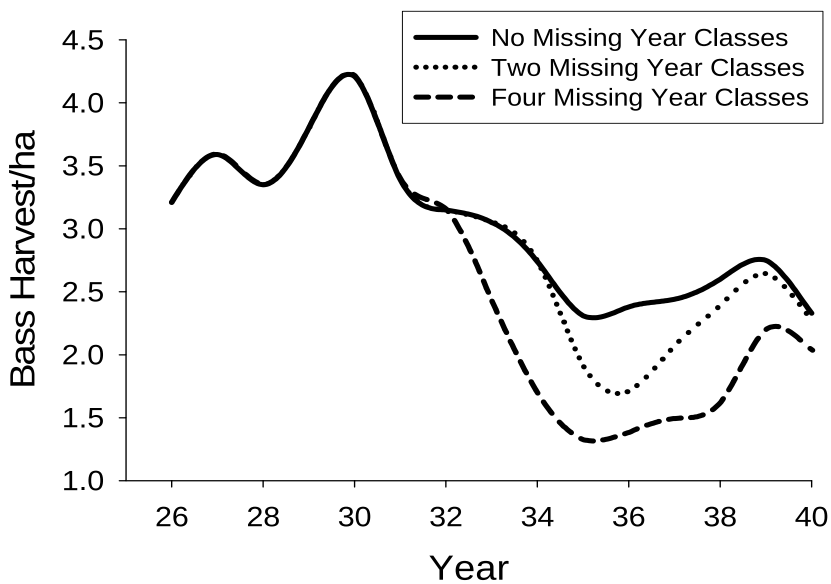




**Figure 6-1.** Simulations of adult largemouth bass (≥ age 2) population abundance (fish/ha, top panel) and angler harvest (fish/ha, bottom panel) through time. Simulations resulted from a 50-year time series of random recruitment (black line) with scenarios of two (dotted line) and four (dashed line) missing year classes introduced at randomly selected years within years 26-40.

I recommend that simulations similar to these be initiated for the KCOL largemouth bass populations, and annual *electro-fishing* surveys could be used to update the model and predict how the largemouth bass fishery is likely to change through time. Such an approach could also benefit from the long-term creel survey data at the KCOL, because trends from the *electro-*

*fishing* data and population model could be verified with the creel survey trend. This approach using all available data could provide powerful inference to predict how habitat changes at the KCOL are likely to influence largemouth bass populations and fisheries.

### 6.5 *Hydrilla* Considerations in Relation to Fish Measures

Prior to discussing fish community measures at the KCOL, I should address *Hydrilla* as a potential confounding variable in fish measures. *Hydrilla* has created littoral vegetated habitat in open water of the KCOL, and has potentially mediated the loss of littoral habitat due to stabilized water levels through time (Figure 6-2). For example, with lake size and hydroperiod relatively fixed after stabilization, *Hydrilla* has created littoral habitat in areas of the KCOL that had previously not contained littoral plants (Figure 6-2). Because historical littoral habitat quality declined with stabilized water levels, *Hydrilla* at the KCOL may have mediated habitat loss inshore resulting in a lack of a decline in fish populations and fisheries. Increases in *Hydrilla* were associated with largemouth bass abundance and angler catch and effort at Lake Tohopekaliga (Bonvechio and Bonvechio, In Revision). Thus, although *Hydrilla* is an exotic and can be an invasive plant, it has value as fish habitat at the KCOL which should not be ignored when addressing fish measures in the system.

In addition to the value of *Hydrilla* as fish habitat, *Hydrilla* will likely confound fish community measures (see Section 6-6). Fish abundance and diversity is typically high in, and *Hydrilla* any fish community measures will likely be influenced by changes in *Hydrilla* coverage at the KCOL. Thus, the KCOL Conceptual Model documents should be clear relative to *Hydrilla* management goals. As a guide for developing goals for *Hydrilla* in the system, the *Hydrilla* management workshop that occurred in 2004-2005 (Hoyer et al. 2005) could be used for specific recommendations. That workshop and associated white paper (Hoyer et al. 2005) achieved a consensus among state and federal management agencies, and made specific management recommendations that can be used to guide *Hydrilla* research and management.

Specifically, *Hydrilla* resistance to Fluridone has changed the management options at the KCOL, and non-target impacts of Fluridone on native plants at the KCOL are now a key issue for use of this herbicide (Hoyer et al. 2005). Use of grass carp *Ctenopharyngodon idella* can control *Hydrilla* but includes a high risk of near complete removal of all aquatic plants over the long term. Research is needed to develop new herbicides and measures to remove grass carp from lakes as *Hydrilla* control methods (Hoyer et al. 2005).

Despite the positive aspects of low to moderate coverage of *Hydrilla* as fish habitat, high *Hydrilla* coverage (> 80%) can have negative impacts on fish communities and fisheries. High *Hydrilla* coverage reduces angler fishing effort and angler catch rates (Colle et al. 1987), and can negatively influence fish growth rates (Colle and Shireman 1980). Thus, *Hydrilla* can negatively influence both fish populations and fisheries when found at high coverages.

I believe that the KCOL Conceptual Model should include low to moderate coverage of *Hydrilla* as a component of the basin-wide submersed aquatic vegetation (i.e., habitat), and high *Hydrilla* (>80%) coverage should be listed as a stressor.

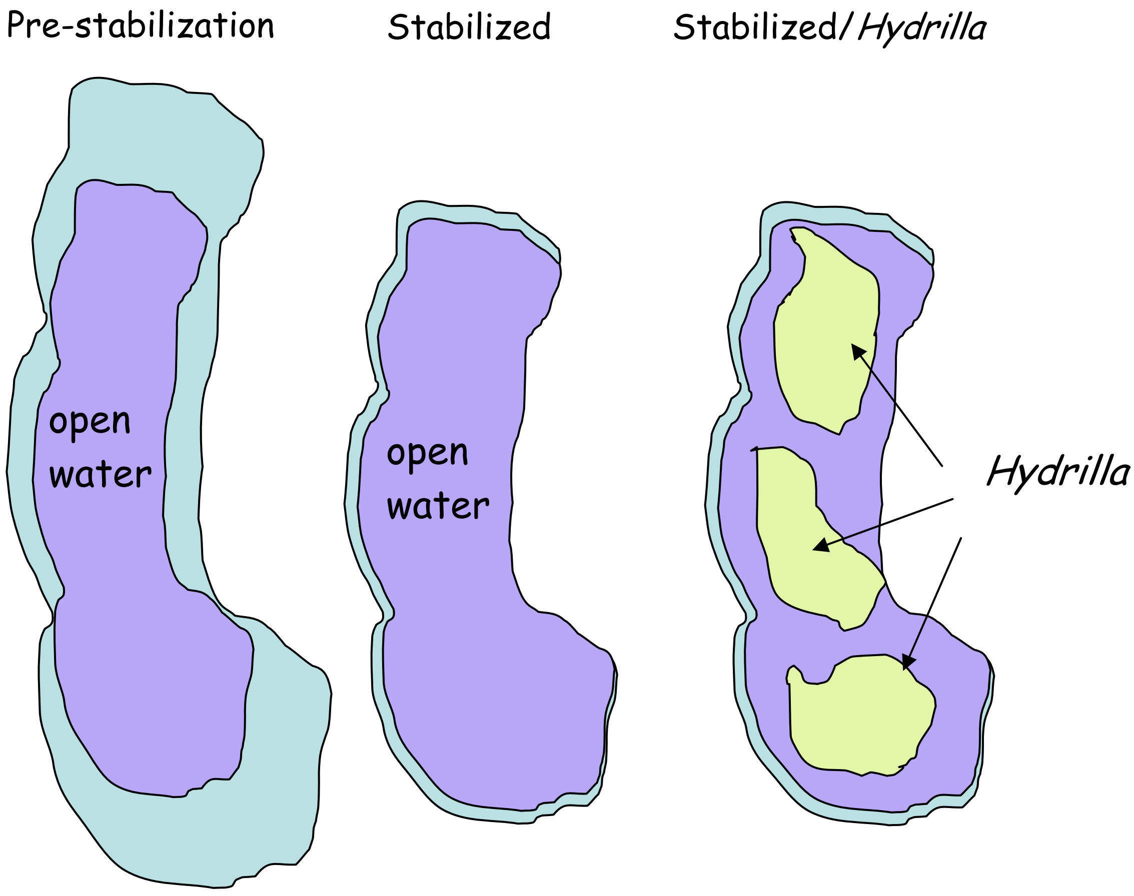



**Figure 6-2.** Schematic of changes in hydrologic variation and *Hydrilla* at the KCOL through time. Prior to stabilized water levels (left drawing), large changes in water level created dynamic connections between open-water and littoral areas, and littoral fish habitat quality and quantity varied widely through time. After stabilization (center drawing), the lake sizes have been relatively fixed, causing reduced and declining littoral habitat through time. After *Hydrilla* colonized the KCOL (right drawing), it created littoral fish habitat in open-water areas that previously had not contained submersed macrophytes, potentially mediating the loss of inshore habitat from stabilized water levels.

## 6.6 Fish Community Measures

Changes in fish community metrics (e.g., richness, diversity) could also provide a measure for how changes in habitat influence fish in the KCOL. Continuous long-term data do not exist at the KCOL, but a monitoring program that samples fish and plant metrics would be a good measure. Mini-block nets (10x10 m) have the ability to quantify fish community composition in different plant types (Rogers and Allen 2005). When combined with detailed aquatic plant maps of lakes in the KCOL, this approach would allow prediction of how changes in plant composition and abundance would influence fish community composition and abundance. The mini block nets primarily sample fish below 200 mm total length, but they typically collect all common littoral fishes found in Florida lakes, including juvenile sport fish. The use of these nets provides allows multiple replicates per day for each habitat type. Alternately, the use of habitat-specific *electro-fishing* could quantify how fish communities vary across habitat types and time. I recommend that such a program be initiated in the future.

A related approach to monitoring fish community measures through time would be an Index of Biological Integrity (IBI), as mentioned in the KCOL Conceptual Model document. The IBI was originally developed for Midwestern streams (Karr et al. 1986), and adaptations of this approach have been used to detect anthropogenic impacts to streams in many regions. The IBI places fish into feeding guilds (e.g., omnivores, insectivores, piscivores) and classifies individual species as “tolerant”, “intolerant”, and “intermediate” with respect to habitat degradation. The IBI also includes fish richness and diversity as metrics. Each metric is assigned a score, and the scores are combined to obtain an IBI score for each stream/site, which presumably will indicate the relative impact on fish communities due to anthropogenic impacts.

Schulz et al. (1999) developed IBI scores for 60 Florida lakes using criteria developed by USEPA (1991) for northeastern U.S. lakes. Anthropogenic impact was quantified using chloride concentrations in lake water samples (an indicator of wastewater input) and road density around each lake (Schulz et al. 1999). The IBI for fish communities was constructed from 0.08-ha block net samples from 60 Florida lakes, and IBI scores were related to trophic state variables, lake size, and percent of the lake inhabited by aquatic plants (PVI). In their analysis, IBI was not related to anthropogenic impacts measures and was positively related to lake trophic state and size. Thus, the IBI did not detect impacts to lake fish communities across the 60 Florida lakes (Schulz et al. 1999).

However, one area that was not addressed by Schulz et al. (1999) is the potential for IBI scores to detect impacts to single lakes through time. Using block net or *electro-fishing* data as described above, an IBI approach may provide a measure to assess how changes in plant/water level/nutrient variables influence fish IBI scores through time. This approach has promise for identifying factors related to fish community changes through time at the KCOL, and could easily be conducted if a fish community monitoring program was initiated in conjunction with aquatic plant mapping activities. Rather than sampling every year, this approach could be conducted at two or three year intervals to monitor trends.

### 6.7 Summary Recommendations Regarding Fisheries

Based on the review of the KCOL conceptual model and the comments above, I have the following recommendations.

A. Include *Hydrilla* as a stressor in the conceptual model only if it occurs at high coverage (>80%) for each water body. Lower coverages should be included in the lake or basin-wide aquatic habitat categories.

B. The relative importance of each stressor should be indicated in the model, to reflect area(s) where monitoring efforts should be concentrated.

C. In the short term (next six months), the involved agencies should request that the FWC provide habitat suitability indices (HSI) for largemouth bass regarding the KCOL hydroperiod. The FWC should provide comment on the duration and periodicity of lake stages that will influence largemouth bass abundance and spawning success. It is important to note that changes in *Hydrilla* or native plant coverage due to aquatic plant management activities may also contribute to the largemouth bass population characteristics. Changes in aquatic plants, including *Hydrilla*, should also be considered in addition to water level fluctuations. Nevertheless, the HSI values based solely on hydroperiod for largemouth bass would provide preferred water level fluctuations assuming relatively stable aquatic plant conditions.

D. Over the next year, the agencies should initiate population modeling for largemouth bass populations in the KCOL as described above. The modeling exercise could then be updated annually to predict how changes in habitat and age-1 fish abundance will influence the largemouth bass fisheries in the future.

E. Over the next year, the agencies should implement detailed aquatic plant GIS maps for the KCOL. Fish community samples should coincide with the plant mapping activity to initiate a fish community or IBI-approach to detecting changes in fish measures through time. The fish sampling would not need to be repeated annually, and perhaps an interval of every two or three years would be adequate to identify trends for both plants and fish.

# 7. Wading Birds

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## 7.1 Summary

The Kissimmee Chain of Lakes Conceptual Ecosystem Model (CEM) is a comprehensive document that draws together a diverse body of literature and distills it down to a useful structure. My general recommendations to the model development process and model structure are to simplify the model figure by showing just the main linkages for the main hypotheses, consider the potential for developing numerical targets when selecting assessment performance measures, and take a landscape-level view of the KCOL. The current CEM treats all lakes as having the same stressors, attributes, and response yet it is likely that some lakes behave differently than others. If the unique spatial properties of lakes are recognized, it could provide additional management flexibility. I recommend development of a wading bird evaluation performance measure in the form of a habitat suitability model. Such models exist for the Everglades and could be modified to fit the KCOL. I also recommend development of a wading bird assessment performance measure that is the interval between years with large nest numbers. Targets for this measure could be based on historic data from Lake Okeechobee and the periodic surveys conducted by the FFWCC, and could reflect the natural variability inherent in hydrologic conditions in lakes and wetlands. Sampling methodology should follow what is being done throughout South Florida under CERP so that data are comparable. This will make it possible to distinguish between a response that is driven by local conditions on the lakes and one that is driven by regional factors unrelated to lake management.

## 7.2 Introduction

This review was done at two levels. The first level (general assessment) critiqued the general approach to developing the CEM and the overall model structure. The second level examined the wading bird section in more detail and offered suggestions for the development of specific performance measures. The second level is structured explicitly around the five questions the panel was charged with addressing. This review contains the details of my oral presentation at the Kissimmee Workshop on 14-15 July, 2005 as well additional information that came to light during discussions at the Workshop.

I use the term assessment performance measure to mean a parameter that can be used to measure the response of an ecosystem to some management action. It is measure in the field and represents actual changes in the system. I use the term evaluation performance measure to mean a model that can be used to evaluate different management scenarios. The model does not require collection of field data but rather could be based on empirical relationships of ecological variables or it could be from historic data at the site of interest. The evaluation performance measure must be developed prior to the management action.

## 7.3 General assessment

### *7.3.1 Strengths*

The Kissimmee Chain of Lakes Conceptual Ecosystem Model document was well written and clearly organized. Having the text relate directly to the conceptual model figure highlighted the relevance of each piece of information and would have made any omissions obvious. Standardized headings made it easy for the reader to retrieve common information from any of the major taxonomic and ecosystem sections. The section with direct evaluation of suitability of performance measures was direct and concise. Collectively, the authors considered an impressively wide range of taxa and ecosystem components as candidate performance measures. The Candidate Indicator Species document was notable in the depth of ecological and natural history information for each species or taxonomic group. The specific management recommendations provided some idea of optimal conditions for the indicator taxa.

### *7-3.2 Suggested modifications*

*Streamline by focusing on the main hypotheses*

Conceptual ecological models are best viewed as heuristic tools rather than detailed ecological models that represent food webs and contain feedback loops (Gentile et al. 2001, Noon 2003, Ogden et al. 2003). As such, the current CEM may offer too much complexity and produce too many performance measures. There is considerable risk in selecting a large number of performance measures that would require so much monitoring as to be unsustainable for years following management actions, when they are most needed.

One way to reduce the model complexity is to start with the main hypotheses that explain how specific attributes have changed (or are expected to change) in response to specific drivers, and carry that process out until the specific parameter associated with a particular attribute has been identified (Fig. 7-1). Ecologists know that most components in the CEM are linked but to be effective, a CEM should only show the most important linkages. At each link in the model there should be a hypothesized relationship between two model components. Each hypothesized relationship can be expressed as a graph and would therefore represent a simple predictive model. The prediction can be as general as a positive or negative slope of a line or as specific as a set of predicted values. The relationships of the model components can be considerably more complex than the simple relationships shown in the CEM. The complex relationships can be displayed separately as more detailed sub-models or described in detail in the text. In either case they should provide the rigorous scientific foundation on which the CEM rests.

A simple example of a hypothesis that was suggested in the text of the CEM is shown in Fig. 7-1. The specific hydrologic effect is identified as dry season reversals in water levels. Dry season reversals are known to increase the flooding of apple snail eggs, which lower egg survival. Reversals also lower wading bird nesting success but the mechanism is a food limitation rather than direct mortality of eggs. This simple set of relationships suggests that apple snail egg survival and alligator nesting success could be providing redundant information but that wading bird nest success is monitoring a different phenomenon. Also it identifies specific candidate performance measures (underlined) and a direction for the target, such as an increase in egg survival from current conditions.

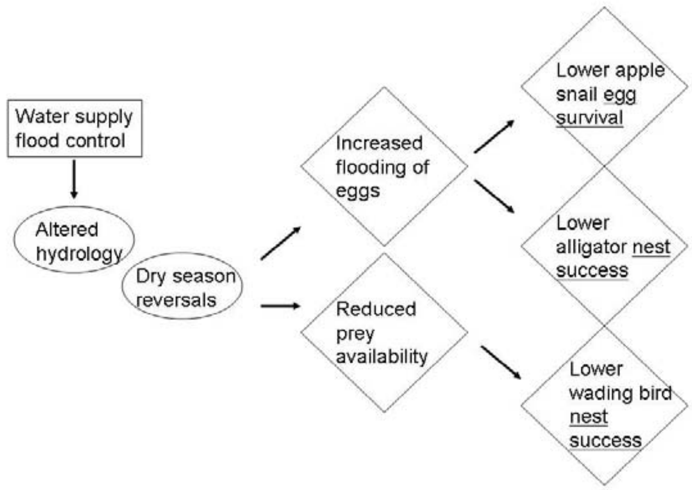


**Figure 7-1.** Simple conceptual model of the mechanistic hypotheses explaining how altered hydrology affects apple snails, alligators, and wading birds. The underlined terms are candidates for assessment performance measures. Note that alligator nest success and wading bird nest success result from the same stressor but are produced by two different mechanisms.

The benefits of streamlining the CEM in this way are that (1) it keeps the focus on the most important linkages, (2) the endpoint is a specific parameter that is a potential performance measure, and (3) it can reduce redundancy in performance measures by identifying multiple measures that might respond the same way to the same stressor.

*Develop numerical targets when selecting assessment performance measures*

For assessment performance measures it is critical that a numeric target can be developed so that the ecosystem state can be evaluated relative to that target at any time. It would help the reader to know whether enough is known about a potential performance measure so as to be able to discern a specific target value. If there clearly is not enough information then it would be pragmatic to drop the candidate performance measure from future consideration. Being able to develop a numeric target is not as critical for evaluation performance measures because often the primary purpose is to compare a response from one management scenario relative to the others.

*Develop a landscape-level view of the KCOL*

The current CEM treats all lakes as having the same stressors, attributes, and response yet it is likely that some lakes behave differently than others. Also, the particular configuration of lakes can have ecological value for species that range over large distances. If the unique spatial properties of lakes are recognized, it could provide additional management flexibility.

## 7.4 Does CEM capture critical drivers, stressors, ecological effects, attributes, and linkages? Are there additions or omissions?

All major components and linkages were represented. If anything, the CEM may have too many linkages for a heuristic tool. The only specific additions might be to add the specific hydrologic alterations that are stressors in the main hypotheses. Doing so would more closely link the stressors, attributes, and response in performance measure. Specific hydrologic attributes could include prolonged high water, dry season reversals, and prolonged low water. The text could also benefit from a specific one-to-one match between text sections and the attributes in the CEM figure. For example, the text sections Wetland, Littoral zone, and *Hydrilla* might all be collapsed into one section called Vegetation Mosaic.

## 7.5 Which attributes should be developed into performance measures?

I largely agree with the assessment of birds as performance measures in the CEM. The exceptions are snail kites and wading birds. The snail kite should be reconsidered as a potential performance measure because it is an Endangered Species and as such, its status will always be of interest to the public and regulatory agencies. If it is likely that a regulatory agency will require some type of monitoring in the future then it would be beneficial to include this species in other monitoring plan at the onset. Interpretation of their patterns can be strengthened, and thus the value of the performance measure increased, by monitoring other closely linked attributes and stressors.

### *7.5.1 Wading bird evaluation performance measures*

Much has been written about why wading birds make good indicators of wetland status and hydrologic conditions (Frederick and Spalding 1994, Ogden 1994, Crozier and Gawlik 2003, Frederick and Ogden 2003). Besides their biological value, they are also a valued resource by the public as evidenced by the steady stream of news stories on wading birds in the popular media in South Florida. Not surprisingly, wading birds have been widely accepted as a primary bioindicator of the CERP (RECOVER 2005) and they are being used as an indicator for the Kissimmee River Restoration (G. Williams pers. comm.). There is also a long record of wading bird nesting data for Lake Okeechobee and there are some nesting data for lakes in the KCOL. For these reasons wading birds may also be good bioindicators for the KCOL. The challenge is to identify the specific wading bird parameter that will make the best performance measure.

Given the constraints identified in the workshop (evaluation performance measures must be developed within 6 months without additional data collection), it is not possible to develop a predictive model of wading nest numbers, population size, or behavior. However, it is possible to develop a simple index of feeding habitat suitability (HSI). Such indices have been developed for the Everglades (Curnett et al. 2000, Gawlik et al. 2004) and could be modified for the KCOL.

The Everglades models are based on the idea that food is a limiting factor, which is controlled primarily by hydrologic conditions (Frederick and Spalding 1994, Ogden 1994). Wading birds are able to exploit small patches of highly available prey and large foraging aggregations indicate good feeding conditions. Species such as the wood stork, white ibis, and snowy egret appear to be more dependent, than are other wading bird species, on high-density food patches to have high reproductive output (Gawlik 2002). They change the location of their foraging sites quickly in response to changing hydrologic changes (Hoffman et al. 1994) suggesting that a foraging HSI should also be sensitive to sudden hydrologic changes. In the Everglades, hydrologic patterns that seem to produce the maximum number of patches with high prey availability are high water levels at the end of the wet season and low water levels at the end of the dry season. Correspondingly, the Everglades HSI models include a hydrologic parameter for water depth and water recession rate during the dry season. Intuitively, it would seem that recession rate would be more important in wetlands than in lake systems; however receding water during the dry season seems to be a requirement for good nesting effort on Lake Okeechobee (David 1994*a*, Smith and Collopy 1995). It was apparent from discussions in the workshop that large water level fluctuations were also a historic characteristic of the KCOL.

The starting point for a KCOL HSI is to select an indicator species that is sensitive to hydrologic conditions, such as one of the three mentioned above. It is assumed that less sensitive species also will benefit from habitat that is suitable for the more sensitive species (Gawlik 2002). Based on the abundance and distribution of the three species in the KCOL (Table 6 in the CEM), white ibis might be the best choice. The HSI should be linked to a hydrologic model so they must run on the same spatial domain and time step, ideally weekly. The HSI should be calculated for each lake (including surrounding wetlands) separately then aggregated as needed. It may be appropriate to aggregate lakes into sub-regions that reflect ecological or management similarity. The most basic parameters in the HSI could be water depth within optimal foraging depths and whether water level is decreasing or increasing. It is not clear that there is an ideal rate of water level recession so this could probably be treated as a binomial function (receding or increasing).

### *7.5.2 Wading bird assessment performance measure*

Because wading birds are already being used as bioindicators for CERP throughout much of South Florida there is considerable value in monitoring wading birds on the KCOL using the same methodology. This will allow scientists to distinguish between a response that is driven by local conditions on the lake and one that is driven by regional factors unrelated to lake management. Metrics include numbers of nests for key species and nesting success. This latter measure should be of secondary importance if there is not enough historic data to develop a target for the KCOL. Crozier and Gawlik (2003) recommended that numbers of nests be used to develop a performance measure that is the interval between years with large nest effort.

The target for interval between years with large nesting effort could be developed by looking at a long string of data from Lake Okeechobee and determining the interval between years with large numbers of nests (e.g., 70$^{th}$ percentile) during a period the lake was relatively healthy. To scale to the number of nests that define a year with “large” numbers of nests in the KCOL it may be possible to look at the FFWCC nest surveys which included all the KCOL but occurred at infrequent intervals. Thus, the Lake Okeechobee data would serve to identify the temporal pattern and the FFWCC data would serve to provide the spatial pattern. Over time the adaptive management process could lead to refinement of the targets.

In CERP, monitoring is done through coordinated systematic surveys of wading nest numbers during the breeding season (January through July). Surveys focus on complete coverage of colonies containing large numbers (>25 pairs) of white-colored species. Small colonies of dark-colored species are not surveyed except incidentally because there is little historic information on which to compare and they are less detectable than the white birds. Information on nest success and productivity is also collected from repeat ground visits to a large sample of individually identifiable nests. Photos are taken of all colonies so their subsequent analysis can be used to adjust and improve the accuracy of the aerial counts. Aerial surveys are flown in east-west transects spaced 1.6 nautical miles apart in a Cessna 172 or 182 at an airspeed of 100 knots and altitude of 800 feet with one observer on each side of the aircraft.

### 7.6 Were important KCOL literature and datasets missed?

All the major data sets with which I am familiar were cited. The temporal coverage of the Lake Okeechobee nest surveys (David 1994*b*, Smith and Collopy 1995) include:

- 1930s-1940s nest surveys by Audubon Society wardens
- 1957-1977 sporadic systematic nest surveys
- 1977-1992 annual systematic nest surveys
- 2005+ annual systematic nest surveys as part of CERP

### 7.7 Are there reference sites that can be used for performance measure development in lieu of historic data?

There are no perfect analogs for wading birds in the KCOL. The best alternative to develop performance measures may be to consider Lake-Okeechobee as described above.

### 7.8 Is there a preferred strategy for finalizing performance measures?

Recommendations:

- Continue the use of multidisciplinary teams to evaluate and develop performance measures.
- Consider whether numerical targets can be established for each assessment performance measure and drop those for which targets are not possible. No matter how attractive an assessment performance measure is conceptually, it is of limited use if numerical targets can not be established to measure progress. Numeric targets are less important for evaluation performance measures because they are providing a relative comparison among alternatives.
- Increase the efficiency of monitoring by bundling performance measures that can be monitored with the same technique (e.g., vegetation mapping and *Hydrilla* coverage from aerial photos).
- Incorporate inter-annual variability in targets rather than making them static (e.g., large nesting event in 3 years out of 5)

# 8. Snail Kites and Related Ecosystem Issues

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## 8.1 Summary

The overall Conceptual Model Report and Guild or Indicator Species Documents used in support of the development of the conceptual model are excellent starting points for initiating the comprehensive planning for the management of the KCOL. With that said, it is critical to recognize that this document is severely constrained with uncertainty due primarily to the lack of information in some critical areas. The efforts henceforth must be driven by recognition of the enormous resource base at stake and carefully address the areas of uncertainty emerging from this and the other reviews. Exotic and nuisance plant control activities must be included as a major driver to the system. Habitat alteration resulting from these activities are becoming absolutely critical to the continued support of critical species including the apple snail and Snail Kite, hence “habitat alteration” needs to be added to the list of stressors. Vegetation monitoring within the lakes is absolutely critical to the adaptive management of these systems. It is highly recommended that the protocols are designed to monitor community structure, both spatially and temporally along the gradients structuring the littoral vegetation. Multivariate modeling approaches are recommended to project and portray responses to various management scenarios. Sandhill cranes and limpkins should be added to the performance measures of the conceptual model. The cranes in particular are dependent on the littoral reaches of the lakes for nesting habitat and given development activities in the region, this habitat is becoming even more critically important. The Snail Kite must be addressed directly as a performance measure in the model. The KCOL is critically important to the continued persistence of the population that is in a declining mode at the present.

## 8.2 General Comments

The comments that follow should be viewed in the context of the perspective of a wetland ecologist whose primary focus is the littoral reach of the subject lakes, particularly ecological structure and function as related to fish and wildlife resources. In addition, given the long-term involvement and on-going nature my personal research program with snail kites and Lake Tohopekaliga (Toho), respectively, many of the comments are anecdotal. The general format of the review essentially follows the topical sequence of the Conceptual Ecosystem Model for the Kissimmee Chain of Lakes (KCOL) Report.

In brief, the materials provided are excellent support documents, well conceived and generally well considered. The staff is to be commended on how well the information was collected and organized. My comments will be directed to areas of specific concern and are intended to be constructive. I have focused primarily on what I consider omissions in the process and areas or items (particularly in regards to the performance measures) for which I have reached a different conclusion.

It is critically important at the onset of this effort at planning the long-term management of the KCOL to recognize and address the enormous fish and wildlife resource base the system currently supports. In addition to selected lakes supporting world class bass fisheries, the KCOL and local environs was selected specifically from among a number of nationally nominated sites for the re-introduction of a non migratory flock of the endangered Whooping Crane, provides critical refugia habitat to the declining population of the endangered Snail Kite, contains the highest nesting density of Bald Eagles in the continental U.S., supports a robust population of threatened Florida Sandhill Cranes, and provides nesting habitat to two species listed as Species of Special Concern to the State of Florida, the Limpkin and Crested Caracara. The stakes are enormous given all this is juxtaposed the logarithmical growth of the Orlando/Disney metropolitan and suburban complex.

## 8.3 Specific Comments

### *8.3.1 Overview of conceptual model*

As stated above, I feel the conceptual model was generally well conceived and relatively exhaustively constructed in terms of drivers. I felt the process would have been enhanced by including and addressing management objectives as part of the modeling process, probably as a level above the drivers. In general, I was not deterred by the complexity portrayed in the model and in fact would suggest that perhaps even more will be required. I would suggest that it be done in a hierarchical approach however rather than attempting to try to portray all the relationships in one simple graphic. The District has employed this approach in past efforts documenting research priorities for the Everglades restoration effort. I feel that it is critically important to address the uncertainties associated with the various pathways detailed in the model. The fact is the uncertainty level is high and the information base supporting performance conclusions is particularly weak. By adopting a hierarchical approach, the model elements could essentially be annotated with a capsulated listing of the information sources (or lack thereof). Given the enormity of the stakes involved (as indicated above), I feel any attempts to design management plans for the KCOL would be viewed as seriously flawed or incomplete with out addressing the nature and quality of the information base that is driving the management plan.

### *8.3.2 Omission of major driver*

One very serious omission to the list of anthropogenic drivers is activities related to the control and management of exotic and nuisance vegetation. I would add the following driver 'exotic and nuisance plant control activities.'

The scope of the combined interagency efforts to regulate and control exotic and nuisance vegetation in the KCOL is absolutely monumental. These activities are generally system wide and given the spatial and monetary scope, dwarf efforts elsewhere, even at the global level. The activities range from applications of herbicides, to drawdowns of the littoral reaches of the systems, to combinations of both, to wholesale scraping of the littoral zone. Given the configuration of the system, drawdowns or systemic application activities in Lake Tohopekaliga affect the remainder of the down stream chain. In the past three decades, Lake Tohopekaliga has been drawn down three times dewatering most of the littoral reach. The last two events included direct removal of vegetation and accumulated mucks. The most recent, 2003, resulted in the removal of 7.3 cubic million meters of muck and vegetation from approximately 1,351 ha of littoral habitat (Florida Fish and Wildlife Conservation Commission 2004).

These activities in addition to connection through the Exotic Plants stressor would connect directly to the Altered Hydrology stressor and all its associated pathways as well as an additional stressor "Altered Habitats" with direct connections to the following ecological effects and pathways:

- Loss of Benefits to Native Emergents
- Composition/Distribution and Biomass of In-Lake Vegetation
- Animal Species Composition and Abundance
- Forage Base, etc.

Each of the above sections (ecological effects, etc.) needs to be linked with suitable text explaining the relationships.

### *8.3.3 Comments specific to stressors inter-related through proposed exotic and nuisance plant control activities driver*

As indicated in the above section, exotic plant control activities should be directly linked to a proposed new stressor "Habitat Alterations" and integrally linked to the Water Quality stressor. The Conceptual Model document addresses *Hydrilla* specifically and includes explanations of the Fluoridone resistant strain of *Hydrilla* that has developed through time in the KCOL. What is neglected is the discussion of the severe habitat alterations to the system that accompany the application treatments. While these alterations may well be fairly short lived in terms of effects to the plant community structure, the consequences to dependent resources may well be long-termed and even catastrophic depending on specific timing. We have direct observational experience in applications of Fluoridone to Lake Tohopekaliga that illustrates the issue and concern (Kitchens et al 2003, Martin et al 2003).

The principle issue is the impact to non-target species of vegetation and subsequently a key stone invertebrate forage base, in this case the apple snail (*Pomacea paludosa*). In response to the Fluoridone resistance, application concentrations have been increased (approx. 4-fold) to levels that are economically feasible only in combination with significant drawdowns of the lake volume. The vulnerability of *Hydrilla* is also seasonal, generally in the mid-to late spring. The resultant is a drawdown that coincides with the peak oviposition season of the snails and the peak breeding season for the endangered snail kite (*Rostrhamus sociabilis*). The snails are essentially a short-lived species, life span on the order of a year. Persistence and abundance of the snails is a matter of annual recruitment. The eggs are typically laid on emergent stems just above the water line, hatching in approximately in two weeks. The stems in the KCOL generally include *Paspalidium*, *Panicum*, *Typha* and others. The Fluoridone is applied in pellet form intended to dissolve to reach target concentrations in specific periods of time. The applications are spatially massive covering thousands of acres in a matter of days, intended to provide a systemic targeted water column concentration. Figure 8.1 provides a graphic depiction of the results. Note the stress to the floating-leafed aquatics and the *Typha* in the background.  In a matter of days following this photo the stems of the of the


**Figure 8-1.** Photograph of site after application of Fluoridone in Lake Tohopekaliga 2002.  (Note the relative robust *Hydrilla* in the water column as opposed to the stressed *Nuphar*.)

emergents were chlorotic, coated with a gel-like slime and most were slumping into the water column.  This application occurred in May 2003. (See Figure 8.2.)  In this instance, the snail egg masses on slumping stems were destroyed by inundation, and the slime coating on the residual stems rendered them useless as oviposition sites and climbing sites for respiration given the snails need to breathe air. This consequence was totally unanticipated.  In addition the approximately 13 or more snail kite nests that were active immediately prior to the application were abandoned *en mass* within 8 days of the application.  The stress was enough for even some of the *Typha* supporting snail kite nests to slump.  We hypothesize that the principal cause of nest abandonment was a result of the slime coatings on the emergent stems impeding snail usage for respiration hence availability to the kites for forage.

The affected areas may or may not recover to pre-treatment conditions, but are severely affected for several critical months.  Treated areas are massive and maintain the distinct smell of rotting and decomposing vegetation.  The impact to water quality is speculative, but certainly results in lowered oxygen concentrations and increased stress for species like the apple snail that essentially is immobile in terms of migrating to more favorable conditions.  No information is available regarding impacts to snail abundances or potential tissue burdens from other herbicides.

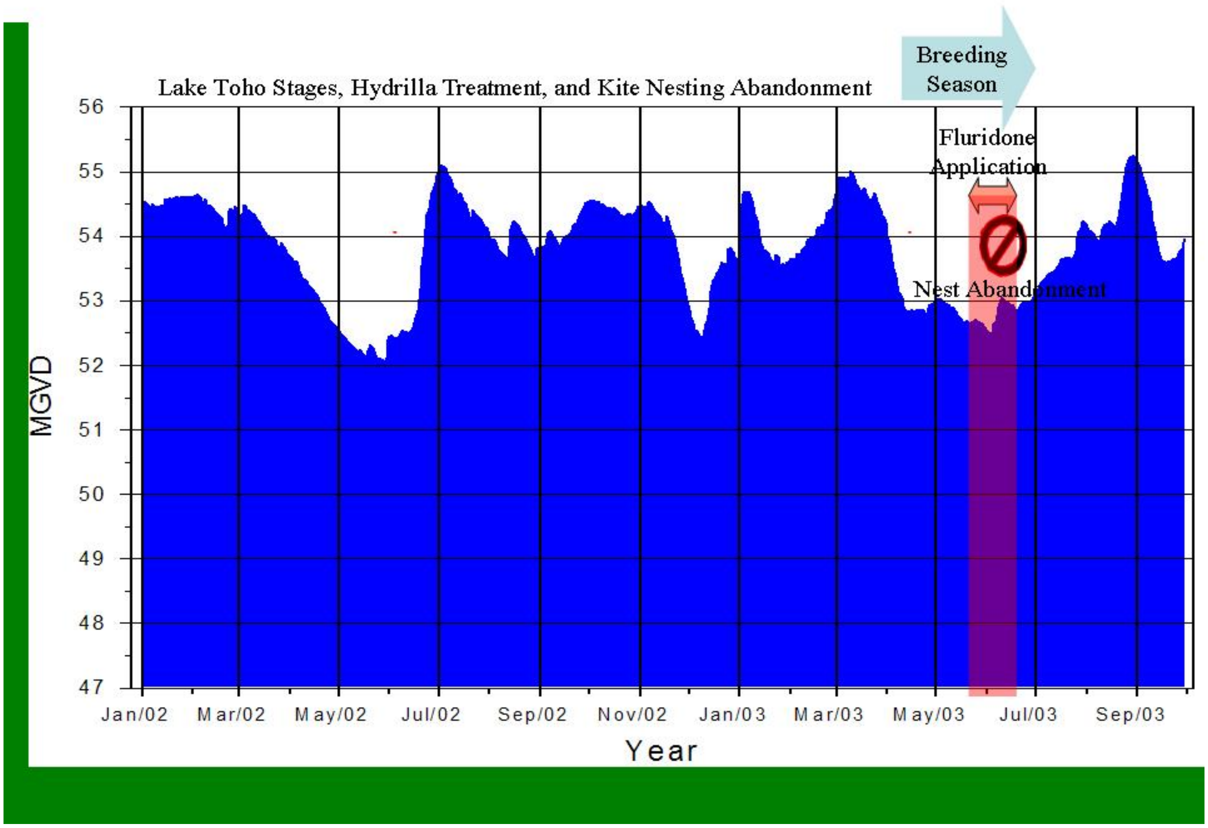
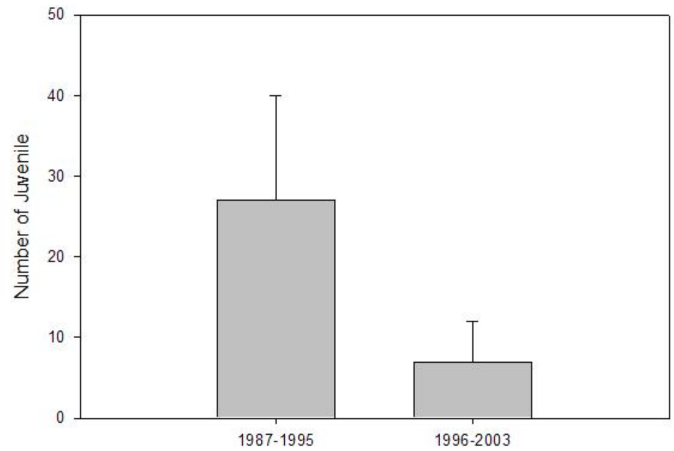



Figure 8-2.  Lake stages, Fluoridone application, and snail kite nest abandonment sequence in Lake Tohopekaliga 2003.

The longer-term consequences of *Hydrilla* treatments and nuisance vegetation management practices on Lake Kissimmee may well be significant.  Figure 8.3 summarizes the reproductive output of snail kites on Lake Kissimmee both prior to- and post-treatment for nuisance aquatic plant management including major *Hydrilla* treatment applications.   The number of birds fledged during the post-treatment time period had been reduced by approximately 75% (Figure 8.3).  Phil Darby has documented an almost identical trend for apple snail abundance for the same time periods.  This factor becomes critically important given the recently documented population declines for the snail kite. The results of viability analyses indicate that unless the reproductive output of the population rebounds to pre-1999 level, the population persistence is highly questionable.  More specifics regarding snail kites will be provided in later sections.




Average number of fledgings in Lake Kissimmee before draw down (1987 to 1995), and after draw down (1996 to 2003). The error bars correspond to the confidence intervals. Data were provided by James Rodgers.

Darby et. al. (2004) documented an almost identical trend for apple snail abundances.

**Figure 8-3.** Comparison of pre-enhancement (including intensive *Hydrilla* treatment) to post-enhancement activities on kite production.

### *8.3.4 Specific comments relative to the following inter-related stressors*

- *Altered Hydrology and Wetland Drainage*
- *Watershed and Shoreline Development*
- *Water Supply and Flood Control*
- *Navigational and Recreational Use*

In addition to the excellent comments in the documentation accompanying the Conceptual Model regarding the above stressors, two important ecological attributes severely impaired by the Central and South Florida Project but omitted in the document are the following:

- Loss of interconnecting wetlands, and
- Confinement within the leveed basins/Loss of lateral expansion.

Prior to the completion of the Central and South Florida Project, given the poor drainage capacity of the soils and low drainage gradients, much of the area was occupied by wetland conditions subject to overflow particularly during wet years. The individual lake basins were generally connected by low lying swamp or wet prairies swales that were subsequently replaced with canal networks and drained. The resultant is individually isolated lake basins and the loss of the wetland continuum in which the basins were embedded. For some species this isolation is a severe disruption to habitat corridors and could represent impacts to faunal movement patterns and exchanges between and among the systems, particularly for amphibians and reptiles. In fact, the loss of these habitats may well be affecting the demography and movement patterns of bird species, particularly snail kites (Martin et al 2005) (See Snail Kite Section).

In addition to constraining dredging canal networks and draining the connecting wetlands, the lake shores were leveed and the stages were managed to dampen or reduce the amplitude of inter- and intra-annual excursions and manage the systems in a relatively stable and high stage condition. Now rather than overflowing out on to a lacustrine floodplain, the lakes are relatively confined to set basins with little lateral expansion in response to volumetric increases. Previously overflow events provided a mechanism to move and deposit massive tussock accumulations to areas in the upper reaches of the floodplain. The resultant was a topographic mosaic that provided habitat diversity. Currently, the managed system only encourages tussock formation and muck accumulation that are now dealt with utilizing costly drawdowns and mechanical scraping.

### *8.3.5 Specific comments on littoral vegetation monitoring*

In vegetation science, the concept of the plant community is fundamental. It is at the community level that populations and individuals of a plant species can be identified and grouped together to characterize the vegetation of an area of a few square meters to several square kilometers. It is also at this level that the effects of allogenic factors are more easily examined and quantified, as interactions between species affect the responses of individual species (Kent and Coker 1992). The metric most frequently used to characterize vegetative communities is Importance Values or IV. Importance value is calculated as the relative dominance + relative density + relative frequency divided by 300. This metric is also an excellent measure of habitat structure and is compatible to the Habitat Suitability Model approach used to derive habitat units for faunal models. Multivariate approaches as per McCune and Grace 2002, provide excellent tools for deriving vegetation habitat responses to alterations in environmental gradients and are particularly useful for wetland and lacustrine systems. Welch and Kitchens (2004) documented major vegetation communities on Lake Tohopekaliga by measuring densities and biomasses of individual species (Figure 8.4 and 8.5), and were able to predict their distributions based on water depths and soil characteristics utilizing Classification and Regression Tree (CART) models (Figure 8.6). This approach is ideally suited to examine the vegetation responses to various hydrologic scenarios.

**Figure 8.4** Average IV's of shallower species at different depths, upon occurrence. Number of absences at a given depth were not included in the averages, therefore values of zero mean the species NEVER occurred in that depth zone.

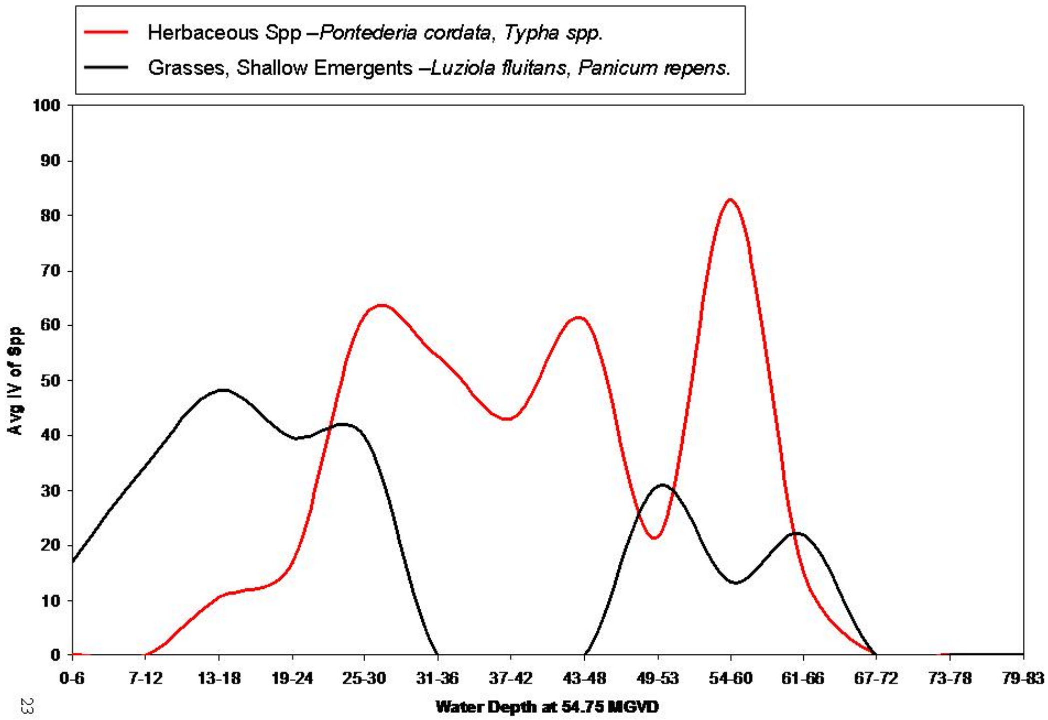



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**Figure 8.5.** Average IV's of deeper species at different depths, upon occurrence. Number of absences at a given depth were not included in the averages, therefore values of zero mean the species NEVER occurred in that depth zone.

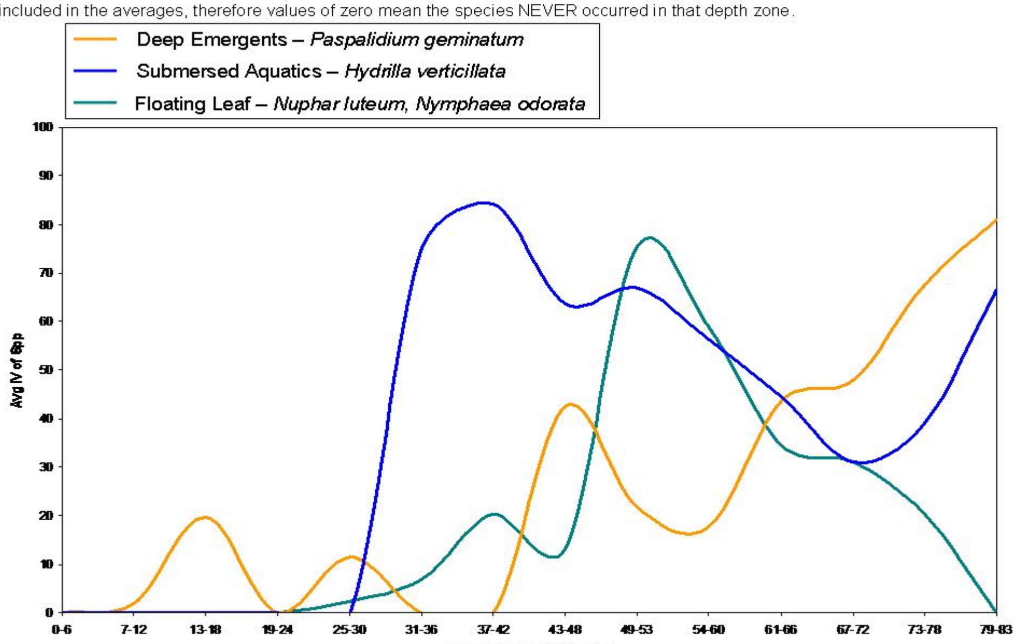


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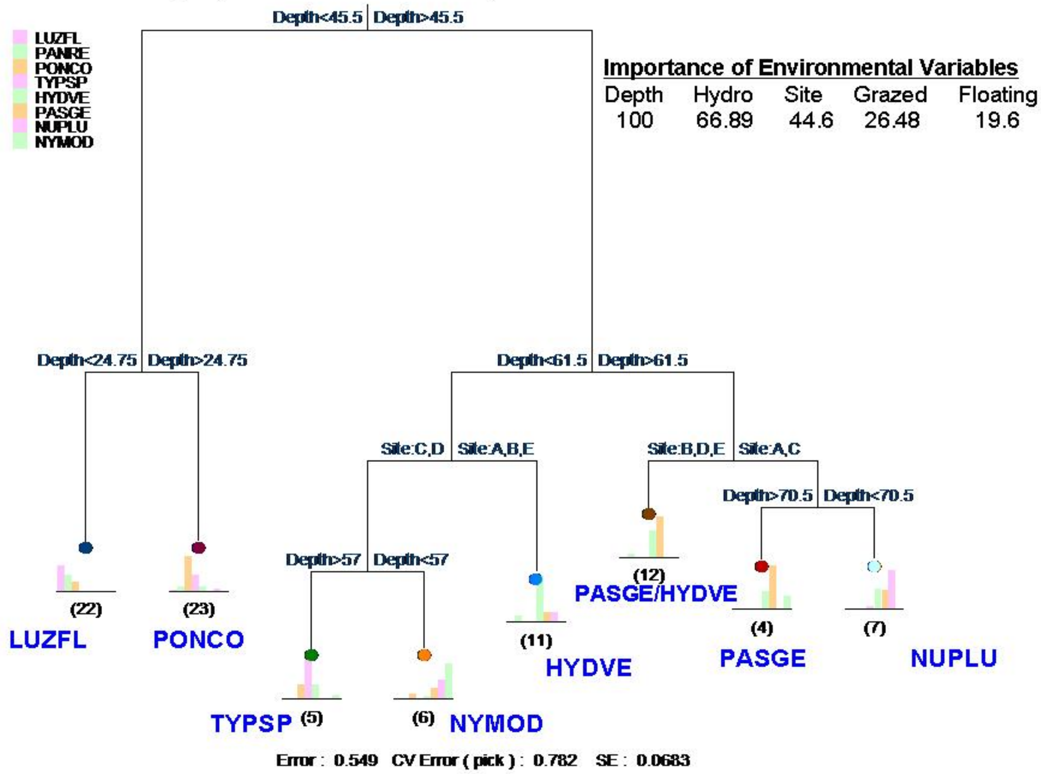
**Figure 8.6** CART model of eight species based on their relationship to the environmental variables listed below.




The CART model above was developed for littoral vegetation of Lake Tohopekaliga (Welch 2004) immediately before and after a major drawdown event. The color swatches in upper left corner are codified to abbreviations of the major community types named for dominant species groups. The bars under each branch of the tree model portray the proportional composition of each of the community types in that branch or leaf. By establishing permanent plots throughout the lake, the quantitative effects of future management efforts can be measured and documented in the future. Such a sample design allows for detection of important changes in habitat structure, whether it's vegetation biomass, density, physiognomy, or species composition, all of which directly affect its value as habitat to microflora (Wetzel 1975) and fauna (Tonn and Magnuson 1982, Pieczynska 1990). Qualitative estimates of habitat quality, whether it's percent cover or presence/absence, provide a quick and dirty picture of approximate species composition and distribution, but are likely to miss subtle changes in habitat structure, or shifts in community compositions. Additionally, without establishing permanent sites to be repeatedly measured over time, spatial variance will most likely outweigh any temporal changes in community characteristics. Other studies on Florida lakes (Lake Watch) have implemented crude biomass measures in an attempt to document littoral communities, but from too few sample locations, from different points over time (no repeated measures), without stem densities, and stratified by community type, rather than an environmental gradient. These studies would be unable to document changes in species abundance, biomass, density, community composition, or community distribution, and are geared more towards overall macrophyte biomass and trophic state of the lake.

### 8.3.6 Specific comments regarding wading birds

The omission of the sandhill crane and limpkin from the performance measures is a serious ecological omission. Both species are listed by the State of Florida as Species of Special Concern and both utilize the littoral habitats of the lakes within the KCOL for nesting.

The Florida sandhill crane is additionally listed federally as a threatened species. The subspecies is essentially a non-migratory flock that range from southern Georgia to the Everglades. It is listed as threatened due to low productivity, habitat degradation through wetland drainage throughout its range and development and direct human encroachment. Cranes prefer to nest in sites of monotypic vegetation as occurs throughout the shallow littoral reaches of the lakes within the KCOL. Typically nests are placed in vegetation clumps in water depths of 30-40 cm. which generally determine the vegetative cover types from year to year (Bennett and Bennett 1987). Figure 8.7 is a map of sandhill nest structure locations in the littoral reaches of Lake Tohopekaliga in 2002 as determined by an aerial survey by helicopter. Nesting pairs often construct several structures before beginning the nesting process. Even assuming an individual pair might construct up to 4 structures, it is evident in Figure 8.7 that the cranes utilize the littoral reaches of the lake with very high nest densities. There were over 200 nest structures in this survey.

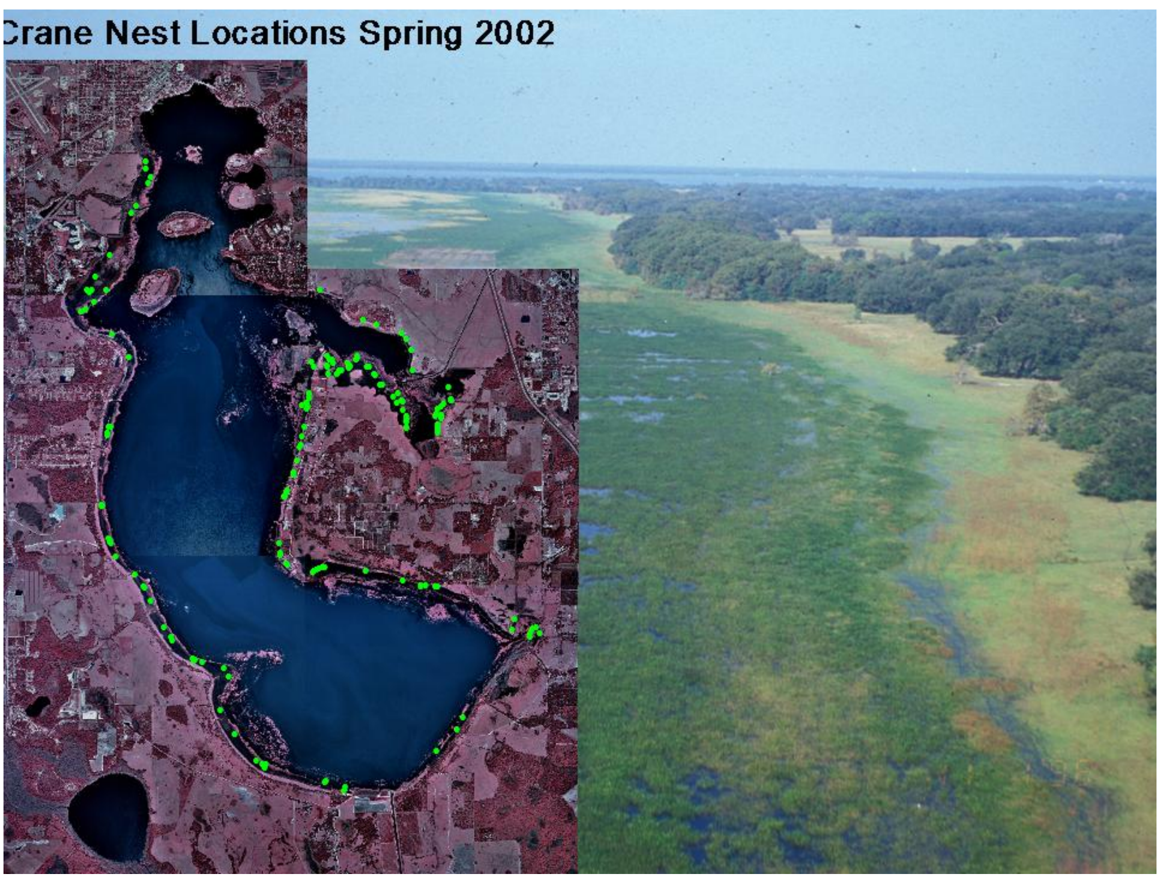



**Figure 8-7.** Sandhill crane nest locations in the littoral reaches of Lake Tohopekaliga. Each green dot represents one nest structure.

As mentioned in the summary section, the KCOL was chosen among a number of potential sites nationally for the re-introduction of the endangered Whooping Crane. One of the criteria driving this decision was the presence of a robust flock of resident non-migratory Florida sandhill cranes as well as ample nesting habitat both within the in-lake littoral habitats as well as palustrine wetlands in the ranchlands surrounding the lakes. The palustrine systems are continually be lost to development making the littoral nesting habitat increasingly more vital to the cranes of both species.

### *8.3.7 Specific comments relative to Snail Kites as performance measures*

Given the recent decline of federally endangered Snail Kite, it is critical that any management action plan potentially affecting kite habitats be carefully evaluated. Given that adult survival is generally high and stable, reproductive success and recruitment are absolutely critical to re-establishing a stable and viable kite population (Martin and Kitchens 2003). Although the carrying capacity of the KCOL for kites is lower than the Water Conservation Areas (WCA's), the KCOL is essential to kites for at least two reasons. First, the KCOL is a major refuge during regional drought as noted in 1990 and 2001. In the absence of this refuge, the population might well have already decreased to non-viable levels. Further, The KCOL has persistently contributed to annual kite reproduction. Over the years 1999-2004, this annual contribution is approximately 20 young birds fledged per year (Figure 8.8).

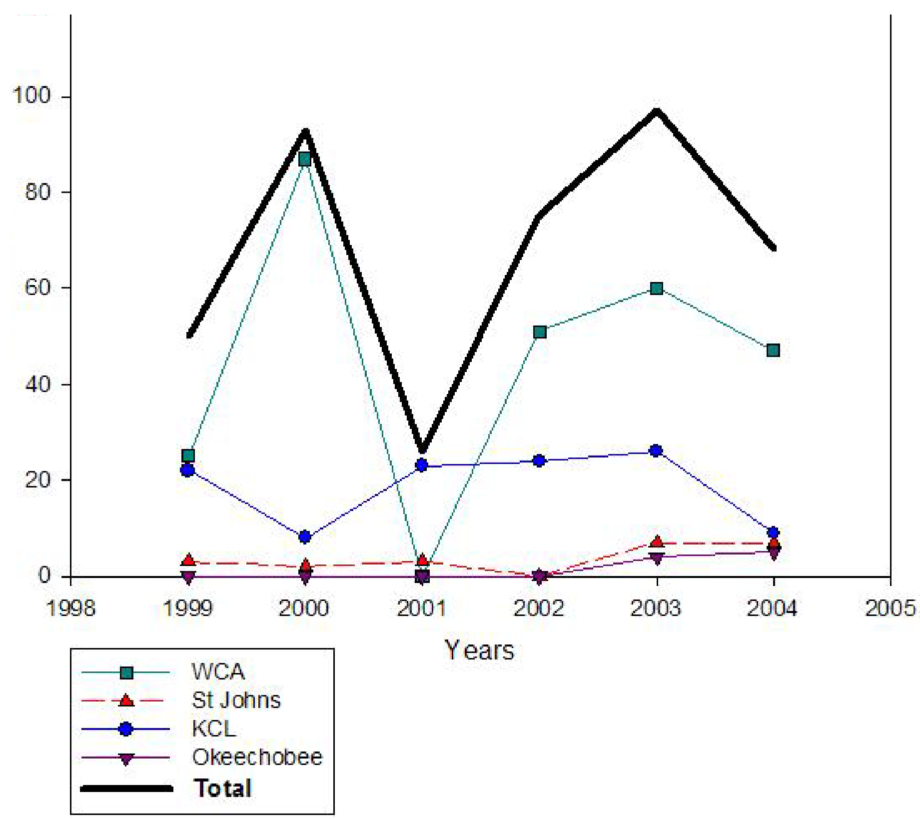



**Figure 8-8.** Number of kites fledged from major habitat units across range.

Proportionally, the contribution is increasing as a result of degradation of habitats and/or the residual effects of past droughts in the WCA's. This is critically important, particularly during this period of population decline as described above. The value of the KCOL to kite recruitment has increased substantially and is vital to population persistence (Figure 8.9). During the 2005 breeding season, 100% of the birds fledged during that year were produced outside the WCA's. Prior to 1999 the KCOL only produced 12% of the total population of young. After 1999 the KCOL produced over 27% of the total number of young fledged in the entire state, making it the second most productive area, after the WCA's. During the 2001 drought, this percentage rose to 88%.

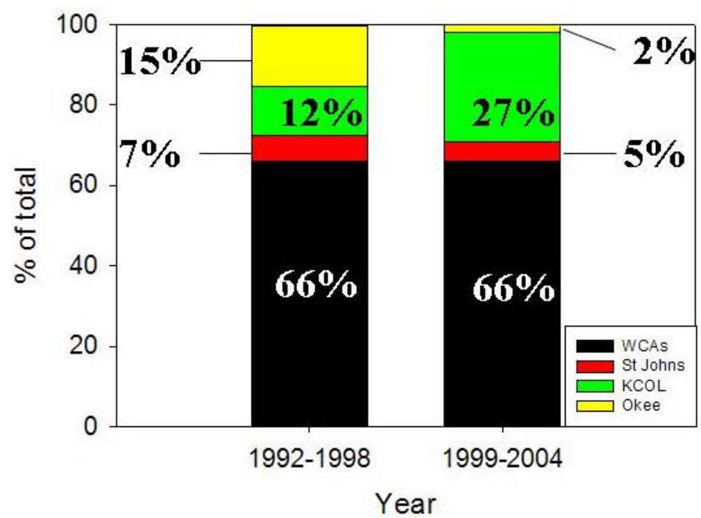



**Figure 8-9.** Proportional production of kites in four major habitats in Florida.

Additionally, kites do not move as extensively as previously thought. Our recent study (Martin et al. 2005), has shown a high level of site fidelity (including natal fidelity) to the KCOL. In the past it was assumed that kites move freely from the most to the least disturbed areas. Recent movement analysis found that the distance between wetlands, wetland size and the extent of matrix areas (areas unsuitable to kites: essentially non-wetland areas), affected bird movement. In particular birds are less likely to move between wetlands that are separated by large extents of developed areas. Thus, we found that movements between the wetlands constituting the KCOL were considerably higher than between the KCOL and any other group of wetlands (e.g., WCA's, Lake Okeechobee, St Johns, West Palm Beach Water Catchment Area). Movement costs (in terms of survival) are likely to be considerably lower when birds move within the lakes of the KCOL than between those lakes and any other wetlands outside the KCOL.

In light of the above considerations it would be a risky strategy to use indirect performance measures as proposed in the draft report. Instead, direct performance measures based on robust estimates of snail kite vital rates would be more appropriate. The most critical vital rates are: Survival, movement rates (caused by management actions), reproduction (e.g., nest success, number of young produced) and population size. All these parameters have been collected for many years. In addition we have been working with Don De Angelis and Wolf Mooij in the development and refinement of an individually based population model of the kites (EVERKITE, Mooij et al 2002) that has direct coupling capability to hydrologic models for assessment of hydrologic scenarios on the kite population. In addition we are in the process of refining an HIS type model that evaluates the impact of hydrologic regulation schedules on the breeding potential for the kite for any given year.

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