IEP Science Advisory Group Review of the IEP Environmental Monitoring Program

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1. INTRODUCTION

A core element of the Interagency Ecological Program (IEP) is the Environmental Monitoring Program (EMP), mandated by the State Water Resources Control Board to document the changing status of water quality and biological communities in the Sacramento-San Joaquin River Delta and downstream embayments of San Francisco Bay. Sustained, uninterrupted operation of the EMP for over 30 years is a remarkable achievement that in many ways serves as a model of successful state-federal partnership in environmental monitoring, providing one of the longest and most valuable records of combined water quality-biological monitoring in the U.S. The State Board was visionary in its monitoring requirement as a condition for operating the State Water Project and Central Valley Project, and the participating state and federal agencies should take great pride in their commitments of resources required to sustain the EMP. Members of the IEP Science Advisory Group (SAG), including outside specialists recruited for this technical review, are unanimous in our strong endorsement of the Environmental Monitoring Program, our recognition of its

enormous value, and our belief in the critical importance of its continuation during this era of fast-paced and high-impact changes to the Bay-Delta ecosystem.

Members of the IEP Science Advisory Group (SAG), including outside specialists recruited for the EMP technical review, unanimously endorsed the Environmental Monitoring Program. We recognize its enormous value, and continuation during this era of fast-paced and high-impact changes to the Bay-Delta ecosystem is of critical importance. Members of the SAG also commend the IEP coordinators for recognizing the importance of self evaluation and independent outside technical peer review geared toward "balanced, scientifically sound, environmental monitoring" designed to address both management needs and critical uncertainties in our understanding of the Bay-Delta ecosystem. Finally, we would like to express our sincere admiration for the manner in which the EMP revision process has been conducted by Zach Hymanson and Anke Mueller-Solger

Early in the review process, members of the SAG identified two practical realities of the EMP that constrain the nature of our recommendations. First, the EMP is mandated to provide data to meet four general informational needs: (1) compliance with standards of drinking-water quality (conductivity), (2) compliance with standards for dissolved oxygen, (3) data for building/testing models, and (4) measurements to document trends of change in living resources. This mandate implies that recommendations of large-scale structural changes in the EMP or its goals would be inappropriate. Second, the levels of funding and human resources dedicated to the EMP are somewhat limited, so it would be equally inappropriate for us to recommend expansion of the scale or scope of the EMP. Given these two important constraints, we viewed our task as one of providing general guidance about how to design the most efficient and useful program of environmental monitoring. We also guided our review with the practical reality that a long list of general recommendations would be of less value to IEP managers than a concise set of recommendations of changes that could have the biggest impact on the efficiency and value of the EMP. Our assessment includes two general recommendations directed toward the IEP Coordinators and

EMP manager, reflecting the consensus view of the SAG about the highest-priority areas of potential EMP improvement. We also include a list of detailed comments and recommendations about methods, sampling design, data analyses and reporting directed toward specialists responsible for the collection and analysis of samples collected within the four sub-areas.

We strongly endorse the proposed re-design of the water-quality monitoring program, giving increased emphasis to the continuous collection of data with moored instruments at strategically-placed sites. This re-design, conceived by members of the water-quality subject area team, uses modern instrumentation to collect high-quality data over a range of time scales that are important to the ecosystem but inaccessible through traditional designs of collecting discrete water samples. The suggested positioning of moored instruments is based on new and refined understanding of bathymetric controls on water circulation, so the spatial sampling reflects the contemporary understanding of how water circulation influences the spatial distribution of biota and water-quality constituents. When done in concert with flow measurements, the continuous measurement of biological and chemical quantities provides a new and important capability of the EMP to measure the transports of these constituents between geographic regions of the Bay-Delta, which are important for identifying the underlying causes of water-quality and biological variability. The precise design (number and location of moored instruments) should involve continued debate and analysis, and the sensor arrays should also be re-considered to include additional instruments for measuring chlorophyll fluorescence, suspended sediments and dissolved oxygen. But the general recommendation to take advantage of modern submersible instrumentation and data-telemetry capabilities is consistent with the goal of a scientifically sound monitoring program, especially when the elements of continuous measurement are closely coordinated and calibrated with measurements on discrete water samples.

Our first general recommendation is that EMP data collection should be tied to specific questions that are germane to the original reasons for initiating the program.

This recommendation is based on the idea that specifying detail in sampling design requires specifying some detail in the questions of interest. For example, if the question of interest is: Do flow diversions affect the supply of organic mattter to the lowest trophic levels of the Bay/Delta, then mass balances on organic carbon (c.f. Jassby et al 1993, Jassby and Cloern 2000) can to be used to evaluate trends in "ecosystem health". In this case, the sampling strategy would need to be designed so as to measure fluxes of materials through critical sections (see also CalFed CCMP document). In this regard, transferring effort to time series stations from fixed stations make sense, although, it also requires that "special studies" be done to develop empirical relationships that would permit fluxes to be computed from point measurements, much as rating curves are developed for stream gauging.

As we discuss below, this issue of connecting question and design was felt to be critical for the benthos sampling for which it was felt that temporal variability of the sampling effort was more than adequate for observing status and trends of the system, whereas the spatial variability, especially between shoals and the channel were not. This case also illustrates the importance of the question: if the interest in benthos is to understand the effect of benthic filter feeders (esp. Potamocorbula and Corbicula) on primary production, then accurate estimates of benthic biomass is critical. Finally, the benthos sampling design also makes an important point that we must acknowledge that the original issues that were used to formulate the sampling design, e.g. more classical ideas of eutrophication and water quality (as explained to us by Zach Hymanson), have been supplanted by newer problems such as the effects of invasive species or the trophic transfers of contaminants like selenium. While the mechanisms through which these affect ecosystem health may be more subtle, there is no question that water project operations play a role in determining that effect and hence should be considered in developing the sampling design.

Our second general recommendation comes from our collective experience teaching that the value of data collected in any research or monitoring program varies in direct proportion to the intellectual investment of the people involved and the

incentive to contribute their results to the larger estuarine research/management community through peer-reviewed journal publication. The quality and value of the zooplankton component of the EMP have been consistently high because the people involved in the design of the program and collection and analysis of samples have made additional investments of their time to explore the data and identify key patterns of change. They also have utilized data collected by other IEP sub-programs to search for mechanisms behind these patterns. Pushing the nature of the work beyond data collection and archival, culminating in publications in the peer-reviewed literature, has ensured that the quality of the zooplankton element of the EMP would meet rigorous criteria of quality control and assurance.

Human nature dictates that we are more careful and self-critical when we are held accountable for our work and when we see that others use our products. The value and quality of monitoring programs are highest when the goal extends beyond the simple collection and reporting of data toward the application of those data to develop useful products – in this case, information about the changing condition of the Delta-Bay system. There are large differences among the four sub-areas of the EMP in this human investment, resulting in large differences in the utility and quality of the data produced by the sub-programs for water quality, phytoplankton, zooplankton, and benthos. The SAG has a high degree of confidence in the quality of the zooplankton data collected within the EMP. This sub-program has been unusually valuable because of its careful documentation of long-term changes in the abundance, biomass, species composition and spatial distribution of this important community of forage biota for planktivorous fish. These practices do not apply to all four sub-areas.

Just as importantly, the changes documented by this program have influenced both our conceptual understanding and management of the Bay-Delta system. Creation of CALFED as a high-visibility entity of resource management and restoration was built on a foundation of monitoring that documented declines of living resources in the Delta and environs. The zooplankton component of EMP was an important brick in that foundation. We encourage the IEP Coordinators and EMP

Manager to extend the level of human intellectual investment made in the other sub-programs, as a step toward both increased data quality and utility.

2. Area-Specific Recommendations & Comments

a. Sampling Design

We recommend that the first analyses of monitoring data be directed toward the question: How should continuous and discrete sampling be designed to meet the specific monitoring goals of the four EMP sub-programs? Although it might be expected that our review could answer this first-order question, because sampling location is closely tied to the goals and aims of a sampling program, we could not. Although the EMP does have stated goals, they are not specific enough to constrain sampling choices. It is possible that different aims require different programs, and that not all aims can be satisfied simultaneously with existing resources. In any case, the first step is to be as specific as possible about aims. Once the aims are prescribed, design of an appropriate sampling scheme will require measurements of the inherent spatial patchiness, regional variability, and temporal fluctuations of the benthos and phytoplankton. We suggest that the goal of "balanced, scientifically sound, environmental monitoring" can best be attained if IEP management launches a new effort combining special studies with analyses of existing data to identify the most effective sampling design for each sub-program, after first identifying the specific aim of each sub-program. Some suggestion as to aims for sampling subprograms are listed at the end of this document.

Sampling time concerns the distribution of continuous and discrete stations, as well as the sampling frequency for discrete stations. Certain situations—mass balance and model boundaries, habitat "index stations", etc.—require continuous monitoring. Locations in particularly high gradients should also be continuously monitored because of their high variability. Discrete sites can be seen as "fill-in" sites primarily for supplementing continuous sites to discern region-wide behavior. Discrete sampling

will also need to take place at “continuous” stations, both as a check on continuous measurements and for variables for which continuous sensors are not available.

The sampling frequency at discrete stations depends on aims in much the same way as the station distribution. For example, sampling alternately at spring and neap tides—the current proposal—decreases bias and is suitable for determining long-term means. On the other hand, for example, if changing seasonal pattern is of interest, it could be preferable to accept bias and decrease noise by sampling at the same stage of the spring-neap cycle. (In either case, the historic method of sampling at fixed calendar intervals is inappropriate.) We note that a first-order estimate of this spring-neap bias can be obtained by spatial translation of observed distributions of properties of interest (e.g. salinity) using tidal excursions derived from current observations or from modeling.

Clearly, interesting and challenging issues arise when we are more specific about the aims of this program. The first step is therefore to consider the aims in more detail. Given a set of aims, many issues about choosing stations can be resolved with the existing record, which should be exploited fully before deciding on the future shape of the EMP. Once an “optimal” set of locations is chosen, it will be important to take advantage of existing programs and eliminate redundancies in them. A comprehensive station database that includes all agencies and is suitable for GIS query and display would be invaluable in this activity and relatively easy to assemble.

B. BENTHOS

The benthic environment plays a fundamentally important role in modifying and regulating many physical, chemical, and biological processes in estuarine systems. Benthic communities integrate both spatially and temporally these biotic and abiotic processes, and provide a biological measure of local and larger-scale environmental conditions. Accordingly, assessment of benthic faunal assemblages has been and continues to be an integral part of the IEP’s Environmental Monitoring Program. This long-term effort has resulted in an extensive database of physical, chemical, and

biological information about the benthic environment in the upper estuary of the San Francisco Bay-Delta system.

Although a wealth of data has been collected as part of the benthic studies component of the EMP, it is apparent to the SAG that comprehensive evaluation of this information and the subsequent insight that it could provide with respect to guiding the direction and scope of ongoing monitoring efforts are lacking. In this regard, we feel that the most responsible recommendation to members of the IEP is to recognize the need to undertake a critical review of the present study design in the context of ensuring that it provides the most cost effective and scientifically sound approach for meeting specific program objectives. With respect to the benthic studies component, it is suggested that specific monitoring objectives be identified that incorporate measures of biological response which best integrate and define the natural and anthropogenic derived changes in the local and regional environment. It is of particular importance that these objectives be framed in the context of how information derived from the benthic studies can be used to develop decision-based models for characterizing existing and changing conditions in the estuarine system. Lastly, we encourage that formulation of objectives be based on consideration of the interdependence of sampling design, data analyses, and overall program goals.

C. PHYTOPLANKTON

The SAG has similar recommendations with respect to the phytoplankton component of the EMP. Careful documentation of changes in the abundance and species composition of the phytoplankton can provide highly valuable information about this important biological community that responds to environmental variability and influences ecosystem status through its influence on the quality of drinking water and the food supply to zooplankton and benthos. Several useful studies have been published by Dr. Lehman of the EMP that attest to this potential. However, the specific objectives of this EMP element have also not been identified so the potentially rich information content of this monitoring element has not been fully exploited. Just

as importantly, the primary-producer subject area team has identified deficiencies in the procedures used to enumerate phytoplankton abundance, such that the quality of this data set is questionable. We applaud the efforts of this team to begin the process of evaluating the quality of past enumerations and to consider establishment of more standard procedures to ensure practices and data that would meet tests of quality assurance and control. Finally, the SAG is disappointed to learn that phytoplankton data are not readily available. The availability, quality and value of the phytoplankton data are substantially less than they could be. Unless the EMP Manager and IEP Coordinators can identify a compelling reason to maintain this EMP element in its current form, we suggest that they consider a substantial re-allocation of the resources used with reduced efforts toward phytoplankton taxonomy, perhaps by thoughtfully compositing samples, and enhanced emphasis on maintenance and calibration of moored fluorometers to measure concentrations and fluxes of phytoplankton chlorophyll biomass.

3. INTEGRATION AND CONCLUSIONS

While the SAG reviewers found the recommendations for the next generation of the EMP to significantly enhance the interpretive power within the four EMP elements, they were disappointed by a patent lack of integration among the elements. Although there was some effort to enhance logistic efficiency between several program elements, such as the Phytoplankton and Zooplankton, during field sampling, there was little indication that data and understanding from one program element would necessarily be used to any significant degree to interpret the results of another element. We do appreciate that each program elements, as we now view them, typically evolved within the EMP over different, punctuated histories. Thus, we hardly expect all-embracing integration at the point of this review. However, while the need for synthesis of products is very appropriately highlighted in the *Environmental Monitoring Program, Review and Recommendations* (Draft II, December 2001), the

authors do not address the need for internal Program integration in this "reborn" version of the EMP.

Considerably more integration of EMP program elements is necessary if interpretation of ecological processes and interactions are expected from the different EMP monitoring data. This is a critical opportunity missed. For instance, the hydrodynamics component of the Water Quality element would or should be generating critical information that would relate tidal currents, water column structure and water quality parameters (e.g., salinity/conductivity) to the composition, concentration and production rates (where applicable) of phytoplankton, zooplankton and benthos. And, were larval fish and meroplankton composition and density/standing stock to become additional EMP monitoring variables, these should not only be directly related to the EMP Water Quality element, but equally to the Benthos element (e.g., where the meroplankton are destined, to some degree).

Such integration must encompass conceptual, sampling design and analytical aspects of the program. At the moment the four elements are almost entirely independent, to some degree in the field but seemingly entirely in analysis and interpretation. In many cases, both an economy of scale/efficiency and scientific integration would benefit from considerably more spatial/temporal overlap in the field sampling. Obviously, this may be problematic and add costs in terms of sampling logistics and long-term data consistency in the case of persistent sampling stations and protocols. However, any new or altered stations/protocols offer enhanced opportunities for integration, e.g., a test of the concept. While in the summary *Environmental Monitoring Program, Review and Recommendations* (Draft II, December 2001), there is some attempt to achieve integration across sampling design by the establishment of 16 "core" stations, it is unclear whether this is simply a spatial correspondence or initiative for more coordinated sampling?

Some (not all) members of the SAG recommend that the IEP should also examine the value of new integrative tools, such as remote sensing, for future consolidation of the EMP. Both satellite and airborne platform sensors offer

comprehensive sampling of a variety of parameters important to, and measured by, the EMP at a variety of resolutions (29-m to sub-meter, depending upon sensor and platform), e.g., chlorophyll/fluorescence, turbidity/suspended sediment, DOC. Although such remote sensing is often limited by the same "snapshot" biases as much of the EMP sampling design, it does provide the power of broad spatial coverage that could be calibrated by strategic *in situ* EMP ("groundtruthing") sampling over the Bay-Delta.

It is the opinion of the SAG that the long term EMP monitoring program is a very good activity that should be continued. Nonetheless, it is clear that the goals must be more precisely defined no matter what modifications are implemented. Water quality, phytoplankton, zooplankton, and benthos sampling and analyses have been carried out in the Delta region from the head of tides of the Sacramento and San Joaquin rivers down into San Pablo Bay with a spatial coverage, frequency, and duration that is truly exceptional in the world of estuarine resource management and science. By combining the beginnings of the food web involving phytoplankton and pelagic and benthic consumers with water quality parameters, a unique data set has resulted that gives ability to assess the ecological condition and impacts of water management activities. Management of water resources based on understanding of down-stream impact provides a Twenty-first Century approach to resource management replacing the older "command and control" techniques of the past. Several European nations and enlightened states in the US are moving in this direction and the IEP is to be praised for the vision in setting up this program. Only through agencies like the IEP is it possible to develop the long-term data acquisition that can be used jointly by resource mangers and research scientists to understand the impact of human activities in the background of natural change. The primary recommendation of the SAG is that the IEP scientists, internally and working with researchers outside the program, dedicate more time to rapid assessment of the data to develop information. As soon as possible after collection of samples and completion of laboratory analyses, the data should be interpreted in relation to spatial and temporal

trends as well as conceptual models and theories. It is necessary to integrate information from water quality, phytoplankton, zooplankton, and benthos to understand linkages and interpret impacts of natural (seasonal, climatic) and management activities. The payoffs of this interpretation are great for being able to modify the monitoring activities for greater efficiency and efficacy and are essential to make the monitoring serve the purpose of guiding resource management.

Aims for sampling design

Alan Jassby

Some aims for sampling subprograms suggested for consideration, and their implications, are listed below.

1. Continuity of the historical record. Some stations go back to 1968 when the USBR data are included. This aim implies retaining these stations. But most stations have large gaps in the data set and are not that precious from this viewpoint. Stations should be ranked by some measure of continuity in key variables. Some of the top ones may be redundant according to other criteria. The few top non-redundant stations should be designated "long-term" stations and kept in operation.

2. Estimating mass balances. There are several examples of critical insight gained through mass balances of chlorophyll and other variables. The region of interest must be chosen (e.g., Delta, Suisun Bay, Delta + Suisun Bay) and flow (and concentration, if possible) should be measured continuously at the upstream and downstream boundaries. In most cases, the export load is important, which requires careful attention to sampling around the export pumps. In the past, P12 and C9 served these purposes. A related issue is the upstream boundary on the San Joaquin. In the past, Vernalis played this role. Although Mossdale is more convenient for sampling, it exhibits unique behavior with respect to chlorophyll and some other variables compared to Vernalis and most other stations. Is Mossdale under the influence of purely local conditions? This needs resolution before a San Joaquin boundary can be chosen.

3. Estimating system-wide averages. Delta-wide (or other regional) averages are important for several reasons, including mass balances and characterizing conditions for wide-ranging organisms. Moreover, variability at individual stations is strongly affected by flow and it is difficult to discern other causal mechanisms at these stations when sampling is discrete. For example, a peak in chlorophyll may simply be translated from an upstream to a downstream part of the region by a flow increase.

From the view point of an upstream or a downstream station, chlorophyll concentration would appear highly variable, whereas a regional average would register no variability. To obtain regional averages reliably and efficiently, it is necessary to stratify the region by magnitude—e.g., some form of cluster analysis—and ensure that each stratum is represented and not over-represented. In the proposed EMP scheme, potential gaps might occur in the southern Delta.

4. Determining mechanisms underlying system-wide dynamics. Unfortunately, stratification for determining causal mechanisms could require a different set of stations than for determining averages. In the case of averages, stations within a stratum should have the same magnitudes. But in the case of dynamics, stations within the same stratum should be correlated in time; their magnitudes could be very different, in principle. Stratification would then be done by a PCA regionalization technique, common in oceanography and meteorology. We believe that previous attempts to regionalize the upper estuary relied on conventional clustering techniques and are more suited to determining averages rather than mechanisms.

5. Characterize habitat types. The program must ensure that each habitat type is represented at least once, preferably by three stations if generalizations are needed about habitat type. Because of the difficulty in analyzing individual discrete stations (see above) and the probable lack of habitat-wide coverage, habitat-specific stations should be continuous.

6. Special applications such as compliance and modeling. There will always be some sites that are important for legal reasons, as boundaries for models, or some other purpose. These sites will usually need to be continuous as well.

Specific Recommendations on Water Quality and Phytoplankton Monitoring

Jonathan H. Sharp

The revised station plan proposed by the Water Quality SAT appears to be very good since it emphasizes more continuous monitoring stations than discrete and has the discrete stations all co-located with continuous stations (see comments from Jassby on specific stations). It is important to keep some discrete stations with regular sampling of parameters sampled over the history of the program and also parameters measured by continuous monitoring. Also, by maintaining these discrete stations, locations are available for future add-ons of regular parameters or experimental ones that can benefit from the historical water quality picture available from the long-term sampling. However, it is necessary to take a close look at the parameters and methods being used for both the discrete sampling and continuous sampling.

In the continuous sampling, it is worthless to measure dissolved oxygen, pH, and chlorophyll fluorescence unless the sensors are frequently calibrated and maintained. Oxygen and pH electrodes will foul and have electronic drift. They must be inspected, cleaned, and have electrolytes replaced with sufficient frequency to overcome fouling from the environment and changes from use. In addition, it is necessary to calibrate them at a frequency at least as often as that recommended by the manufacturer, and maybe more often. Fluorometers used for *in vivo* chlorophyll a fluorescence read in relative fluorescence units and there is no absolute correlation with chlorophyll a concentration. Each fluorometer must be individually calibrated by collecting a discrete sample for extracted chlorophyll analysis at the same time that a relative fluorescence reading is recorded. The discrete sample should then be analyzed for *in vitro* chlorophyll a in the same fashion that is used for the regular discrete sample chlorophyll analysis (see discussion below). Because the relationship between *in vivo* and *in vitro* fluorescence is not absolute, it is necessary to collect a number of samples for this calibration (on the order of 10 samples preferably from varying chlorophyll concentrations). Depending on empirical analysis of drift, it will probably be necessary to recalibrate the continuous measurement fluorometers every 6

to 12 months). This calibration activity need not necessarily be done as a special or separate activity, but can be carried out by having discrete sampling at a station done with recording of the fluorometer reading at exactly the time of the discrete sample.

The parameters sampled at the discrete sample stations should be re-evaluated partially by examining data from the past; the suggestions below come from my experience with long-term multi-state agency water quality monitoring on the Delaware Estuary combined with interpretation from my own research sampling at the same sites over the past two and one-half decades.

The measurement of total dissolved solids (TDS) probably shows little important information; it is a measure of the total ionic and organic content of the water. A conservative measure of the fresh water ionic content that is both easy to measure and can be an informative parameter is the electrical conductivity. For salt containing samples, electrical conductivity is used to measure salinity. At salinities below 0.5 (on the Practical Salinity Unit Scale), salinity is often not calculated from the conductivity since the individual non-marine origin ions will be equally or more influential than dilute seawater ions. However, the electrical conductivity can be recorded in these waters as an accurate estimate of the inorganic TDS. This can be informative in a tidal setting showing the gradient between the head-of-tides ionic content and that of dilute seawater. Simple direct conductivity measurements can be made at the time of sample collection for discrete samples and can also be included in the continuous monitoring. It may be necessary to modify slightly the instruments currently used for salinity measurements. For salinity, the conversion from conductivity in some cases is based on an older third-order polynomial that will give negative salinity at very low conductivity; a better fifth-order polynomial will not give negative salinities.

The measure of volatile suspended sediments (VSS) is an indicator of organic content of the particulate matter in the water sample. It is probably more informative to directly measure particulate organic carbon and nitrogen (all modern particulate carbon analyzers simultaneously measure nitrogen). I recommend that particulate

C/N be measured instead of VSS. If there is concern of consistency, analysis of particulate C/N and VSS could be made on paired samples for one year to calibrate the changed parameter. The VSS as a measure of total particulate organic matter should be equal to approximately two times the particulate C concentration.

Water quality monitoring often includes Total Kjeldahl Nitrogen (TKN), which is used as an indicator of organic nitrogen when the inorganic nitrogen content is subtracted. On unfiltered samples, it would include particulate organic nitrogen as well as dissolved. The problem with TKN measurements is that the chemical decomposition of the sample does not use a strong enough oxidant to assure complete conversion of all organic compounds. In addition, depending upon practice, either ammonium nitrogen or total dissolved inorganic nitrogen (ammonium and nitrate plus nitrite) is subtracted from the TKN to calculate the organic nitrogen. Nitrogen chemistry is complex and varying degrees of oxidation and reduction can co-occur resulting in incomplete recover of the inorganic nitrogen compounds. I strongly suggest abandoning TKN. In place of this measure, I would suggest measuring total dissolved nitrogen (TDN). Recent research shows very good success with TDN measurements in seawater by several different methods. With this complete conversion of the organic nitrogen compounds and inorganic ions to the final analyte, TDN measurements allow accurate determination of dissolved organic nitrogen.

I would also add measurement of dissolved organic carbon (DOC) as a routine parameter. For a modest one-time capital expense, a modern analyzer can be purchased which will allow rapid, easy, and accurate analysis of DOC and TDN simultaneously on single samples. Direct measurements of particulate C/N (suggested above) and DOC/TDN allows complete coverage of the particulate and dissolved organic carbon and nitrogen pools. Measurements of these parameters allows estimates of fluxes of organic matter from various compartments in the monitoring region. By abandoning the currently used TDS, VSS, TKN, and DON measurements and substituting particulate C/N and DOC/TDN, simpler, more direct and more accurate determination of critical parameters will result. Once instituted, these

modified determinations should ultimately be less expensive than those currently measured.

I recommend substituting fluorometric analysis for spectrophotometric analysis for chlorophyll a on extracted samples. There are several reasons for this substitution. First, the fluorometric analysis is considerably more sensitive and thus can be done easily with low chlorophyll concentrations. Second, smaller samples can be used for the chlorophyll analysis allowing faster sample processing. Prolonged filtration necessary to collect sufficient sample for spectrophotometric analysis can cause cell lysis and underestimate of the actual chlorophyll content. Third, the fluorometric analysis is faster and easier to perform than spectrophotometric analysis. Fluorometric analysis should be calibrated directly against spectrophotometric analysis and thus should measure the same parameter. Calibration should be done every 6-12 months.

For light penetration into the water, Secchi Disc measurements are made regularly from which light attenuation coefficients can be calculated. I have carefully compared Secchi Disc estimates to those made with a PAR quantum light meter, both for open ocean conditions and in a turbid estuary. The two methods can be shown to be comparable but the Secchi Disc measurements are very difficult to make accurately in waters with disappearance depths less than one meter; a condition common to Delta waters. I recommend substitution of the Secchi Disc readings for direct PAR meter readings. A simple and accurate PAR meter can be purchased that can be easily used on board any sampling vessel.

On the phytoplankton monitoring, I concur with the comments above in our group report. I think that a combination of methods should be the most informative for identifying algal species or groups. Analysis of pigments by HPLC will allow differentiation of several important algal groups. This analysis could be done on a relatively small subset of samples compared to the chlorophyll a analysis (done on all discrete samples and also part of the continuous monitoring). A smaller subset, possibly selected on the basis of blooms or another indicator, would have microscopic analysis to algal species. Thus, on a sampling density basis, the

microscopic analysis would be on a few samples, HPLC analysis on a larger sample subset, and chlorophyll analysis on all the samples. Even larger areal coverage could be made by remote sensing. Satellite imagery is available on a daily basis through the SeaWifs program of NASA and NOAA. Currently this imagery is considered very accurate for chlorophyll determination in clear oceanic waters but quantitatively less accurate in nearshore waters. There are efforts to make nearshore imagery more accurate by accommodating for suspended sediments, bottom reflection, and colored dissolved organic matter. Recent efforts by NOAA and NASA with airplane overflights using laser fluorometry appear to be very accurate for east coast nearshore waters. It is probable that similar overflights could be made routinely over the Delta and San Francisco Bay waters to coincide with boat sampling for ground truth and this should be explored. These remote sensing techniques allow the highest density synoptic picture of the phytoplankton distribution in the waters of interest and when done in conjunction with the continuous and discrete sampling allow very powerful field information.

Benthos Monitoring

Terry Short

In spite of the commendable effort by members of the EMP in meeting the general status and trends objectives of the benthic monitoring program, the succession of ideas and evolution of study design stemming from this effort have not fully progressed. Again, we would argue that the most logical remedy in solidifying the future success of this element of the estuarine monitoring program is to ensure that the direction of the benthic studies be question-driven. To this end, we feel that questions specifically addressing the use of benthic fauna as bioindicators of environmental change need to be formulated and expressed. For example, it is not clear what specific biological measures have been proposed to characterize spatial-temporal patterns of species assemblages, and what criteria have been considered for deciding the environmental significance of changes in these patterns. The success in using biological indicators depends in large part on the ability to identify meaningful baseline or reference conditions. One approach that may be helpful in addressing the issue of how baseline conditions can be characterized relies upon the fact that the estuarine environment is a system of gradients that can be defined in relation to spatial changes in physical-chemical variables, such as salinity, temperature, hydrology, and substrate. Changes in the assemblage structure of benthic communities along these gradients may be indicative of spatial thresholds representing preferred physical-chemical conditions. Once identified, these species-specific environmental optima can be used to provide a baseline of conditions for delineating change. Using this approach, habitat suitability models for targeted native or introduced species can be developed. These predictive models could be useful tools for managing human impacts on estuarine benthic communities.

In addition, there is a lack of integration of the benthic studies with other elements of the EMP. It is apparent that coupling of the physical, chemical, and biological elements have not been fully considered. In this regard, we recognize that the scale at which communities are studied affects the detection of relationships

between disturbance and biological response. For example, the spatial scale of species turnover is related to the rate and magnitude of disturbance events. A lack of consistency of scale when assessing causal relationships may confound interpretation of how species perceive environmental variation. Benthic fauna are largely responsive to proximate factors associated with near-bed conditions. Accordingly, it is of particular concern among members of the SAG that information acquired as part of the larger-scale EMP effort may not necessarily lend itself to a better understanding of smaller-scale (local) events and processes. Therefore, the SAG members strongly support an effort to identify specific program objectives that account for and integrate important biological and physical-chemical processes operating at both local and regional scales.

Once specific questions defining the scope and purpose of the benthic sampling program have been identified, we feel that a comprehensive review of existing benthic and accompanying ancillary information is highly warranted. This retrospective analysis would help determine whether the information being collected as part of the present EMP sampling design is consistent with program objectives. Moreover, the assessment of existing information will identify information needs and, in the process, provide a sound basis for deciding the direction of future studies or possible changes in the existing design framework. For example, are present sampling methods for the benthos providing data consistent with information needs? While acknowledging that collection of replicate benthos samples provides a measure of site-specific variability in sampling effort, given the present sampling design it is not clear to us how this information contributes to the understanding of spatial heterogeneity in local community structure and physical habitat? Would a composite sample provide information of similar or same value for addressing monitoring objectives and, at the same time reduce sample processing costs? In addition, we feel that it would be helpful to evaluate the extent of integration of the benthic community assessment and the Bay-wide physical-chemical monitoring effort. Does the hydrologic and water chemistry data collected routinely as part of the ongoing EMP effort adequately characterize conditions affecting benthos at both the regional and local scales? Again,

the adequacy of the present benthic sampling design should become apparent when evaluated in the context of meeting specific program objectives.

Ultimately, we feel that a more refined understanding of sampling objectives and a thorough review of existing data will provide a scientifically credible basis for determining the utility of present and future monitoring efforts. Moreover, it is apparent that one of the most important benefits from these efforts is that of providing focus and direction to the more process-based special studies. While acknowledging the difficulty in providing funding support for the benthic special studies, the members of the SAG recognize the valuable contribution that these studies can bring to the benthic monitoring element of the EMP. In this regard, we are hopeful that a reevaluation of the present benthic monitoring program may provide new opportunities for reallocation of resources to augment these critically important studies.

Comments on IEP EMP and Review
Ed Houde

I read the materials on the website and on the CD sent by Anke Mueller-Solger, including each of the SAT reports and the December 2001 draft of the review report. My comments mostly focus on the zooplankton component or, in a few cases, on monitoring issues in general. Overall, I was impressed with the scope of the EMP and the potential for long-term monitoring to contribute to understanding how the San Francisco estuary behaves. I also was impressed with the review, which makes many important recommendations to improve the EMP and use of data from it.

Comments

1. The EMP has documented many of the major changes in the estuary over the past 40 years, including the shifting dominance of benthic and planktonic species, especially the establishment of introduced species and the fates of native species. This is not 'rocket science' but is a very important contribution from the viewpoints of science and management, and I suspect legal viewpoints as well. Documenting trends itself is a strong argument to continue EMP activities since it is these trends that can signal major shifts in the estuary's 'health.'

2. Where does Monitoring end and Analysis/Synthesis begin? In the case of the benthos and phytoplankton components of EMP, the emphasis of the reviews indicates a desire to shift focus towards the analysis/synthesis phases and to support 'special studies.' This is good; it is necessary to move beyond simple examination of trends to understand dynamics of production and regulation of processes. But, there will be a demand for new funds to support these phases of activity, some of which will be done by institutions not directly involved in the monitoring. Can the analysis/synthesis and special projects be supported with available funds? It wasn't clear to me that this was the case from reading materials that were provided, but I am not familiar with the budgeting of IEP and the new CALFED.

3. I was pleased to see what apparently was consensus to continue the major elements of the EMP in a consistent manner. Consistency makes for ease of comparison over the years but should not be an excuse for continuing to employ inferior methods or inappropriate sampling protocols. In some cases, it may be desirable to continue to use traditional sampling methods (e.g., some zooplankton sampling), but the need to calibrate and evaluate the methods should be emphasized in a continuing EMP.

4. In reviewing the QA/QC sections of reports, I found nothing specific with respect to evaluation of the zooplankton sampling and subsampling methods.

Perhaps there is sufficient quality control and the protocol simply needs to be documented in writing. Is this the case, or is there a need for better controls on zooplankton methodology?

5. I agree with the recommendation to expand the zooplankton sampling of EMP into the lower Bay and San Francisco Bay.

6. As the SAT recommended, some changes in the zooplankton sampling methods of the EMP will be desirable. Effects of changes in methods that may be instituted need to be documented. Special studies that serve to calibrate past and new methods will be necessary.

7. The 10-min tows for zooplankton seem far longer than necessary as the SAT indicated. But, reducing the time of these tows to approx. 2 min will not save much time in the broad, expanded surveys that were recommended. Nevertheless, the smaller samples may serve to shorten processing, handling, and analysis time in the laboratory. As the SAT recommends, bigger pump samples filtered onto plankton netting during collections are desirable. And, the SAT is correct in warning EMP not to combine the abundances of organisms from pump and net samples in obtaining estimates.

8. It was noted in the EMP review that larval fishes are not included in the present monitoring, but may be a desirable, if expensive, element. If the larger plankton net recommended by the zooplankton SAT were adopted, it would sample fish eggs and larvae, and ichthyoplankton then would be included in the EMP. The costs of adding an ichthyoplankton element to EMP, even if there were no added field costs, needs to be considered. I know that there are tow-net surveys for larval fishes run by other elements of IEP as part of pre-recruit surveys of abundance, but these surveys presumably are not conducted over the broad area of the estuary that is surveyed by the zooplankton element of EMP.

9. I thought that the SAT recommendation to calculate gelatinous zooplankton filtering rates, based on their abundance and sizes in collections, stepped beyond monitoring and well into the analytical phase. That may be important to do, but not routinely as part of EMP. The SAT appreciates this. On the other hand, it is easy to document the larger jellyfishes in zooplankton collections by simply picking them from the collection bucket, counting them, and measuring their biovolumes in a graduated cylinder at the time of collection to obtain indices of abundance/biomass. Since there is an indication that jellyfishes are increasing in abundance in coastal ecosystems globally, and that they are an indicator of stresses on estuaries and coastal seas, it would be good to document major jellyfish abundances/biovolumes in the San Francisco estuary.

10. I think that more emphasis in EMP on size of organisms in the phytoplankton, zooplankton, and benthos elements would be good. Size spectra can be easily and quickly derived if size information if routinely collected. There is a modest 'rebirth' of emphasis on application of size-spectrum approaches to document the status of ecosystems, potential productivity, and changes in these properties with respect to environmental shifts. Obtaining the spectra would not require 'special studies,' and could provide important information.

11. As I read the review reports, I did not see a lot of emphasis on 'cross-cutting' application of the various measured properties and organism abundances. Some of these cross-cutting applications that combine results from program elements are a legitimate part of a monitoring program. Others would certainly be analysis/synthesis. Simple combinations of monitoring results from phytoplankton, zooplankton, and benthos elements could, for example, lead to indices of biodiversity, relative dominance by introduced species, trophic dominance, size structure, overlaps of taxa and water quality parameters, etc. This could be termed a kind of 'integrative monitoring' that may be a useful emphasis for the EMP.

12. I was pleased to see the attempt to prioritize needs within EMP, especially for special studies or new/expanded elements that were proposed. I can add nothing to these prioritizations, which I presume were derived after much thought and discussion. It is important to set appropriate priorities and this hopefully was accomplished in the EMP review.

EMP Review Notes
Alan Jassby

1. Aquatic Base Producer Subject Area Review and Recommendations

Page	Par	Comment
6	Fig 1	· In support of ABP relevance: TOC, hypoxia. These can be problems without nuisance blooms. They are highly relevant for the Delta right now. The overview in this report could benefit from a brief discussion of the role of phytoplankton in drinking water TOC and in hypoxia of the Stockton DWSC.
7	4	· How many continuous stations?
9	1	It would be unfair to expect this report to contain a comprehensive and well-structured review, but just to set the record straight: · NPP is 43% lower, while Chl is 59% lower, because the drop in Chl is ameliorated by the increase in transparency. · Blooms in the southern Delta have gone over 300 µg/L, I believe. · The Suisun Bay results are from the budget in Jassby et al. 1993 · The phytoplankton balance results are actually in Jassby et al. 2002, rather than Jassby & Cloern 2000, and these estimates were made on the basis of Chl, not TON. · Jassby and Cloern 2000 found that *TOC* comes mostly from river inputs, but that when converted to edible particles is actually the same magnitude as NPP in spring and summer. Moreover, Müller-Solger et al. 2002 found that the nutritional value of the NPP was far greater than the non-phytoplankton POC. · According to the TON budget in Jassby and Cloern 2000, the upper estuary is not a net producer in summer of even critically dry years, probably because the organic matter has a larger residence time and more opportunity to be utilized. · The contribution of phytoplankton to bioavailable POC is also strongly supported by the analyses of Jassby and Cloern 2000 and the experiments of Müller-Solger et al 2002.
9	2	· Explain how Lehman's results are connected to the *Potamocorbula* issue.
9	3	· I believe Alpine & Cloern 1992 is the primary reference for suppression of Chl after the *Potamocorbula* invasion. · Spelling should be "*Aulacoseira*"
11	3	· The separation of sources in the Sacramento raises questions about cross-channel variability that need to be addressed more specifically as an issue in this report. This is clear in the vicinity of Rio Vista to many people, but I wonder how serious this problem (small scale variability) is near other stations as well.
12	2	· Zooplankton impacts may be largely unexplored, but the main variability modes have been identified and do not appear to be related to zooplankton variability. Zooplankters are more likely passive responders to phytoplankton abundance in the Delta.
12	-	· A discussion of variability and causes in San Pablo Bay is missing from this section. See Jassby et al. 1996 and the recent understanding added by Dugdale and colleagues.
14	1	· Macrophytes may not be important on a Delta-wide basis, but of course they are very important in certain subregions.
15	3	· The benthic microalgal habitat based on measurement of intertidal areas in open water habitat is quite small in the Delta (although not of course in the Bay). But there may be a lot of benthic microalgal habitat in wetted perimeter areas of sloughs and channels that has been overlooked.
16	3	· *Microcystis* also produces microcystin-LR, a hepatotoxin that increases certain liver enzymes and can cause chronic liver damage. There is concern in some states (New York, I believe) that subacute microcystin levels are a valid drinking water issue. Conventional

Page	Par	Comment
		treatment is ineffective at removing these toxins and management at the source is important. I suspect that microcystin may eventually become a regulatory issue here and understanding of its variability in the Delta correspondingly important. One hopes the enumeration program will take special care with species of special importance.
19	3	· Does the demand for data merit a very large effort in maintaining web-accessible phytoplankton data? This is rather specialized data and I wonder how many people need this type of access. Why not just give out a CD or have an ftp site?
20	3	· Reporting should include the needs of colleagues as well as resource managers. Many people do not understand the role and importance of the various aquatic base producers, so there should be a dual effort at explaining the importance and on updating any notable trends or phenomena. Neither is done very well at the moment. Both could be accomplished with a single site or publication. Somehow including or linking to the downstream areas in terms of reporting should also be explored. · One technique that could be of benefit both for reporting and for imposing a more disciplined, ongoing analysis of the data is the use of quality control charts for critical variables, such as certain species at certain stations in the Delta. The use and utility of methods such as Shewhart and cusum charts has been explored in detail (e.g., T.P. Ryan, 1989, *Statistical methods for quality improvement*, John Wiley), including for water quality data (in an issue of *Environmetrics*, I believe).
22	1	· I believe that the "regionalization" to identify redundant stations was carried out on the basis of some form of cluster analysis. Apart from the statistical problems in cluster analysis, especially in deciding the significance of clusters, this type of regionalization identifies stations of similar magnitude, but not stations with similar dynamics. This means that the regionalization acts as a kind of stratified sampling scheme and allows for estimation of estuary-wide statistics such as means. On the other hand, it is not a good way to group stations if one is interested in the underlying causal pathways. Consider a situation with four stations, A-D. Stations A and B have similar high values, and C and D have similar low values. But stations A and C are well-correlated in time, as are B and D. So one would want the subregions to be {A,B} and {C,D} if estimating estuary wide statistics and trends were the aim. But one would want the subregions to be {A,C} and {B,D} if understanding causality were the aim. Both are legitimate aims of the EMP, which means that the stations are best left ungrouped in this case. For that reason, I believe that another look is warranted at the historical data set, with a view to satisfying these aims simultaneously. It is likely that stations can be found with both similar magnitudes and similar dynamic behavior.
23	1	· Both the continuous monitoring records and the high-resolution horizontal transects may provide extremely valuable data for optimizing sampling locations and time (both frequency and actual position on the tidal cycle). The MIDAS transects in the Bay were very useful in understanding the appropriate inter-station distance and its effects on the variability of estuary-wide estimates. The continuous records can be analyzed in a similar way. I suggest that getting these data into usable format (tables in some standard format on CDs) should be a high priority.
24	2	· There are some big discrepancies in the optical data sets that exist for the estuary. The overall relation between PAR attenuation coefficient k_d and TSS using EMP historical data has a different intercept (almost double) than using USGS data. Some of this discrepancy may disappear when the time periods and stations are the same, but it definitely needs investigation if we are to reconstruct historical conditions accurately.
25	2	· From an ecological point of view, the traditional variables that are of direct importance are k_d (for NPP estimates) and TSS (for understanding many things, such as interference with filter-feeding) (VSS in the historical database is a related, interesting organic matter surrogate that I believe is underutilized for retrospective analysis). I believe the program

Page	Par	Comment
		should focus on measuring these two directly or show, in a special study, that they can be replaced with more suitable methods (perhaps nephelometry, OBS) that calibrate to them reliably. Secchi depth, although easy to do, is very insensitive in turbid waters and could be dropped with little loss. Below about 3 m photic depth, it starts to lose its value quite rapidly. Remember that the spatial and temporal variability in Chl is high and it does not make much sense to strive for exceptional accuracy in k_d if NPP (which also depends on Chl) is the goal. · The recommendation here needs to distinguish better between questions and variables. For example: If the question is NPP, then measuring k_d or a reliable surrogate should be the goal. What questions motivate the need for particle size distributions? I suppose the special study is going to deal with the questions as well, but this seems too much like the cart driving the horse. What are legitimate optical questions? Aside from NPP, I can see the need for good optical data for hydrodynamic models and remote sensing calibration. I would hope that the special study attempts to understand the special needs of these three different applications. · An overall worthy but perhaps ambitious goal would be the ability to estimate all apparent optical properties on a first-principles basis from measured variables. Is this feasible? What are the variables?
25	4	· Would additional flow measurements be done by the EMP or through existing programs?
28	1	· A related and critical issue is the ability to transform these pigment measures into biovolume or C or dry weight community estimates. The C:Chl ratio is especially necessary for calculating budgets, which are in turn of great value in understanding causality. Although we all know that this ratio varies by an order-of-magnitude, there is no practical alternative to assuming a fixed value in many applications. What are a reasonable set of values for the Delta or subregions? Ratios suggested by different sources are highly variable and some systematic investigation and decision is needed here.
29	1	· I do not believe that "yearly primary productivity incubations at several sites" is worthwhile. The variability is simply too high. But a more intensive undertaking is probably not a good use of resources. Just knowing the value of $BI_0 z_p$ should be informative, perhaps supplemented with a special more comprehensive measure of Ψ every few years.
29-31	-	· I strongly support a thorough revision of this program, adherence to standard methods, and quality control. The current species composition dataset does not inspire confidence as far as community-wide analysis is concerned. Fortunately, data may be good for certain key species.
32	3	· I believe that remote sensing deserves real attention here. For much of the Delta much of the time, phytoplankton are simply too small a fraction of SPM to be detectable remotely. But blooms should be evident and, as the Delta continues to clear, the sensitivity will improve. Irrespective of the current situation with phytoplankton, remote sensing will give a better assessment of Delta-wide SPM concentrations and of its spatial and temporal variability. This will help define the trend in SPM more accurately as well as resolve outstanding issues over the origin of this trend. Given the controlling influence of SPM on primary production directly through effects on k_d and indirectly through effects on primary consumers, this should be a higher priority item. There are collaborators readily available, such as the NASA group using Lake Tahoe to calibrate satellite-based sensors.

Following are some comments related to specific tables. They may repeat some of the above comments on the text.

Table	No.	Comment
2	2	· It is not practical to conduct regular Ψ measurements. There is too much variability and the effort would have to be too great. · Loadings are not accurate without continuous data, so these measurements are only worthwhile where continuous flow and water quality (e.g., Chl) measurements are available.
	3	· This special study needs more direction or specification. The variation in PAR is almost all due to variation in TSS, so we really need to understand TSS dynamics. This is a geological/hydrological problem, not an optical one, so the expertise needs to be appropriate.
	4-5	· These studies also need to be more precisely specified.
	7	· Could historical analysis be part of the current A. Müller-Solger CALFED grant? One of the original aims was to identify a time series of phytoplankton community nutritional quality, but results may be unreliable given recent information on the community composition data set. It might be preferable to identify species that are of importance and for which good data exist, and focus the historical analysis on those species.
3	5	· I would change this to "potential productivity" calculations based on Ψ, and flux estimates where continuous flow and water quality data exist. I also wonder whether Delta-wide estimates can be made without having too many stations.
4	-	· The revised database (Table 4) looks like a big improvement. Should "shape_model" also be included in the revised database?
5	4	· Consider composite samples over a subregion (e.g., transect), and emphasize quality of count rather than number. This may be a good strategy when communities are simply being moved in space but remain largely the same. Looking at many individual stations to assess changes over a subregion is a lot less efficient and accurate than simply compositing the samples and replicating the count. The variability at any station could be very strong but not that important (ie, it could represent a spatial displacement by flow).
5	5	· Just restarting the PAR k_d measurements, continuing the TSS, and calibrating continuous sensors for TSS would be a big improvement. Secchi depth data are too insensitive to be of real value in this turbid estuary.
5	-	· The priority rankings in this table seem appropriate.
6	2	· This does not merit a high priority, especially until the issues are better defined. I would turn this into a high-priority item by focusing it on remote sensing of TSS (and less practically Chl and k_d). What can be sensed practically and cost-effectively? What deductions can be made about TSS, Chl, k_d without additional measurements such as particle size, etc. What additional measurements would improve the calibration of remote sensing data?
6	8	· Size fractionation can replace enumeration only if size is the only useful information given by enumeration. What about nuisance species, nutritional and other information? Also, there are many problems with size fractionation—breaking colonies, burst cells, etc. A low priority is appropriate.
6	9	· Good biovolume estimates are going to be essential for resolving this.
6	12	· I would bump up the priority on this one. We need to know how variable the ratio of 1-m grabs to water column mean is.
7	C7 (10)	· It concerns me that Mossdale may be the end-member and the only representative of the upper (relative to Delta boundary) San Joaquin River for some measurements. It behaves very oddly with respect to chlorophyll, being the only station which does not show pronounced down-trends. This region needs some careful thought before stations are abandoned.

Overall, this review document has done a commendable job of getting to the most critical problems and suggesting procedural and research approaches to the problems. The recommendations are extensive and some activities are bound to remain undone, so ranking the studies is critical. It is important that these special studies are driven by specific questions and that the questions are important to the EMP. There are a few places where rankings need to be thought out some more, and a few of the proposed special studies need to be more carefully laid out.

2. Benthic Monitoring Element Review and Recommendations

Page	Par	Comment
1-15	-	· It isn't clear to me from this overview how the Delta stations have improved our understanding (the observations that communities are zoned by salinity or that abundance and composition responds to major hydrological events are elementary, general facts about the estuarine benthos). Is this perception true? If so, what have the barriers been? Lack of data analysis? Difficulty of interpretation? Inadequacy of spatial coverage?
14	2	· Could the time series of grain size spectra give us an index of change for bottom sediments, perhaps throwing some light on the long-term trend in water column TSS?
18	-	· 8b. Undertake a time-series analysis of the grain size data? · 9. Can we find evidence in the historical record that the existing spatial resolution is sufficient for Delta-wide averages? Can we find evidence that temporal resolution is sufficient to understand important event-related changes? In other words, try to use the historical data to examine the appropriateness of the current sampling scheme.
19	-	· 6) Cross-channel variability is only part of a more general small-scale sampling issue that is fundamental to the data credibility and needs more systematic attention. Is it feasible to determine the variograms of abundance at different locations and times? If these can be established, then some deductions can be made about the number and spacing of replicates. There should be studies from other estuarine systems that can be used as guides.
19	-	· 8) There are many scattered pieces of information on diet from direct examination, isotope and other data. Is it time to begin gathering these together in some coherent database, for the benthos, plankton and nekton? Perhaps the benthic part of this effort would be an appropriate activity for the BEET.
20	Line 13	· A rotating panel design that is adaptive with respect to water year type is a promising approach that needs to be investigated.

In general, I believe that a fundamental issue this program needs to grapple with more is the appropriateness of the current sampling scheme. A study to examine changes in space and time at higher resolutions than the current sampling scheme is the only safe way to decide on the efficacy of this scheme. But even before this is done, a reconsideration of program aims is in order: Detection of invasive species? Estimates of macrobenthic filter-feeding? Etc.?

In examining the *Corbicula* data, I noticed that monthly time series at individual stations, at least around the peaks, had high serial correlation, whereas time series from different stations had very little coherence. This suggests to me that some of the temporal effort could be reassigned to spatial effort. For example, rather than sampling 4 stations monthly, a rotating panel design could be used in which a total of 16 stations were sampled quarterly.

3. Water Quality Monitoring Element Review and Recommendations

Page	Par	Comment
18	2	The diversity of physical settings and circulation patterns is certainly clear, but how big is the homogenizing influence of a 20-km tidal excursion on water quality? This seems like a useful question for addressing with the continuous horizontal measurements.
22	4	This may be the most important strategic move of this revision: Shift as much resource as possible from discrete to continuous monitoring.
23	2	Sampling at fixed points on the spring-neap tidal cycle may increase the bias, but it decreases the scatter. So it is important to understand why the data are being collected. If the goal is time-averaged statistics such as the mean, then alternating between spring and neap tides is appropriate. But if the goal is to understand long-term patterns, then sampling at the same tidal stage is proper. This decision needs more consideration.
23	4	For discrete sampling and horizontal transects, it seems optimal to center the sampling on the time when the rate of change of each WQ variable is the smallest. Unfortunately, this is not the same time for all variables. For example, the diel cycle in Chl versus the tidal cycle in mineral suspensoids. Again, some more consideration is needed here to find some appropriate compromise.
24	2	A much bigger emphasis on remote sensing may be the next most important move of this revision.
27	2	Measures taken to ensure continuity among the two sites are extremely important. Maybe there should be some predetermined standards to assess how well continuity can be assumed, including possible development of empirical data transformations between the sites.
32	1	What about the famous photo showing that the river is sometimes a highly structured group of adjacent streams flowing past Rio Vista?
32	3	Can Secchi depth be dropped in favor of a more sensitive measure, a measure of absorbance (as opposed to scattering, which is what Secchi measures)?
34	1	Just like sampling in time, optimal sampling in space depends on the goals. Which goals are paramount? Finding region-wide (e.g., Delta) statistics such as the mean? Finding region-wide dynamics, i.e., causes of long-term change in seasonal, annual and decadal behavior? Or finding these answers for specific habitat types? These issues need more reflection and possibly analysis.
34	5	Caution: Mossdale appears to behave uniquely, at least with respect to Chl trends.
36	1	The understanding has improved somewhat over this description. See Jassby et al. 2002 L&O 47(3).
36	2	This description seems vague and needs to be laid out better.
47	-	The station coverage in the south seems sparse. Nothing at Clifton Court? Also, is the need for mass balances being considered? If so, this will determine station placement for inputs and outputs.
50	Note 4	Stations 24 and 25?
54	Tbl 5	Isn't TKN redundant, given both TON and NH_4? Also, can we get a more appropriate optical measure than Secchi, such as PAR attenuation (surface and 1 m) or transmissometry?
55	Tbl 6	It would be useful to see the stations discontinued in 1995 in this comparison.

It is heartening to see the determined move to continuous monitoring. The discrete monthly data can be very difficult to interpret, and it seems almost miraculous that we have been able to discern patterns in that dataset. It is necessary to group the discrete stations carefully and calculate regional statistics, because each individual station is dominated by tides and flow and cannot reveal nearly as much on its own. The continuous stations, on the other hand, will allow local as well as regional dynamics to be assessed. That said, the choice of stations is critical and, I believe, needs ongoing consideration. It would

be helpful to encourage this activity by developing a database of stations/variables for mapping purposes. Something such as the following:

Station name	Coordinates	Depth	Agency/program	Variable1 sampling	Variable1 duration	Variable2 sampling	....
				Perhaps a code to indicate whether continuous or discrete, and whether single or multiple depths	Perhaps a code to indicate one of several characteristic periods in which sampling took place (e.g., 1975-1995, 1975-present,...)		

This would enable one to choose any single variable and obtain an estuary-wide map of how it has been sampled.