Contaminant Concentrations in Fish: 2000
by Ben Greenfield and Jay Davis

What follows is a transcript of the Oral Presentation presented by Ben Greenfield at the Regional Monitoring Program Annual Meeting, on Friday March 22nd, 2002.

The accompanying PowerPoint presentation contains all of the slides.

This presentation presents draft data, which should not be cited or quoted without contacting the authors. Feel free to contact Ben Greenfield at Ben@SFEI.org or 510-746-7385 with any questions.

Slide 1: Contaminant Concentrations in Fish 2000

Slide 2: The work that I'm about to present to you is a collaborative effort of a number of organizations including folks from Moss Landing Marine Labs, the Water Pollution Control Lab, John Wilcockson, a modeler from EVS Environmental Consultants, guidance from people at the Regional Board including Fred Hetzel, and a number of us at San Francisco Estuary Institute, who prepared and analyze the data and have prepared this talk.

Slide 3: The Contaminant Concentrations in Fish 2000 sampling plan includes an effort to monitor general patterns in contamination and also special studies which focus on evaluating specific mechanisms behind these patterns. In general this plan is organized in similar fashion to the RMP and in particular this includes a monitoring effort focusing on status, trends, and spatial patterns and also the special studies. The status evaluation tries to collect good baseline data that can be used for human health guidance and establishing new advisories. An interim advisory was established in 1994 and the fish monitoring data should be usable for updating advisories such as this. Trend evaluation focuses on collecting good data that can be used to determine long-term trends (every three years sampling is done in a similar fashion) and also evaluation of trends within given years. Finally , the status monitoring includes determination of spatial patterns and for this we collect replicate samples at several locations in the Bay. Once we establish general patterns we can look at specific mechanisms behind these patterns by conducting studies designed to look at these mechanisms. For example, if the patterns and trends in time have changed then what is the mechanism causing these changes.

Slide 4: The Contaminant Concentrations in Fish 2000 report will be due out at the end of this summer as a final version. We are currently finishing up the analyses, and preparing the draft report. The report itself will include all aspects of the study and this includes extensive chemical sampling focusing on toxic chemicals and chemicals that tend to bioaccumulate; chemicals that are important for human health considerations. These include trace organochlorines such as PCBs, DDTs, chlordanes, dieldrin and dioxins. Also in 2000 we started to sample polybrominated diphenyl ethers (flame retardant compounds). These also include the trace metals, mercury and selenium, with the selenium effort being limited to white sturgeon. There are also a number of special studies geared toward understanding biological mechanisms behind the chemical patterns. A seasonal croaker study was done in 2000 to evaluate whether trace organic contamination in croaker varies over over a year . A food web study including gut content analysis and modeling of PCB uptake into food webs is geared towards evaluating the importance of dietary choice among fish for their contamination levels. Stable isotopes also look at the importance of diet. Stable isotope analysis can be used to determine food web position (i.e. trophic position). A biomarker study was conducted to determine biological effects of the contamination observed and finally, in 1998 in 1999 some samples were captured of different types of shellfish to determine to what extent these are contaminated.

Slide 5: The finfish that were sampled, 7 were chosen and these were emphasized to be species that are of human health concern due to being eaten by people or alternatively species that are useful spatial indicators.

Slide 6: These were the jacksmelt

Slide 7: Shiner surfperch which is a small fish and is therefore useful in indicating spatial patterns because it has limited home range.

Slide 8: White croaker

Slide 9: California halibut and by the way thanks are due towards Cassandra Roberts and Marco Sigala of Moss Landing Marine Labs, who provided the photographs for this talk.

Slide 10: Striped bass, the most popular sports fish species in the Estuary

Slide 11: Leopard shark, here being ably modeled by Cassandra Roberts.

Slide 12: This is a white sturgeon, which Rusty Fairey has successfully wrestled and is showing his catch

Slide 13: The sampling locations were essentially identical to those in 1997, the goal being to achieve consistency so as to see long-term patterns in time. The only difference is that we were unable to capture fish in Davis Point but all the other sites were the same. Sampling consists a variety of methods including trammel nets , gill nets, hook and line, and bottom trawling, to sample the variety of species and locations that we sample.

Slide 14: Once fish are captured, they are brought back into the lab and are dissected using clean techniques and then analyzed for chemical contamination.

Slide 15: And now what I'm going to do is show you the types of analyses that we are conducting to show how these different aspects of the fish contamination study are achieved. I will start by discussing status. Here what we are talking about is how contaminated are the fish now in 2000 and how does this contamination compare to screening values which would indicate potential human health adverse effects for PCBs.

Slide 16: In this plot, the gray bars are the medians and each dot is an individual sample- either an individual fish or a composite of fish. The dotted line at the bottom of the plot indicates the screening values that we have chosen. Above that dotted line this indicates that further research and monitoring is necessary and that there may be adverse human health consequences. What we see first of all is that almost every sample exceeded the screening value. About 90 percent of the samples were above the screening value indicating that there are potential concerns for human health and that further research is warranted on PCBs. Additionally what we see is that contamination varies widely by species. In particular, white croaker, shiner surfperch, and to a lesser degree jacksmelt are the most contaminated fish. These species are high in lipid content and this high lipid content is one of the causes of the contamination because trace organic contaminants tend to adhere to lipid tissue (i.e. they are very lipophilic).

Slide 17: A very different pattern was observed for mercury. Leopard shark had the most mercury contamination followed by sturgeon and striped bass. The other thing that's important to notice is that a number of the samples do exceed the mercury screening value. This is particularly the case for striped bass, leopard shark and sturgeon. So mercury has a potential adverse effect as well. It's also worth noting that the species that are most contaminated tend to be the largest species. Mercury bioaccumulates up the food web and tends to increase in with fish age.

Slide 18: Looking at the overall data in general we see that of the six contaminants that I here compared to screening values all of them exhibit at least some exceedances other than chlordanes. As I mentioned previously, PCBs and mercury have the largest proportion of samples that are above screening values with chlordanes having no samples above screening values. The chlordane pattern is interesting because it's different from 1997, when there were some exceedances. Another important difference between this year and previous sampling periods is that we now have some exceedances in selenium. This is because a more conservative screening value was recommended to us by the Office of Environmental Health Hazard Assessment. But the overall message is that in general the contaminants are present at concentrations where some potential caution is warranted.

Slide 19: We can also compare our data to previous years' data and look at long-term time trends.

Slide 20: The general patterns that were seen with the RMP data are that there's not a lot of pattern over the three sampling periods. 1994, 1997 and 2000 all exhibit very similar median concentrations. This is particularly true in the example I've shown you for white croaker PCBs but this pattern is found for other contaminants as well. One interesting exception to this which you can read about in the upcoming report is mercury. In 1997, concentrations were elevated as compared to 1994 and 2000. We are not exactly sure as the biology of this but it's particularly apparent in striped bass and it might have something to do with varying food web position or varying spatial pattern in terms of whether they have been residing in more contaminated areas.

Slide 21: In terms of variation within a year there was a special study done to evaluate this for white croaker trace organic contamination. What we found that was very interesting was that spring concentrations of PCBs and other trace organics were considerably lower than other seasons. This is a statistically significant pattern and is probably related to the fact that the fish captured in the spring have much lower lipid content in their tissue. The biological mechanism behind this are not clear at this time.

Slide 22: Moving onto spatial patterns that can be monitored, an effort is made to collect replicate samples of shiner surfperch, jacksmelt and white croaker at each of the five sampling locations and this has revealed some interesting spatial patterns.

Slide 23: Here we see a statistically significant difference in jacksmelt PCB concentrations in the Estuary and in particular Oakland Harbor and South Bay Bridge is more than twice as high as most of the other sites. So there are some spatial patterns which from a management perspective might suggest the value of establishing region-specific consumption advisories in the future.

Slide 24: So we've seen all these different types of monitoring data which revealed some very interesting patterns. This is where the special studies come in to understand the mechanisms operating behind these patterns. We need to understand our indicators. In particular what I'm going to talk about is this pattern that we just looked at that there is spatial pattern in jacksmelt PCB concentrations and why is that spatial pattern occurring. I'm going to discuss two potential hypotheses. One is the hypothesis that PCB concentrations vary spatially in fishes because they're variable spatially in the sediment.

Slide 25: This plot contains data of surface sediment concentrations collected by the RMP and the Bay Protection Toxic Cleanup Program data. This plot was prepared by Eric Wittner and Jon Leatherbarrow. This is a draft plot showing PCB concentrations in surface sediment samples throughout the Estuary. The main point that I want to show is simply that there exists considerable spatial variation in the Estuary in sediment PCB concentrations which may lead to varying fish concentrations.

Slide 26: But there's an alternative hypothesis as to why fish contamination varies spatially which is that there's spatial variation in the diet of the fish. Here I'm going to refer to work by Marco Sigala of Moss Landing Marine Laboratories. Also Cassandra Roberts and Rusty Fairey and others were involved in the study.

Slide 27: Marco extruded the guts of jacksmelt, shiner surfperch and white croaker and he painstakingly analyzed the contents of these. Marco had the joy of picking through and found out whether there's dietary variation within the Estuary.

Slide 28: What was found was that there were some very interesting patterns in jacksmelt diets. Here we see that in San Pablo Bay in the northern Estuary, the predominant prey item was polychaete worms. In contrast, the predominant prey item in Oakland Harbor was algae and down by the South Bay, in Redwood Creek, the primary prey items were copepods and Potamocorbula clams. This dietary variation may explain some of the variation in jacksmelt PCB concentrations because different types of invertebrates may bioaccumulate PCBs more readily.

Slide 29: So then we turn to another special study, the results of which are not completely in yet, to understand which of these hypotheses is more is more important in this case. This is a modeling study of PCB uptake in the food web. John Wilcockson of EVS Environment Consultants is building a Microsoft Excel spreadsheet model that mechanistically simulates the process of PCB uptake from the sediments into the different types of invertebrates and finally into fish. With this model it will be possible to test different hypotheses by changing the input parameters. For example, to compare my two proposed hypotheses, one could vary sediment PCB concentrations and alternatively vary dietary composition. These variations would be based on field data that we collected so the models become very useful synthetic tools for integrating all of the RMP data. Ultimately we see which one has more of an impact on the modeled jacksmelt PCB concentrations and get a better idea of which is the most important hypothesis.

Slide 30: In conclusion, the RMP Fish Contamination 2000 monitoring effort focuses both on evaluating patterns in the data and understanding the mechanisms behind these patterns. We've seen that PCB concentrations in general are above screening values, and this is particularly the case for PCBs. Therefore we do have some cause for concern. We have also seen that trace organic contamination concentrations vary seasonally, indicating that future sampling efforts, and possibly consumption guidelines, may need to account for seasonal variation. Then we moved on to ask questions about the mechanisms behind the spatial patterns that are observed in jacksmelt PCB concentrations and found that dietary variation could indeed be important. It is through the synthesis of the monitoring and the special studies that we achieve the best understanding of fish contamination in the Bay.