California Fish and Game Commission
P.O. Box 944209
Sacramento, CA 94244-2090

Dear Sirs:

This missive concerns fish kills and possible programs for their treatment plus some aspects of possible harbor monitoring. The Santa Cruz harbor opened in 1964. Almost immediately it's first fish kill occurred. Starting in 1968 I began teaching the Santa Cruz County Office of Education Vocational Education class in Oceanography. The program was very well funded and the students had to be seniors with math and chemistry requirements. Each Monday's class consisted of processing top and bottom samples from three harbor locations plus the end of the Santa Cruz pier (the city calls it a wharf) for 18 parameters.

The upper harbor opened in 1974 and had its second kill. I started working summers to solve the problem. During the next few years I worked with Fish and Game wardens to collect fish in the harbor and other activities.

The enclosed Water Quality Management At Santa Cruz Harbor has me listed as the author. While most of the text is my research, it is not my writing. Hence, the Calif. Fish and Game question mark on the cover sheet. The text gives me credit for the kill curve graph. While the data collection is all mine, your dept.'s mathematicians constructed the graph. The help was greatly appreciated and they deserve the credit.

Santa Cruz harbor had a kill last year and is in one now. The harbor should never have a kill. The science is known and a prevention system (aeration) is in place. The problem is a lack of a monitoring system. I believe this is a problem with every harbor on the coast. When a kill occurs there is rarely, if any, data collection. Just a combination oxygen/temperature instrument would provide a "picture" of a harbor's condition.

With a warming climate creating a variety of oceanic parameter changes, monitoring data from each harbor on the coast could prove to be invaluable. Your dept. sponsoring a data collecting monitoring system along the coast could be a great collaboration effort.

Another reason to gather hard data has begun i.e. the judiciary field. Crescent City harbor had a kill a few years ago and was sued by an ex harbor commissioner who was raising abalone inside the breakwater. One of the two defense lawyers contacted Brian Foss of the Santa Cruz Port District concerning anybody with fish kill experience. Mr. Foss contacted me to see if I was interested. I contacted the lawyer and said I would be available, hopefully, as a friend of the court. My contact got married and left on a honeymoon and his partner dismissed me. I learned about a year later that harbor lost to binding arbitration to the tune of one million dollars.

Curiosity took me to Crescent City where I conversed with various harbor personnel. My lasting impression is neither side had much, if any, hard data. In a later correspondence I said they were criminally underrepresented.

Considering the foregoing I would like to propose the following for your consideration. Every harbor has a monitoring program collection data for your science department's benefit and the harbor's defense against any litigation. Observing the Redondo Beach harbor complex after a kill (another story), I was amazed that they had not been sued. No data, just guesses. In a courtroom, hard data will usually beat "I think."

Feel free to distribute the enclosed Water Quality literature.

Sincerely,

T. Robert Byington

T. Robert Byington
[redacted]

3 letters to
SC Harbor Commissioners

Dear Sirs: 12 Aug 14

This letter concerns the current fish kill at the Santa Cruz Port District. Enclosed are two letters to the Port District. There has been no acknowledgement concerning their reception. Not too surprising as they probably think I'm another kook with an axe to grind.

Over the last 30 years the Port District has spent a considerable amount of time collecting a mass of data concerning their fish kills, their recovery and their prevention.

The enclosed Water Quality Management at Santa Cruz Harbor was not written by this writer. I do not know who the writers were. However, most of the text is taken from my research reports as were all of the graphs. Unfortunately, due to changing Harbor and politico personnel, the report is probably unknown.

This missive is directed to the effects of a kill to a community and its financial status. The community and harbor should/have to come to some kind of agreement on monitoring. The dynamics of oceanic variations from the beginning northwest winds to their effects on local upwelling and the times of fish egg laying, etc. can coincide to provide massive fish populations. The cost to monitor these parameters (men, ships, supplies, etc.) would be a considerable burden. Who is willing to pay for it? Essentially, that leaves the monitoring to the local harbor and its communities. Monies need to be provided for collection equipment, personnel to do the collecting and a facility to process the chemistries desired. Monitoring does not have to be year round. The most likely time for a kill, based on Monterey Bay occurrences, is between May and November and especially during July and August.

Aeration operation takes a lot of electricity. It is far cheaper to monitor for oxygen levels than run aerators. It is also far cheaper to pay for electricity than a kill cleanup and repairs to vessel metal replacements.

Sooner or later someone is going to awaken to the legal possibilities of a kill. That happened to crescent City harbor a few years ago and the litigant collected ONE MILLION DOLLARS under binding arbitration. Don't think it can't happen here. The insurance companies will appreciate increasing your rates.

Sincerely,

T. Robert Byington
[redacted]

24 Jul 14

Dear Sirs:

Under Brian Foss, the Santa Cruz Port District led the way in fish kill research and prevention. After the 1974 kill, Port Director Jerry Barney started the program and I did the research. I had an oceanography program at Harbor High School funded with Vocational Education money to pay for extensive instrumentation.

By working each summer, 1975 through 1979, the harbor had over 900 water samples and 6300 individual tests with observations of fish stress through fatality. The results were turned over to Calif. Fish and Game mathematicians who developed a fish kill graphic curve. This curve was used to predict the 1980 kill almost to the hour. The harbor under Brian Foss's direction, installed the first set of aerators. During the summer of 1981, the daily monitoring strongly indicated a fish kill occurrence on 35 days except for the aeration. During the summer of 1982, the aerators were repositioned for better results. The aerator care program (installation, monitoring, storage, etc.) was established.

The 1984 kill was due to the aerators not being installed after repeatedly instructed to do so (another story).

After both kills, the harbor was chemically monitored until recovery occurred. During the 1984 recovery, the full compliment of aerators was installed plus considerable added oxygen generation.

The June, 1996 ANCHOR Watch has an article concerning how the harbor stopped a beginning fish kill. Over the years the Port District and I learned a lot of science.

Prevention of a kill starts with knowledge, personnel and an Oxygen/temperature instrument (about $1200). At the risk of offending some people, there is no excuse for a kill to ever occur in the harbor. The science has been done and a program installed. Diligence and knowledge have to be continuous. The above is a very brief summary of over 22 years of work.

If I can be of any service (informational, educational, program-wise, etc.) I can be reached at the following:

T. Robert Byington
[redacted]

Port Commissioner Members
Santa Cruz Port District
135 5th Avenue
Santa Cruz, CA 05062

5 AUG 14

Dear Sirs:

This is a follow-up letter concerning your current fish kill. I would like to bring to mind three major components to the kill problem i.e. ignorance, personnel changes, monitoring.

Ignorance – not knowing, some stupidity (arrogance?). The harbor is a special environment. Personnel learn their trades, professions, specialties, etc. and then apply them to the harbor's needs. All of you commissioners bring knowledge to the harbor. All of you, and others, then have to adapt to harbor needs, rules and law. The learning curve takes time, often years.

Fish kills are a sporadic condition that may or may not occur during one's harbor tenure. Understanding a kill occurrence demands some knowledge of the physical, chemical, biological, geological, meteorological, and astronomical relationships occurring in ocean waters. Your present kill has parameters involving all of the above sciences and their inter relationships. Following are areas of basic knowledge involved with fish kills.

General circulation of the atmosphere and oceanic currents affecting climate and weather.

Basic oceanic topography

Basic food chain dynamics

Density of water – its importance

Tides – causes, importance

Upwelling causes and dynamics

Basic biochemistry – aerobic, anaerobic.

Oxygen and water relationships

Schooling fish relationships

Most likely set of conditions for a kill

Recommended – a basic handbook, manual or syllabus for the above topics. Background at this time would be of value to each of you to understand what is happening and which actions to take, when.

As personnel changes, so does the need to educate. Question – why do we and the fishes need to breathe oxygen? 'Without it we would die" is not an answer. Yet, it is paramount to this whole situation. See oxygen and water relationships above.

Monitoring and the collection of data is crucial. I am willing to bet that not one single datum has been collected during this episode. How can you know what you are doing without data? Just the collection of oxygen and temperature throughout the harbor would open an amazing picture of the harbor's dynamics. Add tidal flow and weather and the picture grows.

Data beats "I think", especially in a courtroom. You have a fish kill. Think what could happen if a boat and /or business owner(s) brought suit (class action?). This has happened in Crescent City. The city went to binding arbitration and lost to the tune of ONE MILLION DOLLARS. Basically, both sides had very little, if any, data. A travesty . Think about what a person such as I could be in a courtroom. I should have been in this case but that is another story. The possibilities for an eager, imaginative lawyer are many. Without data, even expert witnesses can be made to look foolish. Enough said. See enclosed.

I care about the harbor. The fish research and monitoring covered 22 years. The Harbor High oceanography covered 15 years of harbor monitoring and 9 years were spent with the dredge and maintenance departments and included the rebuilding after the earthquake, safety and hazardous materials officer and expeditor after retiring from teaching. I do have some experience!

Sincerely,

T. Robert Byington
[redacted]

WATER QUALITY MANAGEMENT AT

SANTA CRUZ HARBOR

Calif. Fish & Game ?
T. Robert Byington
Santa Cruz Port District
January 26, 1990

Introduction

The Santa Cruz citizens' vision to construct a harbor endured for more than one hundred years before its reality. When the harbor marked its 25th anniversary in 1989, citizen commitment remained strong. A decade of research, data collection and an aeration system in the harbor results in a safe aquatic environment. The aggressive water quality management program implemented in 1980 ensures the California harbor will stay vibrant well into the 21st century.

Local boaters, commercial fishermen, businessmen and residents sought the construction of the harbor in the 1860's. Formal funding requests were submitted to and rejected by the federal government repeatedly from 1873 to 1935.

Following World War II, a strong local support group secured the attention of the state and federal governments. The U.S. Army Corps of Engineers resurveyed Santa Cruz, recommending a Port District be formed. The Santa Cruz Port District was officially formed in 1950 under the guidelines of the State of California Harbors and Navigation code. In 1958, Congress authorized the harbor project.

The lower harbor facility, which empties into Monterey Bay, became operational in 1964 serving 360 slips initially. The harbor's success generated interest in expansion. An additional 455 slips were added in 1973 with the construction of the upper harbor.

The Santa Cruz Harbor currently has space for 1,000 wet-berthed and 275 day-stored vessels. Roughly 15 percent of these vessels are commercial fishing boats, 35 percent are pleasure power boats, and 50 percent are pleasure sail boats.

Approximately 10,000 visitor nights are spent each year by boaters using Santa Cruz as a harbor of refuge. The launch ramp is used about 15,000 times a day. Almost 2000 local people crew on boats regularly. Of the 1,100 persons waiting for slip space, 50 percent are from Santa Cruz County. Hundreds of thousands of people enjoy the harbor's concession, beaches and grounds.

Background

Throughout the 1970's and early 1980's, Santa Cruz Harbor and Marina experienced severe water quality problems. The marina experienced four extensive fish kills of anchovy (Engraulis mordax), prompting a thorough study of the harbor.

Brian E. Foss is Port Director of Santa Cruz Harbor, a position he has held since 1973. Foss, along with Harbormaster Stephen B. Scheiblauer, were responsible for the rigorous clean up following a kill.

Periodic fish kills had occurred along the California coast for many years. Kills generally occurred in enclosed waters or in areas with limited exchange with open ocean water. Although explanations for the kills were numerous, little actual monitoring of the water and fish had taken place.

In 1975, Foss commissioned T. Robert Byington to head an investigation of the harbor. Holding a master's degree in biology from Kansas State University, Byington had established an outstanding marine biology program at Santa Cruz' Harbor High and had been under contract at various times for the Port District.

Byington and others at the Santa Cruz Port District conducted research that yielded biological and chemical profiles of the harbor waters (Bourret and Byington, 1976; Byington, et al., 1977; Byington, 1980; Foss, 1980; Byington, 1984). The studies included numerous parameters: dissolved oxygen, ammonia, pH (acidity), number and types of fish, tide and currents, wind speed, air and water temperature, plankton, etc.

The result of these studies has been to identify key water quality parameters and management strategies for improving water quality conditions to eliminate disastrous fish kills. Two factors are primary: oxygen and ammonia. Byington developed a mathematical 'stress' curve for these variables.

In 1981, the Port District launched a systematic attack on the problem based on the results of the studies. The most dramatic action was the installation of 20 AIRE-O_2 aeration devices, primarily in the upper harbor. The equipment was manufactured by Aeration Industries International, Inc. of Minneapolis, Minnesota. The units were selected because of their oxygen transfer efficiency and environmental adaptability to a harbor setting.

Along with the aeration equipment, a marine lab was built at the harbor. From this lab, Byington, his lab assistants and the harbor crew conducted summer long, round-the-clock monitoring of the water conditions. More than 5,000 chemical tests were completed.

Santa Cruz Port District publication **ANCHOR WATCH** in its October, 1981 issue reported, "We can say without equivocation that the aeration was a success. It kept the water values well above the 'stress' curve...it kept the fish alive."

In 1984, another major kill occurred. The aeration equipment had not been operating. Immediate start up of the aerators, along with continuous water monitoring, showed that aeration greatly speeds up the recovery process. The aeration kept the decay process aerobic, preventing the development of anaerobic gases, especially hydrogen sulfide, and their attendant problems.

This report describes more than a decade of research findings and the method of water quality improvement implemented by Santa Cruz Port District for the harbor and marina.

Harbor Dynamics

The ocean and the harbor are very complex systems of which the anchovy (or any other schooling fish) are only a small part. Typically, the dynamics of the systems are studied only a part at a time making comprehensive analysis impossible. The whole problem of bottom sediments, water chemistry, biological interactions, and their possible effects on the system are largely unknown. All of these problems and many others need to be examined further.

Contrary to appearance, large bodies of water are not homogeneous. Essentially three bodies of water must be considered: the "outside" water of Monterey Bay, and the top and bottom water layers "inside" the harbor. That these various waters have very different physical and chemical properties has been established from examining available data. Figure 1 presents a schematic drawing of Monterey bay and Santa Cruz Harbor with the effects of temperature, tides, and circulation on these three general bodies of water.

The Santa Cruz County Office of Education Oceanography class has conducted detailed monitoring of the harbor. Water at four stations (top and bottom at the Santa Cruz Municipal Wharf, Aldo's Pier, U Dock, and J Dock) has been tested. These tests have verified the existence of several relationships to be discussed in the following sections.

Physical Properties

Water Density

Density (weight per unit volume) is a critical parameter. Water will stratify vertically, often with very sharp divisions between layers, according to its density, the denser ("heavier") water being on the bottom. The density of water is established by its salinity (more dissolved salts implies denser water) and temperature (colder water is more compressed, or denser).

Freshwater may layer on the surface of brackish or saltwater especially after heavy rainfall. This layering (freshwater lens) is due to the differences in density of the fresh and salt water. The saltwater is heavier and more dense.

Mixing

The shelter of the harbor decreases circulation and therefore allows two new bodies of water to form from the one "outside" water. Fresh water inflow (decreasing salinity by dilution) and significant warming from solar radiation create the less dense inside surface water. Mixing between this and the denser (i.e. colder and saltier) outside water creates the inside bottom water, which is intermediate in properties. The extent of mixing between these three bodies of water depends upon location, tide, and weather.

When moving up harbor, a reduction of water volume circulation and outside influence occurs. Thus the division between surface water (inside water) and bottom water (more oceanic) in the harbor is not horizontal, but may be pictured as slanting so that the surface layer is deeper at the upper end of the harbor than it is at the mouth (see Figure 1).

Tides

Water movement due to fluctuations in tidal height is the major factor causing mixing. There is a considerable variation in the extent of this influence every two weeks (spring and neap tides). Figure 2 presents a typical tide curve for a 24 hour period. The water levels between low and high tide may vary as much as six feet but are generally 4-5 feet.

Weather

Weather also has a dramatic effect on harbor conditions. Wind and/or storms can cause considerable mixing through wave action, especially at the harbor mouth.

Rainfall may cause an increase in the total coliform bacteria population of the harbor as a result of runoff (usually an indication of contamination from fecal matter). However, most of the coliform contamination is nonfecal in origin. It can also cause an increase in the silicate concentration in the harbor due to runoff. Sand and many other geological materials are composed primarily of, or contain, silicates. Rainfall also decreases salinity, especially at the water surface, by dilution from runoff and direct precipitation.

Chemical Properties

Temperature

In contrast to O_2 levels, water temperatures at fixed locations within the harbor vary inversely with the tide depth. As the tide rises, water temperatures drop, and as the tide drops, water temperatures rise. This inverse relationship occurs because the inside water is warmer than the outside water.

Sunshine can be the controlling factor in temperature fluctuation instead of the tide, especially if it is not constant during the day. The effect of the sun upon water temperature is more pronounced in the upper harbor than in the lower, and also upon top water than on bottom. Because it is a weaker factor, the sun may be capable of overriding tidal influences only in the upper harbor.

During the summer, water temperatures at Aldo's Pier are usually 0.5 to 1°C warmer than the outside water, and they are 1 to 2°C warmer in the upper harbor than the lower harbor. This is an extremely rapid gradient.

There is a heat exchange between surface water and the air in which the warmer body loses heat to the cooler one. Thus, during the summer, when the air is warmer than the water, heat flows into the surface water making it warmer than the bottom. The opposite occurs during winter, heat flows out of the surface water into the air making the surface water colder than the bottom water. This cooling can increase the density of the surface water to the point where it is heavier than the bottom water, and overturn occurs.

Oxygen

In any body of water, O_2 levels are affected by many parameters as shown in Table 1. However, three major parameters affection dissolved oxygen levels include: 1) temperature, 2) mechanical agitation on the surface, and 3) living organisms - plants put O_2 in as a waste product and animals take it out for their use. Due to temperature and agitation, outside water always has a greater O_2 content than inside water. Therefore, O_2 levels at a fixed location within the harbor change <u>in phase</u> with the tide, increasing as the tide rises and pushes water inland, and decreasing as the tide falls and water moves seaward. The effect of the tide upon O_2 levels is more pronounced on bottom water than top, and also upon water closer to the ocean than farther up harbor. The tidal effect can be obscured by extensive mixing between top and bottom waters.

O_2 levels in the harbor are normally between 3 and 8 ppm (parts per million in terms of weight/volume). These values are often 2 ppm lower at Aldo's Pier than outside, and decrease going up the harbor.

Ammonia

Normal background levels of ammonia (NH_3) in Monterey Bay are up to 1 μM and sometimes as much as 2 or 3 μM (rarely) near a sewage outfall[15]. Twelve harbor water samples taken on the 2nd and 9th of August 1976 had ammonia concentrations of 8.7 to 21.7 μM. These levels of ammonia are toxic to fish and other aquatic life.

Ammonia attacks the respiratory process and increases the susceptibility of an organism to unfavorable conditions[16].

After several weeks of exposure to sublethal (and minute) levels of ammonia, a variety of physical damage to fish results. A major effect is hyperplasia of the gills - a rapid growth causing fusion and lesions of the gill tissues[2,7,13,16]. This reduces gill surface area and thus drastically reduces gaseous exchange - the fish cannot get enough O_2 or get rid of NH_3 or CO_2. Exposure to these ammonia conditions is a precursor to gill disease[7,16]. Finally, damage to the liver (which removes many toxins from the blood, among other things) and destruction of red blood cells (which carry O_2) results[16].

In higher concentrations, ammonia damages and kills by disrupting various biochemical processes. The concentration of ammonia in fish blood is directly related to the ammonia concentration in the surrounding water[7].

One reason that ammonia can cause so many problems is its ability to carry out the following reaction: $NH_3 + H^+ \leftrightarrow NH_4^+$. The equilibrium point of this reaction is dependent upon pH. At the pH found inside fishes, almost all ammonia is in the NH_4^+ form.

Transport of ions (charged molecules) is essential to many biological processes. NH_4^+ disrupts ion transport in gills and mitochondria (part of cell where energy is extracted from food), possibly by substituting itself for the proper ion[13]. In order for the mitochondria to produce energy, there must be an H^+ gradient across the mitochondria membrane. The NH_3/NH_4^+ system can destroy this gradient by equalizing the H^+ concentration on either side and thus reducing or stopping energy production[13].

If NH_3 or NH_4^+ builds up internally because of increased external concentrations, it can cause localized changes in pH through the above reaction. Organisms normally maintain their internal pH within very narrow limits because changing pH can upset enzyme catalysis (controlling which chemical reactions occur when, and thus life itself) and Ca^{2+} transport in the sarcoplasmic reticulum (which controls muscular action), as well as affecting the stability of many membranes[13].

Ammonia also affects gases in the blood. At about 0.3 ppm external ammonia, O_2 levels in fish blood begin to decrease. At 1 ppm ammonia, there is only 1/7 of the normal amount of O_2 present[3]. Also at 1 ppm ammonia, blood levels of CO_2 are increased 15 percent above normal, which in turn causes a decrease in utilization of the available O_2[3].

Since ammonia affects the oxidative metabolism of an organism[13], lowered O_2 levels compound the problem. The fish begin consuming more O_2 (one study showed a 50 to 100 percent increase[7]) in an attempt to overcome the decreased efficiency, which further lowers the O_2 level of the surrounding water.

At a given NH_3 concentration, fish will survive longer if the O_2 concentration is increased, especially at lower NH_3 concentrations[6]. At a given O_2 concentration, increasing NH_3 decreases survival time[6]. Low O_2 levels also increase the amount of physical damage to fish by ammonia[16].

Increasing water temperature increases ammonia toxicity for two reasons. Most importantly, an increase in temperature causes an increase in metabolic activity in cold blooded organisms, such as fish[3,7,13,16]. This increase in metabolism causes both an increase in respiratory needs[16] and an increase in internal production and excretion of ammonia[3,7]. Secondly, at a given pH, an increase of temperature increases the amount of ammonia present as NH_3 by changing the equilibrium of the NH_3/NH_4^+ reaction[16].

While both NH_3 and NH_4^+ can penetrate biological membranes[13], NH_3 is vastly more permeable due to its lack of charge[7]. Since ammonia must pass through membranes to cause damage, ammonia toxicity depends upon the concentration of the NH_3 form[6,7,10,13]. The pH has an effect on the amount of NH_3 present and therefore upon ammonia toxicity. A rise in pH increases NH_3 and thus the toxicity[7,10,16].

pH and CO_2

In the oceans, CO_2 participates in a very effective buffer system which serves to keep pH relatively constant by shifting the equilibrium in a chain of chemical reactions involving H^+. This system is: ($H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{-2}$). Adding CO_2 pushes the reactions to the right, which increases H^+ and therefore decreases pH.

It is the pH at the gill surface, where ammonia can enter the fish and CO_2 leaves, that determines ammonia toxicity. The greater the difference in CO_2 levels between the external water and the blood, the greater will be the local drop in pH at the gills as the CO_2 is excreted. The more the pH drops, the greater will be the conversion of NH_3 to NH_4^+. Therefore, because higher ambient CO_2 levels imply a smaller difference in CO_2 levels between the water and the blood, a rise in CO_2 increases ammonia toxicity due to the decreased detoxication[10]. High levels of CO_2, as a result of biological activity, rather than pollution, are usually accompanied by low O_2 levels[14,16]. It has been established that an increase in CO_2 causes a decrease in the utilization of O_2 by fish[4]. Also, CO_2 might decrease the ability of the fish blood to transport O_2; however, conflicting results in the literature have not established this.

Chlorophyll A

Chlorophyll is a measure of the phytoplankton population in the water. Measurements have shown that a more concentrated phytoplankton population is found in the inside harbor as compared with the "outside" waters.

Biological Properties

All organisms are dependent in several ways upon their environment, and fish are no exception. Being cold blooded, water temperatures control their activity and metabolic rate to a large extent. Fish need a flow of water past them to bring O_2 and food (anchovies use gill rakers to strain plankton out of the water), and to take away, or dilute, CO_2 and other toxic wastes.

Outside, in the "open" environment of the ocean, this need for water can be satisfied by either swimming through the water or remaining at a place where water moves past. Inside, in the "closed" environment of the harbor, getting this new water can be a problem due to the reduced circulation and volume of water within the harbor, and the resulting differences in what are normal levels for various chemical and physical parameters. The interior harbor, having even less circulation, exacerbates any undesirable conditions.

Fish Population

Why anchovy come into the harbor in large numbers is still a mystery. This is the sort of question which requires long term research and considerable man hours to answer.

A. Feeding

Results of a limited number of stomach and pre-anal content analysis on anchovy indicate that they are not selective feeders, but take in whatever is present, including a considerable amount of silt and detritus. It would therefore appear that there is no reason for the anchovy to take advantage of the fact that plankton populations inside and outside the harbor are often different in composition by coming into the harbor to feed. The authors have not been able to correlate fish movement with plankton composition.

On the other hand, these same results do indicate that digestion may be selective. Also, the literature indicates that anchovy may actively seek out and "bite" copepods and the other large zooplankters instead of relying solely upon their gill rakers to supply food. Finally, chlorophyll a measurements indicate that there is usually a more concentrated phytoplankton population inside the harbor than outside. Thus, the question of feeding is unresolved.

B. Reproduction

The fact that anchovy consistently show up in the harbor at the same time of the year, late summer, is a strong argument for some process involving timing to be the cause of their arrival.

Reproduction may be such a process and is frequently mentioned. However, studies indicate that anchovy reproduce in offshore waters; not in enclosed waters such as the harbor.

C. Migration

The anchovy populations move around during the year, so it is possible that they show up off Santa Cruz in late summer and just happen to swim into the harbor.

D. Predation

It does not appear that anchovies are coming into the harbor as a result of predators. They have to contend with predation year round and a harbor is not usually available for refuge. Further, the harbor does not appear to offer protection. Seals have been observed to move in and out of the harbor mouth with the fish.

Interaction of Fish Population and Environment

Due to its water restrictions, the harbor may be viewed as a large, closed aquarium system. Large or concentrated populations of fish have the capacity to drastically alter their environment by putting various chemicals into the water and taking others out. This modification usually has a desirable effect,[3, 16] a fact that often makes successful aquarium operation difficult.

It is an unquestionable established fact that fish use 0_2. What is important in this case is that fish are capable of producing a rapid decline of 0_2 levels in a closed system. A decreasing population (from nine organisms to two) of small (about 7 to 10 cm in length) anchovies in a 25 gallon tank reduced dissolved 0_2 by half during a 7 1/2 hour test. During August 1975, O_2 levels of under 1 ppm were observed on several occasions in an anchovy school located in the harbor entrance, while nearby inside water at Aldo's had 2 to 3 ppm O_2. In the case of the herring, O_2 levels were about 4.5 ppm inside the enclosure and about 5.5 ppm in the immediately adjacent water outside the net.

The second major environmental change brought about by the fish, and apparently the deadly one, is the buildup of ammonia. NH_3 is the major toxic waste excreted by fish [13, 16]. It is eliminated primarily by diffusion through the gills, with a trace amount in the urine.[3, 4, 13, 16]

Studies of anchovies in fish tanks confirmed two fairly obvious points about ammonia excretion: the amount of ammonia excreted is proportional to the number of fish, and circulation water does carry the ammonia away. Ammonia levels in two tanks without circulating water approximately doubled in eight hours, in spite of rapidly declining anchovy populations. In the next sixteen hours, the remaining fish (about one-fourth of the original population) caused a further increase of about 50 percent. At the same time, ammonia levels in two tanks with flow-through water circulation decreased with the fish population. Although we did not test for the parameter, it is reasonable to assume that within large populations of fish CO_2 levels increase, especially since CO_2 is much more soluble in water than O_2[14].

Stress Conditions

O_2 is required for respiration (the process by which an organism gets its energy). Many fish can survive at O_2 concentrations of about 1 ppm, and under otherwise favorable conditions.[4, 5] For more sensitive fish, a concentration of about 2 ppm O_2 is the limiting level.[5] Normal activity is possible for most fish at 3 ppm O_2, and there are relatively few fish which have difficulty surviving at this level except under extremely adverse (and therefore usually laboratory) conditions.

When O_2 is supplied below that necessary to maintain normal life the metabolic rate is reduced by cutting back on unnecessary activities and functions.[4, 5, 11, 13] This saves energy and thus the amount of O_2 required. For example, swimming can cause a 50 percent increase in O_2 consumption.[11] Over long periods of time (weeks) at this low resting metabolism, growth is stopped and weight is lost.[5]

By allowing them to produce an abundant supply of energy, high O_2 levels increase the ability of fish to survive stress situations caused by other factors. However, this does not enable fish to overcome any situation. For example, mechanical agitation brought O_2 levels inside the bait enclosure up to about 7.5 ppm, but the herring continued to die.

Ammonia levels above 0.1 ppm (about 6 μM) are considered to be harmful for fish culture.[2, 3, 13, 16] It is difficult to determine beyond this what levels are toxic, due to the many variables involved and the confusion in the literature resulting from the complicated chemistry of ammonia in sea water. It can exist in several forms of varying toxicity (NH_3, NH_4 +, NH_4 OH, etc.); the amount of each determined primarily by pH.[8,14] Toxic levels in fresh water have been reported in the range 2 to 7 ppm ammonia [5, 14], and a source unconfirmed by the authors' literature research reports that ammonia is more toxic in salt water than fresh water.[9]

Fish have two responses to raised ammonia levels. First, they can alter their excretions to minimize adding to the problem. This is accomplished by 1) reducing the overall amount of nitrogenous waste excreted, and 2) by excreting more in other, less toxic forms than ammonia[7]. A second response is changing their heartbeat pattern. By beating in bursts (and opening the gill cover at the same time) followed by rests of five to ten seconds (with gill cover closed), only a minimum amount of exterior ammonia can come into contact with the gills (unpublished research).

Although fish populations can turn their environment into a very favorable one, they do not just give up and die. In general, living organisms can adapt to extremely adverse conditions and survive. This usually requires changes or restrictions that drastically modify the organism's lifestyle, but at least it is still alive.

How quickly their environment changes greatly affects the conditions that an organism can tolerate. It has been repeatedly shown that slow acclimatization to a new condition will allow an organism to survive much worse situations than when exposed to rapid change.[4, 5, 11, 13] Finally, actual tolerance levels depend upon which species is involved.[4, 5, 1, 13] It has been the experience of the authors that, under similar conditions, attempts at keeping fish in aquaria showed anchovy to be hardier than either herring or smelt. Mechanical damage suffered by fish during transportation may invalidate this judgment.

Fish Kill Studies

Periodic fish kills have occurred along the coast for many years. Almost invariably the kills have occurred in enclosed waters or in areas with limited exchange with open ocean waters. Explanations for the kills, as varied as the persons offering them, include; lack of oxygen, water too warm, red tide, disease and predators chasing the fish into crowded conditions.

Effect of Major Water Quality Parameters

Life may be defined as a complex series of chemical reactions involving carbon chains and energy. Green plants and some bacteria use the processes of photosynthesis to make carbon chains onto which light energy is placed. All organisms (plants, animals, bacteria, etc.) break down these carbon chains to release the energy and carry on their life processes. The reactions breaking down the carbon chains are collectively called respiration. Respiration reactions may be anaerobic (use no oxygen) or aerobic (use oxygen). In nature aerobic reactions produce considerably more energy from the breakdown of a carbon chain than does anaerobic reactions on the same chain and are, therefore, the basis for multicellular and advanced plant and animal life with its high energy consumption.

Oxygen rarely becomes a limiting factor to life on land. Oxygen concentrations in the atmosphere are about 600 times that in water, per unit volume. Oxygen concentrations in the water are far more tenuous. All aerobic organisms consume the oxygen, reducing its presence in the water column. Processes to replace oxygen in the water column are concerned with photosynthesis and mechanical agitation.

Photosynthesis demands light and the concentration of light controls the rate of photosynthesis and the production of oxygen. Turbidity of water limits the depth to which light can penetrate the water column, controlling photosynthetic rates. Even if light is abundant and the water column is clear, nutrients, especially nitrates and phosphates, have to be present for photosynthesis to occur. Under ideal conditions, which often occur in Monterey Bay waters, photosynthetic processes may actually supersaturate the water with oxygen. It is to be noted that the colder the water, the more oxygen it can hold in solution.

Mechanical agitation is due primarily to wind action. Very little oxygen moves across the boundary between the atmosphere and water if the boundary is flat and quiet. The transfer that does take place is very slow. Transfer is greatly speeded as winds make waves, increasing the surface area and mixing the aerated water down the water column. The greater the turbulence, the greater the transfer of oxygen. In the harbor itself, another mechanical agitation, the tide, can be significant. Unfortunately, the harbor has periods of "good" tidal flush (spring tides) alternating with periods of reduced flush (neap tides).

Summarizing, oxygen concentration in water is increased by photosynthesis (controlled by light concentration and nutrients) and mechanical agitation (winds, wave action and tidal flush). Oxygen is depleted by respiration of the biomass present. Temperature tends to increase or decrease oxygen depending on whether it is low or high respectively.

Ammonia is a waste product produced when carbon chains, especially protein, are utilized as an energy source by organisms. In humans this ammonia is quite noticeable in the urine during the first year of life. As we get older the ammonia is converted to urea in the liver before excretion. In water, the fish especially, eliminate their ammonia through the gills. Once in the water the ammonia is taken up by plants during photosynthesis as a nitrogen source. This process may first include a bacterial conversion to nitrate. Under normal conditions the amount of ammonia in the water is balanced between photosynthetic and respiratory processes.

A simplified, generalized model of a living system consists of three components: producers or plants, consumers or animals, and decomposers. Plants utilize light, water, carbon dioxide and minerals from the surroundings to make carbon chains. As a source of carbon chains, the plants are consumed by animals. The animals become a source of carbon chains and they consume each other. In the end all plants and animals die and are consumed by decomposers who return the minerals to the environment and the cycle begins again.

Decay activity is usually nothing more than aerobic respiration involving a succession of microscopic organisms (usually bacterial), each utilizing particular sets of carbon chains in a sequence until the carbon chains are reduced to carbon dioxide and water. If, however, the mass of the dead matter is large enough, the rate of decay may remove the ambient oxygen faster than it can be replaced.

Under ideal conditions, bacteria may reproduce every 20-30 minutes and can rapidly consume available oxygen under those conditions. Decay, however, does not stop with the depletion of the oxygen. Other ubiquitous bacteria continue the decay, utilizing oxygen from nitrates. As the nitrates are depleted another group of bacteria utilize the oxygen from sulfates, producing H_2S (hydrogen sulfide) and its characteristic rotten egg smell. Still another group of bacteria utilize no oxygen as they break down proteins. The foregoing represents anaerobic decay and is a natural part of the decay processes. In the anaerobic state, H_2S can be utilized by some bacteria in photosynthesis instead of water, helping to remove the H_2S from the water.

Prediction Technique

The preliminary Anchovy Project Report presented to the Santa Cruz Port District in September, 1977, 1) a graph showing stress and kill conditions, based on oxygen and ammonia values, was established from computer analysis of extensive kill tank and harbor data; 2) the most likely conditions for a fish kill were hypothesized; and 3) two immediate steps to prevent a kill were proposed. A limiting factor for the report was time, i.e. how long the fish (and indirectly the harbor) could remain under stress.

During meetings with representatives of the Santa Cruz Port District, California Department of Fish and Game, U.C.S.C. Costal Marine Studies and Moss Landing Marine Laboratories to evaluate the data, the effects of increasing numbers of plants and animals becoming established in the harbor were discussed. It was noted that fish kills had occurred when the lower harbor (1964) and the upper harbor (1974) first opened. Neither area had any established life on its pilings, docks, banks, etc. Since the openings, a large number of very diverse organisms have become indigenous. It was hypothesized that biochemical reactions within the harbor community were able to withstand and/or mitigate the stress conditions of a transient population of fish or other organisms. Again, the problem of time was an unknown. How long could the harbor withstand what extent of stress?

Major Kill in 1980

The week of 19 July 1980 through 25 July 1980 provided a test of one hypotheses proposed in the 1977 report and the role of one harbor's increasingly enriched life. On Friday, July 18, 1980, a few herring were found floating near the gas dock. A population of anchovy was located near the harbor entrance and making incursions into the harbor. A neap tide period was beginning and the weather was generally overcast with very little wind - the conditions hypothesized for a potential kill condition. Monitoring began on Saturday, 19 Jul 1980.

Review of the Anaerobic Decay Period

Oxygen - At the beginning of the kill, surface oxygen levels were all below 1 ppm inside the harbor. Bottom oxygen levels were not detectable. Mechanical agitation from propeller action in the upper harbor increased the oxygen concentrations and, at station 9, the level was raised a surprising amount.

By the fourth day (7 August) there was no oxygen in the water form the bridges on up the harbor. Surface oxygen was not found in the samplings for the next two weeks even in the lower harbor. No oxygen was detected at stations 9, 11 and 12 through the 28th of August. The salt water wedge of flooding tides brought the only oxygen into the harbor, slowly increasing bottom levels, with the lower harbor levels rising more rapidly than the upper harbor.

Hydrogen Sulfide - Hydrogen sulfide levels increased moving up the harbor and stations 9, 11 and 12 had considerably higher values than the other stations throughout the anaerobic period. On a few days, the hydrogen sulfide level was over 1 ppm outside of the harbor. Surprisingly low levels occurred at station 8 and 10 (bottom on both sides of the bridge) almost from the beginning of the anaerobic period, often being less than the lower harbor. Another surprise was that the surface waters usually had higher levels than bottom waters at the same location. Whether this was due to actual decay activities or gases rising from bottom decay was not determined.
Generally the hydrogen sulfide levels at each station were within a small range until the third week when all values began to fall rapidly.

Ammonia - Ammonia levels reached over 5 ppm in the initial decay stages in the upper harbor. As with hydrogen sulfide, ammonia levels were generally higher on the surface than lower in the water column at the same location. An almost steady, slow decline in concentration occurred at all stations through 28 August, until only stations 11 and 12 were considered excessive. All of the stations had higher levels of ammonia before the kill began.

Plankton - At the beginning of the fish kill a few Ceratium (one of the organisms associated with a red tide condition locally) were present, but in insufficient quantity (approximately 1 percent of the biomass) to have been a factor in a fish kill. This was true for about one week after the kill when they bloomed, forming red areas covering many square miles of Monterey Bay and adjacent waters to above San Francisco. This condition persisted well into September and extended for at least ten miles offshore. If the organism is a threat to fish life in our own waters, there certainly would have been a kill outside the harbor during this period. By 28 August large numbers of salps were in the water column feeding on the Ceratium.

Inside the harbor some very interesting events occurred. A variety of marine worm larva were found in the lower harbor in large numbers. Their role as adults is primarily to filter decaying matter from their surroundings. The question is whether their appearance was somehow triggered by harbor conditions or were they collected during a normal period of their life cycle coincidental to the kill? Also, why were they in the lower harbor and not the upper harbor or outside the harbor?

The upper harbor plankton content for 25 August was the most unexpected event of the whole kill. Nine species of diatoma were found, only one of which was present in outside or lower harbor samples. Where did they come from? None of the species are associated with water conditions then existing in the water column. Almost as perplexing is their disappearance from the water column two days later. An individual shrimp and fish larva in the upper harbor samples were also unexpected as the appearance of the copepods, although copepods have been reported in zero oxygen conditions elsewhere.

In summary, the following observations can be made:

1. The fish kill curve developed for the harbor has validity for at least a few days duration.
2. The establishment of a large number and variety of organisms within the harbor does have a mitigating effect, but won't prevent a kill.
3. There is a fine balance between oxygen consumption and production which can be easily interrupted at 1 ppm levels.
4. Even during spring tide periods, the upper harbor waters do not flush or mix very much.
5. The harbor acts much like an activated sludge secondary treatment sewage plant, especially when a large biomass (anchovies) is added.
6. Knowing the above, aeration units similar to those in activated sludge plants should help prevent a kill and, if a kill occurs, to maintain aerobic decay conditions.
7. More needs to be known about the decay conditions on the bottom year round.

Major Kill in 1984

On Saturday, July 21, 1984, at 0700 hours, harbor oxygen values ranged from a low of 4.1 to a high of 7.8 ppm. About 0800 a very densely packed school of anchovy entered the lowest harbor. By 1300 a kill had begun and by 1400 the oxygen values at the launch ramp and turning basin had dropped to below 1 ppm, top and bottom. Tidal flush just prior to the fish incursion had been 0.9 ft on an ebb and a 2.8 ft. flood during the fish incursion. As the fish did not move into the upper harbor the oxygen concentration was still above 2 ppm at J dock until after 1700 hours. By 1500 hours boat owners had been asked to run their engines and turn their props to move water, aerators not installed were in place and operating and various pumps were spraying water. The result was a slight increase in oxygen values. By 2130 oxygen values in the harbor ranged from 0.4 to 1.3 ppm. A large mass of fish had moved into the upper harbor and died there as well. Air compressors were ordered and slowly began to arrive.

The worst case scenario had occurred: massive biomass, minimum tides, warm water and on a weekend. The density of this school was very surprising, being 3-5 times as many fish/meter^3 as is usually seen, except in some small schools, or pockets. During Sunday, July 22, early oxygen values had increased slightly throughout the harbor due to the aeration and bottom tidal wedge. By the afternoon more fish were entering the harbor and netting operations were begun about sunset. By late afternoon and evening the upper harbor water had deteriorated considerably due to the dead fish being carried there by tidal and eddy action. Oxygen values dropped as low as 0.1 ppm.

Monday, July 23 found the oxygen values reaching 0.0 ppm in the upper harbor and dropping below 0ppm everyplace in the lower harbor. By the evening of Tuesday, July 24, the harbor was effectively anaerobic. On that same day, there was two more incursions of anchovy, creating two more kills on a smaller scale in the area between the entrance and the gas dock. Apparently, anchovy do not actively avoid poor quality water gradients. There was direct evidence, as well, that these small schools were being pursued by schools of mackerel. The rest of the ensuing week was spent improving methods for gaining greater efficiency from the air compressor units. Plans were made to install a flushing system and it was in operation by the end of the week. Air bubble curtains across the harbor at various points apparently worked the best. The most effective example of this type aeration was at the harbor mouth.

One measure of a kill is the hydrogen sulfide (H_2S) produced. By Wednesday, July 25 the chemicals and procedure were set up and H_2S monitoring began. During the first four days of the kill most of the surface debris had been removed, leaving the bottom debris and suspended matter to produce H_2S. Concentrations were generally in the 1-3 ppm range, occasionally reaching 3.5 - 4.0 ppm at J dock. After one week all aeration was terminated for 24 hours to assess its effect on H_2S concentrations. Values increased about 50 percent in the lower harbor (2.8 to 4.0 ppm) and doubled in the upper harbor (4.0 to 7.8 ppm).

After only eight hours of resumed aeration, H_2S values were reduced almost to the previous concentrations, strongly indicating that the aeration oxygen was reacting with, and reducing, the H_2S. By August 3 only trace amounts of H_2S were found except for 1-2 ppm near J dock. No H_2S was detected on or after August 10 or 20 days after the kill began.

Comparing 1984 H_2S values with 1980, two things are evident: 1) the 1984 values were one-half to one-third the 1980 values and 2) the 1980 H_2S production lasted more than twice as long (over 40 days).

After the initial oxygen depletion to about 1 ppm and the subsequent kill, aeration efforts maintained traces of oxygen for three days in most of the harbor before anaerobic decay processes took over. During the 1980 kill no surface oxygen was found in the J dock area for over 40 days. Oxygen returned on the bottom with the tidal wedge, taking three weeks to periodically penetrate into the upper harbor. In comparison, the 1984 kill, with its aeration, had oxygen back in the lower harbor almost immediately and all of the upper harbor had some oxygen by the end of 20 days. Aeration was terminated in the upper harbor on August 13, 23 days after the kill began and steelhead (a fish requiring high quality water) were present in the entrance to launch ramp area. By August 25 steel-head had reached the bridges and oxygen values had increased far beyond normal, even at J dock.

The water was a reddish color, strongly indicating along with the high oxygen values, that a bloom of dinoflagellates was occurring, living on the high concentrations of nutrients released in the kill by decay. These dinoflagellates were probably responsible for the supersaturation of the water with oxygen, given off by their photosynthetic chemistry. The bloom lasted about one week when the waters returned to normal for that time of year.

The attempt to flush the upper harbor water out by bringing water from the west side of the jetty to the upper harbor was not successful. The incoming water was absorbed so rapidly by the ambient water that its effects could not be chemically noticed 12 feet away.

It takes far more oxygen to decay a dead fish than to keep the same fish alive during the same period. The fact that the harbor aeration system was able, with help, to keep the harbor aerobic for three days after the kill and that the anaerobic period was halved, strongly supports its use. As stated before, by this writer, both sections of the harbor should have the equivalent of at least 20, 3HP AIRE-O_2 units. This may not completely eliminate the possibility of a fish kill, but it should handle 95 percent of potential kill incursions

Alternative Solutions

This section presents a variety of possibilities for preventing a fish kill in the harbor, along with the major advantages and drawbacks of each. It should be emphasized that the authors do not know which systems will work and which won't, nor what side effects may be unwittingly produced. Therefore, none should be implemented without adequate prior testing on a small scale situation. It has also been the authors' experience this summer that the major problem involved with such testing is obtaining an undamaged supply of fish to use.

Solutions fall into two categories: 1) keeping the fish out of the harbor entirely, or 2) trying to clean up the water so they won't die once inside. The first alternative is generally undesirable because restricting anchovy movements will also probably restrict other organisms, with unknown effect upon the natural systems in the harbor. It appears that the harbor is increasingly developing into a productive area biologically, and this is a change which should not be halted. Also, before attempting to keep the fish out, it should be definitely known why they are coming in, so effects of the action may be better anticipated.

Some of the alternatives that have been proposed include bubble screens, hydrophones, nets, electricity, propeller noise, plants & bacteria, spray system, circulation, alarms and aeration.

Santa Cruz Solution to Fish Kill Problem -- Aeration and Circulation Using AIRE-O_2 System

Monterey Bay has a resident population of anchovy that move around the bay and surrounding coastal waters. During the spring months they lay their eggs for the year. Depending on the development period of the Pacific high pressure system and its attendant northwest winds, upwelling of the coastal waters occurs, bringing nutrients on which diatoms and other plankton thrive to the surface waters.

As the water warms in the northern part of the bay, productivity is very high and the anchovy move into the warmer, food rich waters. The Santa Cruz harbor is a natural extension of the bay and the fish schools, moving in the shallow waters, enter with normal swimming patterns. Between 50 and 75 other kinds of fish are found in the harbor during the year, why not anchovy?

Occasionally (four times in 20 years) the fish biomass is more than the harbor waters can supply with oxygen and provide waste removal and a kill occurs.

Control of the problem may be divided into 3 parts; 1) keep the fish out with mechanical barriers, 2) keep the fish alive once they have entered, 3) drive the fish out, if they are causing stress to the harbor and themselves. A mechanical net or other type of barrier would be extremely expensive to install and maintain and would create vessel traffic problems. Controlling fish movements with lights, sound, electric shock and bubble curtains have all been tried repeatedly around the world. Results have been mixed and nothing has worked for more than 10-30 minutes before the fish accommodated themselves to the new stimulus. That leaves keeping the fish alive when they enter the harbor.

Because the fish kill themselves by depleting the water of oxygen, oxygen has to be replaced. In 1981 an aeration system was installed and evaluated extensively. From that year's data and subsequent data it became obvious that a kill could have occurred on any of at least 30 days in 1981 if the aeration system had not been in operation.

Aeration serves two purposes; keep the fish alive and keep the decay process aerobic if a kill occurs, reducing the smell and damage.

The kill of 1984 was comparable in biomass to the kill of 1980. The difference in results of the kills was due to aeration. In 10 the oxygen was depleted immediately and the decay process was anaerobic (without oxygen) with the attendant production of hydrogen sulfide. Oxygen levels were non existent in the surface waters for six weeks and hydrogen sulfide was produced for almost the same period.

The 1984 kill had aeration throughout. As a result the first three days cleanup operations was aerobic, greatly reducing odors. During the anaerobic decay period, the constant aeration caused a chemical reaction with the hydrogen sulfide and its concentration was kept to 1/2 to 1/3 the levels of the 1981 kill. At the end of the 20th day after the kill began, the hydrogen sulfide production had stopped and all areas of the harbor had oxygen. On the 23rd day steelhead had entered the harbor waters as far as the bridges.

The quick reaction by harbor personnel, from the Port Manager and Harbormaster to the maintenance crew, deserves a tremendous amount of credit for mobilizing cleanup crews and the installation and operation of backup aeration units. Their efforts kept the problems to a minimum.

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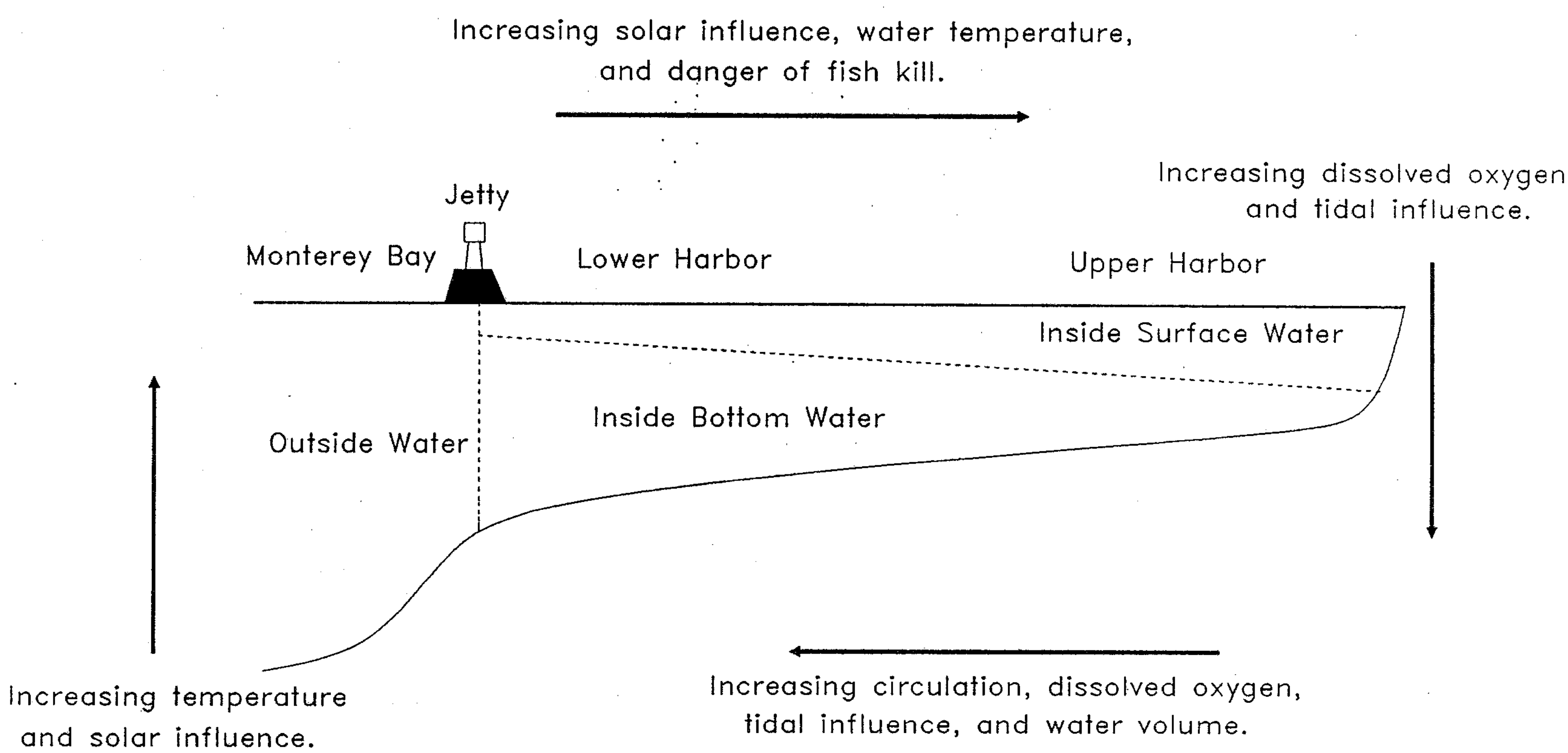
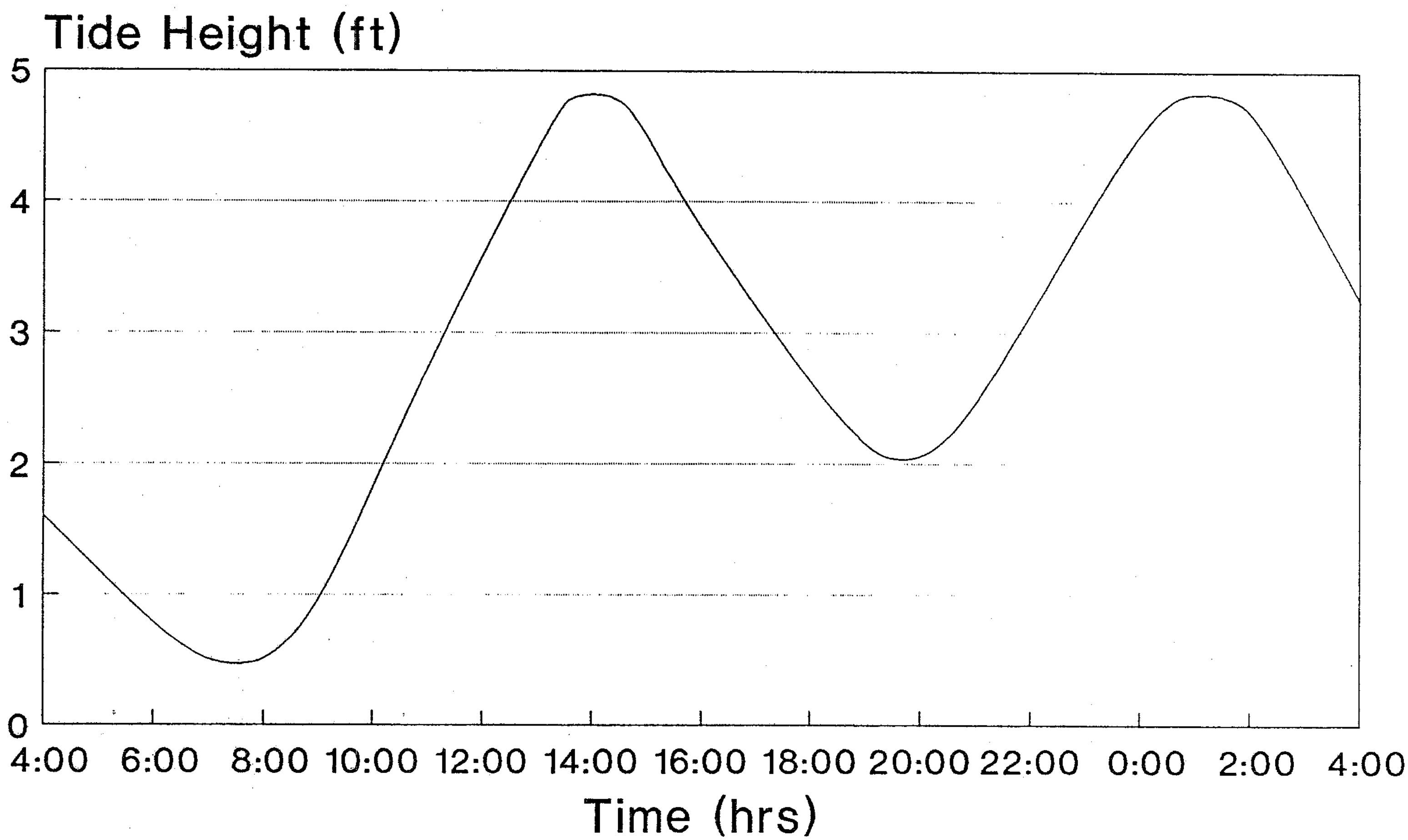
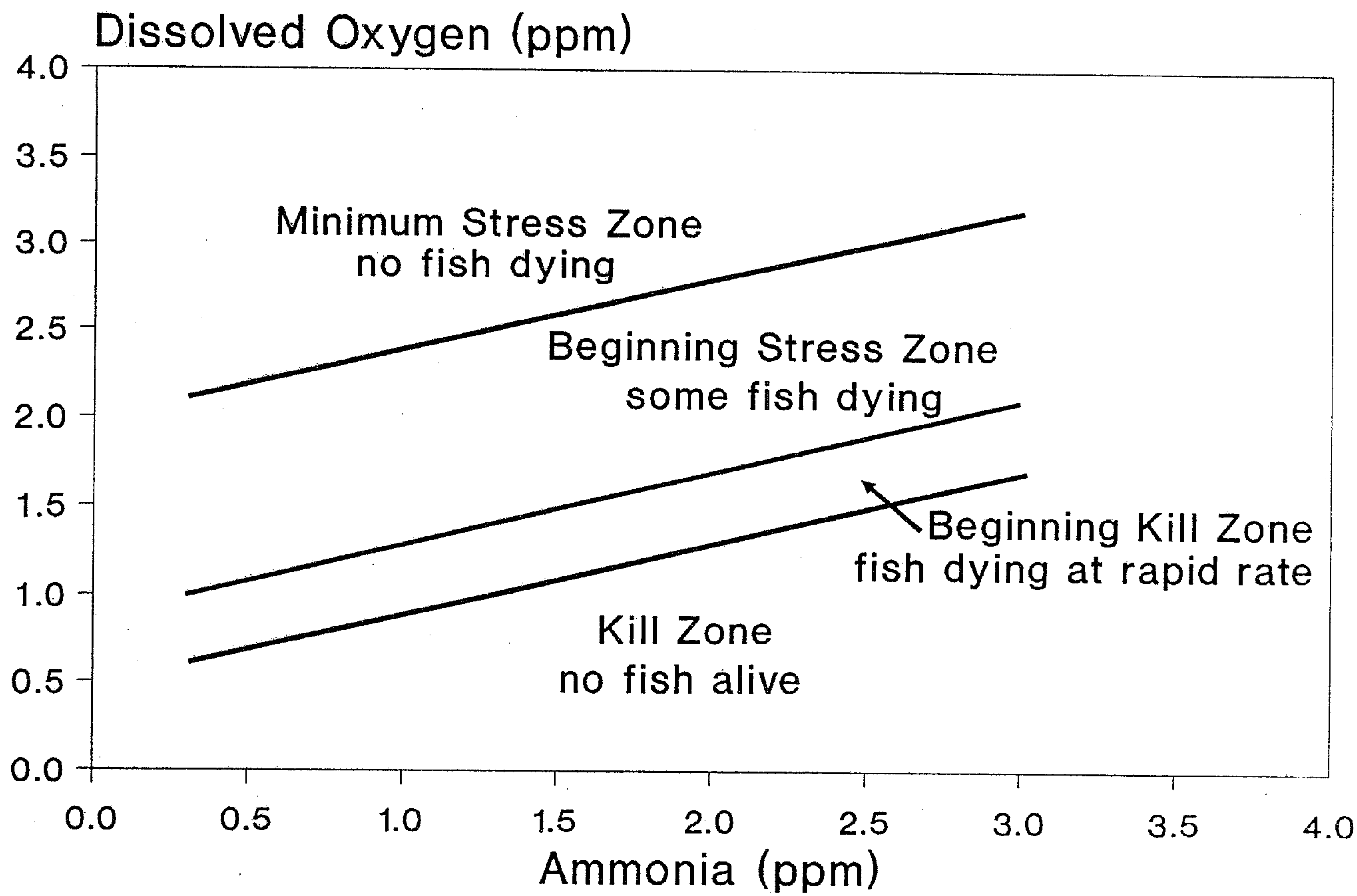

Increasing solar influence, water temperature,
and danger of fish kill.
Increasing dissolved oxygen
and tidal influence.
Jetty
Monterey Bay
Lower Harbor
Upper Harbor
Inside Surface Water
Inside Bottom Water
Outside Water
Increasing temperature
and solar influence.
Increasing circulation, dissolved oxygen,
tidal influence, and water volume.

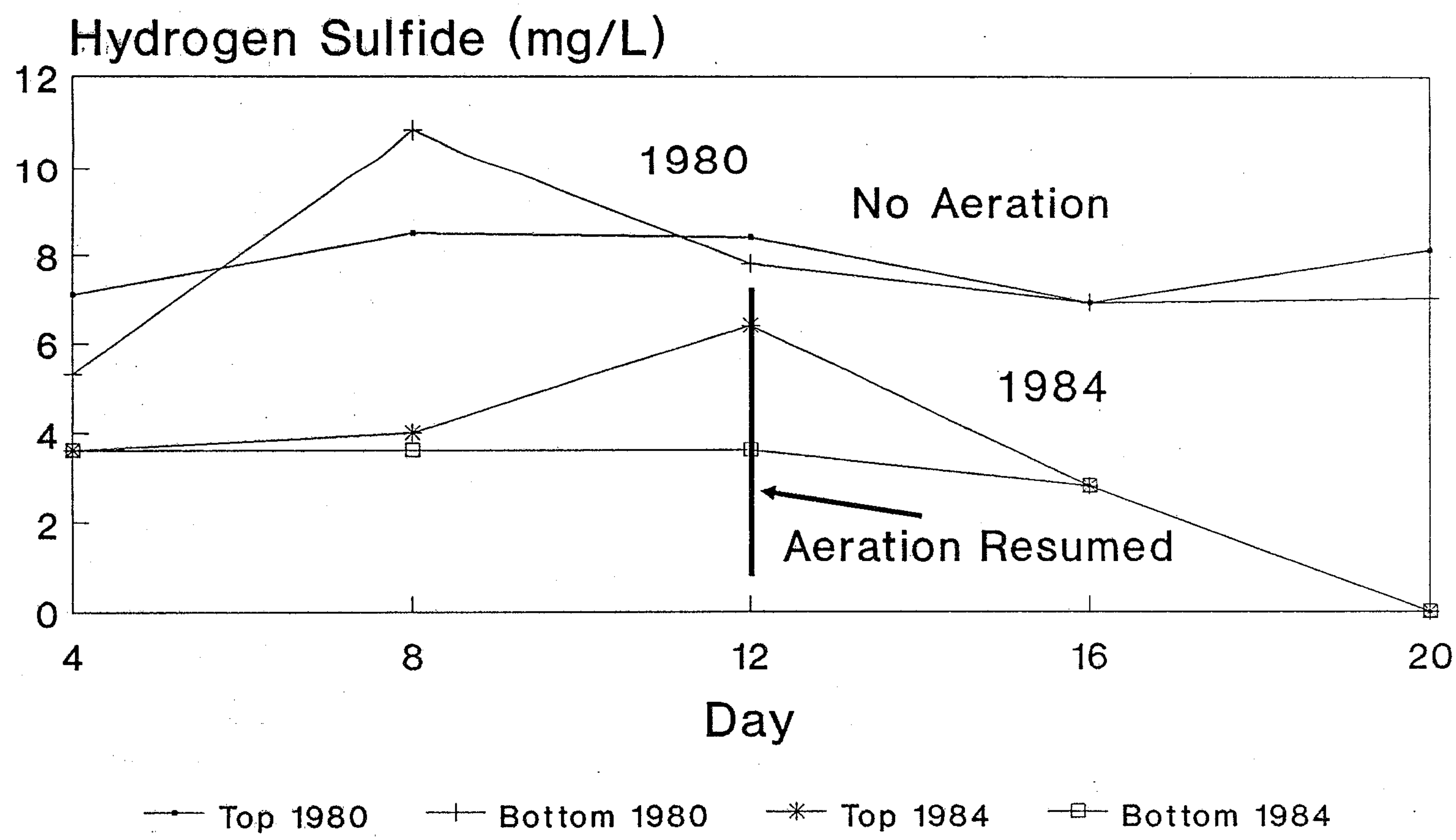
Typical Variation in Tide Height
Santa Cruz Harbor



Predicting Anchovie Kill

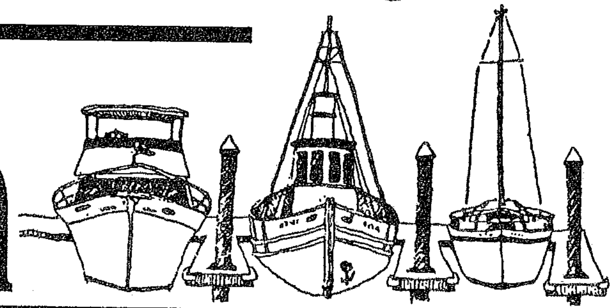


Comparison of Sulfide Levels
1980 and 1984 Kill Recovery Periods



March 36-

Anchor Watch



SANTA CRUZ PORT DISTRICT JUNE 1996

Port Commission Adopts FY 97 Budget

The Port Commission stared rising costs in the face and didn't blink. As promised, there will be no rate increases for FY 97. Slip rents will remain frozen until at least July 1997.

It hasn't been an easy promise to keep. General earthquake repair and renovation costs for the lower harbor docks are pressing harbor resources – especially since the Port District no longer receives tax funds.

On the other hand, the harbor is doing somewhat better on the revenue side. Launching, concessions, and visitor service revenue all increased this past year, reflecting both increased efforts in those areas by the Port District, and a California economy that continues its painstaking economic recovery.

Chairman Joe Townsend explained the rationale: "While the budget deliberations focused on the cost side, we knew we had some latitude based on improved revenue, so we went with the premise of no slip rental increases. Port Commission and staff also wanted to contain expenses while keeping services at a high level. Finally, we wanted to continue capital improvements that enhance customer services."

Included in the Port District's capital budget are two financed projects: Phase III of the turning basin project which includes road and sidewalk improvements, a seawall, walkway, utilities and a small office for charter boat services; and the lower harbor dock renovation – a $750,000 program to upgrade decking, flotation, pilings and electrical services.

"Both of these projects are necessary for the long-term," said Chairman Townsend. "The turning basin was left out of the 1964 construction and has never had a proper finish. The road and a walkway are long overdue. And, the lower harbor docks are 32 year old, so we need to upgrade."

In This Issue

Shop at the numerous harbor businesses. It helps prevent increases in your slip rental rates.

Fish Story

by Brian Foss

1840 hours, Monday, May 13, 1996. STAT – STAT – STAT. Orderlies to emergency! Fish jumping in the upper harbor! Oxygen levels under two-parts per million and dropping! Vital signs deteriorating. Oxygen! Get the Paddles! Stand back!

Your mind races. You're in shock. It can't be happening – it's May! That terrible anchovy history unreels in your mind: 1964, August; 1974, August; 1980, August; 1984, July 27. You remember that one; it was your birthday. Fish don't die in May. It's not happening. It's more likely to snow. You drop the phone. You race to the harbor. All the signs are there. Pelicans and shearwaters are diving wildly – fish are flashing on their sides, jumping, darting, looking for air. The water is dark, agitated, alive – you hope.

1900 hours. The alarm goes out. I'm on auto-pilot. "Get the aerators installed; call everybody: maintenance, operations, grounds. Get 'em here now." Byington, the scientist, has just finished surveying the harbor with his oxygen instruments. He looks grim. He's been here for all the "kills." "Oxygen levels are below two parts per million," he says.

The sound of jumping fish is broken by the "clack... clack" of the roll-up door and the clatter of the diesel tractor starting. VHF radios start to crackle. Men speak in loud voices, sometimes disagreeing, though not for long – no time to

Cont'd on page 3

Fish Story

Cont'd from page 3

my head. 1980: $100,000 in clean-up costs. $200,000 in boat damage. Six weeks of a smelly harbor. Fish oil everywhere... everywhere. "Damn," I think. "Outfoxed by little fish again. May! Sardines! Damn!"

2350 hours. They're all in and churning. A procession of vehicle lights in single file clamber slowly counterclockwise around the harbor. Tired men return to the maintenance shop. Spent. Bob Wise sends most of them home. They can do no more. It is up to those little bubbles now.

0000 hours. Bob Wise and Bob Byington relieve me on "Odd Job" and motor off to do oxygen counts. Lenny Hewitt and I wait on the dock. Three-tenths of one-part per million of oxygen would be a huge swing. We stare into the water. I wonder why we can't get smarter fish.

0030 hours. "Odd Job" returns. Byington's ecstatic, "We did it. Oxygen levels are all over two ppm against an outgoing tide. I can't believe we pulled this off. Five hours from a standing start... unbelievable!"

"I told you not to worry," says Bob Wise in mock coolness.

0045 hours. We have now thrown all the switches we own – no more to do. I leave the churning harbor to the lone night deputy. We won... for now. Whirling thoughts continue.

I can see the headline. *The Monterey Bay Sardine Returns.* Some folks will think that's swell.

0100 hours. Arrive home. In the darkness, a sleepy and mystified wife asks, "How could there be a fish kill in May?"

"Don't ask."

"Well, at least it's not your birthday," she replies.

"Very funny."

FF-Dock Landside Improvements

The Port Commission has awarded the contract to B&B Concrete Construction to complete the turning basin project. The contract includes an elevated walkway at the seawall, all new paving throughout the area, public amenities such as benches and landscaping, reconfiguration of the UCSC fenced storage area, new concrete stairs to the Murray Street bridge, and a 400 sq ft building to accommodate charter operations and public restrooms.

The total project is $281,526. Construction will begin June 1 and take approximately 150 day to complete.

We appreciate your patience during this construction as parking will be restricted during the week. We will work with the contractor to maximize parking on Wednesday nights and weekends.