TABLE OF CONTENTS

PREFACE

Local fishermen say that clamming for cockles and littlenecks is now very poor compared to what it used to be. The small native oysters also seem to be in short supply. Starry flounders have all but disappeared from the bay. Jellyfish seem to swarm in greater numbers lately. Upon occasion, Cladophora algae have proliferated and drifted ashore in large smelly mats. In the past few years, the native marsh grass (Spartina) has rapidly colonized many acres of sediment laden tidal flats. By-and-large, Tomales Bay water quality still seems relatively good, but these obvious changes are reason for concern. What is causing them? What other changes, perhaps not as obvious to the casual observer, are occurring? What might the future bring?

The Fourth State of The Bay Conference seeks to bring together those who know most about these changes, so that we might learn why they are occurring, what they mean in the big scheme of things, and how watershed planning and education might protect what is still Tomales Bay's most precious asset - water quality.

Photo Notes:
“Overlook Tomales Bay” was taken in November, 1996, by Point Reyes, California photographer Marty Knapp. The Lagunitas Creek delta and the Inverness Ridge are seen just before sunset.

Acknowledgement:
The cover photograph is from a large collection of images created by Marty Knapp that feature the natural world in and around the Point Reyes National Seashore in California. A catalog of his work can be seen online at www.martyknapp.com. Visitors are also welcome at his Olema, California studio. Phone 415-663-8670, or email: marty@martyknapp.com

Fourth State of Tomales Bay Conference
October 6 & 7, 2000

SPONSORED BY
The Environmental Action Committee of West Marin
The Inverness Foundation
The Tomales Bay Foundation
Point Reyes National Seashore
Gulf of the Farallones National Marine Sanctuary
University of California Cooperative Extension/Sea Grant

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and especially those others whose assistance is greatly appreciated.

IN PARTICULAR
The Steering Committee wishes to thank the speakers and moderators
who gave unselfishly of their time.

TOMALES BAY

for Richard Plant and Jules Evens, its guardians

A long finger of the ocean's hand
exploring our coastline,
following the seam of the San Andreas
drowned a valley,
made of it a pristine bay
filled with black geese,
butternoses and bluebills,
skates and rays,
herring and halibut,
ghost shrimp and moon snails,
eel grass and sea lettuce,
sea stars and sea squirts,
sharks and shorebirds,
patrolled by yellowlegs
and willets with semaphoric wings.
Occasionally rising from the depths
near the mouth, like a dream,
the long head of leviathan,
beaded with barnacles.
Tomales Bay: Its waters
comb the tail of Baja, languish along the
Equator,
skirt the Philippines,
wash the shores of Japan
and of old Mother Russia,
coast the Aleutians,
break on the beaches of Alta California,
as they slowly spin in the Pacific Gyre.
Tomales Bay edged
with bare hills on one side of the fault,
black forest of pine on the other
before the naked spear of its point.
Tomales Bay gathers our streams,
a long lovely ladle,
for cockles, money shells, horsenecks
and underwater gardens of oysters.
At its opening, currents swirl
like Spanish skirts,
waves break on its bar
like the clash of samurai swords,
the ocean's roar from one shore
hums like a Miwok chant,
a Buddhist prayer, a Catholic mass;
fogs cozy it like samovar steam.
Tomales Bay, rich rose of its mud,
the unconscious of our watershed,
from which our inspiration comes
shooting into mind like red salmon
into the shallows of our inland streams,
its surface morose or sparkling with
sunlight,
it teems below with hidden life.

Michael Whitt -- written for the Fourth State of Tomales Bay Conference

REQUIESCANT IN PACE

With a sense of great respect and gratitude we would like to acknowledge people who, in the course of their lives, made significant contributions to the environmental health of Tomales Bay and its watershed.

Senator Peter Behr
Sally Behr
Congressman Philip Burton
Leo Cronin
Bill Filante
Jerry Friedman
Al Giddings
Allan Johnstone
Jack Kent
Clayton Lewis
Senator Milton Marks
Congressman Clem Miller
Corwin Mocine
Virginia Norris
David N. Plant
Anne West

4th STATE OF TOMALES BAY CONFERENCE
October 6 & 7, 2000
AGENDA

Friday Afternoon 10/6/2000, 1:00 PM to 7:30 PM, Inverness Yacht Club
Moderator: Maria Brown - Farallones Marine Sanctuary Association

1:00-1:15	Registration
1:15-1:25	Introduction by Richard Plant - Tomales Bay Advisory Committee
1:25-1:35	Dr. Mike Whitt – Poems: Tomales Bay and Coho
1:35-2:15	Watersheds, Water Quality and Shellfish Aquaculture: The Need for Science-Based Management. Dr. Paul Olin, Marine Advisor, University of California Cooperative Extension/Sea Grant
2:15-2:55	Tidal Water Fishes of Lagunitas and Walker Creeks - Dr. Michael McGowan and Jennifer Pearson, Romberg Tiburon Environmental Center and San Francisco State University
2:55-3:15	***Break***
3:15-3:55	Impacts of Introduced Species on Coastal Food Webs and Aquaculture in Tomales Bay Dr. Ted Grosholz, University of California, Davis
3:55-4:35	Spartina in Tomales Bay, Friend or Foe? - Dr. Debra Ayres, University of California, Davis
4:35-5:10	Giacomini Wetland Restoration, Hydrologic Response and Role in Bay Water Quality Brannon Ketcham, Hydrologist, Point Reyes National Seashore.
5:15-7:30	***Refreshments***

Saturday Morning 10/7/2000, 8:30 AM to 12:15 PM - Dance Palace, Point Reyes Station
Moderator: Don Neubacher – Superintendent, Point Reyes Seashore

8:30-9:15	Coffee & pastries; Registration
9:15-9:35	Introduction, Preface & Review of Past Conferences - Don Neubacher
9:35-9:55	The Short Happy Life of the First Consensus About Tomales Bay - John Hart
9:55-10:40	National Science Foundation LMER/BRIE Studies Tomales Bay, 1987 to 1995 Dr. Randy Chambers
10:40-10:45	***Break***
10:45-11:25	Seasonal and Spatial Distribution of Coliform Bacteria and *E.coli* in a Rural California Estuary - Dr. Rick Bennett
11:25-11:35	Tomales Bay Agricultural Group - Robert Giacomini, Dairy rancher
11:35-12:15	System Assessment to Improve Water Quality Management on Agricultural Lands David J. Lewis, University of California Cooperative Extension
12:15-1:00	***Lunch***

Saturday Afternoon 10/7/2000, 1:15 PM to 4:40 PM - Dance Palace, Point Reyes Station
Moderator: John Kelly - Cypress Grove Preserve

1:15-1:30	Preface to afternoon - John Kelly
1:30-2:10	Tomales Bay Shoreline Plants: The Exotic and the Rare - Barbara Moritsch, Point Reyes National Seashore
2:10-2:45	Sewage Systems and Tomales Bay - Ed Nute, Nute Engineering
2:45-3:00	***Break***
3:00-4:00	Tomales Bay Advisory Committee – Tomales Bay Watershed Council Harry Seraydarian, Environmental Protection Agency Michael Mery, Tomales Bay Watershed Council
4:00-4:40	It's the Math, Stupid ! - Dr. Jim Lawry

Saturday Evening 10/7/2000, 5:00 PM to 8:00 PM - Inverness Yacht Club

5:00-6:15	***Refreshments and Barbecue***
6:15-7:55	Guest Speaker: Ed Ueber, Manager Gulf of the Farallones National Marine Sanctuary

Watersheds, Water Quality and Shellfish Aquaculture
The Need for Science-Based Management.

Dr. Paul Olin
University of California Cooperative Extension Sea Grant

Tomales Bay, and the concerns people have for its water quality, natural resources and beneficial uses, is a microcosm that mirrors situations found in estuarine systems around the world. Throughout history, people have increasingly turned to the oceans and coastal areas seeking their livelihoods and recreational opportunities. On a global scale, less than two percent of the earth is habitable coastal zone, yet approximately 60 percent of the world's population currently lives within that minuscule area, and this is projected to increase to 75 percent by the year 2020. Such increases in coastal populations have contributed to the degradation of water quality and coastal resources on every continent.

In California, a remarkable 80 percent of the state's 34 million people live and work within the 20 counties bordering the Pacific Ocean and its estuaries. It is estimated that California's coastal industries contribute more than $17 billion to the state's robust economy and provide employment for 370,000 people. Of this $17 billion, $10 billion, or almost 60 per cent, results from coastal recreation and tourism. A study by the State Lands Commission reported that 86 cents of every dollar spent on tourism in California was spent within coastal counties. This intense level of habitation and commerce has had disastrous consequences on many marine and coastal ecosystems

Over 90 percent of the historical wetlands in California no longer provide habitat for resident and migratory birds, fish and shellfish, having been diked, drained, filled, and developed for other uses. Fortunately, the value of these ecosystems for wildlife and as biological filters for storm runoff are now well recognized, and a general policy of no net loss of additional wetlands has emerged. However, current wetland restoration and mitigation is a developing science and the highest priority should be the protection of existing estuarine systems like Tomales Bay.

In order to protect Tomales Bay, we must first know how it functions and how its components are integrated. While these questions are simple to ask, collecting the data to synthesize the answers is exceedingly complex. During the Year of the Ocean in 1998, Vice President Al Gore stated " There's no other natural resource upon which we depend so much but about which we know relatively so little. Together we must find new ways to protect and explore and harvest the oceans that are so critical to the fabric of life itself." To accomplish this will require a significant commitment of time and resources.

People have so dramatically altered the landscape that every resource must be managed today, and management plans should be developed for the future. Natural resources and the ecosystems they comprise evolved over many millions of years, and it would be desirable to manage them for such longevity. Unfortunately, as humans, we tend to be extremely short sighted in our planning efforts. In the University system, long range planning is considered to be five to ten years. Timing varies widely in industry, with technology businesses being created and made obsolete seemingly overnight. Recently an oil industry association issued a statement that there were no significant future concerns, as there were adequate known oil reserves on the planet to last forty years, certainly enough to cover the careers of those in the association, or for two generations of humans. Such is the state of long term planning. With natural resources like Tomales Bay and its watershed, long term planning with an evolutionary perspective is more appropriate. Once again, to accomplish this will require a significant commitment of time and resources.

Fortunately, the resolve to protect Tomales Bay and its watershed is there. There are many dedicated individuals willing to commit their resources, time and effort towards this goal. In these efforts, it is of the utmost importance to make decisions based on the best available scientific information, yet not be prone to inaction because complete information is unavailable, as that is usually the case. Basing management decision on science whenever possible will help to avoid conflict and controversy. As Senator Patrick Daniel Moynahan once said “Everyone is entitled to his own opinion, but not his own facts.”

The scientific method is based on questioning what is observed through the development of an hypothesis, subsequently designing experiments to test that hypothesis, and then evaluating data generated in order to answer the questions asked. Natural resources should be managed based on information generated through this process. If this is not the case, the following quote of Carl Sagan’s darkest vision may become a reality.

“It’s a foreboding I have -- maybe ill-placed -- of an America in my children’s generation or my grandchildren’s generation... when clutching our horoscopes, our critical faculties in steep decline, unable to distinguish between what’s true and what feels good, we slide almost without noticing, into superstition and darkness.”

Dolphin Safe Tuna – Is it True or Does it Feel Good: A Marine Example Illustrating the Complexities of Multiple Resource Management

In the 1950’s a purse seine fishery replaced a pole and line fishery for migratory tuna in the Eastern Pacific. This new fishery was made possible by new stronger netting materials, purse seining techniques, improved freezer technology and larger vessels in the fishery that allowed significant increases in landings to supply expanding markets.

Purse seiners often identify schools of tuna because they can spot dolphins on the surface that often feed on the same schools of baitfish preyed upon by tuna. In purse seining, small chase boats herd the dolphin-tuna-prey complex and surround it with a mesh net 1.6 km long and 200 m deep. There is a float line at the surface and a cable travelling through rings at the bottom of the net. When a feeding group of dolphins and tuna are spotted, usually three to five small chase boats begin to surround the fish and concentrate them in an area. The seiner then circles the school with a net, the cable at the bottom is then drawn tight, closing the net and trapping the fish in the “purse”. The catch is then brought aboard the larger seiner. One unfortunate side effect of this technique is that numerous dolphins become entangled in the net and drown. At the height of this fishery in the 1960’s, various estimates of dolphin mortality ranged from roughly 350,000 to 650,000 per year. Populations of spotted, spinner and common dolphins were declining, and public outrage over this was one of the driving forces behind the Marine Mammal Protection Act

(MMPA) of 1972. Following passage of the Act, the National Marine Fisheries Service (NMFS) instituted a number of regulations, established an observer program, and the industry developed a number of tactics to reduce dolphin bycatch. One of the most effective is for the seiner to back down after the purse is closed, this allows the float line to submerge slightly and the dolphins are able to swim out of the net. Another is to maneuver the speedboats herding the school to exclude dolphins from the tuna, and finally, fisherman in small boats can assist dolphins in escaping the nets after the purse has been closed. As a result of these techniques, dolphin mortality in this fishery dropped from approximately 500,000 in the 1960's, to 133,000 in 1986. Public concern, the MMPA, NMFS regulations, and improved fishing techniques were largely responsible for these declines.

At this time, a number of environmental groups targeted any dolphin mortality in the tuna fishery as unacceptable and launched an aggressive dolphin-safe tuna campaign. Millions of dollars were collected by these organizations to publicize dolphin mortality in the fishery, promote dolphin-safe fishing techniques and product labeling. By 1989, the U.S. Eastern Pacific Tuna fleet was shut down, closing a $250 million dollar a year fishery. Changes in fishing methods elsewhere continued to reduce dolphin mortality which declined to 2,600 in 1996. In the decade between 1986 and 1996 mortality per set on dolphins dropped from 12 to 0.33, and the number of sets with zero dolphin mortality climbed from 40 percent in 1986 to 88 percent in 1996. Levels of mortality in 1996 represented less than 0.1 percent of the population, while conservative estimates of dolphin recruitment are two percent.

In reducing dolphin mortalities through "dolphin safe" approved techniques, fisherman relied heavily on alternate fishing techniques referred to as log and school sets. Assemblages of fish will develop under floating objects in the ocean and typically these are large logs. Tuna boats can encircle these communities and net them. Fisherman can also set their nets on schools of tuna that are not associated with dolphins. Both techniques result in very low dolphin mortality and are therefore considered "dolphin safe." Unfortunately, these techniques are not optimal from a management perspective because they do not maximize yield from the fished tuna populations, landing primarily small, sub-reproductive tunas, and there are significant bycatch discards. Data on the types of bycatch and average size of yellowfin tuna taken using the three fishing techniques; sets on logs, tuna schools, and dolphins can be found in **Table 1** (Hall 1998) on page 4.

Table 1. Bycatch and discards by fishing technique per 1000 tons of yellowfin landed, based on combined data from 1993-1996. (Hall, 1998)

Species	Log sets (n=10,607) mean wt. 1.2kg	School sets (n=13,112) mean wt. 2.5kg	Dolphin sets (n=19,570) mean wt. 8.5kg
Dolphins	0.1	0.2	35
Marlins	58	6	2
Sailfish	2	10	3
Other Billfish	4	0.5	0.1
Blacktip sharks	829	132	16
Silky sharks	292	24	4
Whitetip sharks	199	5	2
Other sharks	339	128	17
Mahi-mahis	26,987	288	2
Wahoo	11,626	40	0.6
Yellowtail	632	824	10
Rainbow runner	743	54	0
Other large fishes	309	681	0.2
Triggerfishes	27,283	112	8
Other small fishes	41,637	1,625	364
Unidentified fishes	42	7	11
Sea turtles	3.6	1	0.3
Yellowfin discards (tons)	189	17	9

Of significant concern is the magnitude of the bycatch resulting from adoption of school and log sets in the tuna fishery and the large numbers of sharks mahi-mahis and wahoos that are captured. These fish are largely sub-reproductive, and there are potential long-term effects the removal of these fish could have on populations. Similarly, the 189 tons of yellowfin discards in the log set fishery are an enormous loss compared to 9 tons in the dolphin set fishery. Another significant concern from a marine resource management viewpoint is the loss of sea turtles, 3.6 in the log set fishery versus 0.03 in the dolphin set fishery. This is particularly important because many of these turtles are threatened or endangered.

The data clearly show that bycatch resulting from dolphin safe fishing techniques are vastly greater than using dolphin sets. The question is, should this abundant loss of marine resources be encouraged in order to save dolphins, even if their populations are stable or increasing with the losses incurred by the dolphin set fishery. Tremendous gains in preventing dolphin mortality were made as a result of the MMPA as well as environmental activism that resulted in improved regulations and fishing techniques. Fishery managers must now look at the big resource picture and question whether the goal of dolphin safe fishing, to the exclusion of sets on schools of dolphin and tuna is worth the toll on other fish and turtle populations.

The complexities of managing the tuna fishery are in some ways similar to the complexities of managing a watershed. Careful consideration needs to be given to each activity that occurs, recognizing that nothing in the watershed occurs independently. Any activity will either directly or indirectly alter other variables within the system, and can result in a cascade of events felt many generations later.

Watershed Management

Agriculture

In the Tomales Bay watershed, early agricultural enterprises included potato farming, and, while this provided economic opportunity and food for the rapidly growing population in San Francisco, it also resulted in increased erosion and sediment deposition to the Bay. Current agricultural land use includes primarily livestock and dairy ranching, and it is largely this economically viable agricultural use that has precluded more residential and urban development in the watershed, which would contribute more pollutants to the system. However, animal agriculture does contribute large amounts of nutrients and bacteria to the watershed that need to be appropriately managed to minimize degradation of water quality.

Tourism

Tourism has developed into a significant industry in the region over the last 30 years, providing economic opportunities for small businesses in the area and highly valued recreational opportunities for residents and visitors alike. However, signs are appearing that increased management is needed to ensure that the natural resources are not compromised in the process. An excellent example of this is the increasing popularity of kayak and boat camping that resulted in the need for the Park Service to initiate a reservation and permitting system. This allows the Park to regulate beach use and educate users about water quality concerns. The final outcome is the long term protection of natural resources.

Shellfish Aquaculture

Shellfish from Tomales Bay have provided food for thousands of years. Originally, local Miwok tribes in a subsistence fishery harvested the native Olympia oyster. Shell middens from 3,000 to 4,000 years ago provide ample evidence that Olympia oysters were an important food source for coastal tribes (Barrett, 1963). Subsequently, western European immigrants developed a commercial fishery to feed the burgeoning population in San Francisco. By the late 1800's, native oyster populations had declined and the commercial fishery ended. Overfishing and siltation are thought to be primary causes for declines in oyster abundance. In Tomales Bay, siltation is most obvious in the Southern reaches of the Bay and at the mouth of Walker creek.

Eastern oysters were shipped to California, beginning around 1870, to satisfy markets created by the native oyster, whose populations had collapsed due to overharvesting. The first introduction of the Pacific oyster to Tomales Bay occurred in 1928, and in subsequent years they were introduced to most California estuaries, where they thrived and supported the oyster culture industry. This industry has prospered in Tomales Bay and continues today. As with any activity occurring in the watershed or in the Bay itself, cultured shellfish interact with many components of the ecosystem.

The value of natural and cultured shellfish in providing habitat for myriad invertebrates and fish is well established in the literature. The importance of shellfish beds is also evident when one observes the richness and diversity of marine organisms occupying the complex three-dimensional habitat they provide. The native Olympia oyster historically provided this habitat, but unfortunately, these oysters are no longer abundant on the Pacific Coast. Significant efforts are currently underway in Oregon and Washington to restore Olympia oyster populations where they historically occurred. These restoration programs are designed to enhance native oyster populations, with a goal to improve water quality and provide habitat for other fish and invertebrates. Research in Puget Sound has identified native oyster beds as excellent habitat for juvenile dungeness crab, and planting of oyster shell in the intertidal zone has been used to mitigate for habitat lost during dredging for ports and harbors. Studies conducted in Tomales Bay have identified over 50 species of macroscopic fish and invertebrates that inhabit oyster culture bags, with almost 5,500 individual organisms found in one bag in Tomales Bay.

One pollution problem found in most estuaries in the world is the volume of nutrient laden water discharged into the ocean by human populations and animal agriculture. These nutrients can promote excessive production of algae which utilize these nutrients to form blooms. These algal blooms are increasing in frequency of occurrence throughout the world. Problems associated with these blooms include production of toxins and depletion of oxygen when dense blooms die and decompose. As filter feeders, oysters effectively filter algae and detrital particles as small as two microns. In this manner, shellfish can aid in mitigating this nutrient pollution by filtering the algal blooms that frequently occur in response to increased nutrient levels. Indeed, many of our coastal waters are impaired as a result of excessive nutrient loading, and removal of some of these nutrients can improve water quality and clarity. At temperatures above 10°C, 200,000 oysters will clear about a million gallons of water a day. Improved water clarity has been shown to promote the growth of submerged aquatic vegetation, like eelgrass, by improving light penetration.

Algae that are not consumed by shellfish or other filter feeders ultimately die off and settle to the bottom, where they decompose or are consumed by benthic scavengers. Undigested algae and other organics excreted by shellfish similarly settle to the bottom, where they decompose or provide food resources for benthic organisms. Shellfish do not create additional waste, rather, they cycle existing algae and nutrients from the water column to the sediments. When the shellfish are harvested, 35-40% of the minerals and nutrients ingested have been incorporated into shell and tissue and are actually removed from the marine ecosystem. This is perhaps the only agricultural enterprise that results in a net removal of nutrients from our overloaded coastal waters.

There are concerns about shellfish growing interfering with view plains, obstructing navigation and altering species composition and abundance beneath production gear. These are valid concerns that need to be managed to ensure the practices are sustainable over the long term.

Of the utmost importance to shellfish growers is the quality of the water where they farm, and deteriorating water quality is a pressing concern in Tomales Bay. The Department of Health Services monitors water quality in Tomales Bay and other shellfish growing regions. When bacterial levels exceed standards, these waters are temporarily closed to shellfish harvest. While water quality in Tomales Bay is generally regarded as good, shellfish harvest was restricted more than 30 days in each of the last three years for exceeding bacterial standards.

In the spring of 1993, oyster growers began observing unexplained mortalities in cultured oysters. These mortalities affected recently outplanted baby oysters as well as market sized adults. A research program to determine the causes of these mortalities is currently underway. Initial data indicate that environmental variables alone are not responsible for observed mortalities, nor have toxicology challenges identified any toxins in the water. There is an anecdotal association of mortality with blooms of the dinoflagellate *Gymnodinium splendens*, which has been shown to cause mortality in shellfish in Puget Sound. This association is supported by evidence of irritation of the gut tissue observed in some oysters consistent with that observed in oysters exposed to toxic phytoplankton. Research is currently underway to identify variables associated with oyster mortalities, monitor phytoplankton and conduct *Gymnodinium* challenges in an effort to discover what is causing this shellfish mortality. If this research succeeds in identifying why this shellfish mortality is occurring, the first step will have been taken. The next will be to remedy the situation through watershed management so shellfish can continue to thrive in the waters of Tomales Bay.

Conclusion

Watershed management is complex because there are numerous interacting variables that need to be managed to maintain ecosystem function and provide for human needs. Reliance on the best available science in this process will ensure people are using the same facts to manage sustainable resources.

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Tidal Water Fishes of Lagunitas and Walker Creeks

Dr. Michael McGowan, Romberg Tiburon Environmental Center, and
Jennifer Pearson, San Francisco State University

Fish and macrozooplankton were sampled in the summer of 1999 in the estuarine portions of Lagunitas Creek and Walker Creek. Ichthyofaunal diversity and abundance were similar between the two creeks, as was the seasonal pattern of occurrence and abundance. The relative abundance of dominant species differed due to patchy distribution of schooling fishes such as Pacific herring. The principal difference between the fish assemblage collected in 1999 and previous collections in Lagunitas Creek in 1983-84 was that fewer non-native species were present in 1999 in the estuarine portion of the creek near the former site of the Giacomini Dam. This suggests that the habitat has improved for native species. The zooplankter Neomysis mercedis, the main food item of juvenile salmonids in the estuarine zone of Lagunitas Creek, was widespread in 1999 in contrast to 1983-84, when its distribution was restricted by the dam. The anadromous American shad was collected in Lagunitas Creek for the first time.

Impacts of Introduced Species on Coastal Food Webs and Aquaculture in Tomales Bay.

Edwin Grosholz, Department of Environmental Science and Policy,
University of California, Davis

Abstract
Introduced species are those that are intentionally or unintentionally moved beyond their natural range by human means. There are a large number of introduced species in the coastal regions of central California, particularly in estuarine and marine habitats. I will discuss what is and is not known about the introduced estuarine and marine invertebrates in the Tomales Bay region. My talk will focus on the distribution and ecology of these invaders, as well as the specific impacts of a small number of well-studied species. In particular, I will focus on the impacts of the European green crab in the Tomales Bay region.

Our work on the ecological impacts of intertidal communities in Bodega Harbor and Tomales Bay has shown that there have been major declines of several key invertebrate species as the result of predation by green crabs. These declines may affect the abundant shorebird populations in the area, which are major consumers of invertebrates. Our work has also examined the impacts of green crab predation on commercial production of Manila clams in Tomales Bay, with a focus on developing culture methods to mitigate the impacts of green crabs. Our results show that changes in time of transfer of Manila clams, as well as augmenting native predators, can reduce losses of clams to green crabs. The prospects for mitigating the broad-scale changes brought about by green crabs are less encouraging. The broader issues of developing a comprehensive monitoring program for the Tomales Bay region and implementing a rapid response plan for new invasions are discussed.

Spartina in Tomales Bay - Friend or Foe?

Debra Ayres, University of California, Davis

Abstract:
Spartina alterniflora, endemic to the eastern U. S., was introduced into the range of a native congeneric species, *S. foliosa*, in south San Francisco Bay 25 years ago. Using RAPD markers and chloroplast DNA, we determined that extensive hybrid swarms have arisen through reciprocal hybridization; both species have been seed parents to hybrids. The primaeval condition of Pacific estuaries leaves vast expanses of open mud in intertidal habitats upon which animals native to the Pacific rely. Both hybrids and S. alterniflora invade this open mud, modify the hydrology, and threaten the native biota. *Spartina foliosa* is virtually absent in salt marshes where *S. alterniflora* was deliberately planted; we found roughly equal numbers of S. alterniflora and hybrid individuals. Hybrids grow vigorously and produce abundant viable seed and pollen. Marshes newly opened to Bay waters were colonized mostly by hybrid seed delivered via tidal currents. There was little temporal overlap in flowering between the two species, and we found few F1 hybrids; interspecific crosses are rare. Hybrids bridge the temporal gap. Robust hybrids, producing copious pollen and seed coincident with the flowering of *S. foliosa*, would predispose hybrids to high fitness in the vast sea of flowers present in a native salt marsh. Thus, hybrids could prove to be an even greater menace to *S. foliosa* and estuary ecosystems than *S. alterniflora*. Based on our genetic, greenhouse, and field experiments, we have made recommendations for recognizing and controlling the spread of hybrid *Spartina*.

Spartina alterniflora, smooth cordgrass, native to the eastern U. S., was introduced into south San Francisco Bay 25 years ago. It has spread by purposeful introduction of rooted plants and dispersal of seeds on the tides. Previous work suggested that smooth cordgrass was competitively superior to native California cordgrass, *S. foliosa*, and that the two species hybridized. In 1997 we began a study to determine the spread of *S. alterniflora* and *S. foliosa x alterniflora* hybrids in California and to examine the progress of hybridization. We used nuclear DNA markers diagnostic for each species to detect the parental species and nine categories of hybrids. All hybrid categories exist in the Bay, implying several generations of crossing have occurred. Hybrids were found principally near sites of deliberate introduction of the exotic species. However, north of the Golden Gate, a hybrid plant was found at Corte Madera (near Paradise Drive) and at least one smooth cordgrass plant was found at Richardson Bay (Blackie=s Pasture). The California coast contained only the native species. Now, in 2000, we have found additional hybrid plants in Richardson Bay and near San Rafael in Marin County. Where smooth cordgrass was deliberately planted, the marsh was composed of roughly equal numbers of smooth cordgrass and hybrid individuals; the native species was virtually absent. Marshes colonized by water dispersed seed contained the full gamut of plant types with intermediate-type hybrids predominating. The proliferation of possibly highly fit hybrids could result in local extinction of the native species. What is more, smooth cordgrass and hybrids have the ability to greatly modify the estuary ecosystem. The primaeval condition of Pacific estuaries leaves vast expanses of open mud in intertidal habitats upon which animals native to the Pacific rely. Both hybrids and *S. alterniflora* invade this open mud and modify the hydrology and physical structure of the ecosystem. The transformed habitat will abridge use of the estuary by both the native biota and humans.

Using RAPD markers and chloroplast DNA, we determined that extensive hybrid swarms have arisen through reciprocal hybridization; both species have been seed parents to hybrids. There was little temporal overlap in flowering between the two species, and we found no F1 hybrids; interspecific crosses are rare. Hybrids bridge the phenological gap. Robust hybrids, producing copious pollen and seed coincident with the flowering of *S. foliosa*, would predispose hybrids to high reproductive success in the vast sea of flowers present in a native salt marsh. Thus, hybrids could prove to be an even greater menace to *S. foliosa* and estuary ecosystems than *S. alterniflora*.

Escape and spread of hybrids to new estuaries are major threats of the next decade for alien cordgrasses in the Pacific. Smooth cordgrass seeds escape every year from Willapa Bay, WA on rafts of wrack to colonize Grays Harbor, 50 km to the north (K. Sayce, pers. comm.). Smooth cordgrass propagules exiting from the Golden Gate can threaten pristine native marshes and open mudflats north of San Francisco at Bolinas Lagoon, Pt. Reyes National Seashore, Tomales Bay, and Bodega Bay. It has been estimated that 65% of Bodega Bay bottom would be covered with smooth cordgrass sward were the plant to invade that estuary.

The genetic patterns we observed provide general guidelines to curbing the spread of smooth cordgrass and its hybrids in California. Control efforts should focus on the complete extirpation of populations that contain few pure native plants since these populations export large numbers of hybrid seed (i.e. Coyote Hills slough, Cogswell marsh, San Bruno marsh). In addition, smooth cordgrass and hybrids should be selectively removed from native marshes that have not been heavily invaded.. Other tactics, aimed at preventing new invasions, are to temporarily curtail opening new areas of unvegetated mud to the Bay, particularly in infested areas, since the populations of seedlings that establish contain large numbers of hybrids. Also, uninvaded marshes should be regularly monitored to prevent invasion and only pure California cordgrass from marshes that have not been invaded by hybrids or smooth cordgrass should be used in restoration projects.

We have also looked at visual aspects of hybrids that will enable managers of native cordgrass marshes to recognize smooth cordgrass and hybrids. Suspect plants can then be selectively removed. It is especially important to closely watch marshes where our genetic surveys have identified hybrids. Under uniform growing conditions in the greenhouse, height and width of flowering culms (stems) vary in direct proportion to the number of smooth cordgrass genes a plant has; that is, California cordgrass plants are generally of shorter stature and have thinner culms than plants more closely related to smooth cordgrass. However, growing conditions in nature are seldom uniform, and height can be a poor predictor of hybridity as plants will be taller under favorable conditions and shorter under harsh conditions, regardless of their genetic make-up. As well, some hybrid individuals will be indistinguishable on the basis of plant size from California cordgrass where ever they grow.

We have looked at several other characteristics in plants growing both in nature and in the greenhouse. The color of the culm at the base appears to be a fairly good indicator of hybridity in plants growing in the greenhouse, less so in plants growing in the field. Generally, the culms of California cordgrass are cream or green colored; the culms of hybrids and smooth cordgrass range in color from pale pink to deep maroon. The timing of flowering is also a good indicator of hybridity in nature; starting in July, California cordgrass flowers first, followed by hybrids, and finally, in mid to late August, smooth cordgrass flowers. The length of the flower bearing portion of the culm (the inflorescence) varies in direct proportion to the number of smooth cordgrass genes the plant contains; California cordgrass inflorescences are on average shorter than those of hybrids and smooth cordgrass.

Because of overlap in characters between the species, variability in the environment affecting plant size, and the somewhat flexible nature of plant growth in general, there are no hard and fast physical attributes which will always be present in smooth cordgrass and hybrids, and never be found in California cordgrass. Instead, we are left with a syndrome of characters that are associated with the alien. The greenhouse data suggest that plant size varies in a predictable fashion with hybridity; in a meadow of California cordgrass, an unusually tall plant should be viewed with suspicion and examined closely. If the plant is late flowering and/or has longer inflorescences relative to the surrounding plants, and/or has culm bases that are pink to maroon colored, and/or has unusually wide culms, then the plant is probably a hybrid or smooth cordgrass. The field data suggest that size alone is not enough to identify all hybrids - some hybrids will not be tall. Marsh managers should focus on plants that seem different from the surrounding California cordgrass - for example, greener leaf color, or greener longer into fall, or greater culm density - and examine unusual plants for the flowering and culm traits of hybrids.

Giacomini Wetland Restoration – Hydrologic Response and Role in Tomales Bay Water Quality

Brannon Ketcham, Hydrologist, Point Reyes National Seashore
Point Reyes Station*, CA 94956*

With the final acquisition agreement in February 2000, Point Reyes National Seashore initiated the process leading to the physical and ecological restoration to the Giacomini Wetland. With its location and size, the restoration will certainly have some impact upon Tomales Bay, its habitat and water quality. As the community is so well versed on how the watershed can impact water quality conditions within the Bay, it should be understood that the wetland restoration alone will not resolve the water quality issues within Tomales Bay. This said, the Giacomini Wetland restoration will certainly play a role in water quality conditions within the inner Bay. Wetlands are commonly referred to as nature's liver. What the Giacomini Wetland represents is such a filter that has been bypassed since the mid 1940's by construction and maintenance of the levees. Restoration will reintroduce the 500 plus acre property to the circulation and ecology of the Bay, providing significant filtration and detention capacity that will benefit water quality. While restoration will have beneficial impacts to water quality, the restoration will primarily focus on ecological function and habitat.

Several other interesting questions related to hydrology and water quality will also be addressed:

- How will restoration impact hydrology and tidal circulation?
- How will restoration impact flooding?
- How will the created habitat impact delivery of pollutants to the Bay?

Water quality goes beyond just measured numbers. It includes hydrologic connectivity and fish passage, continuity of mixing zones in estuarine areas, proper ecological function, and, finally, measured pollutant parameters. Regulations require us to measure water quality parameters that indicate how our actions impact the natural system. As we saw with the Giacomini Dam, physical structures may impact water quality in abstract ways, creating separation between fresh and saline water and thus a 'physiologic barrier' to aquatic species. The physical restoration of the Giacomini wetland will facilitate the development and function of natural tidal and floodplain processes across the land currently excluded from natural ecological function by the levee system.

Physical changes to the land, potential hydrologic response, and habitat creation will be used as a basis to discuss the impact of restoration on the more classic water quality issues, such as nutrient uptake and sediment detention. While possibly the largest, the Giacomini Wetland is not the only restoration opportunity within Tomales Bay.

Project Status Update:

In February 2007, the National Park Service will take over management of the entire property. Planning, assessment, and environmental documentation will be completed by that time for immediate implementation of the restoration plan. The Seashore is in the process of hiring the restoration project coordinator. The role of this position will be to coordinate working partnerships between agencies and within the community, develop and implement baseline physical and ecological studies, determine appropriate management of existing property, and submit environmental documentation as part of the compliance process. Synthesis of the research data will culminate in the development of a restoration plan necessary for implementation of the project.

The Short, Happy Life of the First Consensus About Tomales Bay

John Hart

In 1972 and the following years, Marin County in general and West Marin in particular came to certain shared views about Tomales Bay and its watershed. In what I call the First Consensus, it was then or soon after agreed: that Tomales Bay, although affected by sedimentation, pollution, dams and diversions in its watershed, was in surprisingly good shape; that waste discharges from agriculture and existing residences were trivial compared with what would result from full-scale urbanization, but should nonetheless be reduced with assistance from the county; that the watershed should remain rural, with even tourist-serving development confined to the neighborhood of the existing villages; that agriculture should be encouraged, for its own sake and for its stewardship of open land; that the first step toward these ends was to outlaw parcel breakup below specified sizes.

In the twenty years following, the First Consensus was consolidated. Ranchers who opposed the land-use restrictions of 1972 became reconciled. In several crises that threatened dairy farms, county government and urban environmentalists came to the ranchers' support, appearing for the first time as allies rather than enemies. Large-parcel A-60 zoning was upheld politically and in court. When a market developed for sixty-acre country home plots, the community responded by creating the Marin Agricultural Land Trust (MALT) to permit the protection of farms in perpetuity.

By the 1990s, however, the First Consensus was showing wear and tear. The threat of trophy home development was renewed. An attempt to get federal money for development rights acquisition—the MALT approach writ large—divided the farm community and strained the urban-rural comity. The growth and needs of the shellfish industry—a bit player in 1972—put new urgency into old and still unresolved water quality concerns. Some fisheries seemed to be in decline. Even the weather challenged the First Consensus, as several heavy rainfall years produced a dramatic shoaling of the Bay. Maybe the situation was not so satisfactory or sustainable, after all!

Out of these conflicts and worries has arisen the Tomales Bay Watershed Council, which is groping toward what I hope will be a Second Consensus, rethinking and refining the First. It need not start over, however. Reviewing the Tomales Bay Environmental Study of 1972, a key building-block of that First Consensus, one sees much that needs elaboration but little that calls for reversal. And thanks to the achievements of the First Consensus, the Second should be able to do still better: most of the options are still there.

Tomales Bay - LMER/BRIE Studies 1987—1995

Randy Chambers

S.V. Smith, Department of Oceanography, University of Hawaii, Honolulu, HI 96822
J.T. Hollibaugh, Department of Marine Science, University of Georgia, Athens, GA 30602, and
R.M. Chambers, Biology Department, Fairfield University, Fairfield, CT 06430

As part of the National Science Foundation's Land Margin Ecosystems Research (LMER) initiative, Tomales Bay research focused on water quality and water flows into and out of the bay. A salt and water balance model was used to obtain reliable estimates of the variable movement of water, sediments and nutrients into and out of Tomales Bay. With this approach, the net fate of organic matter in the bay—whether as seagrass material, algae or terrestrial plant debris—could be determined. Over the 8-year study, more organic matter decomposed than was produced in Tomales Bay, indicating the bay was—and probably still is—heterotrophic. Organic matter from both terrestrial and oceanic sources fuels this decomposition, but at different rates: terrestrial runoff includes plant debris that is slow to decompose; inputs from the coastal ocean include algae that are broken down quickly. Because inputs from the ocean during summer vary as a function of the intensity of coastal upwelling, much of the annual variation in the net amount of decomposition in Tomales Bay is driven by marine inputs. The effect of significant year-to-year variation in runoff of plant debris from the land (drought vs. flood years), however, appears to be dampened by the relatively recalcitrant nature of that organic matter.

Eutrophication has been defined as an increase in the rate of supply of organic matter to an ecosystem. LMER/BRIE research shows that the external supply of organic matter to Tomales Bay varies over seasonal and annual time scales. Further, the quality of that organic matter varies as a function of its source (from land or sea). The rates of external inputs of organic matter to Tomales Bay may change in the future in response to regional changes in land use and/or in response to climate-driven changes in watershed-estuary-ocean interactions. Additionally, internal generation of organic matter in the bay (algal blooms) could be stimulated by increased runoff of dissolved inorganic nutrients. To date, however, the most significant impact of terrestrial runoff on the structure and function of Tomales Bay has been via sediment transport and infilling of the Bay. Relative to other U.S. estuaries, Tomales Bay remains fairly pristine.

Seasonal and Spatial Distribution of Coliform Bacteria and E.coli in a Rural California Estuary

Richard Bennett, Ph.D.[1], James Knight, MS[2], Tetsuro Sasaki[2], James Johnson MS [3], and George Chang, Ph.D[4].

Estuaries along the California coast are unique and provide critical habitat, esthetic value and numerous commercial benefits. The most prominent estuary in California is the San Francisco Bay. Tomales Bay, located slightly more than thirty miles to the northwest of San Francisco, in western Marin County, is another estuary of important natural and commercial value. Unlike the San Francisco Bay, the Tomales Bay watershed is sparsely populated and consists, in part, of the Point Reyes National Seashore. There are no industrial operations in the watershed, nor are there permitted municipal waste discharges into the Bay.

Commercial uses of the watershed include livestock grazing, dairy agriculture, aquaculture, tourism, and recreation. In the last two decades, dairy agriculture has intensified with greater numbers of animals being housed and fed in confinement. The size of dairy farms has increased by as much as 50% with an average herd size in the region of 330 milk cows per farm CDFA 1986, 1996). Such confined animal feeding operations (CAFO) are subject to state and federal regulations, the objectives of which include "minimizing pollution from CAFOs to the greatest extent possible" (USEPA-USDA 1998).

Aquaculture has become a prominent commercial activity in Tomales Bay. Shellfish production in the Bay is a significant part of the 2400 acres of growing waters in California. Of this total acreage, 96% is conditionally harvested due to microbial contamination of the water (Alexander 1998). Fecal bacterial contamination of shellfish is a matter of significant public health concern (Rippey 1994). The microbial quality of the growing waters is subject to regulation and conditional use by state and federal agencies. The fecal coliform bacteria standard for growing waters is 14 organisms per 100 ml of seawater (USDHHS 1995). In Tomales Bay, sales of shellfish are suspended whenever significant rainfall (0.4 to 0.6 in) occurs in a 24-hour period. Hence, in the winter months, harvest and sales of shellfish can be restricted for prolonged periods.

Recreational uses of the Bay include fishing, swimming, kayaking, and sailing. The bacterial criterion for recreation water prescribes a fecal coliform level of not greater than 200 organisms per 100 ml. of water (CA DHS 1998).

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[1]Executive Director, Trilogy Oceanic Institute PO Box 5182 Kailua-Kona, Hawaii 96745, DoctrRick@aol.com
[2] J. Knight and T. Sasaki, CPS, Santa Rosa, CA.
[3] J. Johnson, Sonoma County, Santa Rosa, CA.
[4] G. Chang, Deptartment of Nutrition, University of California, Berkeley, CA.

The relatively low human population and the substantial livestock inventory in the watershed prompts much controversy as to the sources of fecal contamination in the Bay. Effective resolution of the problem will require careful and systematic study of the Bay and its tributaries. We, and others (Langlois 1997), conducted parallel studies on the tributaries in the hope that these works will provide meaningful information for the benefit of the estuary and its sustainable beneficial uses. This study was undertaken to describe the wet and dry seasonal and spatial distribution of *E. coli* and other coliform bacteria in Tomales Bay, such that the possible sources of the fecal contamination might be identified.

The coliform and fecal coliform tests, as provided by public health laboratories, are performed under strict protocol and are difficult to conduct under field conditions. Moreover, the coliform and fecal coliform tests have serious limitations for ascribing health risk (Ford and Colwell 1996). We chose to use new commercial technology that adds greater specificity and simplicity. The objective was to measure *E. coli* directly as an indicator of fecal contamination. The natural habitat of *E. coli* is the intestinal tract of humans and animals (Brooks et. al.1991). *E. coli* is a well-established indicator of fecal contamination. However, its presence or absence does not correlate well with the occurrence of other pathogenic bacteria (Ford and Colwell 1996). Coliform organisms of the family *Enterobacteraciae* include intestinal flora as well as microbes that reproduce in the free environment (Moore et. al. 1988). This duality makes interpretation of coliform data alone difficult at best.

The Colitag ™ system employs the use of two color indicator systems for the detection of *E. coli*. One detects the metabolites of coliforms and the second that of *E. coli*. Thus, in a single test, the presence or absence of coliforms and/or *E. coli* is established. The Colitag™ system can be used as a simple presence-absence test, or it can be used to measure concentrations of organisms, such as the Most Probable Number (MPN) methods (Eaton et al. 1995). We chose this method, because it is one that can be used by field personnel, aquaculturists, and agriculturists for water quality screening.

Methods

Two bay samplings, one in the winter wet season of 1998 and one in the end of the dry summer season 1998, were undertaken to distinguish the spatial and seasonal distribution of *E.coli* and other coliforms in Tomales Bay. We collected 168 samples at the same 84 stations throughout the Bay at each sampling. The location of each station was determined using global positioning system (GPS) coordinates.

Bay water samples of 100 ml were collected into sterile 150 ml vials and stored at 40 degrees F until lab processing. Sample days occurred on strong outgoing tide differential of 7.7 feet (wet season sample) and 2.9 and 6.9 feet (dry season samples).

A one ml aliquot of each water sample was aseptically transferred to each of two tubes containing 9 ml of the Colitag ™ media. The inoculated media was incubated for 24 hours at 35 degrees centigrade. Color and fluorescent reactions include none (no coliforms), yellow (coliform), and fluorescent (*E. coli*). At 30 hours of incubation the results were redetermined to allow slower reactions to develop.

(Colitag ™ CPI The Alternative Supplier, Inc. Santa Rosa, Calif. 95406)

Ten 100 ml stream water samples from a number of locations on the east side of Tomales Bay were taken from November 1997 through May 1998. These samples were collected in sanitized plastic containers and analyzed for temperature, pH, conductivity and dissolved oxygen by electronic metering. Ammonia-nitrate measurements were collected by spectrophotometric methods (Hach Chemical Inc.). Bacterial counts were performed as described for Petrifilm™ the E. coli and Coliform media (3M Company).

Results

The two-tube method for evaluation provides measures of probability estimation based on the Poisson Distribution (Eaton 1995)**.** Samples that were positive in both tubes had a higher likelihood (98%) that they contained 200 colony-forming units (CFU) per 100 mls of water. Samples with only one tube positive yield a slightly lower likelihood (86%) of containing 200 CFU per 100 mls.

Wet Season Sample

Of the 84 samples collected throughout the Bay, 86.9% of the sites tested positive for *E. coli* (Table 1.) Both sample aliquots were *E. coli* positive in 67% of the total *E. coli* positive sites, suggesting that the majority of sites had E. *coli* concentrations of at least 200 CFU/100 mls of estuary water. Non-*E. coli* coliforms and negative sites accounted for 13.1% of the sites. The spatial distribution of the bacterial results is shown in Figure 1.

Dry Season Sample

In distinct contrast to the wet season sample, only two of the 84 sites tested positive for *E. coli* (2.4%) in the dry season sample. Both of these positive readings were detected in only one each of the paired aliquots. Similarly, non-*E. coli* coliforms and negatives were 52.4% and 45.2% respectively (Table 2.) Comparison of wet and dry season samples is depicted in Table 3. The spatial distribution of the dry season bacterial results is shown in Figure 2.

Geographic Distribution of Bacterial Isolations

Data from Figures 1 and 2 were analyzed for differences in north-to-south and east-to-west distribution. The distribution of *E. coli* was not statistically different for the wet season sample (Table 4). In contrast, the summer distribution of non-*E. coli* coliforms was significantly greater in the south end of the Bay with a distinction at latitude 38 degrees, 10 minutes (Table 4). Distribution of bacteria isolated on the west and east shorelines demonstrated that, in the wet season, *E. coli* predominated in the east shore area. All of the east side sites were positive for *E. coli*, whereas 70% of the west side sites were positive for *E. coli*. In contrast, the dry season sample sites were not significantly different (Table 5.). In general, lower densities of *E.coli* or coliforms tended to be on the west side and north end of the Bay.

Stream Flow Data

The bacterial and chemical water quality data from east side watersheds is shown in Table 6. The average *E. coli* content of the stream flows for the winter season varied greatly and ranged from less than one *E. coli* per milliliter to over 13,000. Estimates of stream flow provide information necessary to calculate the daily flow contribution of *E. coli* from the watershed. Flows ranged from 1.8 CFS to 450 CFS and did not appear to correlate to bacteria concentrations. Statistical analysis of individual stream data to establish the actual correlation remains to be completed.

In certain streams, small flows were associated with very high total daily loads of *E. coli*. The small stream at MM 32.12 had an average flow of 1.83 CFS, yet had an average daily load of 610 trillion *E. coli*. In contrast, the stream at MM 38.54 had an average flow of 5.36 CFS and a daily load of 39 billion, approximately four orders of magnitude less than the stream at MM 32.12. The average winter flow for the eleven sites was 794 CFS and at this rate, approximately 1590 trillion *E. coli* flow downstream daily. The largest contributions came from Walker Creek in the north and the creek at MM 32.12 in the south. These drainages, one very small and one very large, collectively account for 95% of the *E. coli* loading from the east side water shed. Remarkably, their respective contributions are about equal with 49% for MM 32.12 and 46% for Walker Creek.

The water chemistry data did not reveal great variations between stations except in one case. The data from the MM 32.12 creek station revealed elevated conductivity, nitrate and ammonia, and was a distinct exception to the other sites.

Weather Data
Rainfall, measured at Tomasini Point prior to the winter sample, is shown in Figure 4. Up to January 1, 1998, approximately 12 inches of rain fell in the region (Ca. DWR, 1998). In the week preceding the wet season sample, only 0.98 inch of rain fell, and that volume was well distributed over the period. The seasonal rainfall up to the sample date totaled over 22 inches. Hence, 10 inches of rain fell in the watershed in January prior to the first sampling.

Land Use and Geography
Figure 3 approximates the general land use in the Tomales Bay watershed. According to census data, there are 1,143 households with an average occupancy of 2.3 persons per household (US Census Bureau 1990). The largest population centers are the towns of Inverness and Point Reyes Station. Most homes utilize subsurface septic systems for household human waste disposal. Housing units on the east side of the Bay commonly front directly on the Bay.

The agricultural use of the land is predominantly that of livestock and dairy operations. According to a previous survey, approximately 10,900 head of dairy animals and 1,320 head of beef and sheep are housed and range in the general watershed (Bennett and Larson 1990). Agricultural census data suggests the dairy populations are greater at this time. Approximately six dairy farms operate in the immediate eastern watersheds of the Bay. Approximately three others operate in the Walker Creek and Keyes Creek area that drains into the north end of the Bay. The Walker Creek watershed is the largest fresh water source in the Bay.

Undeveloped public lands occupy the majority of the northwestern watershed. This land is habitat for elk, deer, and other small animals. Tomales Bay is open to the Pacific Ocean at its north end, and all tidal flows move through the north end of the Bay.

Discussion

Data from this two-season sample of Tomales Bay waters reveal that fecal bacterial contributions to the Bay are winter or wet season related. Dry or summer season data indicate a vastly lower presence of fecal bacteria. Given the very low occurrence of *E. coli* in the dry season, significant fecal contributions from wild land and marine animals do not appear to occur during this time. Marine mammals are more common in the bay during the winter season. Previous research has demonstrated that fecal bacteria die off rapidly in seawater as a function of sunlight penetration into the water column. In the presence of sunlight, 90% of the bacteria in clear salt water die off in 90 to 180 minutes (Fujioka 1981). The widespread and prevalent distribution of *E. coli* in the wet season sample, and rapid die-off rates for fecal bacteria in salt water, suggest that there is a reservoir of fecal bacteria feeding into the Bay. Given the general turbid state of the bay, the die-off rates may not be as dramatic as reported for clear waters.

Just prior to the wet season sampling there had been rainfall, yet no major storm events, consequently, the bacteria demonstrated in the Bay were transported in non-storm stream flows. *E. coli* was common and in higher density in the northern regions of the Bay, near the mouth of Walker Creek, during a strong ebbing tide. In the same region, and to the west near the deep-water channel, *E. coli* was less prevalent. Previous wet season research data on Tomales Bay and its tributaries (Langlois, 1997) shows a clear and pronounced trend for elevated fecal coliform bacteria in stream flows into Tomales Bay. Fecal bacteria were the greatest immediately after and during rains, and much less during periods well after rainfall.

In this study, rainfall prior to the wet season sample date was sufficient to create stream flows. Yet in the week prior to the wet season sample there were no significant storm events. Consequently the results reflect data from waning stream flows and not turbulent flows from heavy rainfall storm events. This is significant, as *E. coli* is shown to reside and reproduce in stream bed sediment (La Liberte 1982). In our work, sediment *E. coli* concentrations are three to five times greater than the water column.

The sources of *E.coli* in this study cannot be definitively identified. Currently available molecular technology can ascribe sources of bacteria with elegant precision. However, given the wet season association and the observation of fecal coliforms and *E.coli* in the watershed drainages, it appears that a significant source of fecal bacteria is from animal agriculture. Numerous research reports describe bacterial contributions of livestock to surface water drainages with fecal coliform counts ranging from 200 to 50,000 per 100 mls of water (Moore et. al. 1988). Even in lands that are sparsely populated with livestock, or lands that are not recently grazed, the fecal bacteria counts are significant. Other researchers have demonstrated that streambed sediments act as a repository for fecal bacteria with prolonged survival in the sediments. Subsequent rains flush bacteria-containing sediments into the water column (Davies 1995; LaLiberte 1982).

Urban sources of pollution in the Tomales Bay watershed cannot be discounted as a coliform source, even with a low-density population on the Bay. Studies indicate lakeshore septic systems can contribute fecal organisms to a water body (Weiskel 1996; Cole 1995). Fecal bacteria in the shellfish-growing waters pose a risk to consumers of raw shellfish foods (Rippey, 1994). The extent to which fecal bacteria from animal sources constitute a public health risk has not been quantified (Stelma, 1992). However, cattle have subsequently been identified as a primary reservoir of E. *coli* O157:H7, a significant human pathogen. This virulent strain was found to be a common although episodic bacteria in most herds (Wang, 1996; Hancock 1997). Hence, the animal source of *E. coli* is no longer a reason to be complacent.

Fecal contamination of Tomales Bay occurs as a wet season phenomena and is related to commercial land uses. To return the Bay to its fully beneficial state, and protect the food-producing Bay resources, disposal of human and animal waste will require more efficient and effective controls. Given the magnitude of fecal bacteria loading in the Bay and watershed, effective containment will require very substantial effort. This major effort is critically needed to have Tomales Bay meet national water quality objectives. More effective controls will come through better understanding of the fate of fecal bacteria in fresh water and estuarine systems. Rapid screening tools, such as those employed in this study, may provide useful management information for the identification of coliform sources and the effectiveness of control measures. The need to re-examine point and non-point control systems for all fecal wastes is critical, not just for Tomales Bay but for all inshore areas world wide. To wait for definitive "proof" about this need, is to wait for a Faustian Bargain.

Table 1 Bacteriological Results for Wet Season Sample Pairs

	E. coli			Coliforms (not E.coli)			No Growth
	Single	Paired	Total	Single	Paired	Total	
Number	49	24	73	4	2	6	5
Percent	58.3	28.6	86.99(a)	4.8	2.4	7.1	6.0
	N=84	(a) p<=.001					

Table 2. Bacteriological Results for Dry Season Sample

	E. coli			Coliforms (not E.coli)			No Growth
	Single	Paired	Total	Single	Paired	Total	
Number	2	0	2	16	28	44	38
Percent	2.4	0.0	2.4(a)	19.0	33.3	52.4	45.2
	(a)	p<.0001					

Table 3. Comparison of wet and dry season samples results

	E. coli		Non-E.coli Coliform		No Growth	
	Wet	Dry	Wet	Dry	Wet	Dry
Number	73	11	6	44	5	38
Percent	86.9 (a)	2.4	7.1 (a)	52.4	5.9	45.2
(a) p<=.001						

Table 4. North-South Bacterial Bay Sample Sites Distribution (Lat. 38° 10 ^{mins})

	Wet Season		Dry Season	
	E.coli		Non E.coli. Coliforms	
	N. (n=36)	S. (n-48)	N. (n=36)	S. (n=49)
Number	30	41	8	35
Percent	83.3 (a)	85.4	16.3 (b)	71.4
	(a)p<=.0001		(b) NS	

Table 5. Bacterial Distribution from East and West Side Sample Sites

	Wet Season		Dry Season	
	E. coli		Non-E. coli. Coliforms	
	E. (n=46)	W. (n=27)	E. (n=46)	W. (n=27)
Number	46	19	28	15
Percent	100 (a)	70	60.8 (b)	55.5
	(a) p<=.0001		(b) NS	

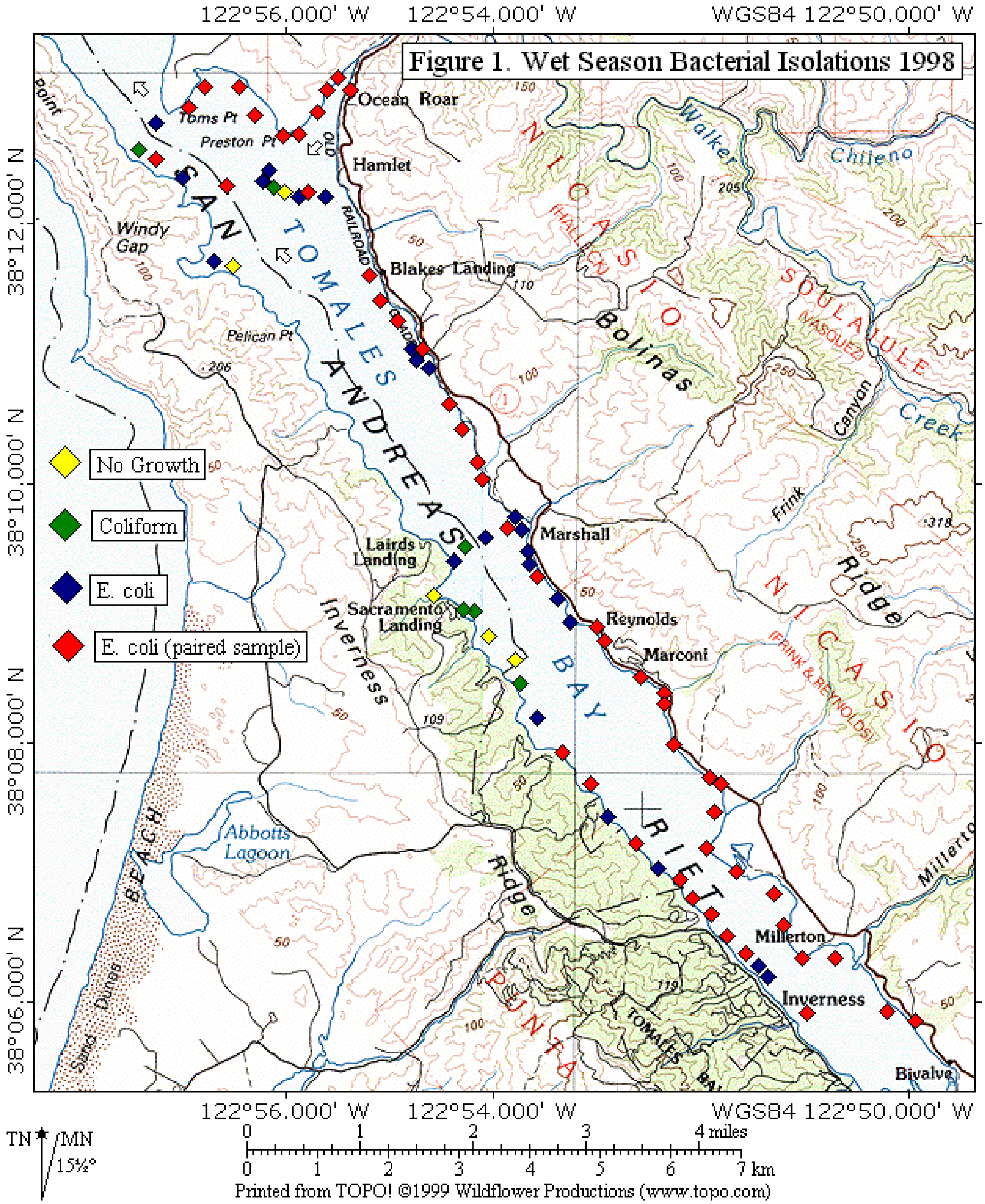
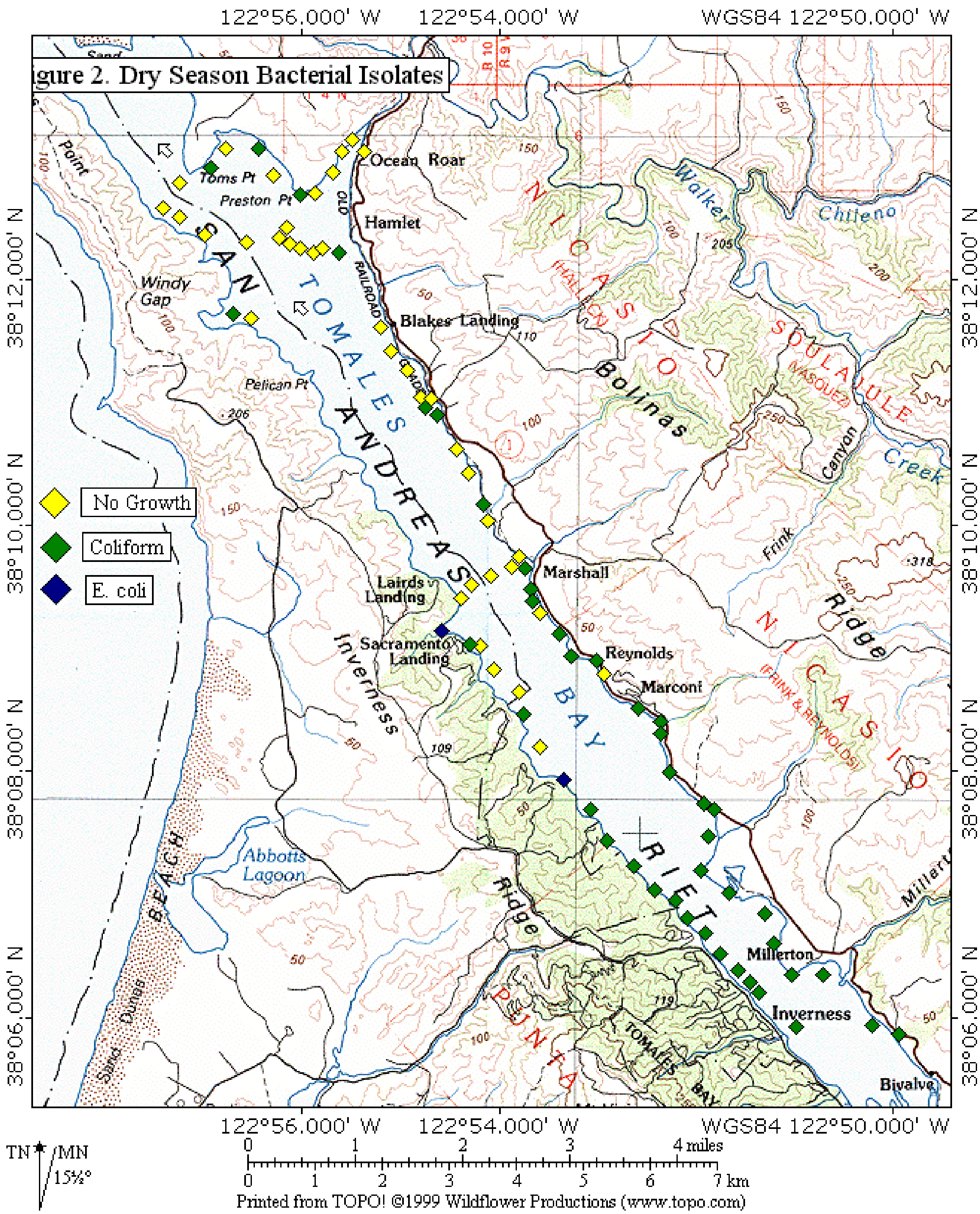


Figure 1. Wet Season Bacterial Isolations 1998



igure 2. Dry Season Bacterial Isolates

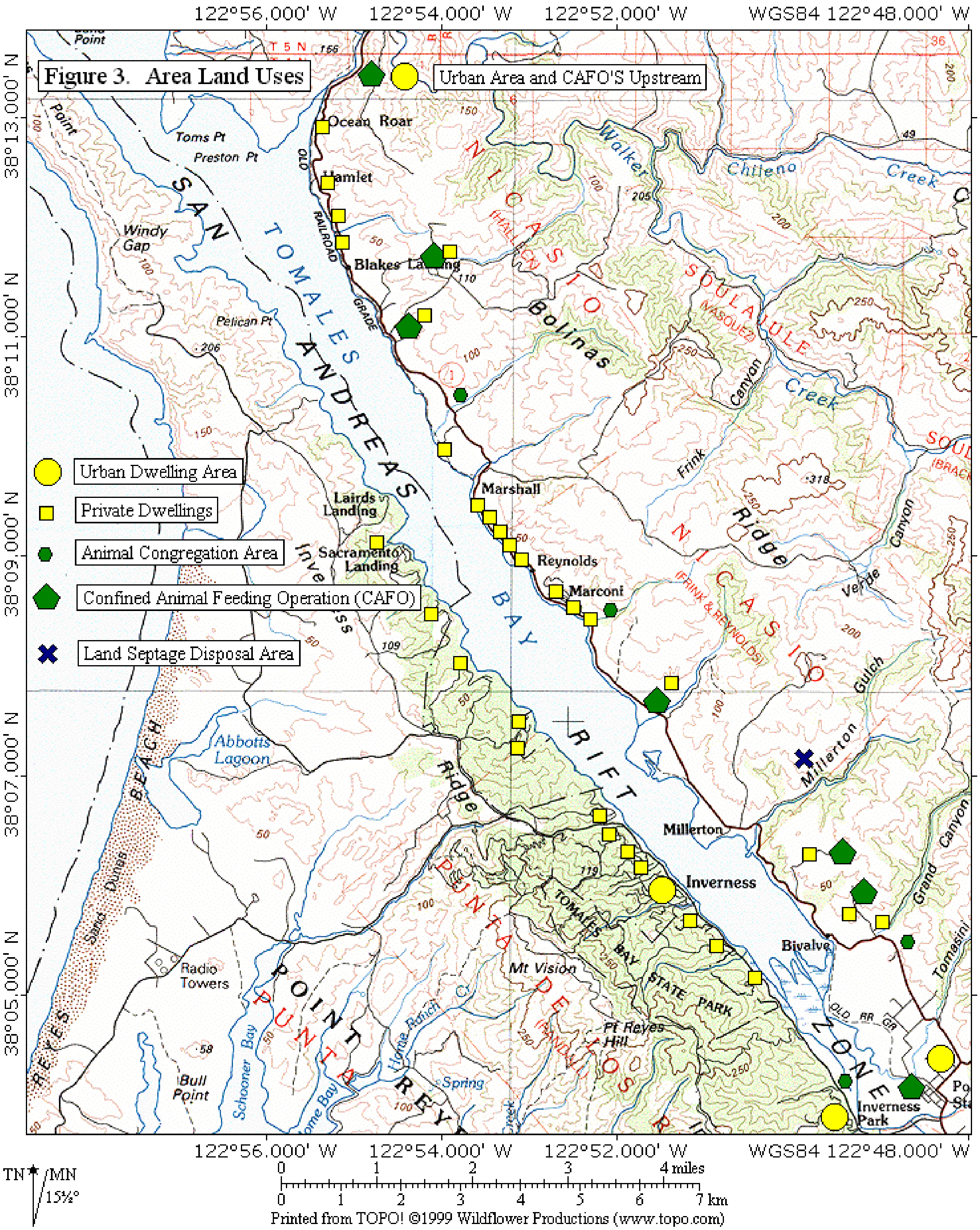


Figure 3. Area Land Uses
Urban Area and CAFO'S Upstream
Urban Dwelling Area
Private Dwellings
Animal Congregation Area
Confined Animal Feeding Operation (CAFO)
Land Septage Disposal Area
122°56.000' W
122°54.000' W
122°52.000' W
WGS84 122°48.000' W
38°13.000' N
38°11.000' N
38°09.000' N
38°07.000' N
38°05.000' N
Ocean Roar
Hamlet
Blakes Landing
Marshall
Reynolds
Marconi
Millerton
Inverness
Bivalve
Inverness Park
Lairds Landing
Sacramento Landing
Toms Pt
Preston Pt
Windy Gap
Pelican Pt
Abbotts Lagoon
Radio Towers
Bull Point
Mt Vision
Pt Reyes Hill
SAN ANDREAS RIFT ZONE
TOMALES BAY
TOMALES BAY STATE PARK
Walker Creek
Chileno Creek
Bolinas
Verde Canyon
Millerton Gulch
Frink Canyon
Ridge
Grand Canyon
Tomasini
TN
MN
15½°
0 1 2 3 4 miles
0 1 2 3 4 5 6 7 km
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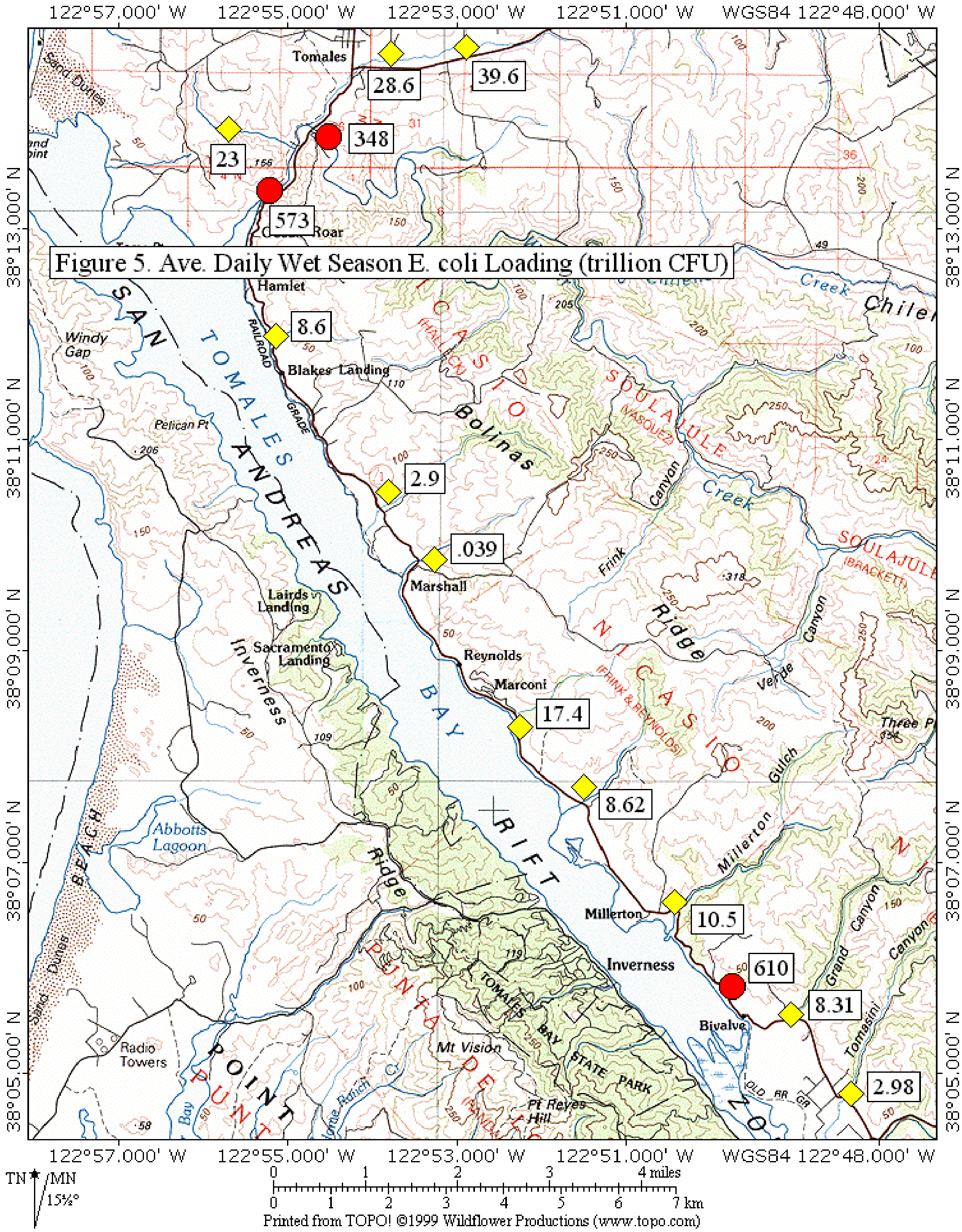

Figure 5. Ave. Daily Wet Season E. coli Loading (trillion CFU)

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Acknowledgements

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Tomales Bay Agricultural Group

Robert Giacomini and David J. Lewis
4th State of Tomales Bay Conference

Abstract - The Tomales Bay Agriculture Group (TBAG) was formed in 1999 to provide direction and support in environmental management for animal agriculture producers. Membership consists of animal agriculture producers in the Tomales Bay watershed. The groups' initiatives include: 1) Participation in the University of California Tomales Bay Water Quality Project (UCTBWQP); 2) Coordination and attendance at riparian management trainings; and 3) Support and participation in the Tillamook Bay Farmer Exchange. Combined, these activities provide producers with information and methods to improve water quality management on their properties. As an example, the farmer exchange was undertaken to connect Tomales Bay producers with their peers in Tillamook that have twenty years of experience in managing water quality and complying with water quality regulations. While Tillamook Bay is more than two times the area of Tomales Bay and receives more than three times the annual rainfall, aspects of dairy manure management systems may have water quality benefits for Tomales Bay dairies. These include: 1) Closed manure storage systems that limit capacity reduction from rainfall and potential run-on and run-off of storm water; 2) Storage of manure as solid through use of straw bedding; and 3) Use of nutrient management plans to increase the agronomic benefits of manure as fertilizer.

Group Background and Function

The Tomales Bay Agriculture Group (TBAG) was formed in 1999 to provide direction and support in environmental management for animal agriculture producers. Membership consists of animal agriculture producers in the Tomales Bay watershed including dairy and beef cattle ranch managers. Each member has contributed $500.00 for a total $7,500.00. This amount has been matched by an equal contribution from Western United Dairyman. TBAG members participate on both the Tomales Bay Shellfish Technical Advisory Committee (TBSTAC) and the Tomales Bay Watershed Council (TBWC). Other activities include:

University of California Tomales Bay Water Quality Project (UCTBWQP): Members of TBAG are participating with UCTBWQP. This has included sampling and analysis of storm water and waste management systems on ten dairy and beef cattle ranches in the Bay watershed. An update, current results, and future steps for this project are presented in Lewis et al. (2000) of these proceedings.

Riparian Management Training: On September 12, 2000, TBAG members participated in a training developed and implemented by the University of California Cooperative Extension and Natural Resource Conservation Service. This training focused specifically on the Conservation Reserve Program, a federally funded program that provides landowners with fence material cost sharing and rent for riparian land excluded from grazing.

Tillamook Bay Farmer Exchange: On August 7 and 8, 2000, a representative group of TBAG members traveled to Tillamook, Oregon to tour Tillamook County Creamery Association member dairies and research waste management methods.

Combined, these activities provide producers with information and methods to improve water quality management on their properties. As an example, this discussion will focus on the content of the farmer exchange, including a comparison of Tillamook and Tomales Bays and discussion of the exchange purpose, Tillamook Bay regulatory framework, and manure management systems.

Tomales and Tillamook Bay Comparison
Background geographic, human population, climatic, as well as agriculture and shellfish harvesting statistics for the Tomales and Tillamook Bay watersheds are presented in Table 1. Tillamook Bay watershed is more than two times larger than Tomales and experiences nearly three times more rainfall. Both human and cattle populations are larger for Tillamook Bay than Tomales Bay.

Table 1: Comparison of Tillamook and Tomales Bay Watersheds.

Category	Tillamook Bay Watershed[a]	Tomales Bay Watershed[b]
Watershed Area (square miles)	597	216
Bay area (square miles)	13	11
Average bay length (miles)	6	12
Average bay width (miles)	2	1
Average bay depth (feet)	7	20
Average rainfall (inches)	90	35
Human population*	25,000	4,500
Cattle population	28,600†	10,970‡
Shellfish Harvesting area (acres)	2,500	483

Notes:
a Data from TBNEP (1998a,b)
b Data from TBTAC (2000)
* 1990 United States Census Data
† Dairy cattle
‡ Beef and dairy cattle

Exchange Purpose
The exchange was prompted by the similarity that both Tomales and Tillamook Bay are coastal water bodies with productive aquaculture and animal agriculture industries and that similar water quality issues exist. Specifically, these issues focus around elevated fecal coliform levels in bay waters that result in closure of shellfish harvesting areas during periods of high rainfall.

In Tillamook Bay, dairy producers have implemented management practices to improve water quality since 1981 with funding through the Rural Clean Water Program (RCWP). It was estimated that water quality has improved 40 to 50% since implementation of these measures (DEQ, 1994). In addition to the management practices implemented through RCWP, landowners have participated in stream fencing and off-channel water development projects to reduce in-stream impacts of cattle grazing.

The exchange was undertaken to connect Tomales Bay producers with their peers in Tillamook that have twenty years of water quality management and regulatory compliance experience. In addition to five dairy tours, attendees participated in discussions on nutrient management plans and the regulatory framework with Oregon State University Extension Service, Oregon Department of Agriculture, regulatory agency staff, and aquaculture industry representatives.

Tillamook Bay Regulatory Framework

The Oregon Department of Agriculture is the lead field agency for inspection of animal agriculture facilities. Confined Animal Facility Operations (CAFO) inspectors regularly inspect facilities in Tillamook County every eight months. Regulations for waste management are performance based and oriented to nutrient management. Inspectors check for proper storage and agronomic use of manure with the assumption that this will lead to improved water quality while maintaining facility viability. Specifically, inspectors are assessing facilities for point source releases of manure, appropriate timing and quantity of manure application to pastures, and an appropriate ratio of herd size to land area receiving applied manure.

Tillamook Bay Dairy Manure Management System

No two dairies are alike in how they manage manure. This is true for both Tillamook and Tomales Bay watersheds. However, there are some interesting general aspects from Tillamook Bay dairy manure management systems that may have potential to improve water quality on Tomales Bay dairies.

Current manure storage systems in Tillamook Bay watershed dairies include above and below ground storage tanks and stockpile areas. The majority of these tanks are closed to rainfall inputs. The stockpile areas are usually cement floors and are covered to prevent the receipt of rainfall or run-on and the generation of run-off. The percentage of liquids and solids stored throughout the year are metered through the bedding of alleys and stalls with straw. In many cases the amount of straw is increased in winter to allow for the majority of manure to be stacked as solid.

Application of manure is conducted through manure spreader trucks or sprinkler irrigation systems. Application is allowed during any "window" of time that surface or ground water will not be polluted. Principally, the determination of an application window and the decision to apply is driven by soil and climate conditions (Moore and Baker, 1985). This strategy capitalizes on the infiltration of manure into soil that is not saturated by rainfall. One tool used to evenly apply manure according to soil and climate conditions is a traveling irrigation gun. These guns irrigate to a length of 3,600 feet at variable application rates.

An increasingly important part of manure application is the management of pasture and forage nutrient needs through nutrient management plans. Currently, methods to record daily information at the pasture scale are being tested for application of nutrients in the form of manure and uptake of nutrients through grazing. These records allow dairy producers to identify pastures that are under or over fertilized and make adjustments accordingly. This has resulted in more even distribution of manure, increased the economic efficiency of artificial fertilizer use, improved pasture and forage conditions, and decreased soil nitrogen levels in the fall.

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System Assessment to Improve Water Quality Management on Agricultural Lands

David Lewis, Kenneth Tate, Edward Atwill, Ellen Rilla,
Stephanie Larson, Dayna Ghirardelli, and Paul Olin

4th State of Tomales Bay Conference

Abstract: The University of California Tomales Bay Water Quality Project has developed and is implementing a “systems approach” study of ten animal agriculture facilities within the Tomales Bay watershed to improve water quality management. Water quality data is being collected from loading units that represent land use practices within these facilities. This data is being used to identify and prioritize areas and practices that can reduce bacteria, nutrient, and sediment loading from Bay tributary watersheds. For example, comparison of fecal coliform storm load indicates there is no significant ($p=0.616$) difference between point and nonpoint source (NPS) loading units. Mean fecal coliform concentration from point sources is however significantly higher ($p<0.001$) than NPS loading units, while point source storm flow is significantly lower ($p<0.001$) than NPS source storm flow. Both sources represent areas that merit attention and management to improve water quality, however, it may be easier in the short term to mitigate units that generate the lowest storm runoff. The project will conduct additional sampling during the 2000-2001 water year, increasing the database to allow for statistical comparisons between and within loading unit types.

Introduction

The Tomales Bay Shellfish Technical Advisory Committee (TBSTAC) confirmed that winter fecal coliform bacteria levels within Tomales Bay are above water quality standards for shellfish harvesting areas in its final report (TBSTAC, 2000). Bay agricultural lands are identified as one of the sources for this bacteria loading, as well as onsite sewage disposal systems and recreational boating and camping activities. Because of these findings, the San Francisco Bay Regional Water Quality Control Board, through the TBSTAC, is developing recommendations to reduce bacteria loading within the Tomales Bay watershed.

To assist water quality management, the University of California Tomales Bay (UCTBWQP) Water Quality Project has developed and is implementing a “systems approach” study of animal agriculture facilities. Water quality data is being collected from land use practices within these facilities, to identify and prioritize areas and practices that can reduce bacteria loading to Bay tributary watersheds.

This project overview begins with a discussion of the rationale for choosing a “systems approach” methodology. This is followed by a summary of project’s first year activities, sampling results for winter 1999-2000, and future project plans.

Choosing a Systems Approach
Studies to identify sources of fecal bacteria, and the percentage contribution of each source constitutes to the total load within a given body of water, is a challenging and worthwhile endeavor that can provide beneficial information. These studies, however, are not without limitations. Decisions to select particular study designs should be based on clear goals and objectives and an understanding of these limitations. Source identification studies are confounded by seasonal variability and often have large margins of uncertainty. As a result, identification of fecal bacteria sources within a given water body may provide limited direction for mitigation efforts. A good example of these benefits and limitations is a study recently conducted in Tillamook Bay, Oregon (Moore and Bower, 2000).

In this study, human and livestock fecal streptococci patterns of antibiotic resistance were established from human and livestock waste management samples. Wildlife fecal source patterns were established with bacteria collected from the Tillamook River, where it was assumed no livestock or human sources of fecal bacteria loading existed. The average rates of correct classification for human, livestock, and wildlife isolates were 73%, 89%, and 88%, respectively. Twenty-six percent of the human bacteria isolated for classification were misclassified as livestock bacteria. Similarly, 9% of the livestock bacteria was misclassified as human and 11% of the wildlife bacteria isolates were misclassified as livestock bacteria.

This reference data set was then use to classify bacteria in water samples collected eight times from December, 1997, to December, 1998, within five tributary rivers. Wilson River results are discussed here. These results confirm that livestock, human, and wildlife sources are loading fecal bacteria into the Wilson River and thus Tillamook Bay (Table 1). No single source consistently contributes more than another. Also, the total number of bacteria and the number of bacteria per group vary seasonally. The greatest number of human classified bacteria was identified in September, 1998, while the greatest number of livestock classified bacteria was identified in December, 1997. Similar seasonal patterns were identified in other tributary rivers of the Tillamook Bay watershed.

Table 1: Distribution of sources and concentrations for fecal streptococci in Wilson River, Oregon

	Fecal streptococci by source (cfu*/100ml)		
Month-Year	Livestock	Human	Wildlife
Dec-97	22	18	4
Apr-98	2	3	0
May-98	4	3	0
Jun-98	11	9	1
Jul-1998	10	6	4
Sep-1998	8	28	5
Nov-1998	4	18	20
Dec-1998	12	14	5

*colony forming units

The confirmation of a diversity of fecal bacteria sources is useful to resource management and environmental regulatory agencies to develop mitigation policies and allocate funds for control measures. What if, however, the September, 1998, or the December, 1997, were the only data collected? How would this influence policy and land use decisions compared to having a more complete data set describing seasonal changes within a given year? Equally important are seasonal changes between years. Bacteria levels in December, 1997, are lower than in December, 1998, and human and livestock sources switch rank in terms of greatest contributor. This could be an artifact of sampling time with respect to the river level, as the researchers recognize, but it could also result from inter-annual climatic variability and changes of human and livestock waste management. Lastly, the average rate of correct classification needs to be revisited. For example, from the 20 cfu identified as wildlife in November of 1998 at least two could be misclassified given the 88% average rate of correct classification for wildlife bacteria.

Having completed a study of this kind, a community still needs to determine how to reduce the levels of bacteria from the identified sources. This is where source identification studies are the most limiting. There is little indication of specific locations and practices that have the potential to generate this loading. Specifically, this information is not useful for the dairy rancher or responsible party for an onsite septic system to direct waste management systems and practices.

Designing a Systems Approach
Recognizing the benefits and limitations of the source identification studies, UCTBWQP has selected a systems approach that better meets project goals to:

1. Provide a science-based link between coliform inputs to the Bay and agricultural practices within the watershed;
2. Evaluate animal waste management practices to reduce pollution;
3. Develop resource management policies and a Hazard Analysis and Critical Control Points (HACCP) plan for waste management that would reduce coliform contamination of shellfish growing waters by tracking potential pathogens in the environment and identifying critical points where they can be eliminated or where management practices can be implemented to reduce exposure.

Individual animal agriculture facilities are being assessed for both point source and non-point source fecal coliform loading units through four steps: (1) Facility tour and sampling site selection; (2) First storm-event sampling; (3) Second storm-event sampling; and (4) On-site preliminary result discussion.

Loading units are grouped into sub-categories including: (1) Waste management systems; (2) Pastures; (3) Lots; (4) Manure stockpiles; (5) Storm drains; and (6) Storm runoff. The purpose of sampling at these units and the presentation of results is not to indicate actual parameter loading to tributary streams or the Bay watershed from these locations. Instead these locations were selected and studied to facilitate comparison of management practices with respect to water quality for the investigated parameters.
Waste management systems samples were taken from material within retention ponds and flush systems that were contained and isolated from Bay tributary streams. These materials were sampled to provide a context of waste generated within the study facilities. They represent nascent materials, with little or no dilution from precipitation in contrast to the other loading units.

Samples collected from pastures represent areas used for stock grazing and include management practices such as manure spreading and irrigation. Lot samples were collected from corrals and sacrificed areas used primarily in summer and scrapped and abandoned in winter. Manure stockpile samples were collected from surface runoff around stockpile areas. Storm drain samples represent water from roof gutter systems. Storm runoff samples were collected from surface runoff along roads and parking areas within the facilities. Parameters used to characterize sampling locations and as covariates in statistical analysis include slope, surface area, herd size, assigned curve number (SCS, 1985), 24-hour rainfall, and 5-day antecedent rainfall. In addition, we determined if each site was used in the winter, scrapped, and included year round livestock exclosures.

In addition to identification and sampling at these loading units, sampling and analysis was conducted within tributary streams above and below agricultural facilities and downstream in control tributary streams. The intent of this sampling is to establish a water quality baseline to measure the benefits of future control measure implementation.

Project Activities to Date

Project staff have implemented the four facility assessment tasks at nine cooperating facilities (Table 2). This included first storm-event sampling at nine facilities and second storm-event sampling at three, for a total of 12 storm-events sampled. Had the rains continued through March and April, second storm-event sampling would have been completed at the other six facilities.

Table 2: Facility assessment task summary.

Task	Numbers of Participating Facilities
Facility Tour and Site Selection	9
First Storm-event Sampling	9
Second Storm-event Sampling	3
Preliminary Result Meeting	9

In addition to these steps, project staff have organized three formal extension activities: (1) Tillamook Bay Farmer Exchange; (2) *Livestock Agriculture & Water Quality: The Real Poop* Presentation; and (3) Riparian Management Field Day. The farmer exchange that took place between Tomales by representatives and Tillamook County Creamery Association producers and staff is described in these proceeding (Giacomini and Lewis, 2000).

The agriculture and water quality presentation was held on August 25, 2000 and co-sponsored by the Marin Agricultural Land Trust, Marin County Resource Conservation District and U.C. Cooperative Extension. Drs. Rob Atwill, Environmental Health Specialist, and Ken Tate, Rangeland Watershed Specialist from the University of California, provided the Tomales Bay Watershed community with an overview of the environmental fate and management of pathogens in watersheds. They presented information and fielded questions from the audience about their ongoing research and education on the fate, transport, and management of water borne pathogens from animal agriculture.

The riparian management field day took place on September 12, 2000 and offered dairy ranchers the opportunity to learn more about riparian pasture management. Participants received information about water quality regulations, practices that can improve water quality, and funding opportunities for project implementation, such as the United States Department of Agriculture's Conservation Reserve Program.

1999-2000 Winter Sampling Results and Discussion

Water quality sampling was conducted from January 24, 2000, to March 9, 2000. Over that time period, a total of 192 samples were collected and analyzed for fecal coliform, pH, turbidity, electrical conductivity (E.C.), dissolved oxygen, temperature, total nitrogen (Total-N), ammonia (NH_3-N), nitrate (NO_3-N), phosphate (PO_4-P), and total suspended solids (TSS). This discussion will focus on fecal coliform.

Sampling was conducted on a storm event basis and timed to capture surface runoff and elevated stream runoff in response to rainfall (Table 3). Precipitation data collected at Tomasini Point, by the California Department of Water Resources, was used for calculation of 24-hour cumulative and 5-day antecedent rainfall for each sampling date. Rainfall within the 216 square mile watershed is variable and cannot be accurately characterized by measurements at only one location. However, the California Department of Health Services uses the 24-hour cumulative precipitation from Tomasini Point to direct shellfish growing areas closures making this measure relevant to UCTBWQP goals.

Table 3: Sampling date precipitation data.

Date	24hr. Cumulative Precipitation (inches)	5-day Antecedent Precipitation (inches)	Tributary Watersheds Sampled
1/24/2000	0.88	1.81	4
2/10/2000	0.75	0.31	5
2/14/2000	0.20	4.29	5
2/16/2000	0.04	3.70	5
2/21/2000	0.04	0.43	5
2/22/2000	0.79	0.43	5
2/29/2000	0.39	1.34	5
3/2/2000	0.36	1.45	5
3/8/2000	0.75	1.14	8
3/9/2000	0.00	1.61	8

Fecal coliform concentrations across and within each loading unit are variable. Ranging from a mean of $4X10^6$ cfu/100ml for waste management system samples to a mean of 850 cfu/100ml for control watershed samples. Concentrations from within the waste management system are consistently the highest, which is anticipated given the nature of the material. Only the concentrations from lots and stockpiles approached similar high levels. Control watershed concentrations were consistently the lowest. It is interesting to note that the concentrations in upstream and pasture samples were not significantly different than control watershed sample concentrations ($p=0.05$). Similar comparisons and more in-depth data analysis between and within each practice are limited by sample size per unit. Winter sampling in 2000-2001 water year has been designed to address this point.

Concentration data is useful information to manage water quality particularly when concentrations are used to regulate water quality. But storm loading by area provides better information for the manager to make comparisons by understanding how concentration and flow have the potential to load fecal coliform in tributary watersheds.

Storm runoff was estimated for each loading unit during each sampled storm through the use of the Curve Number Method (SCS, 1985). Total storm load for each loading unit, including the control tributary watersheds, was calculated by multiplying these volumes by the fecal coliform concentration (Figure 1). With these calculations, prioritization can be appropriately informed by total load, storm runoff, and concentration. Land use managers will want to focus on units with the greatest total loading when they are allocating time and money to reduce fecal coliform loading. These can include point source (lots and stockpiles) and nonpoint source areas (upstream areas and pastures).

Any allocation of resources for water quality management should recognize that there are long and short-term priorities. One potential method to select these long and short-term priorities is to separate those areas with high total loads because of large storm runoff from those with high total loads because of high concentrations. For example a 30-acre pasture or upstream area could have a storm runoff volume of 1.9 acre-feet resulting from 0.75 inches of precipitation, and have a fecal coliform concentration of 23,555 cfu/100ml. In comparison, a 3-acre lot could have less than 0.01 acre-feet of storm runoff from the same storm with a concentration of 49,333,333 cfu/100ml. Which unit presents the greatest storm fecal coliform load and which would be the easiest to mitigate?

Comparison of the natural log transformed mean fecal coliform storm load indicates there is no significant ($p=0.616$) difference between point and nonpoint source loading units (Figure 2). Natural log transformed mean concentration from point sources is, however, significantly higher ($p<0.001$) than for NPS loading units while point source natural log transformed mean storm flow is significantly lower ($p<0.00$) than NPS loading unit storm flow. Both sources represent areas that merit attention and management to improve water quality. However, it may be easier in the short term to mitigate units that generate the lowest storm runoff.

Figure 1: Estimated fecal coliform storm load by loading unit.

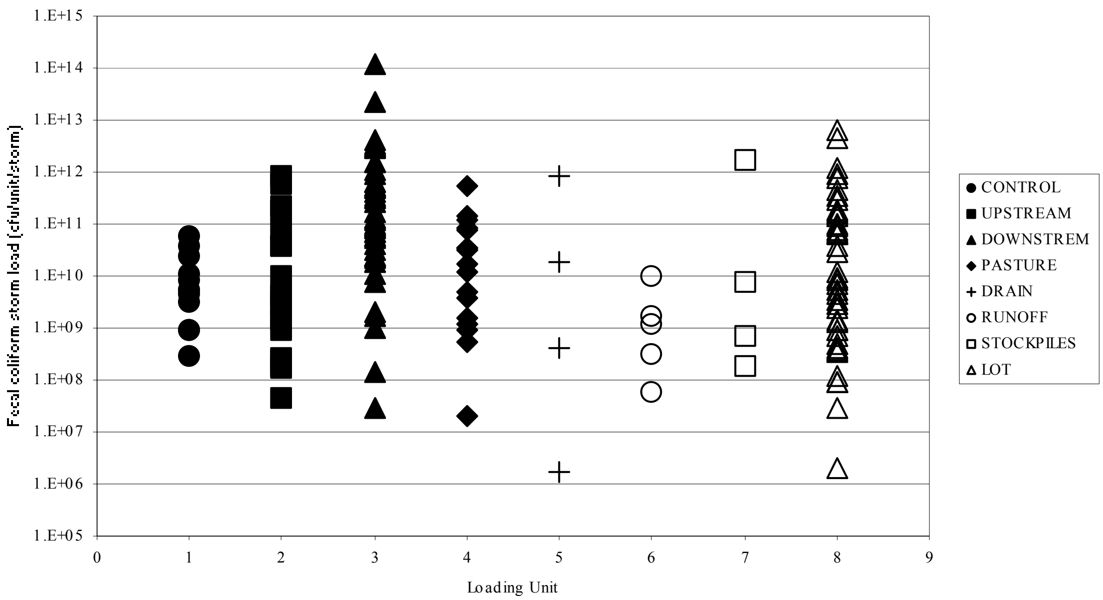
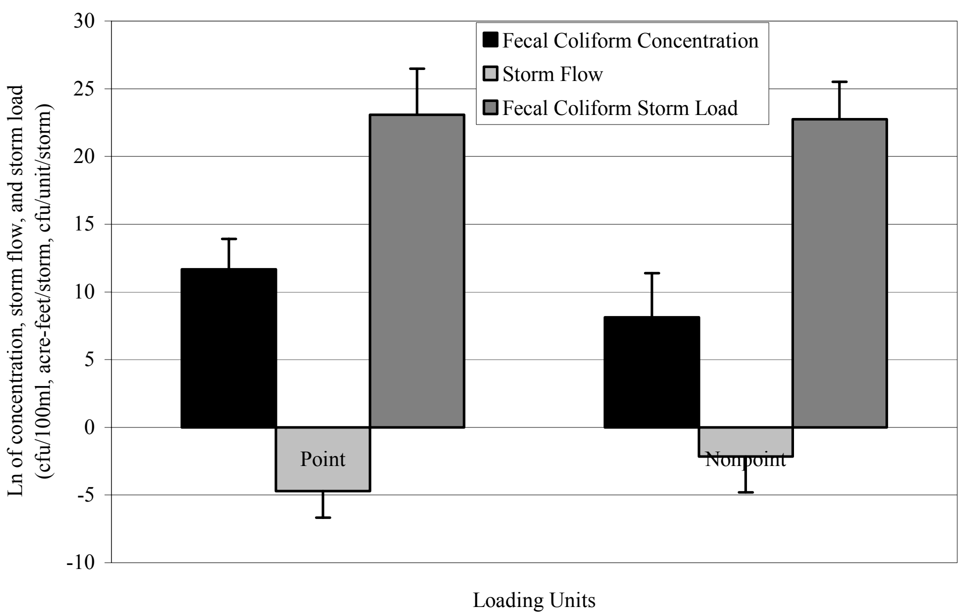


Figure 2: Fecal coliform concentration, estimated storm runoff, and estimated f. coliform storm load for point and NPS loading units. Point and NPS concentration and storm flow are significantly different ($p<0.01$) but storm load is not ($p=0.616$).



Future Project Plans

The information generated from this systems approach project has been beneficial to each individual participating facility manager. In addition, it demonstrates the importance of prioritizing control measure implementation based on total storm loading, as well as corresponding concentration and storm runoff. Small sample size is limiting the ability for conclusions and recommendations to be drawn regarding specific management practices at this point. However, discussions of results with individual cooperating facility managers have provided mitigation direction at the facility level. Continued project efforts will be to:

1. Conduct additional storm sampling at the identified loading units so that recommendations regarding specific practices can be developed.
2. Investigate relationships of nutrients and fecal coliform levels to methods of waste storage, handling, and manure application on fields and pastures.
3. Collaborate with the Natural Resource Conservation Service, Marin County Resource Conservation District, Western United Dairymen, and other University Staff to develop tools for comprehensive nutrient management plans.

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Acknowledgements: We would like to thank the Marin Community Foundation for its support of this project. In addition, the participation and cooperation of the Tomales Bay Agricultural Group members in this study has been pivotal to its progress and demonstrates their commitment to finding solutions to the Tomales Bay watershed's water quality issues.

Tomales Bay Shoreline Plants - The Exotic, The Rare, and…Iceplant

Barbara Moritsch, Plant Ecologist, Point Reyes national Seashore

Expanded Abstract

The watershed that surrounds Tomales Bay supports a wide variety of plant communities that are comprised of both native and exotic plant species. Plant community types include Bishop pine forests, oak, bay and Douglas-fir forests and woodlands, grazed annual grasslands, and coastal salt marshes and dunes that form the interface between land and water.

Healthy functioning of Tomales Bay ecosystems, both terrestrial and aquatic, is directly dependent on the health of the vegetation surrounding the Bay. The plant communities serve to minimize soil erosion by intercepting rain and maintaining soil structure, mitigate the effects of flooding, and improve water quality. They provide food and habitat for a range of both common and rare wildlife species, serve as refuges for populations of rare plants, and give the immeasurable gifts of scenery and aesthetic values.

The diversity of plant communities around the Bay is matched by the diversity of land ownership and land use occurring in the watershed of Tomales Bay. Included within this mix are lands administered by the National Park Service (NPS) at Point Reyes National Seashore and the Golden Gate National Recreation Area. A variety of programs and projects are underway in the parks to ensure protection and maintenance of the plant communities on lands administered by the NPS. Current projects include mapping and classification of all plant communities occurring on NPS land and on adjacent state park land, a park-wide wetlands inventory, documentation and monitoring of rare plants, removal of highly invasive exotic plants, including cape-ivy, iceplant and European beachgrass, assessment of oak mortality, and riparian and dune habitat restoration.

Through these and other programs, the NPS is working to protect and manage vegetation within portions of the Tomales Bay watershed. As pressure continues to increase on watershed lands, our collective responsibility as land stewards becomes ever more complex, and we cannot afford to act in isolation. Plants, particularly exotic invasive plants, do not recognize political boundaries. Long-term, comprehensive protection and maintenance of plants and ecosystems in the Tomales Bay watershed will require the input and cooperation of the many landowners and land managers within the watershed. The efforts currently underway by the planning groups and the Advisory Committee to develop the *Guidelines for Protection and Use of Tomales Bay* exemplify the type of regional interaction that is required. The Guidelines represent a solid foundation upon which a regional approach to vegetation stewardship and management around Tomales Bay can be developed.

SEWAGE SYSTEMS AND TOMALES BAY

By: W. Edward Nute, Nute Engineering, San Rafael

Tomales Bay is very fortunate in that it still has relatively good water quality. One reason for this is that most of the watershed has escaped intensive development. Although development would most likely bring sewers and sewage disposal it would also bring increased urban runoff, siltation and air pollution.

The waters of Tomales Bay support recreation, fishing, commercial and sport shellfish harvesting, as well as habitat for rare and endangered species. Curiously, Tomales Bay is so remote in the thinking of the regulators that the Regional Water Quality Control Board has neglected to list any beneficial uses for the bay and most of its tributaries in its Basin Plan. Consequently, Tomales Bay lacks a regulatory basis for its protection.

The principal method of sewage disposal in the Tomales Bay watershed remains the individual sewage disposal system, commonly known as septic systems. A septic system generally consists of a septic tank, which receives the sewage and retains the solids behind a baffle. The septic tank effluent flows into a drain field where it is percolated into the ground. The idea is to loose the effluent in such a way that it does not surface or enter a waterway where it could create a health hazard or cause pollution. Soil contains bacteria which break down and purify the septic tank effluent. Septic tank effluent is rather nasty. It is black and odorous and can plug up a drain field over time.

In recent years the individual sewage disposal system technology has become more creative. Mound drain field systems and recirculating sand filters are two examples.
A mound system is basically an elevated drain field and is used where ground water is shallow or the soil is tight. The French Ranch and Lagunitas School use recirculating sand filters which treat the sewage to a rather high level before it is applied to the drain field. Clear treated sewage does not plug up the drain field as easily as septic tank effluent.

The community of Tomales operates a conventional sewer system with a pond and field where the effluent from the pond is sprayed on the ground. As long as the spraying is not done during rainy weather and not too intense, the effluent will soak into the ground and not runoff into Keys Creek.

Conventional sewers have long been preferred by engineers and regulators. Sewers are relatively easy to design and are generally part of a fair sized project. Regulators like sewers because they then only have to deal with a one central agency which is responsible for the sewers as well as the sewage treatment and disposal facilities.

The Marin Countywide Sewerage Plan of 1967 envisioned the construction of conventional sewers, formal treatment plants and ocean outfalls to serve the planned urbanization around Tomales Bay as well as at Bolinas and Stinson Beach. Fortunately for West Marin the urbanization never came and so the sewer systems were not built.

At that time there was a strong prejudice on the part of the regulators against individual septic systems and in favor of conventional sewer systems and ocean outfalls. Some of the planning of that era for the San Francisco Bay area envisioned monster projects and outfalls.

The Bolinas and Stinson Beach project, which was being seriously pushed by the County and State, was never constructed. There were a number of reasons for the failure of the Bolinas/Stinson Beach project including then Governor Jerry Brown's "small is beautiful" philosophy.

Around Tomales Bay the urbanization never came largely because of the creation of the Pt. Reyes National Seashore and the A60 zoning adopted by the county.

Eastern Marin, as well as the communities around San Francisco Bay, are served by conventional sewer systems. Very few individual septic systems remain in these areas. Agencies with sewer systems must operate under a permit issued by the Regional Water Quality Control Board.

In the San Francisco Bay system one of the most critical issues is mercury. Mercury is very toxic and magnifies in the food chain. Most of the mercury in the Bay Delta system originated from gold mining in the 1800's and is still coming through the sediments of the bay. Other sources of mercury include reagents used by hospitals and chemical laboratories, broken mercury thermometers, dental amalgams, broken florescent light bulbs, pigments, crematoria, etc. Municipal waste discharging agencies only account for 1% of the total mercury load to the bay but they are highly regulated and must meet extremely stringent mercury standards.

There was a mercury mine in the Tomales Bay watershed which has recently been remediated. Hopefully, this input of mercury has been stopped. I don't think anyone has studied the other potential sources of mercury in the Tomales Bay watershed.

In the last few years the EPA and State regulators have started to implement a "watershed approach" to protecting water quality. The watershed approach acknowledges that direct dischargers, which operate under a permit, may only account for a fraction of the pollutants entering a water body. Other sources of pollutants are atmospheric deposition, runoff from roads and developed areas, runoff from agriculture, siltation, disposal of household wastes, etc. It is very difficult to regulate these sources because they don't come out of the end of a pipe. The watershed approach requires cooperation between regulators and a diverse group of "generators".

What is the future of septic systems and sewers in the Tomales Bay watershed?

Proper disposal of human waste is an essential element of a watershed approach or any other approach to pollution prevention. To date individual sewage disposal systems have worked reasonably well around Tomales Bay. They should continue to work well providing they are conservatively designed and have appropriate setbacks from wells and water bodies. The new non-traditional types of individual waste disposal systems such as mound systems and sand filters can also provide reliable sewage disposal.

Conventional sewers can also play a role in the Tomales Bay watershed. The town of Tomales is now served by conventional sewers. However, before sewers are constructed to serve other areas their advantages and disadvantages should be explored.

The advantages of sewers include:

- Sewers can be used to eliminate failing septic systems.
- Sewers can convey sewage away from developed areas.
- Sewers can allow easier control and oversight by regulators.
- Sewers can usually be extended to eliminate additional failing septic systems.

The disadvantages of sewers include:

- Sewers can overflow during wet weather if they become overloaded with extraneous ground water and rain water.
- Sewers can overflow because of stoppages.
- Pumping facilities, which would be needed around Tomales Bay, can fail and overflow.
- The collected sewage must be treated and disposed of somewhere.
- Sewer systems are subject to increasingly stringent regulation.
- Under the newly enacted SB709 each and every violation of a discharge requirement is subject to a mandatory $3,000 fine.
- Sewer systems and sewage treatment and disposal systems can usually be extended to serve additional development.

Sewers are very expensive to install and require appropriate treatment and disposal of the sewage. There are some Federal and State grants for small communities which could help finance sewers. A large development might be able to finance a sewer system which could be sufficiently oversized to allow additional connections.

The state requires that a public agency operate and maintain a community sewer system such as the county, a city or special district. Such an agency is funded by the people it serves, who, of course, are responsible for the operation and maintenance and will be liable for any penalties or fines that are assessed.

In the final analysis, the main issue around Tomales Bay is growth and urbanization. This is not an easy issue to resolve because it cannot be denied that sewers could allow additional development on land which cannot support individual sewage disposal systems. However, disposal of human wastes are only part of the problem. Urban runoff, deposition from polluted air and disposal of solid wastes are all contributors of pollutants to our waterways.

TOMALES BAY ADVISORY COMMITTEE
TOMALES BAY WATERSHED COUNCIL

Harry Seraydarian, Environmental Protection Agency, and Michael Mery, Tomales Bay Watershed Council

Tomales Bay

Tomales Bay and its 218.8 square mile watershed with a perimeter of 141.7 miles is remarkable for its beauty, its diversity of wildlife, including nearly 500 bird species, hundreds of invertebrates, and many fish species including the listed coho salmon and steelhead trout. Its main tributaries are Lagunitas, Olema and Walker Creeks; and its watershed enjoys the benefit of including parts of the Point Reyes National Seashore, the Golden Gate National Recreation Area, the Tomales Bay State Park and Samuel P. Taylor State Park, and the lands of the Marin Municipal Water District and the Inverness Public Utility District. The waters of Tomales Bay are part of the Gulf of the Farallones National Marine Sanctuary. The Tomales Bay Watershed supports many beneficial uses, but is significantly impacted by the growing presence of people, mostly clustered in nine villages with a population of approximately 8,000. Tourism brings over four million visitors annually. Other significant human activities include recreational boating, agriculture and mariculture. Such user impacts have likely contributed to the Bay's listing as an impaired water body by the Regional Water Quality Control Board.

Water quality issues and habitat loss result from our human activities. Key problems include increased sedimentation, high coliform counts and nutrient loading. Also significant is the decrease in the size of the bay due to sedimentation, loss of estuarine habitat and riparian corridors, and decreasing numbers in many species, most notably coho and steelhead.

In the past, planning efforts to address issues included the State Coastal Conservancy Tomales Bay Estuarine Enhancement Program of 1984, which resulted in a number of erosion control/habitat oriented restoration projects throughout the watershed. The University of California Cooperative Extension Project of 1994 addressing Coastal Watershed Enhancement helped to address a greater understanding of nonpoint source pollution and organized a successful ranch planning effort. Both offer significant information and recommendations for an expanded planning effort to build on. A number of current efforts offer opportunities for partnerships and information exchange, including:

1) National Park's Coho and Steelhead Restoration Project
2) Marin Community Foundation's grant to the Tomales Bay Agricultural Group to conduct water quality and agricultural waste management planning
3) Marin Municipal Water District's Lagunitas Creek Sediment and Riparian Management Plan
4) Marin Resource Conservation District's extensive sediment control work
5) USDA Natural Resources Conservation Service Environmental Quality Incentives Program and the Conservation Reserve Enhancement Program.

In addition to the efforts above, several community-based organizations have coalesced to address issues: the Tomales Bay Shellfish Technical Advisory Committee, the Tomales Bay Advisory Committee, Tomales Bay Association, Tomales Bay Agricultural Group, Environmental Action Committee and the Inverness Foundation are examples. In the late 1990's the activities of these groups and of the Point Reyes National Seashore, the Gulf of the Farallones Sanctuary, the Regional Water Quality Control Board, and the California Department of Health Services were heightened by the outbreak of the "Norwalk-like" human virus in Spring of 1998, resulting in 170 people becoming ill after eating raw oysters. The source of the virus remains unclear. Lack of clear information about pollution sources and fear of enforcement by agencies has created division between some interest groups. A comprehensive understanding of the issues and problems is urgently needed, supported by broad educational programs, leading to a significantly strengthened understanding of the Bay resulting in water quality improvement projects and restoration efforts.

The listing of coho salmon and steelhead trout as threatened species in the last three years and associated enforcement regulations under the Endangered Species Act add further importance and value to planning efforts at this time.

Formation of the Tomales Bay Watershed Council

All of the organizations mentioned above are keenly interested in the health of the Bay, but none has the broad representation of all interest groups, nor addresses the full spectrum of the problems facing the watershed. Under the leadership of the Tomales Bay Advisory Committee, a proposal for a broadly representative effort was discussed with the intention of addressing the full scope of the issues through local consensus. As a result, the Tomales Bay Watershed Council was convened in January of 2000, with 24 members representing: 1) residential and community groups; 2) agricultural interests; 3) environmental groups; 4) mariculture; 5) recreational interests; and 6) public agencies. Members have committed to participate in the Council for at least two years. The group is also fortunate to have a facilitator with experience in addressing complex water quality issues in our region, in addition to a distinguished career in the U.S. Environmental Protection Agency.

<u>Progress to date</u>

- The Council has succeeded in organizing a membership of 24, representing all appropriate interest groups and agencies. The Marin County Resource Conservation District has agreed to act as the Council's fiscal agent for funding received.
- It has met eight times and has formed a funding committee, a representation and organization committee, a vision/goals committee and a planning concepts committee. We have agreed upon a Vision and Goals statement and have a preliminary timeline developed.

- The Council has received the following funding:
    1. $10,000 from the County of Marin for the first year through the efforts of Steve Kinsey.
    2. $25,000 for the second year from the County of Marin and Supervisor Kinsey's office.

3. $66,000 from the Marin Community Foundation for the first year of a Watershed Coordinator's position and opening a local office.
4. $10,000 from a private family foundation expected to be received this fall
5 Application to the California Department of Fish and Game for $64,000 for second year Coordinator support.
6. Anticipated October or November submittal of a grant proposal to the Coastal Conservancy for support to develop the watershed plan including support for habitat and geomorphology studies.

- The Council expects to have hired the Watershed Coordinator by the beginning of the Conference.

Project Methodology

The Council's efforts will be managed by the Watershed Coordinator who will provide administrative and organizational support, data collection, education and outreach, oversight of the planning effort and implementation of the plan. The Coordinator will have an extensive natural resources background and experience in working with community and environmental groups with diverse interests.

A two-year planning effort will be conducted by a Planning Consultant under the direction of the Council and Coordinator. Work of the Planning Consultant will include performing assessments in the watershed based on existing research and by conducting or commissioning new studies as needed; and writing the plan with the guidance of the Council. The scope of the plan will include making recommendations, such as defining best management practices (BMP) across different disciplines, to agencies regarding policies, and regarding developing legislative proposals. It will identify specific projects to be accomplished, e.g., research, habitat restoration, water quality improvement, and so forth.

Community and Environmental Benefits

There will be many tangible and intangible benefits to the community and the environment through this planning effort.

A centralized and publicly available information source and related public outreach will increase the community's knowledge of the issues and promote an understanding of the watershed and the bay, the resources it contains and our impact on this fragile environment. This knowledge is intended to diminish the friction between interest groups, and foster a collaborative spirit in resolving the watershed's problems. It will also encourage greater local control over health and environmental issues. Public meetings will help to focus communications and establish a more unified articulated vision for the future of the region. An increased commitment to this stewardship of our ecosystem will help sustain the natural function of our watershed, resulting in a stronger understanding of sustainable levels of human activities including agriculture, mariculture, recreation and simply living here.

The work of the Council and the Coordinator will provide tangible achievements including:

1) A central office serving as an information resource to the community

2) A comprehensive record of historical activities and related changes in the Watershed, and the creation of a repository or library of all earlier work, including studies and data on existing conditions
3) A list of all interest groups and coordination of exchange of information between those groups
4) A comprehensive record of current activities in the watershed
5) Grant applications to fund the planning effort and other projects
6) Publication of newsletters and press releases
7) Educational events, including events in public schools

The plan itself will be a landmark asset, organizing existing data and providing new factual information on the status of the watershed. It will identify science-based, community supported restoration projects in its streams, uplands and marshes. The plan will call for specific actions, including regulatory recommendations, and address, among other issues, human and agricultural waste management, grading standards, and streamside protection standards. It will recommend further studies where more technical information is needed. A comprehensive plan will assure the attention and support of the appropriate agencies and encourage funding. The implementation of the plan's recommendations will provide measurable improvements in the environment, such as increased habitat and improved water quality.

Summary

The Tomales Bay Watershed Council has the opportunity to address the continuing watershed problems most of which are inevitably reflected by deteriorating conditions in Tomales Bay. Our efforts are based on the active cooperation of all local groups and the relevant agencies which have the formal regulatory responsibility for the health of the bay. As we all know, effective regulation is only possible when there is broad agreement on the part of the stake holders which translates into the political will required to address our problems. The Tomales Bay Watershed Council hopes to play a crucial role in providing the planning and support necessary to address the problems affecting the state of the Bay.

It's the Math, Stupid

James Lawry

State of Tomales Bay Conference 2000

"La Guardia is getting kind of like the George Washington Bridge: a constant rush hour. There are peaks and valleys, but the peaks and valleys are getting a whole lot closer together."

A chart of all La Guardia aircraft movements -- those of big jets, commuter jets, private jets and propeller planes -- shows that last year, for example, there were 371,000 takeoffs and landings, up from 358,157 in 1998 and 345,647 in 1996.

And even if, by some magic, La Guardia could add a few runways and triple its taxi space, there would still be traffic jams like the one that rainy Friday, because the next choke point in the system is the air traffic control system, also overburdened from the region's other airports.

But any way you look at it, he said, "adding another 600 flights a day – it just can't happen."

New York Times 8/25/00

ABSTRACT

To study the effect of introduced species on the Tomales Bay ecosystem, be they Green Crabs or people, we need to understand Tomales Bay as a complex system. We might expect that by knowing enough about all the parts of the bay and how they interact, we can know how the system works and then how to keep it healthy. This is not possible, because Chaos Theory governs Tomales Bay.

Part One: Tomales Bay Is Unknowable

What makes the Tomales Bay system a system, and not just a group of animals, plants and water in a fault, are the connections and interactions between its components, as well as the linkages between the bay and its surroundings. Organisms multiplying where food is limited, species competing to add genes to the gene pool, epidemics and pollutants spreading through populations; all might be isolated to study individually, if not in laboratories then in the minds of biological theorists. Seen together these combined actions are unknowable.

The situation in Tomales Bay is many times worse than the classical three-body problem.
The three-body problem shows how limited our abilities are to understand complex systems. We can write equations for the behavior of two planets or stars orbiting each other in terms of the elementary functions of mathematics, such as powers, roots, and the trigonometric functions. For example, to extend these equations to forecast the movements of just three bodies is impossible. We cannot combine the solutions of the two-body problem to determine whether a three-body system is stable. Thus, the essence of the three-body problem resides somehow in the way in which all three bodies interact. Any approach to the problem that severs even one of the connections between the bodies destroys the very nature of the problem. This is a case in which complicated behavior arises as a result of the interactions between relatively simple subsystems. Tomales Bay is much more complex than the three-body problem.

Tomales Bay and Emergence

Tomales Bay is a complex system. Why is this so? The short answer is because the behavior of the bay is completely inexplicable even after, if this were possible, a complete analysis of the systems' parts. All complex systems generate emergent behavior, and emergent behavior is unpredictable. Emergent behavior is just one of the things that makes a complex system complex. To dissect a complex system to understand how it functions means changing the system and losing information.

Suppose we give a TV to a monkey and tell him to learn about TV. He watches the tube a few minutes, then being very intelligent, pulls the plug and dissects the set. After a week he turns his observations of the parts into a wiring diagram, but the diagram cannot help him explain the commercials he interrupted. Commercials are not a property of the parts of the TV, and they cannot be deduced from physical theory or knowledge of electronics. TV and Tomales Bay are emergent complex systems where the whole always equals more than the sum of the parts. Precisely how to model emergence--that is, to devise mathematical laws that explain or predict emergent behavior--is a major problem that has yet to be solved by complexity theorists.

Computer Models Aid Analysis of Complex Systems

In everyday thought we frequently label a system, like TV or Tomales Bay, composed of many interacting components whose behavior or structure is difficult to understand, as complex. Complex systems are not new, but for the first time we have tools (computers) to study such systems in a controlled, repeatable, scientific fashion. Previously, study of complex systems, such as the Tomales Bay ecosystem, was simply too expensive, too time-consuming, too dangerous or too impractical to tinker with the system as a whole. Instead, only bits and pieces of the bay or a few processes within the Tomales Bay system could be looked at in a laboratory or in some other controlled setting.

However, with today's computers, we can build surrogates of the Tomales Bay system and manipulate a "model" of Tomales Bay in ways that would be unthinkable for its real-world counterparts. What happens to the flora and fauna when a foreign species invades might be a question we could ask of a model. Another might be how much sewage might enter the bay from Point Reyes Station produced in the peak months of rain and drought as a function of the number of human inhabitants and their housing.

Computer models always remain guesses, because the information used to make them is always incomplete. The complexity of the Tomales Bay ecosystem is not a property of that system we can analyze in isolation. Complexity is a joint property of the system and its interactions with other complex systems that include it, such as the San Andreas Fault, the global weather system, and the editors of the *New York Times* Travel Section.

A journalist visits Tomales Bay. She writes an article that appears with pictures. The run is on. Airlines are crowded. B and B's are booked, and after a few weeks a New York strain of *E. coli* appears in the bay. No one, even one having infinite knowledge of the workings of the bay, could have predicted the article, the response to the article, or the bacterial strain. Such complex interactions in which the bay is linked to national news and how such small random events can flip the system around are part of what's meant by calling Tomales Bay a complex system. Thus complexity defeats any modeling even with our most powerful tools.

Informal Use of the Word "Complexity" Complicates Its Scientific Use

A second key point is that we use the word "complex" informally as well as scientifically. The word is typically used for something counterintuitive, unpredictable, or hard to understand. So to create a science of complex systems (something more than just anecdotal accounts), any informal notions of complexity must be compressed into a more formal, stylized language. If we sharpen our words, complexity theory becomes a tool.

One problem is that to transform complexity into a mathematical science involves making that which is really fuzzy and poorly defined in some way precise. We must formalize what is really informal. We must formalize what scientists mean by a complex system.

To see what complexity is scientifically, let's compare a simple and a chaotic pendulum. (Simple and Chaotic Pendulum Demonstration)

(Demonstrate Simple Pendulum)

We can accurately predict what simple systems do. Simple systems are predictable and repeatable--the pendulum swings back and forth in an arc. Simple systems have simple parts: a rod, a pivot point and a weight. Dissection permits study of the parts in isolation. Putting them back together recreates the behavior. In simple systems control is generally concentrated in one, or at most a few, locations. The length of the rod, the size of the weight and gravity determine the period of the swing. One changes the period of the arc by changing the length of the pendulum. This change is predictable. Control here lies in the length of the rod. The change is clearly traceable back to the bob's position.

(Demonstrate Chaotic Pendulum)

Complex systems are surprising. If we start the swing here, it behaves like a simple pendulum. However, if we start the swing from here, complex processes generate counterintuitive behavior that is full of surprises. This new system is chaotic. No one can write equations or computer algorithms that will predict where the pendulum will go. It behaves irregularly and chaotically, and does this because, like all complex systems, this pendulum is complexly connected.

Complex systems generally involve a large number of components, and no single interactions dominate the linkages between the parts. Complex systems generally contain many invisible feedback loops. Feedback loops enable the complex system to modify the interactions between its parts, thereby opening up or closing down its chances for a wider range of behaviors. After a strain of bacteria enters the bay and gains a foothold, it grows unseen. It may cause illness for awhile but not forever, because other parts of the system take over.

Complex systems cannot be broken into parts. Like our monkey dissecting TV, pulling the plug helped him dissect the set without getting electrocuted, but his act of investigation destroyed the complex phenomenon he was studying. Complex processes are irreducible.

Complex systems may seem to have a central controller, but in actuality the power is decentralized; a number of parts combine to generate the actual systems' behavior as in the complex pendulum. Where are the bay's controllers? Did the *New York Times'* travel writer cause the *E coli* in the bay? Controllers appear in different places at different times. Now let's see what happens to a very simple complex system. Then we'll see what happens when we disturb or flip it.

Part Two: Complex Systems Over Time

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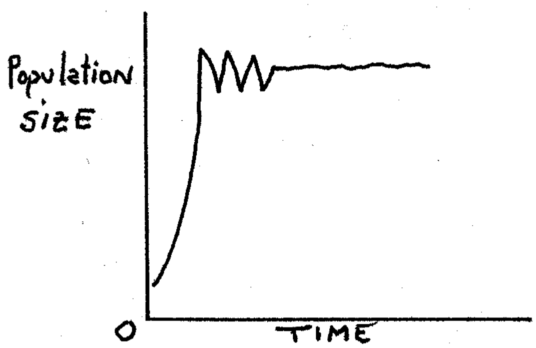
You are now a graduate student. You decide to simplify the problems of Tomales Bay for your thesis and study just Green Crabs. You build a computer model. Helpful insights come readily if you model some change in snapshots taken at discrete intervals of time. You begin with a very simple problem; just Green Crabs and food. What happens if you start with a small number of crabs and continue to feed them as they grow in numbers?

You will sample your model population of Green Crabs at yearly intervals. You take a few samples of crabs from the bay to estimate a starting number of crabs for your model. You use an equation that approximates life, the logistic equation*. As the crabs multiply they should eat more and more food. Because crabs are piggy and will have many babies, they should starve unless you keep increasing their food. To keep things simple you ignore egrets, other predators, crab diseases and watch just the numbers of crabs as you increase the food supply. You think the crab population should settle into some kind of long-term behavior. You and your colleagues think this should be a steady state. After all you've taken away disease and egrets and all those other nasty variables…

*Note: A website that lets you see the logistic equation in action is:
http://www.apmaths.uwo.ca/~bfraser/itermaps/logistic.html

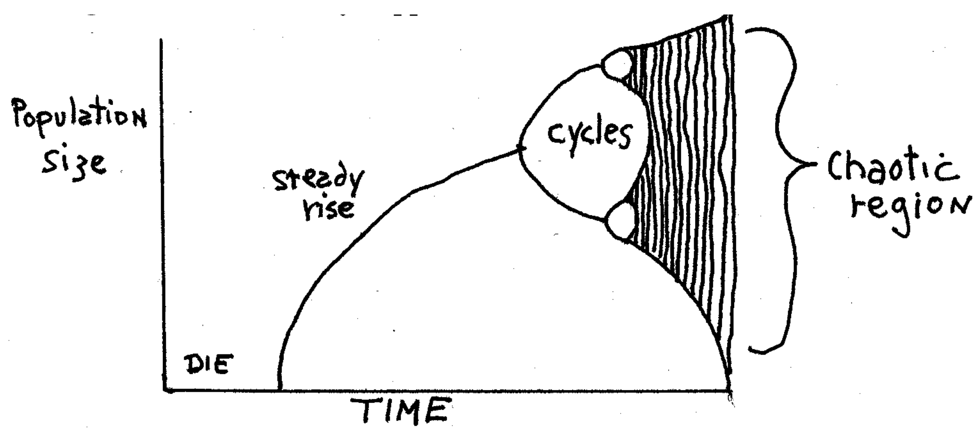
Surprise!

Figure of what you expect to happen:



Legend: The population reaches equilibrium after rising, overshooting and falling back.

Figure of what actually happens:



Legend: The crab's boom/bust cycling and the final population are plotted on the vertical axis. Time is on the horizontal axis. If the food is insufficient, the population of crabs dies out. If food is available, and a few crabs are present, the size of the population rises. As food increases more, the numbers you measure for the population of crabs now appear to alternate in succeeding years between two different levels (low, high, low, high…). As food increases even more, the alternations occur faster and faster. At last the population becomes chaotic, and the population can have infinitely many different values.

What you thought was a simple system is really a complex one. As food increases, the original crabs mate, and because the babies have plenty to eat, the number of crabs in the population increases up to a level set by the available food. You keep adding food, but the numbers of crabs you find each year starts to level off. The numbers you find each year, however, are not what you expected. One year you find more crabs. The next year you find fewer. The numbers of crabs you find each year cycle; one year you find more, the next year you find fewer, then more, then fewer… The pattern of these repeating boom-bust breeding cycles breaks down little by little as food increases. You certainly don't expect this. After all with plenty of food, the crabs should just keep increasing their numbers, not cycling!

You keep increasing the food. A population alternating on a 2-year cycle now starts to vary on the third and fourth years as well. The cycles are regular, but the alternations come faster and faster and start getting mixed up. The cycling then suddenly breaks off and never settles down at all. Here's where the chaos starts.

The year after chaos begins you find no crabs. The next year you get thousands, the next year you get 71. You begin to think from your samples each year that the crabs have gone bonkers, and that their population is now random. So you compare the numbers of crabs you've gotten over the last few years during chaos with a series of random numbers and, your crab numbers look random. You keep getting random looking numbers of crabs for a few years more, and then suddenly in the middle of all this chaos and complexity, stable cycles return. Even though you are still increasing the food, a window in the population over time suddenly appears showing a regular period-the boom-bust cycles now repeating on a three-year or seven- year cycle. Then the population flips back into chaos. During chaos you can't predict from one year to the next how many crabs you will find.

Part Three: Can You Control Chaos?

Your research drives you to the Internet and your books. You learn that many systems behave as your crabs do. Measles, rubella and other epidemics rise and fall in frequency cycles and then enter phases when the number of people getting sick appears random.

To get your mind off your problems you go to a bar and play pinball. You watch the ball as you flip it, and you see that your more powerful flips may shoot the ball a longer distance, but that you still can't control the ball's direction. The ball moves around much like your crabs. You kick and tilt the machine to try to control better your flip on the ball. You now ask what your chaotic crab population would do if you kicked it suddenly. You build a computer model of your crabs and try inoculating your crab-model with different starting numbers of crabs. You observe the results. You add more food. You see the results. You suddenly take away food. You see the results. You add egrets that eat crabs. You see the results.

You find each time you do something that instead of a smooth change in an expected direction, you see large oscillations when you attempt to flip your system. These large changes bear no obvious relation to the size of your "flips". You cannot control what the system does. It just seems to act crazy more of the time after you flip it. The system appears exquisitely sensitive, however, to any changes you impose on it. You go back to your computer and learn that data from other real systems behaves similarly. You learn that all complex systems are sensitive to minute changes in the initial conditions. You learn, for example, that a campaign to wipe out gonorrhea by giving shots in San Francisco showed a sharp increase in infections after the start that was interpreted by the health officials that the program was a failure. They did not understand all the initial conditions, and they never could have done so.

Part Four: You Take Your Green Crab Analysis Globally
People, not crabs, are the introduced species having the greatest flipping power to Tomales Bay. Your isolated crab populations behaved unpredictably in the simplest model. People in real life are more complicated than crabs; they don't just eat and reproduce! They come to Tomales Bay with increasing resources and financial power. They build homes. Some flip the bay harder than others. They bend the rules because they can. We have the complex system of people together. We make rules, such as no second units, to control our collective flips on the bay. The questions we now ask of Tomales Bay, a system we scarcely understand, are highly complex. They resemble the questions asked of La Guardia Airport.

These last two days we have really been asking how will the bay respond to the flips of earthquakes, reduced inflows in the creeks, more boats, more wastes, more developments, more roads, more visitors?

As more "megaflippers" come down by the bay, we may not realize that our OWN seemingly idiosyncratic decisions become quite typical collectively, and are recreated many times over on a grand scale. Because folks are increasing, more and more folks have the same ideas we have. As each of us privately decides to go to the beach on a warm day, we find a traffic jam, and individual family planning decisions become a population explosion; one dog owner's decision not to scoop…one leaky septic…one more SUV…

How will Tomales Bay adjust to all the flips? That's like asking how, exactly, the Inverness Ridge will look after the Mt. Vision fire. That fire flipped the forest's complex system. Now there are lots of new niches for pink stucco houses, for example. We hope not to contribute to chaos in our bay. The form chaos takes is *always* unknown, and chaos doesn't seem to reverse. Only change is assured.

Conclusions
The bottom lines here are three.

First: How complex systems respond to inputs is always unknowable.

Second: When the numbers are large enough, a system's complex local behavior becomes complex global behavior. Once a person realizes he/she is a part of a complex system, rationality suggests that person must now act as if one's secret individual actions were *always* to be multiplied many-fold. The increasing numbers of people multiply all our actions, good bad and indifferent. As we flip things towards chaos, might some bad outcomes be postponed if each of us reflects carefully about his or her own place in the complex system before indulging in the naively selfish act?

Third and last. We have seen that when complex systems become chaotic, they change irreversibly, and that chaotic changes cannot be manipulated once they start. So it follows we need to avoid flipping our bay into something vastly different, like a Slough of Despond.

A readable, non-technical starting book:
Roger Levin (2000) Life at the Edge of Chaos. 2nd edition, University of Chicago Press. $13.50

Speakers and Moderators

4th State of Tomales Bay Conference
October 6 & 7, 2000

Maria Brown is the Executive Director of the Farallones Marine Sanctuary Association (FMSA). She was instrumental in establishing the FMSA and has a strong background in marine education. She received her B.S. in Conservation Resource Studies from the University of California at Berkeley, and a Masters Degree in Urban and Environmental Policy from Tufts University.

Richard Plant is chair of the Tomales Bay Advisory Committee, has lived in Inverness since early 1960, and is a member of various environmental groups interested in protecting Tomales Bay.

Dr. Michael Whitt has been a physician living in the West Marin area for 30 years and has a particular interest in waterbirds. For a period of time he made trips to the Farallon Islands and explored Tomales Bay with an authentic Monterey Clipper that he owned. He has written three books of poems on the outdoors and a journal of his trips to the Farallones.

Dr. Paul Olin is a Marine Advisor with the University of California Cooperative Extension/Sea Grant. His areas of specialization are aquaculture, biotechnology, salmon habitat restoration, and water quality. Recent projects or publications include: Investigations to improve oyster survival, evaluation of environmental interactions of shellfish aquaculture, and restoration of salmon habitat. He recently completed *Review of North American Aquaculture FAO — NACA.* Aquaculture in the Third Millennium Proceedings.

Dr. Michael McGowan earned his Ph.D. in biological oceanography at the University of Miami. He is currently a senior research scientist and adjunct professor at the Romberg Tiburon Center and San Francisco State University. His area of specialization is the application of ecological theory to practical problems in aquatic environments. Recent projects include monitoring dredge spoil impacts offshore and in San Francisco Bay.

Jennifer M. Pearson is a candidate for an M.A. in marine biology at San Francisco State University. She has recently studied the fish and mysids in two creeks in Marin County, California.

Dr. Edwin Grosholz holds a Ph.D. in zoology from the University of California, Berkeley and is now is a member of the Department of Environmental Science and Policy, University of California, Davis. His primary responsibility is that of Assistant Specialist in Cooperative Extension. His areas of specialization are ecology of aquatic and marine habitats, conservation and restoration ecology, ecological impacts of introduced species, coastal natural resource outreach and education. Recent projects/publications include: Grosholz, E. D. in press. Ecological and evolutionary consequences of invasions: Addenda to the agenda. MIT Sea Grant Publications; Grosholz, E. D. The impacts of the European green crab *Carcinus maenas* in central California. Dreissena, in press; E. D. Grosholz, G. M. Ruiz, C. A. Dean, K. A. Shirley, J. L. Maron, and P., G. Connors. 2000. The impacts of a nonindigenous marine predator in a California bay. Ecology 81: 1206-1224.

Dr. Debra Ayres is a scientist at the University of California, Davis specializing in estuarine ecology and the introduced marsh plant Spartina *alterni flora*.

Brannon Ketcham is a hydrologist at the Point Reyes National Seashore. He holds a Masters Degree in Water Resource Management from Duke University. His areas of specialization are watershed management, land policy and geomorphology. Recent projects include administering the Point Reyes National Seashore's water quality monitoring program and the coho salmon, steelhead and trout restoration program.

Don Neubacher is Superintendent of the Point Reyes National Seashore and was instrumental in helping to produce all of the previous Tomales Bay Conferences.

John Hart holds a B.A. from Princeton and works as a freelance writer. His professional interests include environmental affairs, poetry and criticism. Recent publications include: *Storm over Mono: The Mono Lake Battle and the California Future* (CUC Press 1996); *Farming on The Edge: Saving Family Farms in Marin County, California,* (CUC Press1991). John wrote the opening chapter of "A Sense of Place" for the Tomales Bay Environmental Study of 1972.

Dr. Randy Chambers was actively involved with the National Science Foundation sponsored LMER/BRIE studies of Tomales Bay in the early 1990's. He holds a Ph.D. in Environmental Sciences from the University of Virginia. He is currently an associate professor of biology at Fairfield University in Conneticut. Recent studies have involved the ecology of estuaries, ecology of invasive plants in estuaries, population biology of marsh turtles, and sediment chemistry in the Florida everglades.

Dr. Rick Bennett holds a Ph.D in Comparitive Pathology from U.C. Davis. Currently he is a science communication consultant and president of Applied Life Sciences. His primary professional interest is in the effects of agricultural and urban land use on surface water microbiology. He has been engaged in a multi year study in Marin and Sonoma counties monitoring urban and rural water quality.

Robert Giacomini is a dairy farmer and member of a family that has been active in dairying in West Marin since the mid 1940's. He has operated his ranch on the west shore of Tomales Bay for 41 years and has received a number of dairy industry awards.

David J. Lewis works with the University of California Cooperative Extension as a watershed management advisor for Sonoma, Mendocino and Marin counties. He holds an M.S. in International Agricultural Development from the University of California, Davis. He specializes in agroforestry, soil science, and watershed management and research. Recent projects include cooperating with the Tomales Bay Agricultural Group as the lead University of California staff for the U. C. Tomales Bay Water Quality Project. Recent publications are on the topic of water quality and hydrology in oak and agricultural lands. David Lewis has published papers in the Journal of Hydrology, the University of California Agriculture and Natural Resource Series and the Journal of Soil and Water Conservation.

John Kelly is the Director of Research and Resource Management at Audubon Canyon Ranch and manages the Cypress Grove research center in Marshall.

Barbara Moritsch is a plant ecologist at the Point Reyes National Seashore. She holds a M.S. Degree in Environmental Science from Oregon State University. Her areas of special interest are rare plants and plant ecology. Recent projects include plant community and wetland mapping and assessment, and research on the effects of fire.

Ed Nute holds an M.S. Degree in Environmental Engineering and is president of Nute Engineering (civil and sanitary consultants in San Rafael). His company designed filters and ultra violet disinfection for the Mt. View Sanitary District in Martinez, the first example of its type in the Bay Area. The company also designed the Las Gallinas wetlands and treatment plant. In May of 1999, Mr. Nute provided useful commentary regarding the Tomales Bay Shellfish Technical Advisory Committee's report on pollution sources impacting shellfish.

Harry Seraydarian received an M.S. in Mechanical Engineering from the University of the Pacific and an M.S. in Environmental Engineering from Drexel University. He additionally holds a MPA degree from Harvard University. He is Associate Regional Administrator for the Environmental Protection Agency, Region 9, and specializes in environmental conflict resolution. Publications include *Resolving Differences for March 2000,* Northern California Society for Environmental Toxicologists and Chemists (NORCAL SETAC). Mr. Seraydarian has been instrumental in the formation of, and actively facilitates the meetings of, the newly formed Tomales Bay Watershed Council.

Michael Mery is a resident of Pt. Reyes Station and is Chair of the Tomales Bay Watershed Council. His family moved to West Marin in the 1940's. He is interested in local politics and environmental issues.

Dr. Jim Lawry holds a Ph.D. in biology from Stanford and an M.D. from the University of California at San Francisco. He is a fellow at the California Academy of Sciences. His primary professional interest is in vertebrate and invertebrate biology, mathematical biology, topology and dynamical systems. Recent projects or publications are *Respiration by Turbulent Diffusion in Frogs*, Siam Conference Dynamical Systems*, 1999*, and *Hydrostatic Michell Framework Supports Frogs Lungs*", Bulletin Mathematical Biology, 61, 683-689, 1999.

Ed Ueber is Manager of the Gulf of the Farallones National Marine Sanctuary. Mr. Ueber has been a good friend to the Bay, attending many local meetings which affect the Bay's welfare and carefully reviewing permits that concern the Bay's waters.

SOURCES OF INFORMATION

Environmental Action Committee of West Marin
P.O. Box 609, Point Reyes Station, CA 94956
415-663-9312

Tomales Bay Association
P.O. Box 369
Point Reyes Station, CA 94956

Inverness Association/Foundation
P.O. Box 382
Inverness, CA 94937

East Shore Planning Group
P.O. Box 827, Marshall, CA 94940

Cypress Grove Preserve, Audubon Canyon Ranch
P.O. Box 608, Marshall, CA 94940

Department of Health Services
2151 Berkeley Way, Rm 18, Berkeley, CA 94704
510-540-3423

Point Reyes National Seashore
Point Reyes Station, CA 94956
415-663-8522

University of California Cooperative Extension – Sonoma County
2604 Ventura Ave, Santa Rosa, CA 95400
707-565-2621

Tomales Bay Advisory Committee
c/o Richard Plant
P.O. Box 684, Inverness, CA 94937

Tomales Bay State Park
Inverness, CA 94937

University of California Cooperative Extension – Marin County
1682 Novato Blvd, Suite 150 B,
Novato, CA 94947
415-499-4204

U.S. Natural Resource Conservation Service
1301 Redwood Way, Suite 170, Petaluma, CA 94954
707-794-1242

Gulf of the Farallones Natlional Marine Sanctuary
Fort Mason, Bldg 201, San Francisco, CA 94123
415-561-6622

S.F. Bay Area Regional Water Quality Control Board
1515 Clay street Street, Suite 1400, Oakland, CA 94612
510-622-2300

Tom Moore, Dept of Fish and Game
P.O. Box 1560, Bodega Bay, CA 94923
707-875-2859

Tomales Bay Watershed Council
c/o Michael Mery
P.O. Box 729, Point Reyes Station, CA 94956

Harry Seraydarian, Environmental Protection Agency
75 Hawthorne Street, San Francisco, CA 94105-3901
415-744-1091

Marin Community Development Agency
Marin County Civic Center, San Rafael, CA 94903
415-499-6269

Marin County Supervisor's Office
County of Marin, Civic Center
San Rafael, CA 94903
415-499-7331

California Coastal Commission
45 Fremont Street, Suite 3200,
San Francisco, CA 94105
415-904-5260

California Coastal Conservancy
1330 Broadway, Suite 1100
Oakland, CA 94612

Tomales Bay Watershed Council

LOCAL GROUPS AND INTERESTS

Michael Mery	Chair
Liza Crosse	San Geronimo Valley Planning Group
Robert Giacomini	Tomales Bay Agricultural Group
Michael McClaskey	Point Reyes Village Association
Stan Gillmar	Inverness Association
Catherine Caufield	Environmental Action Committee
Tom Yarish	Tomales Bay Association
Webster Otis	West Marin Chamber of Commerce
Anne Grimes	East Shore Planning Group
John Finger	Hog Island Oyster Company
Merv McDonald	Walker Creek Watershed Advisory Group
John Kelly	Cypress Grove Preserve, Audubon Canyon Ranch
Kate McClain	Blue Water Kayakers
Bill Vogler	Lawson's Landing

AGENCIES

Sally Gale	Marin Resource Conservation District
Don Neubacher	Point Reyes National Seashore
Carlos Porrata	Tomales Bay State Park
Harry Seraydarian	Environmental Protection Agency
Alex Hinds	Marin Community Development Agency
Paul Olin	U.C. Cooperative Extension Sea Grant
Dale Hopkins	S.F Bay Area Regional Water Quality Control Board
Gregg Langlois	California Department of Health Services
Ed Ueber	Gulf of Farallones National Marine Sanctuary
Steve Kinsey (ex offic.)	Supervisor, County of Marin

COHO

Silver salmon, *Oncorhynchus kisutch*

I. Return

Oh swimmers,
oh people of the sea,
oh ocean travellers,
oh gallant fish
returned to us
to spawn and die
in natal pools
far inland,
returned through the arms
of our rivers,
through the hands
of our estuaries
into the fingers
of our streams,
along the nerves
of our hills
into the hearts
of our mountains
to spawn and die
on a rocky redd,
the bones of our planet
worn smooth and round
by clear cold water,
your natal bed,
your death bed.

Oh swimmers
of the salt
and fresh water worlds,
oh anadromous fish,
for us you change
your chemistry,
fresh at birth,
salt in life,
fresh again
in love and death,
hurtling rapids,
climbing ladders,
leaping dams
to reach the bed
of your and our rebirth.

Oh swimmers
come back to us,
oh salmon people
altered by purity
of purpose, altered
by love and by lust,
your flanks burning
red with desire
and with divinity,
your noses, oh men
of the sea, hooked

like the hawk's beak,
scrambling in a drought year
through shallows, wriggling
walking almost, running legless
over the stones, waiting
for rain in the shadow
of tree shaded pools.

Oh swimmers,
oh lovers
of the long way.

II. Rebirth

The female less red,
her face dark,
moves quietly
behind the male
up the rapids,
resting in the shadow
of stones water dark.

Finding a riffle --
the male swimming
back and forth over her tail,
nudging her flanks --
she begins to dig
by rolling on her side
and undulating, sucking
out the gravel with her tail,
rolling back, resting --
the male over and beside her --

then over and over again thrashing,
winnowing out the place of love
until the nest of stones
is ready, the redd dug;
then quietly, as they tread
water side by side,
the female passes the eggs,
her mouth wide open,
her life climaxed;
the male, mouth agape,
releases the milt,
a cloud drifting
from his flanks,
floating down.

The female, half out of water,
moves up and begins digging,
the male, his dorsal fin cast over,
moves into place beside her;
the rock from her new redd
buries the eggs in her old.

III. Death

Oh swimmers
of the wide ocean
and the small final stream,
oh swimmers
make us worthy of your return.

Born of the freshet,
matured in the sea,
vast salty range
of shark, sea lion, whale,
passing from the smallest stream
of mother earth
to the wave mad, wind wild,
infinite ocean,
returning in your prime,
silvered with experience,
once more finding
the ocean bar, the bay,
the long arms and small fingers
of the natal streams,
riding into rock and forest,
into the minds of men
to die and to be reborn.

In the last hour
you are masked
by the white pencil of death,
mouth and nose limned with white
and a white mane
down your tired spine,
the two of you swimming
slowly now, waiting
in the green pool for death;
dead you will fade
into the alder leaves
at the pool's bottom,
your red flanks,
old warriors,
like the embers of a fire
banked for the night,
the hollow sockets
of your dissolved eyes
like the masks of heroes.

Oh swimmers,
oh lovers,
oh silver salmon people
slowly swimming
in the last pool
in the green shadows
touching without breaking
the water's surface,
sending out circles.
spreading circle
        within circle
                within
                        circle.

<u>Michael Whitt</u>
Inverness Park-Taylor Park 1977

Draft Resolution

WHEREAS, Tomales Bay water quality is generally acknowledged to be of good quality,

WHEREAS, good water quality is beneficial to wildlife and plants, oyster growers, sport-fishermen and recreational users,

WHEREAS, there are a number of agencies at the state, county and federal levels that can be expected to take an active role in protecting the water quality of Tomales Bay,

THEREFORE, the attendees of the State of Tomales Bay Conference 2000 urge that:

1. The lines of authority and coordination among the various agencies and groups in addressing water quality problems be clearly established.
2. The evidence required for an agency to determine and respond to a water quality problem meriting investigation be clearly specified.
3. The nature of the response of each agency be clearly specified.
4. The legal and enforcement consequences to a private party or a business who knowingly or carelessly causes pollution of Tomales Bay be unambiguous.
5. The various responsible government agencies support public information and educational efforts to discourage actions which cause pollution in Tomales Bay.
6. Action be taken to regularly inspect and correct, where needed, various types of sewage disposal systems in the Tomales Bay watershed.
7. The practice of transporting sewage and other wastes from Sonoma and other counties to holding ponds in the Tomales Bay watershed be carefully reviewed.
8. Responsible agencies and groups, including the newly formed Tomales Bay Watershed Council, work diligently toward a full assessment of sewage systems, and the ultimate destination of sewage and its breakdown products within the Tomales Bay watershed.
9. The Watershed Council work to develop grants or implement existing low interest loan programs to assist property owners in making necessary improvements to their sewage systems.

EVALUATION FORM

Thank you for attending the 4th State of Tomales Bay Conference. Please help us make the next conference even better by sharing your thoughts on the following:

Were the talks well presented?

Was the subject matter well chosen?

Did the moderators provide a clear sense of continuity through the various presentations?

Did the conference provide a clear sense of the environmental problems affecting Tomales Bay and how they might be solved?

If you would be willing to participate in solving such problems, please indicate your name, address and telephone number and what you think you could do to help.
Name:(please print) ____
Address:____
City:_____________________**Zip:**___________**Phone:**____________________
I can help with:

Comments on the audiovisual presentations:

Which of the printed materials did you find to be useful?

Suggestions for topics, speakers, etc. for future conferences?

Comments on food and beverage?

Please place your response in the box provided, or mail to: Post Office Box 382, Inverness, CA 94937.

<u>Please append further comments on the reverse of this sheet.</u>
Thank you for your assistance.

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