Friday Harbor
MARINE HEALTH OBSERVATORY

Second annual review

The Friday Harbor Marine Health Observatory, a collaborative effort of the Lopez based nonprofit conservation laboratory Kwiáht and WSU Beach Watchers, has deployed volunteer teams monthly on Port docks since January 2010, conducting an inventory of invertebrates living on docks, floats and pilings. After completing a baseline inventory of invertebrate species utilizing the Port as habitat, volunteers selected a preliminary suite of indicator species to count monthly, year-round, at six stations around the Port docks and, as a comparison site, the Friday Harbor Labs dock. Comparable month-by-month species counts are now available for 2010 and 2011, and are reviewed in this report.

What's new at the Observatory

In 2010, local students helped test sediments under the docks for Total Petroleum Hydrocarbons, PAHs, zinc and copper. In 2011, Observatory volunteers monitored two structural classes of dissolved hydrocarbons in surface water on a monthly basis. Spring Street International School students also began a baseline assessment of PAHs in mussels and limpets attached to W dock. Chemical assessments of water, sediments, and selected organisms will continue to play a role in the monitoring program of the Observatory.

An underwater color video camera, the *Eye in the Eelgrass*, was installed in May and provided clear images from the bay floor for five months before it was shut down for the winter. The Eye was used solely for educational purposes in 2011, but will become a research tool in summer 2012, aimed to "see" passing schools of fish, and monitored by high school students who will also serve as interpreters for visitors to the Terminal.

2011 Biodiversity Results

This second annual report has a new, more concise look: Bioindicator species are compared as functional groups. Sessile species that live attached to the docks with little or no mobility are compared with mobile species that we encounter only seasonally in the bay. Mobile animals can respond quickly to any threat they perceive. Sessile animals are more likely to be affected by persistent physical and chemical conditions in the bay, no matter how subtle, which they cannot escape. Moreover, because of their brief residence time and exposure, mobile animals may survive sub-lethal threats that produce chronic effects in sessile animals. The distribution of sessile organisms is therefore suggestive of chronic stressors, while the distribution of mobile organisms reflects "acute," severe, or seasonal conditions.

As before, letter codes refer to Marina docks. FD is the fuel dock. FHL refers to the Friday Harbor Labs dock, which we include as a "negative control" site—one that is sufficiently distant from the downtown, storm sewer and sewage treatment outfalls, and docks, and exposed to greater circulation and dilution from San Juan Channel. Although invertebrate diversity and abundance were greatest at FHL in the baseline assessment, the difference is not as dramatic now that we are using a fixed list of bioindicator species for monitoring.

In 2011, mobile species were much more abundant at E dock that other docks we monitored. They were least abundant at the Fuel Dock and docks J and K.

Figure 1

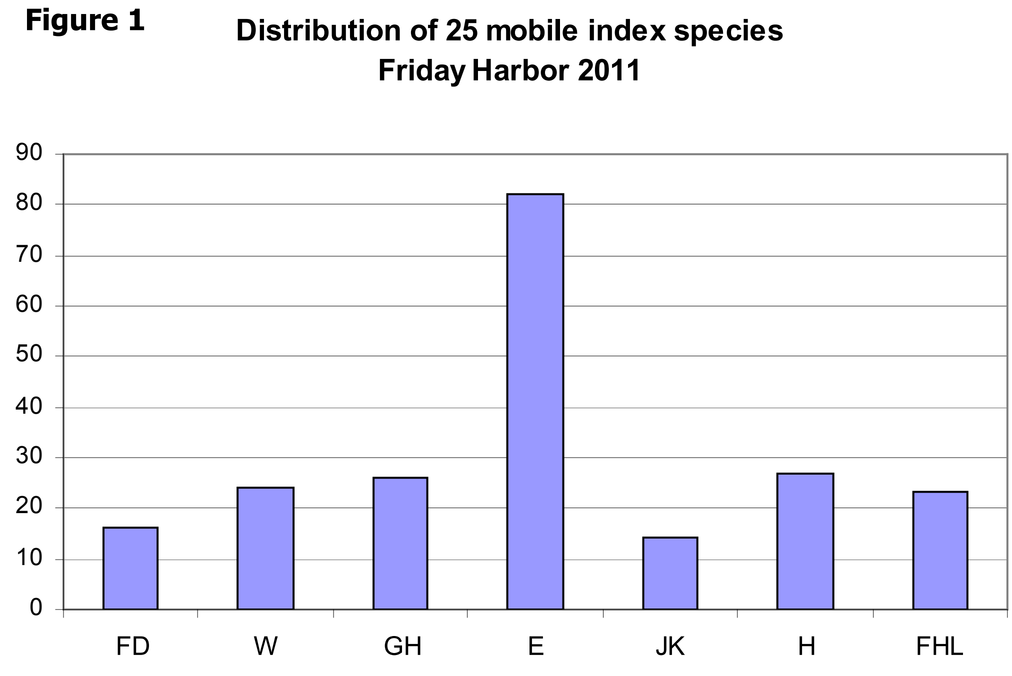
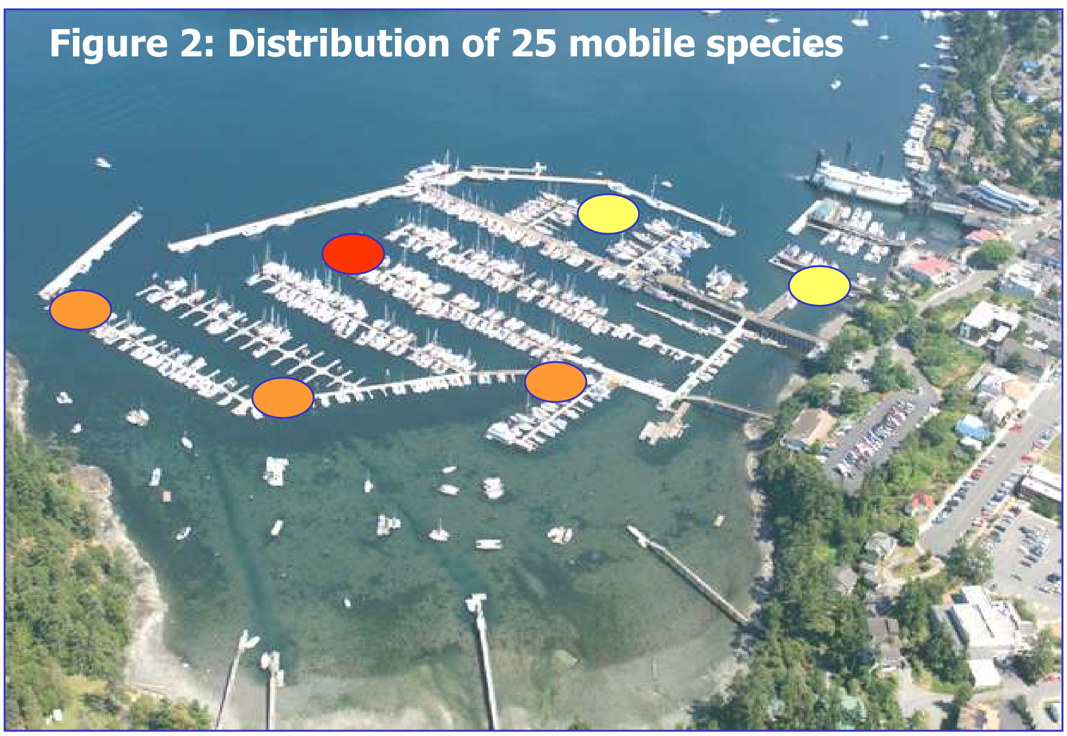
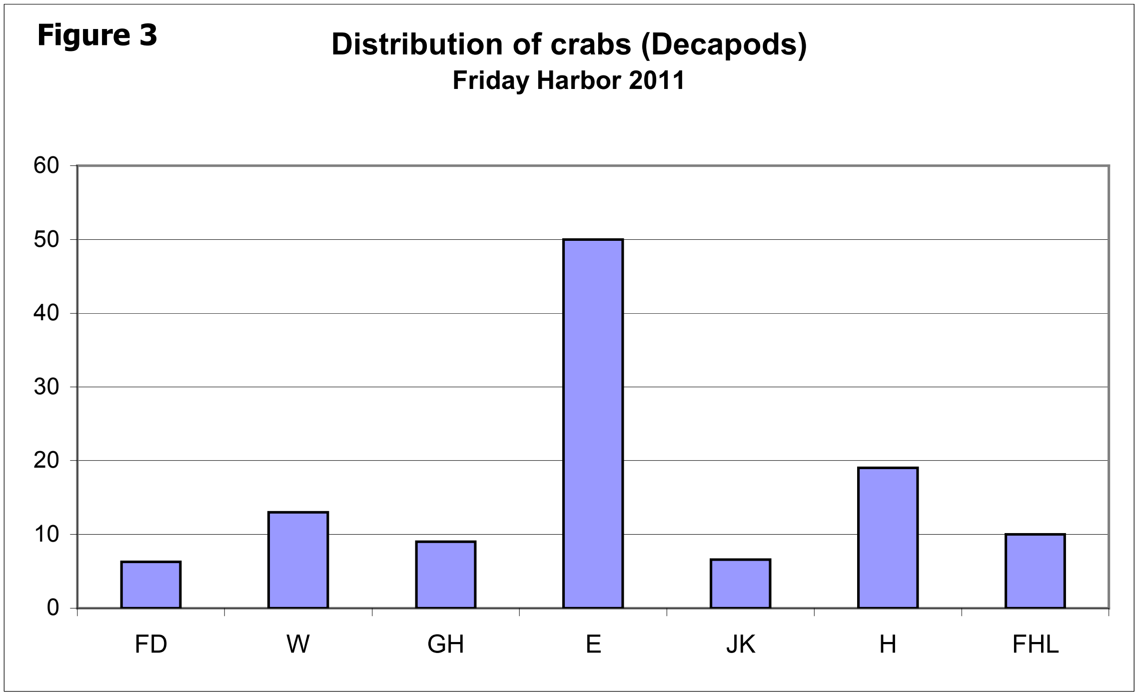


Figure 2: Distribution of 25 mobile species



This effect was mainly due to the behavior of crabs. What might explain crabs' preference for dock E is 2011? One possibility is the location of the Town sewage outfall at the far end of this dock. The crabs in our bioindicator set are scavengers. Outfalls are rich in dissolved nutrients and nutrient-rich particles, and may attract suspension feeders, filter feeders, and in turn, scavengers and predators.



The 2011 distribution of sessile organisms in our bioindicator set was not quite as skewed (Figure 4). However, it suggests a preference for shallower, warmer waters.

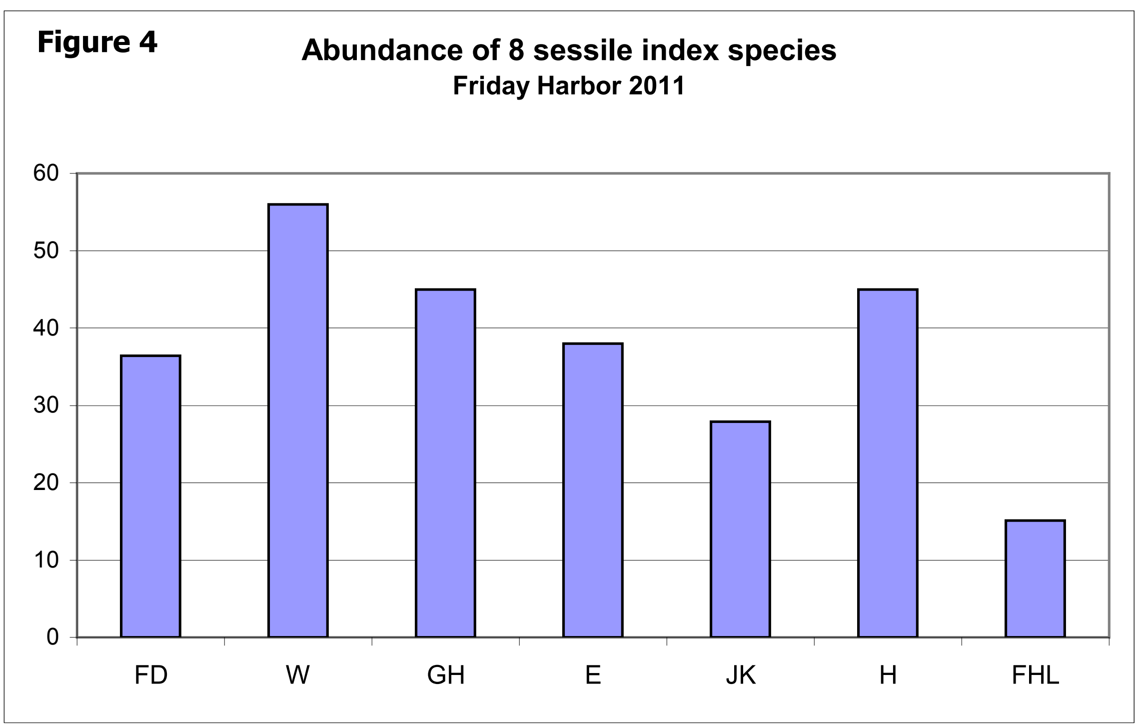


Figure 5: Distribution of 8 sessile species

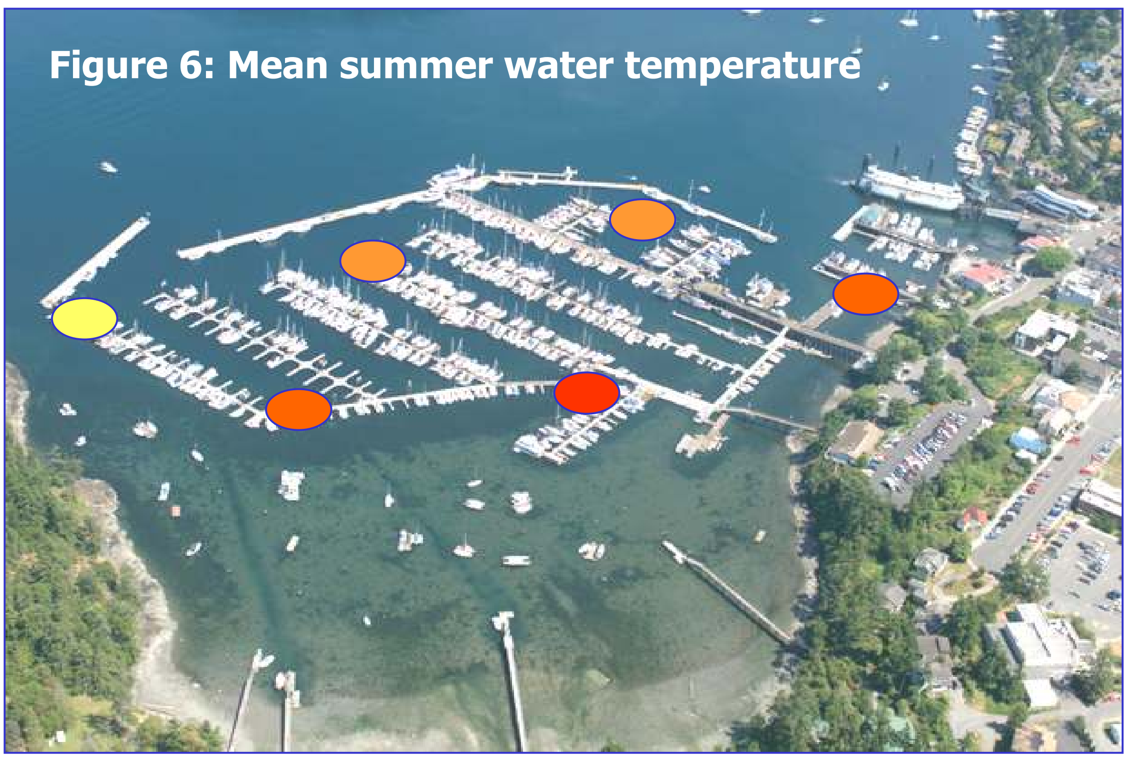
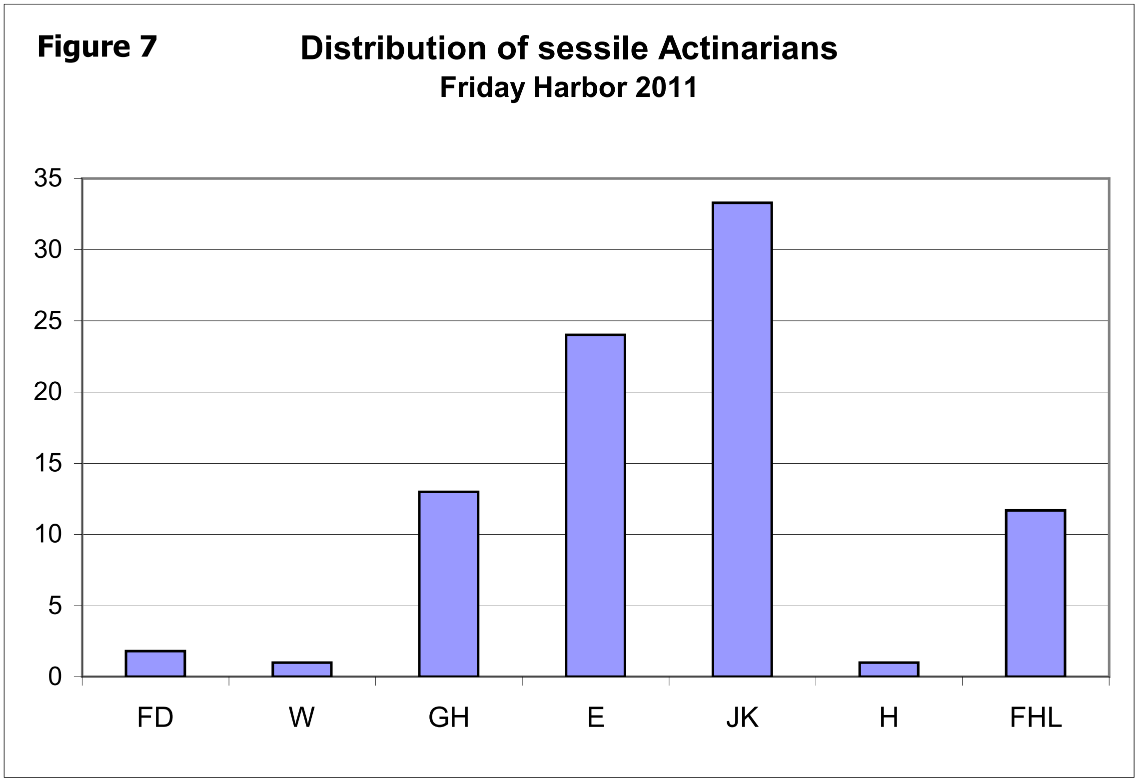
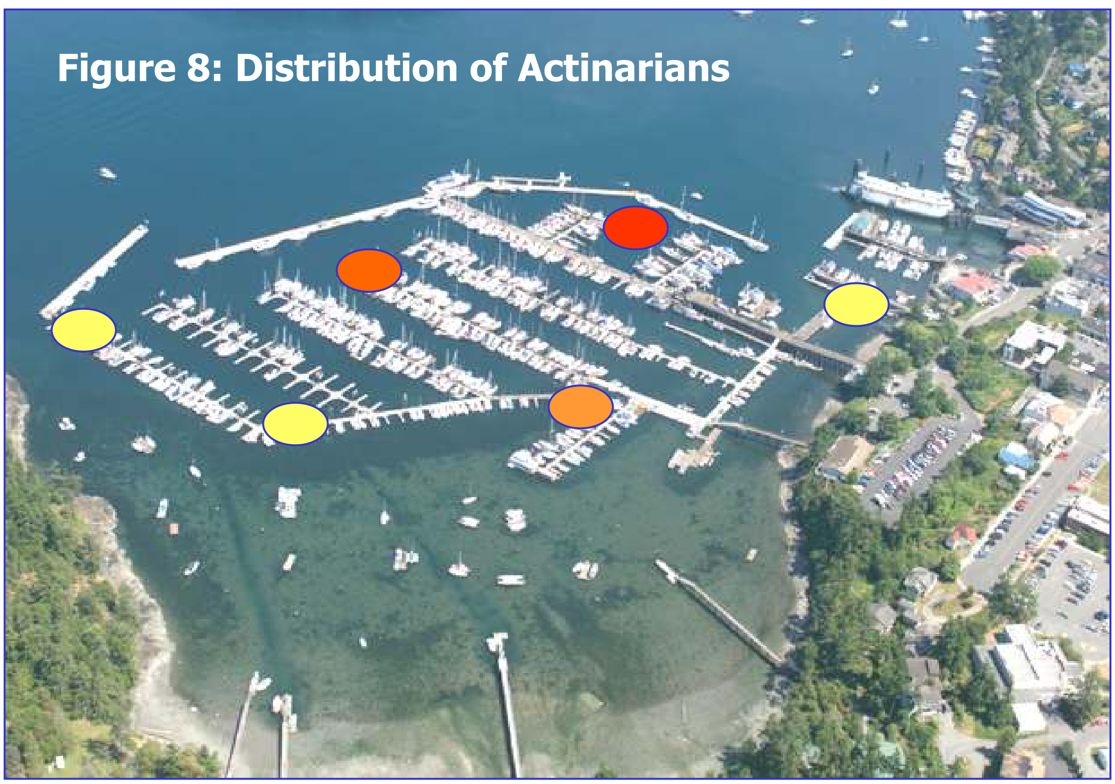


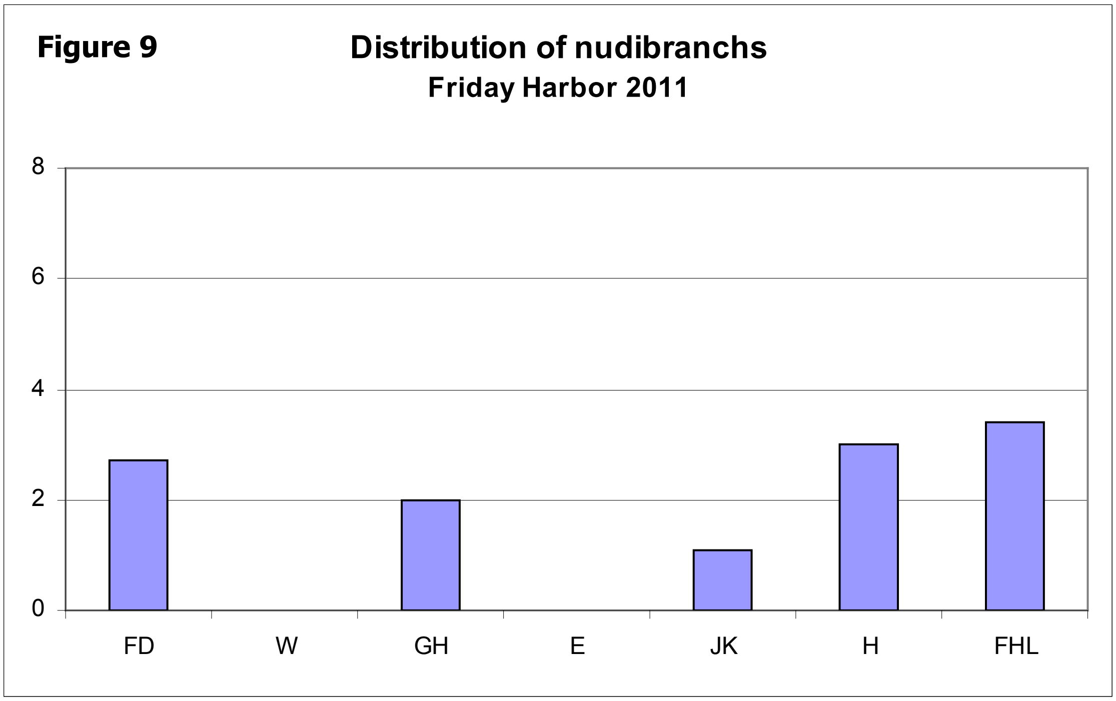
Figure 6: Mean summer water temperature

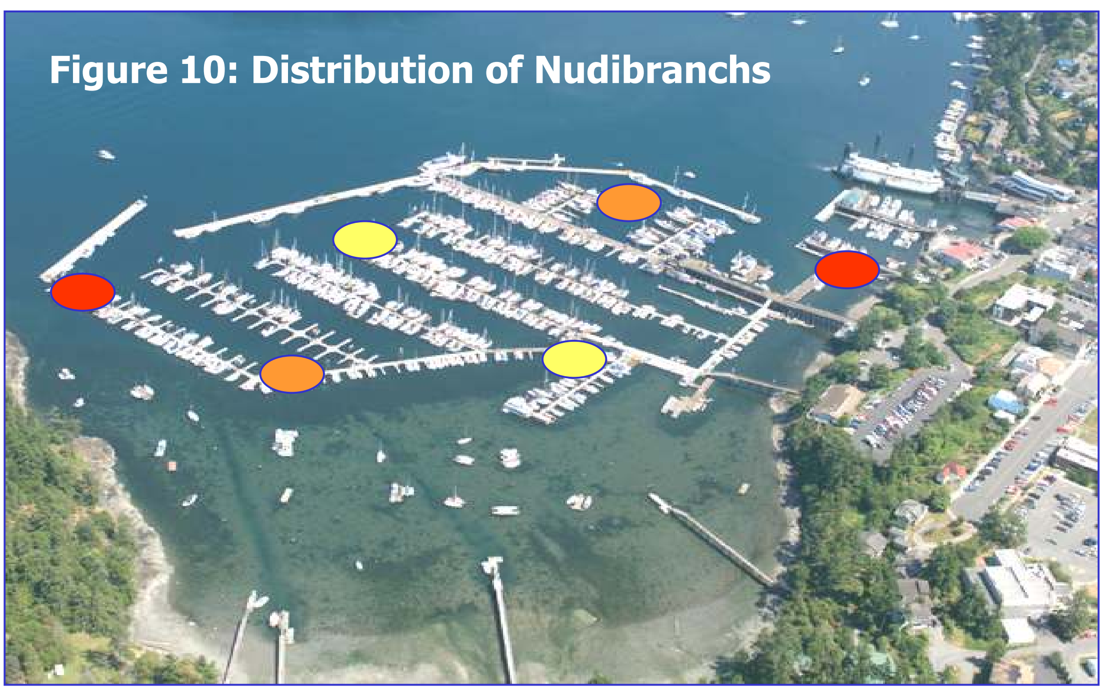
A different habitat relationship appears if we focus on sea anemones (Actinaria). In 2011 they clearly preferred E, GH, and JK docks, perhaps due to higher circulation as well as proximity to the Town sewage outfall at the end of E dock (Figures 7 and 8).





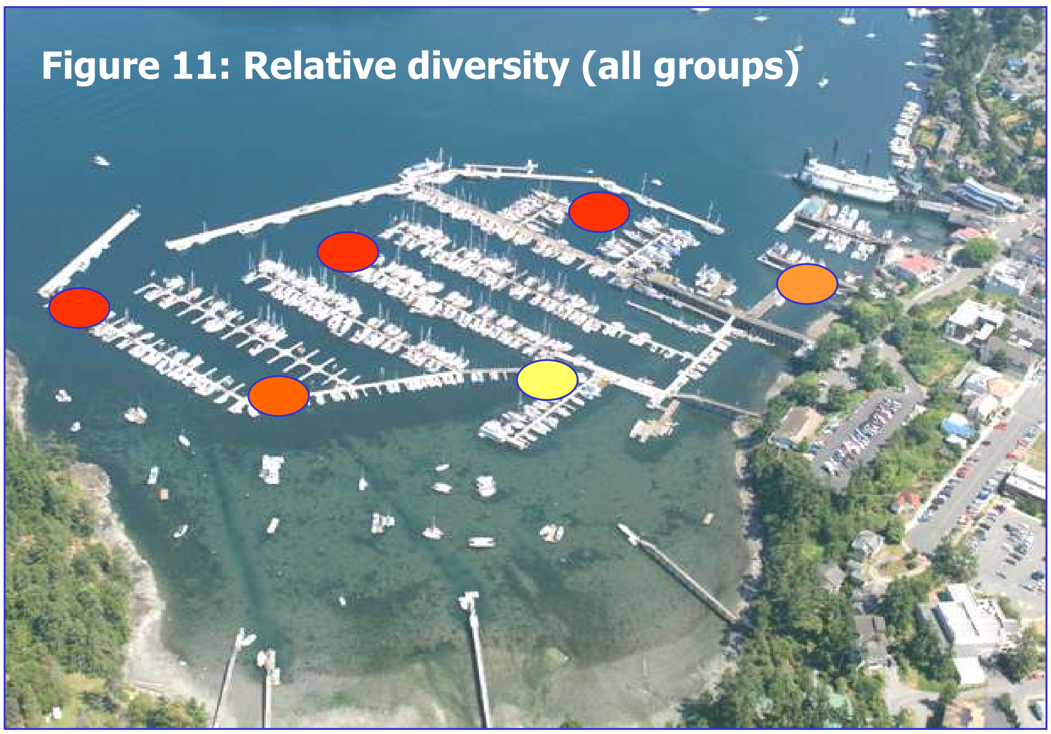
Nudibranchs were conspicuously fewer on the docks in 2011, for reasons that we do not yet understand. As our Indian Island Marine Health Observatory on Orcas Island has observed since 2009, different species of nudibranchs aggregate seasonally in shallow waters to mate and lay their egg ribbons—mainly in winter (December through February) although we have found that some species wait for warmer spring or summer conditions. Nudibranchs were abundant and diverse at the Marina in winter 2010, led by the brightly colored Clown nudibranchs that were chiefly at the Fuel Dock. Only a few Clowns were seen in winter 2011, and only a few so far in winter 2012. Nudibranch life histories have not been studied extensively in Northwest waters and these animals may, like oysters and other Mollusks, have sporadically large reproductive events separated by several years of dispersal and modest population numbers.





As in 2010, nudibranchs were seen at the Fuel Dock; but also at other, relatively higher circulation sites. Numbers were too small to draw any conclusions, however.

Looking at all sessile and mobile species, diversity was greatest over deeper water and where there was higher circulation (Figure 11). This should not be surprising, insofar as filter feeders and suspension feeders form the largest guild of marine invertebrates and benefit from strong circulation to keep moving food particles their way. In Friday Harbor the Town sewage treatment plant outfall is located in the Marina's high circulation zone, presumably enhancing its attraction for the filter-suspension guild. Only animals seeking warmer water (such as mating crabs) or greater shelter (possibly the nudibranchs) may be attracted to the shallows closer to shore and to Town storm sewer outfalls.



The beneficial effect of circulation (and sewage effluent nutrients) may confound our effort to assess the ecological impact of polluted runoff from Friday Harbor streets. The distribution of species shown in Figure 11 could be the result of circulation alone; or it could reflect a combination of circulation and polluted runoff, since both factors would seem to favor higher diversity at greater distance from the shore.

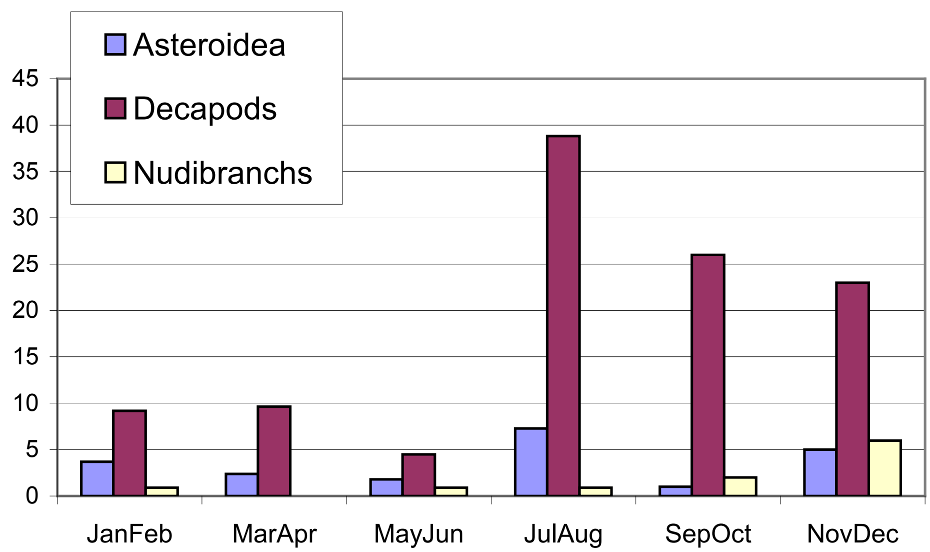
These data do not suggest that any part of the Marina (such as the Fuel Dock) is particularly inhospitable to marine invertebrates. All of the floats studied are lively, only with different combinations of species, and some difference in the total number of species we have seen. Nor is there consistently greater abundance or diversity at the Labs, where disturbance is lower and circulation even greater than within the Marina. While there is a need to continue collecting data under varying year-to-year conditions—as demonstrated by the dramatic inter-annual variation in nudibranchs that remains unexplained—it is not unreasonable to hypothesize at this stage that the ecological value of the docks in adding, or replacing structure in the bay, outweighs the adverse impacts of added disturbance due to boat traffic and boat-sourced pollution. Ensuring this kind of balance (if that is indeed what the data continue to show) will be an ongoing challenge for the Port.

Seasonal patterns

Apart from the question of the relative physical and chemical impacts of the Port and Town on marine life in the bay, there is the possibility of long-term changes driven by changing weather patterns and "ocean climate". Climate change can alter the range of organisms: for example, allowing heat-loving animals to extend their ranges farther north along the Pacific Coast—a process already observed in the islands with the appearance of large numbers of Anchovy and Shad from northern California and the Columbia River.

Another effect of a changing climate is altering the seasonal timing of migrations and reproductive events: phenology. At Indian Island, for example, crabs mated later last year in response to cooler La Niña conditions. We might expect the timing of activity in Friday Harbor also to reflect the cooler spring and summer of 2011.

Figure 12 **Seasonality of three major index groups**
Friday Harbor 2011



Crabs congregated in Friday Harbor after July in 2011 (Figure 12), compared with 2010 when their abundance peaked in April-May. Similarly, starfish showed a very weak peak in abundance in mid-summer 2011, whereas starfish peaked strongly the year before in spring. The differences of 2-3 months are presumably due to cooler 2011 conditions.

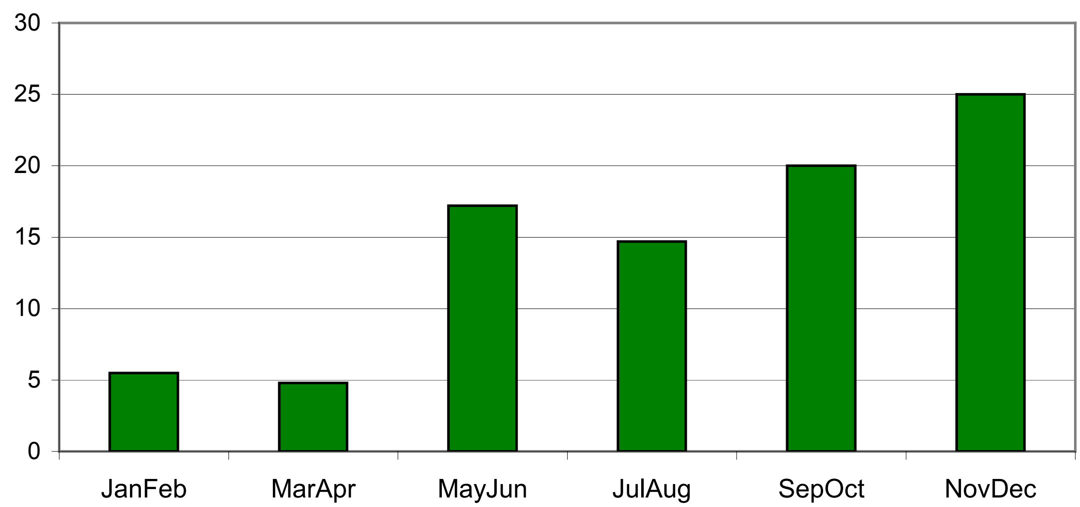
Nudibranchs were very plentiful in winter 2010 but few were seen in winter 2011. Most of the nudibranchs seen in winter 2010 were a single species, the Clown nudibranch (*Triopha catalinae*), and it seems likely in retrospect that nudibranch abundance that year was simply due to an unusual "swarm" of Clown nudibranchs that may not be seen again for several years. A swarm (of the pelagic nudibranch *Melibe leonina*) was seen at Indian Island in fall 2009, and a swarm of newly hatched Opalescent nudibranchs (*Hermissenda* *crassicornis*) in spring 2011. Further observations are needed to determine which species are regular visitors, as opposed to unpredictable, sporadic swarms.

While mobile animals such as crabs may visit for only a few months of each year, utilizing the bay and dock structures seasonally for a specific purpose such as mating and egg deposition, sessile animals can also vary seasonally. When they reproduce, numbers can increase; and predation reduces their numbers. Over the course of several years their abundance may vary considerably in the balance of these forces.

Our data offer an interesting example: the sea anemones (Actinaria), which do not move fast or far, although some are capable of small movements and even hops. Figure 13 summarizes data from five species; we did not count the ubiquitous white *Metridium* species. As can be seen, there appeared to be a steady increase in anemones from early summer through the end of the year. This suggests successful recruitment: more new sea anemones settled on the docks, than died or were eaten.

Figure 13

Seasonal abundance of Actinaria
Friday Harbor 2011



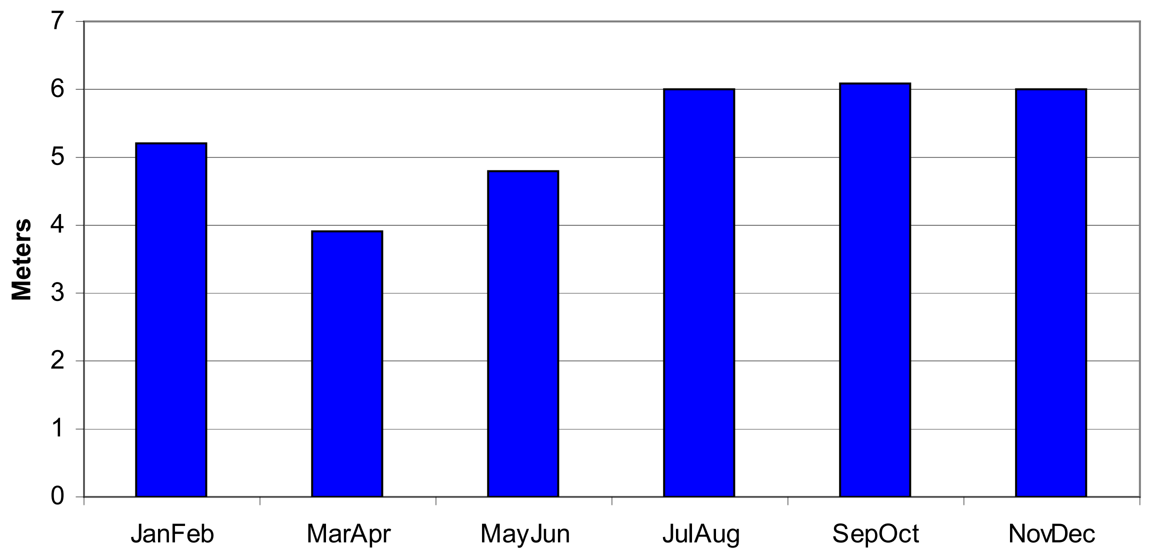
A completely different pattern was recorded in 2010. Anemones peaked in spring and then declined by a little more than half over the course of summer and fall. Why was 2011 a better year (apparently) for anemones than 2010?

One possibility is a difference in the availability of food. Most sea anemones are suspension feeders, and as such they should benefit from increased algal and zooplankton production. Small organisms growing and dying at the water's surface quickly become food particles sinking to the seafloor past the feeding tentacles of anemones. Variation in plankton production may be enough to influence the growth and survival of anemones in Friday Harbor.

Unfortunately we did not measure plankton production in 2010. In 2011 we used an indirect measure: Secchi depth, a way of measuring water clarity. Our concern at first was the possibility that water clarity biased observations of invertebrates under the docks: when clarity tends to be low, in warmer months, our dock monitors cannot see down into the water as far as they can in winter, when the water tends to be clearer. In actuality we found that water clarity varied relatively little for most of the year (Figure 14), averaging more than five meters except in spring when there were major plankton blooms.

Figure 14

Secchi depth, all Friday Harbor sites, 2011



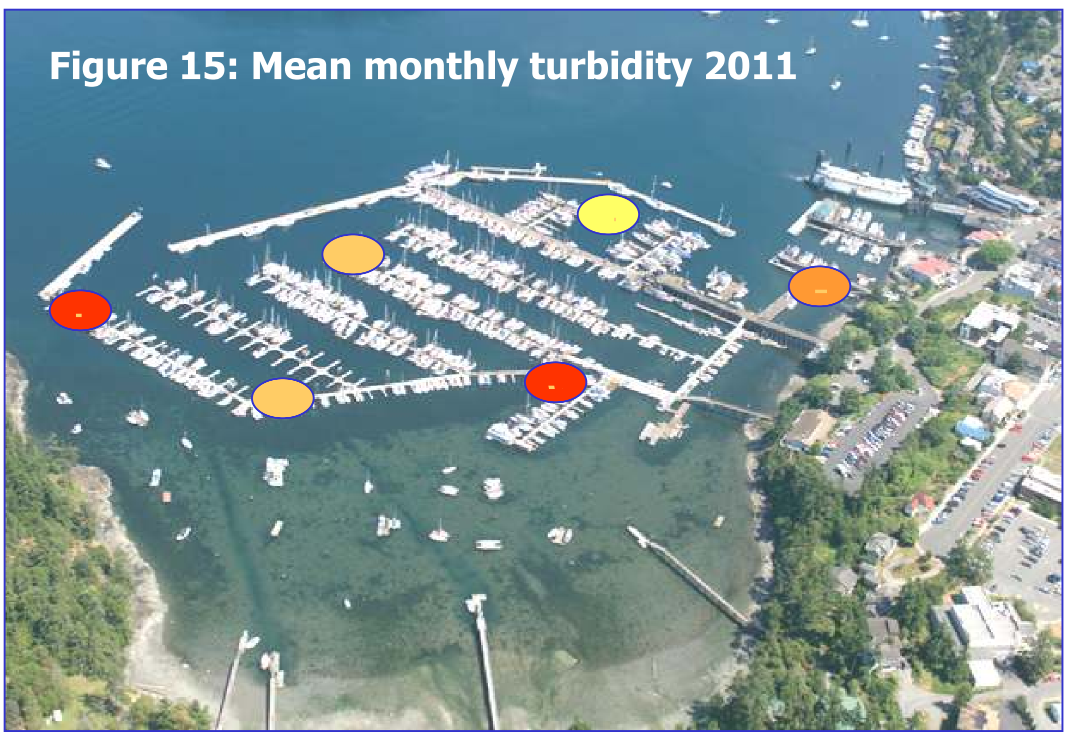


Figure 15: Mean monthly turbidity 2011

Figure 15 summarizes differences in average turbidity between our study sites in the Marina. Red indicates Secchi depths of 3-4 meters while yellow indicates 7-8 meters. Turbidity was greatest closest to silty shallows with poor circulation, rather than the ferry terminal. Turbidity was lowest at J and K docks, where there is greater depth and stronger circulation.

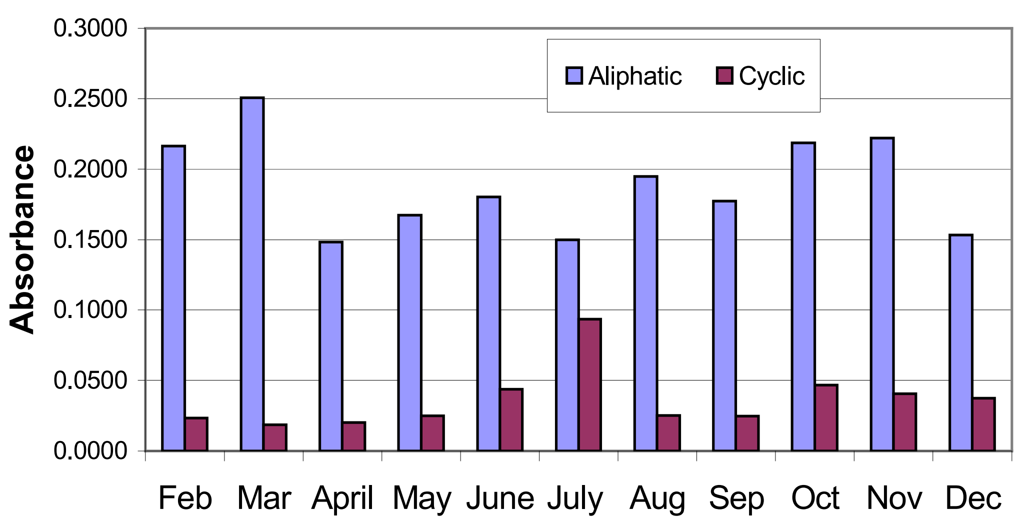
But compare Figure 15 (turbidity) with Figure 8 (distribution of sea anemones): it appears that anemones are most abundant at lower-turbidity study sites. This suggest that the turbidity most influencing Secchi depth is not biological, but silt, which anemones are unable to metabolize and, indeed, must expend energy to remove from their tentacles.

These observations recommend that we pay greater attention to turbidity in future years of monitoring, and make direct measurements of plankton biomass and silt loading.

Dissolved hydrocarbon Results

Dissolved hydrocarbons in surface water of the bay varied seasonally, with cyclic compounds peaking in July, and aliphatic compounds in March. Aliphatic hydrocarbons are composed of open chains or rings of carbon atoms and include sugars and starches, as well as many of the constituents of petroleum used for fuels, such as octane and paraffin. Since plants are largely constructed of aliphatic compounds (cellulose and lignin), natural soils and streams can be rich in these hydrocarbons. By comparison, cyclic hydrocarbons with conjugated double carbon bonds are enriched in petroleum and other fossil fuels and combustion products, but relatively rare in nature, where they often function as hormones and neurotransmitters. High ratios of cyclic to aromatic hydrocarbons imply petroleum product contamination, and tend to be associated with toxic threats to organisms.

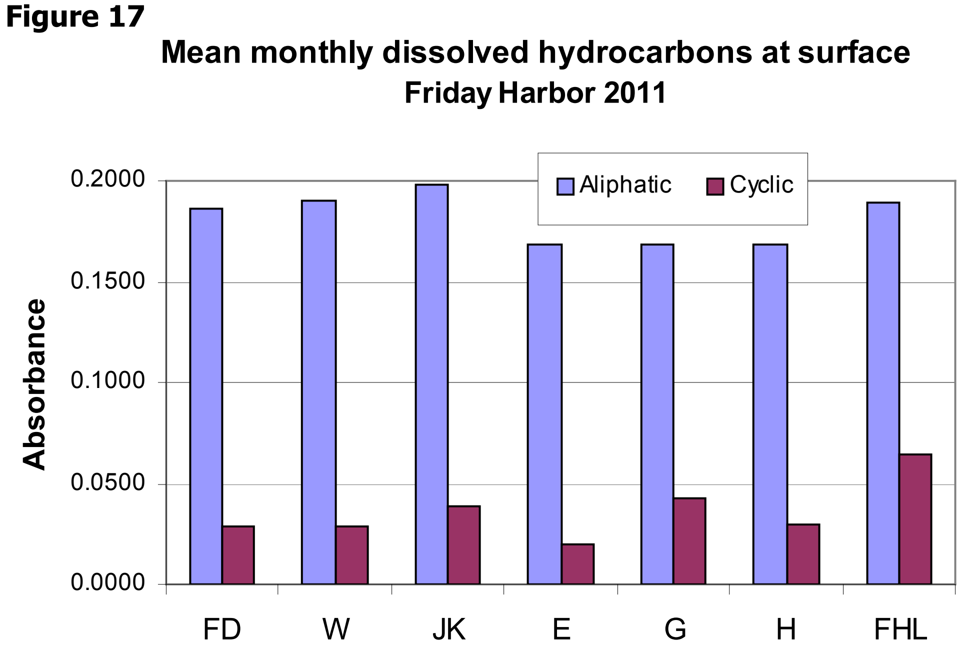
Figure 16 **Mean dissolved hydrocarbons at surface by month Friday Harbor 2011**



The seasonal pattern suggested in Figure 16 is reasonable insofar as hydrocarbons from natural sources are likely to be flushed to the bay by winter rains, whereas summer boaters and car tourists are probably the source of most of the cyclic hydrocarbons in the bay. Unfortunately, the variance in our measurements was considerable, and the apparent seasonal pattern is not statistically significant. A larger number of measurements in 2012 may provide us with more definitive results.

High variance within each month's measurements implies that hydrocarbon loads vary greatly from dock to dock within the Marina, obscuring any overall seasonal pattern. In fact, we found no statistically significant differences between docks over the course of the year (Figure 17), and again this was associated with high variance in measurements at each dock from month to month. The fact that there was so much variation from sample to sample regardless of location or time of year, suggests that (1) the sources of dissolved hydrocarbons are fleeting in time and space, as would be the case for spills from boats, or leaky motor vehicles on Spring Street; and that (2) the signals from these sporadic events disperse quickly, making them difficult to pin-point.

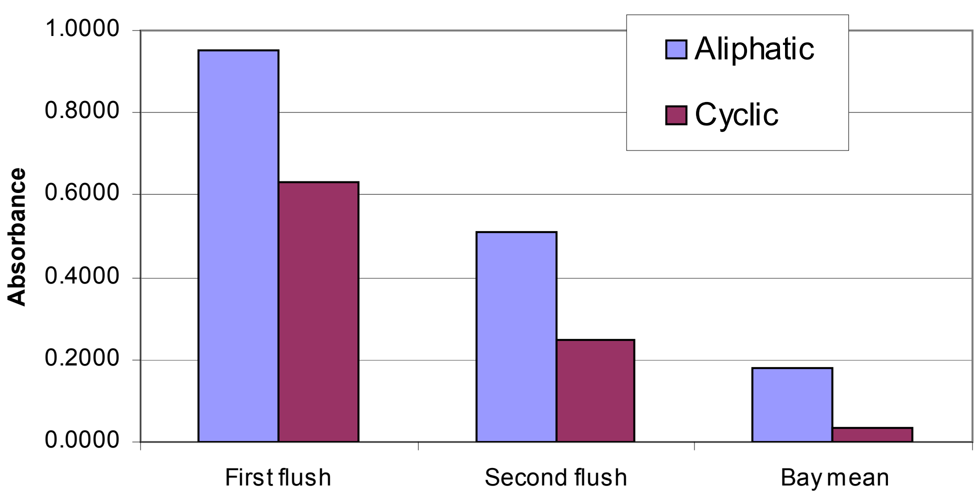
Figure 17



The Fuel Dock would be the obvious place to look for a strong consistent cyclic signal from boat spills (and it is nearest of our study sites to the Spring Street storm sewer outfall), but we did not observe it. On the contrary, the strongest cyclic signal, as well as the greatest month-to-month variation, was recorded at Friday Harbor Labs.

What can we say, then, about the role of street runoff in contaminating the bay? In October and November 2011, we measured dissolved hydrocarbons in the influent to the county "rain garden" at Herb's Corner. This represents the signal from one city block with 12 parking spaces. The “first flush” of fall rain was predictably more contaminated than the next major precipitation event (Figure 18). The mean contamination we observed in the bay water was considerably less than our samples of street runoff, no doubt due to strong tidal circulation and dilution, as well as adsorption to sediments on the bay bottom.

Figure 18 Dissolved hydrocarbons: street runoff and bay Friday Harbor 2011



How much is dilution, and how much goes to sediment? We also measured PAHs at Herb’s Corner, and (in 2010) sediments under the docks. Mean concentration of PAHs in the sediments was 35 times greater than levels in street runoff. Relatively hydrophilic species (more water soluble) may be effectively dispersed by bay circulation, whilst more lipophilic species such as PAHs are more likely to accumulate in bay sediments.

What’s ahead

Our data thus far suggest that potentially toxic dissolved hydrocarbons from storm sewer outfalls or boat spills are rapidly dispersed, resulting in comparable concentrations in waters throughout the port. Differences in the distribution of marine life between the docks may be influenced mainly by temperature, depth, and circulation. These factors, in turn, are affected to some extent by the configuration of the docks—which provide nearly all of the “structure” along the waterfront for invertebrate communities—and distribution of energy from prop wash and vessel movements. This is not to suggest that toxic inputs are unimportant, but rather that they may not account for the patterns we have observed at the Marina over the past two years.

A confounding factor is the chaotic nature of much invertebrate reproduction and dispersal—most notably, in our monitoring of island waterfronts thus far, the nudibranchs that have been widely used as key indicators of total marine biodiversity. In the next few years, we may be able to learn more about the frequency of nudibranch swarms, and what local conditions tend to produce them. Like the puzzle of predicting toxic phytoplankton blooms, studying nudibranch swarms may reveal a role for anthropogenic factors such as nutrient loading of nearshore waters, and removal of competitors. And what about ocean climate change--temperature, acidity, storminess?

Trends may only emerge clearly after many years of data collection; two years of data can only be suggestive.

Broadly speaking, 2010-2011 data suggest that crabs and starfish move to shallow water and aggregate on the Marina docks as soon as water temperatures are conducive to reproduction, which can be any time between April and August; while many nudibranchs prefer cooler conditions and are mainly found in the Marina from winter through spring. Exact timing of arrivals and departures will eventually provide us with an index of annual variations and long-term trends in ocean conditions, insofar as they affect marine life.

Trends in water temperatures are relatively easy to corroborate using underwater electronic loggers. Trends in ocean pH are more subtle and beyond the limit of detection of most electrochemical instruments. Kwiáht is committed to developing inexpensive biomechanical sensors for pH that can be left underwater to integrate data for years, and has proposed a "design challenge" to local high school chemistry students.

As discussed above, our 2011 suggest the utility of making direct measurements of plankton biomass and silt loading, as well as documenting algal blooms. We plan to:

- Measure turbidity of water samples with a nephelometer (light scattering).
- Filter solids from water samples, extract into 90% acetone-water and measure Absorbance in the extract at 630 and 664 nm for Chlorophylls *a* and *c*.
- Invite the Friday Harbor community to use Kwiáht's ITOX telephone hotline to report algal blooms so that FHMHO volunteers can collect and identify the organisms responsible within 24 hours.
- Explore the feasibility of collecting water samples more frequently.

Now that we have completed a baseline inventory of species, and settled on field methods and checklists that our volunteers have approved and mastered, our annual data reports will be rigorously comparable for quantitative purposes.

Continued recruitment and training of committed volunteers is fundamental to our ability to collect reliable data over the long term. At the same time, we hope to engage an audience that is capable of acting together to manage the bay wisely. Boaters, businesses and the Town must be more engaged in producing data and weighing the results.

Methods Appendix

Volunteers are organized in seven teams, and each team is assigned to designated parts of a different dock to visit monthly. Each team monitors an equal number of meters of dock, observing all animals within sight or reach from a prone position, with the aid of an Aquascope if there is glare or choppiness. All field observations are normalized to a standard number of observer-days. In 2010, data were shown as organisms per observer-day. In this report, data are shown as organisms per month (ordinarily seven observer days total per month) and 2010 data have been revised accordingly.

Dissolved hydrocarbons were measured in bulk by spectrophotometry. Aliphatic hydrocarbon bonds selectively absorb ultraviolet light in the 220-nanometer range, whilst cyclic hydrocarbon bonds selectively absorb ultraviolet light at 254 nanometers. Surface water was collected monthly at the Observatory's seven permanent monitoring stations in 125-mL Nalgene bottles and scanned the same day as collection in Friday Harbor Labs' Shimadzu spectrophotometer, using UV-transparent quartz cuvettes. Absorbance at each target wavelength was measured and recorded three times, and averaged.

Polycyclic Aromatic Hydrocarbons, a class of cyclic hydrocarbons, are measured by an ELISA magnetic particle format immunoassay (Strategic Diagnostics, Newark, NJ) that works by competitive binding of sample PAHs and PAH analogues enzyme-linked to a chromophore with a goat antibody to phenanthrene. Color is inversely proportional to the concentration of phenanthrene and other low-weight PAHs in the sample. Antibodies do not cross-react significantly with other chemical species, and can detect PAH levels as small as one part per billion (one nanogram/litre).

Apparent differences between docks or seasons were explored by calculating and comparing standard deviations of each suite of measurements and where mathematically appropriate, computing Student's T-test for difference between means.