MASSACHUSETTS DIVISION OF MARINE FISHERIES

Potential impacts to lobsters and lobster habitat from chlorinated sewage outfall effluent in Massachusetts Bay and Buzzards Bay: A review of existing information.

September 2010

In July 2010, the Marine Fisheries Advisory Commission (MFAC) received complaints from lobster fishermen that chlorinated sewage treatment plant effluent is having adverse effects on lobster abundances and hard bottom habitats utilized by lobster and other marine organisms in Massachusetts Bay and Buzzards Bay. In response, *MarineFisheries'* examined existing information relevant to these claims. Three specific claims are addressed in this report: 1) Are chlorine levels released in sewage effluent responsible for killing lobsters? 2) Can chlorine concentration levels around sewage outfalls be consistently high enough to be detectable on the surface by lobstermen during fishing? 3) Are chronic effluent discharges damaging hard bottom habitats near outfalls? The report starts with a background of the issue, then addresses the three questions specifically for Massachusetts Bay and Buzzards Bay.

In order to help address these questions, this report provides detailed information on current and historic National Pollution Discharge Elimination System (NPDES) reporting requirements for Massachusetts Water Resources Authority (MWRA) Deer Island Treatment Plant in Massachusetts Bay and New Bedford Wastewater Treatment Facility (NBWTF) in Buzzards Bay.

Background Information

Treatment Plants:

Buzzards Bay is a shallow, well-mixed estuary that is estimated to have a full turnover of its water volume every ten days (Howes and Goehringer 1996). Wastewater facilities in the Buzzards Bay watershed include Wareham, Dartmouth, Fairhaven, Marion, and Falmouth. All release effluent directly into Buzzards Bay with the exception of Falmouth, which releases into the groundwater. Currently the NBWTF is the only plant within the Buzzards Bay watershed that uses chlorine as its primary disinfectant instead of ultraviolet sterilization (UV) which eliminates the need for chlorination (Coalition for Buzzards Bay). The Coalition has submitted public comments in an effort to get the city to move towards eliminating the use of chlorine and using UV technology, but the EPA has determined that the current method of treatment has been successful and does not warrant a change (EPA response to public comments for NDPES permit MA0100781). NBWTF services the Greater New Bedford area and discharges into Buzzards Bay through an outfall located off Clark's Point in approximately 30-foot deep waters. NBWTF began operating in 1974 as a primary sewage treatment facility and was upgraded to provide secondary treatment in 1996.

MWRA services the Greater Boston region and discharges into Massachusetts Bay through a 9.5-mile outfall that terminates in approximately 100-foot deep waters. Effluent is discharged through more than 50 diffuser heads spanning the final 1.1 miles of the outfall, each with 8 small diffuser ports. The outfall has been in operation since 2000.

These facilities are required by NPDES permit, authorized under the Clean Water Act, to conduct secondary wastewater treatment, meaning that heavy solids and floating material are removed by settlement and skimming (primary treatment) and the remaining liquid is treated with microorganisms to remove dissolved and suspended biological matter (secondary treatment). After passing through primary and secondary treatment, wastewater is disinfected with hypochlorite (free chlorine) to kill bacteria in both plants. Finally,

sodium bisulfite is added to reduce the levels of chlorine discharged into the environment to concentrations that will not threaten marine organisms.

Chlorine toxicity:

Effluent toxicity monitoring provides an overall view of effluent quality, ensuring that the effluent does not adversely affect the environment. Significant improvements have been made in the reduction of contaminant levels, including chlorine, in sewage effluent released into the marine environment at both facilities over the past decade. NPDES permit standards for levels of chlorine in effluent were established using the best available scientific information. Currently, the EPA has established guidelines for regulating total chlorine residual discharges in effluent through NPDES permitting for the protection of aquatic life from the impacts

Conversion information	
1mg/L = 1000µ/L	1 milligram per liter is equal to 1000micrograms per liter
1mg/L ≈ 1ppm	1 milligram per liter is approximately equal to 1 part per million

of exposure to chlorine. These guidelines are based on supporting data demonstrating acute and sublethal effects from total chlorine residual levels of less than 100µ/L (micrograms per liter) (Szal 1991). In 1976, the effects of chlorine on lobsters was studied using the larval stage (stage 1 larvae) based on the assumption that this is the most vulnerable life stage. In laboratory experiments, lobsters show signs of respiratory stress at levels of 5000 µ/L of free chlorine and a LC50 of 16.3 mg/l (16,300 µ/L) of free chlorine (sodium hypochlorite) at 25 degrees Celsius (Capuzzo et al. 1976). An The LC50 (Lethal Concentration 50%) test is the concentration of effluent in a sample that causes mortality to 50% of the test population during the duration of the test. LC50 tests at 20 and 30 degrees Celsius found no significant mortality at 20 degrees and exposure at 30 degrees resulted in an LC50 of 2.5 mg/l (2500 µ/L).

Chlorine contaminant monitoring:

Effluent contaminant monitoring for chlorine toxicity is achieved using two different techniques: 1) daily monitoring of residual chlorine levels and 2) routine whole effluent toxicity (WET) testing using *Mysid* shrimp as the primary indicator for impacts to crustaceans. Mysid shrimp are more sensitive than lobster to chlorine and other measured toxins, thus this testing is considered protective of lobsters (Mitchell et al., 1998).

	NPDES Permit Information		
Chlorine Residual		**MWRA**	**NBWTF**
	Max daily limit	631 µ/L	117 µ/L
	Monthly Average	456 µ/L	67.5 µ/L
	Max measurement (last 3 years)	100 µ/L	60 µ/L
	Permit violations – last 3 years	0	0
Whole Effluent Toxicity (LC50)			
	Frequency	Monthly	quarterly
	Duration	48 hr	48 hr
	Dilution	50% (1:1)	none
	Permit violations – last 3 years	0	0
	Test organism	*Mysid* shrimp	*Mysid* shrimp

Total chlorine residual (TCR) monitoring measures all combined forms of chlorine that may be present after the effluent is dechlorinated before it is discharged. The constituents of total residual can vary depending on what else is in the water and the measurement technique (Goldman et al. 1979). All wastewater plants permitted under the EPA NPDES Program are required to use uniform EPA approved methods to measure total residual chlorine concentrations in effluent that discharges at the end of pipe. Wastewater treatment plants dechlorinate their effluent to eliminate the formation of chlorine compounds such as chloramine that can be toxic to lobster and other marine crustaceans. Chloramines and free chlorine were found to be harmful to American lobster stage 1 larvae depending on the concentration, temperature, exposure duration and form of chlorine (Capuzzo et.al., 1976).

WET testing is required by permit to occur monthly for MWRA and quarterly for NBWTF. All testing, monitoring, and event reporting results are required by permit and are available to the public via the EPA (for New Bedford) and MWRA web sites. A 48-hour acute static toxicity test using the *Mysid* shrimp (*Americamysis bahia*) measures the short-term lethal effects caused by the effluent. This test uses LC50 (Lethal Concentration 50%) a 24-hour composite of the whole effluent that shall cause no greater than 50% mortality in that sample during the duration of the test. Greater than 50% mortality is a reportable permit violation. Additionally both treatment plants are required to conduct tests (quarterly for NBWTF and monthly for MWRA) using whole effluent diluted to 12.5% with dilution water to determine the chronic-no observable effect concentration (C-NOEC).

1. Are chlorine levels released in sewage effluent responsible for killing lobsters?

Massachusetts Bay

No. This question was previously addressed by a panel of experts assembled during the planning of the MWRA outfall location in 1997 after members of the lobster fishery raised concerns about potential impacts to lobsters. The location of the outfall site was selected because water depth and current patterns promote effective dilution, ensuring that effluent will not reach beaches or shellfish beds within a tidal cycle, even if currents are shoreward. The Outfall Monitoring Science Advisory Panel (OMSAP), an independent panel of scientists established by EPA and MADEP to provide advice on scientific and technical matters related to the MWRA's Boston outfall and any potential impacts of the discharge on its receiving waters mandated two technical reports to review potential impacts to lobsters from the proposed Mass Bay outfall site. Both reports

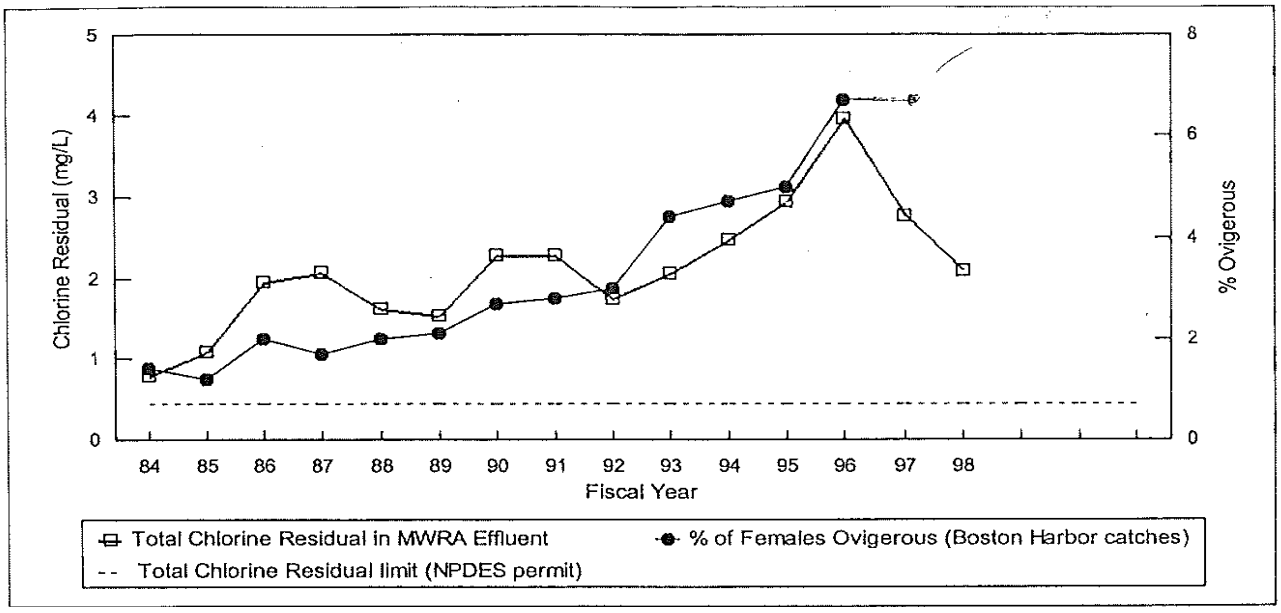

Figure 1: Comparison of annual chlorine residual in MWRA effluent discharged at Deer Island (MWRA NPDES reporting) with the percent of egg-bearing females from lobster caught in Boston Harbor as part of Massachusetts Division of Marine Fisheries lobster population monitoring (figure copied from Mitchell et al 1998).

specifically address impacts of chlorine.

The first report, Biology of the lobster in Massachusetts Bay (Mitchell et al., 1998), is a qualitative evaluation of potential risks from outfall discharge to lobsters. This evaluation included documentation by *MarineFisheries* of a 4-fold increase in the proportion of egg bearing females in the commercial catch in Boston Harbor between the mid-1980s and mid-1990's (Figure 1). During this period (prior to the more dilute discharge from the Mass Bay outfall coming online), annual chlorine residual levels discharged into Boston Harbor routinely exceeded 1000 ppb and were well over the NPDES total chlorine residual limit allowed in their previous permit. Relative to expected future chlorine discharge levels the report concluded, "No impact is expected from residual chlorine in the effluent because after the initial dilution, the concentration of chlorine will be below water quality standards and will likely not be present at detectable levels once discharged" (Mitchell et al. 1998). In addition, increased solids and BOD removal allowed a reduction in the amount of chlorine required for disinfecting effluent since 1996, leading to a substantial reduction in the mean chlorine residual. The report concludes that the NPDES permit conditions set conservative limits for toxics, including chlorine. The indicator species used for required toxicity testing (*Mysid* shrimp) is more sensitive than lobster to chlorine and other measured toxins so is adequately protective of lobsters. Additionally, the report concluded that exposure of larval and post larval stages (stages II and III) to effluent is unlikely since their occurrence coincides with late summer stratification (thermocline) trapping the effluent plume below the surface (Figure 3) and larvae aren't typically found in waters as deep as the outfall.

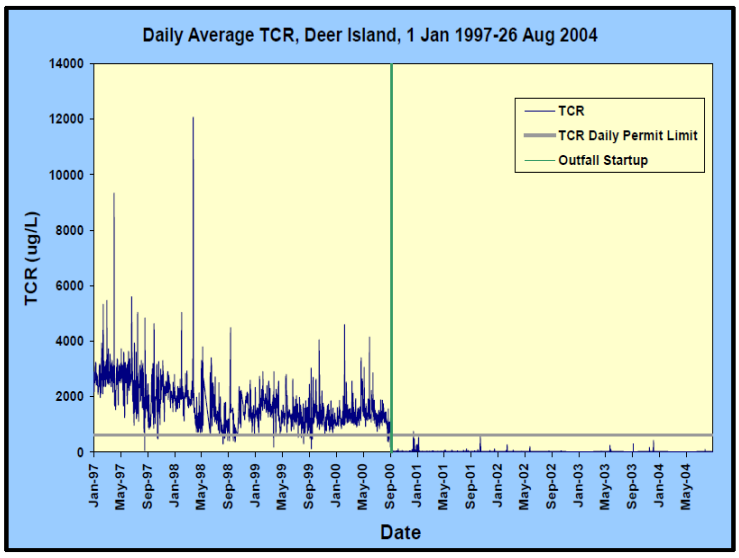

Figure 2. Daily average total chlorine residual (TCR) 1997 – 2004. Green line depicts transfer of effluent discharge from Boston Harbor to Mass Bay.(figure copied from Werme and Hunt 2004).

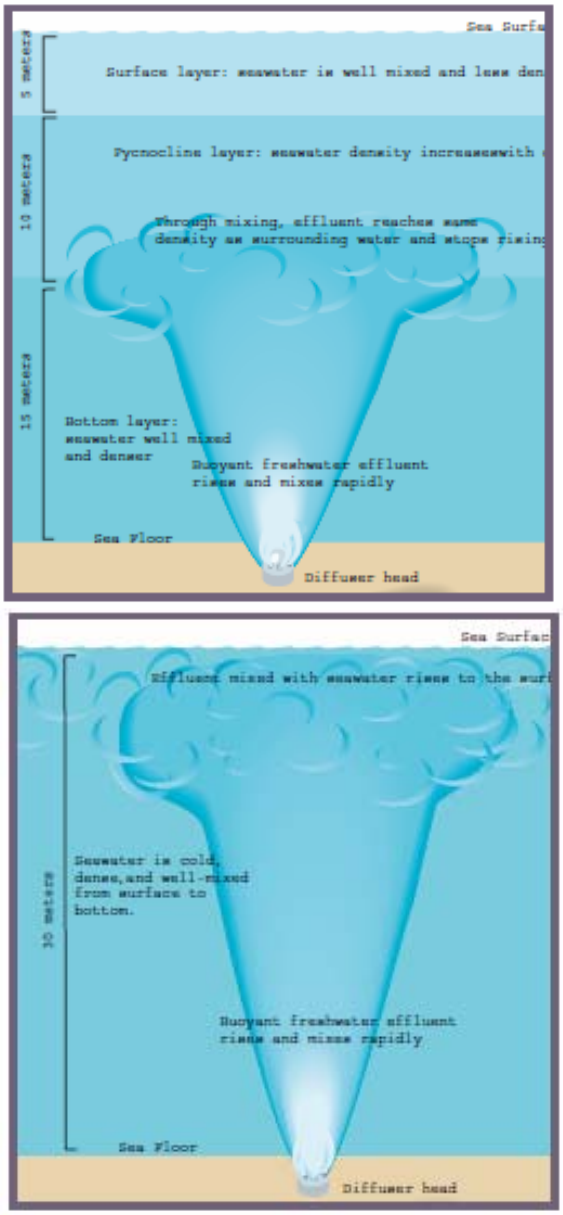

Figure 3. What ultimately happens to the effluent plume depends upon seasonal effects on the density of ocean water in Massachusetts Bay. Seawater density is controlled by temperature and salinity. Warmer temperatures and lower salinity make seawater lighter, while cooler temperatures and higher salinity make seawater heavier. In the winter, the waters of the Bay are about the same density top to bottom and are well mixed. When the seawater has a relatively uniform density top to bottom, the effluent plume will rise to the surface as it mixes. In the summer, the surface water is warmed and becomes increasingly lighter, setting up a layering effect. The level where the density change is most abrupt is called the pycnocline. Effluent becomes increasingly dense as it mixes with seawater, and will rise up only to the depth where it is no longer lighter than the surrounding water—at the pycnocline. Thus the effluent plume will be trapped below the pycnocline. At the outfall site, this is about 50 feet (15 meters) below the surface (figure copied from Mitchell et al 1998).

The second report, Abundance of juvenile lobsters at the new outfall site: comparison with inshore abundances and discussion of potential impacts on lobster populations (Lavalli and Kropp 1998) examined and compared the densities of YOY and shelter restricted juvenile lobsters at the proposed Mass Bay outfall site and two inshore sites previously identified by *MarineFisheries* as lobster settlement areas. Study results found densities of all lobsters were significantly different between the inshore and potential outfall study sites and comparisons between the proportion of non-zero quadrats inshore versus outfall sites revealed significant differences for all sizes. The report concludes:

> "…the behavior of post larval and early benthic phase lobsters, the thermal conditions present at the outfall, and the results of this study all demonstrate that the outfall vicinity is not a significant site for settlement and probably contributes significantly fewer individuals per unit area to future larger-juvenile, adolescent, and adult populations than do nearby inshore sites that have greater densities."

Copies of these technical reports are available for download on the MWRA website (http://www.mwra.state.ma.us/harbor/enquad/trlist.html).

MWRA NPDES permit limits for total chlorine residual (TCR) discharge is 456 µ/L (ppb) average monthly with a 631 µ/L (ppb) daily maximum limit. Chlorine residual levels have not met, or even approached current NPDES permit limit levels for the Mass Bay outfall in over 10 years (Figures 2 and 4). In addition, chlorine residual levels are measured at the point where the effluent leaves the treatment plant, therefore are conservative since levels continue to drop as the effluent travels the length of the 9.5-mile outfall and into Mass Bay.

The NPDES permit also requires monthly whole effluent toxicity (WET) testing. A reportable permit violation occurs if a sample of 50% effluent (1:1 dilution) causes greater than 50% mortality in the sample over the duration of the test. Over 120 acute static toxicity tests using *Mysid* shrimp have been conducted since the Mass Bay outfall came on line in 2000 with no permit violations.

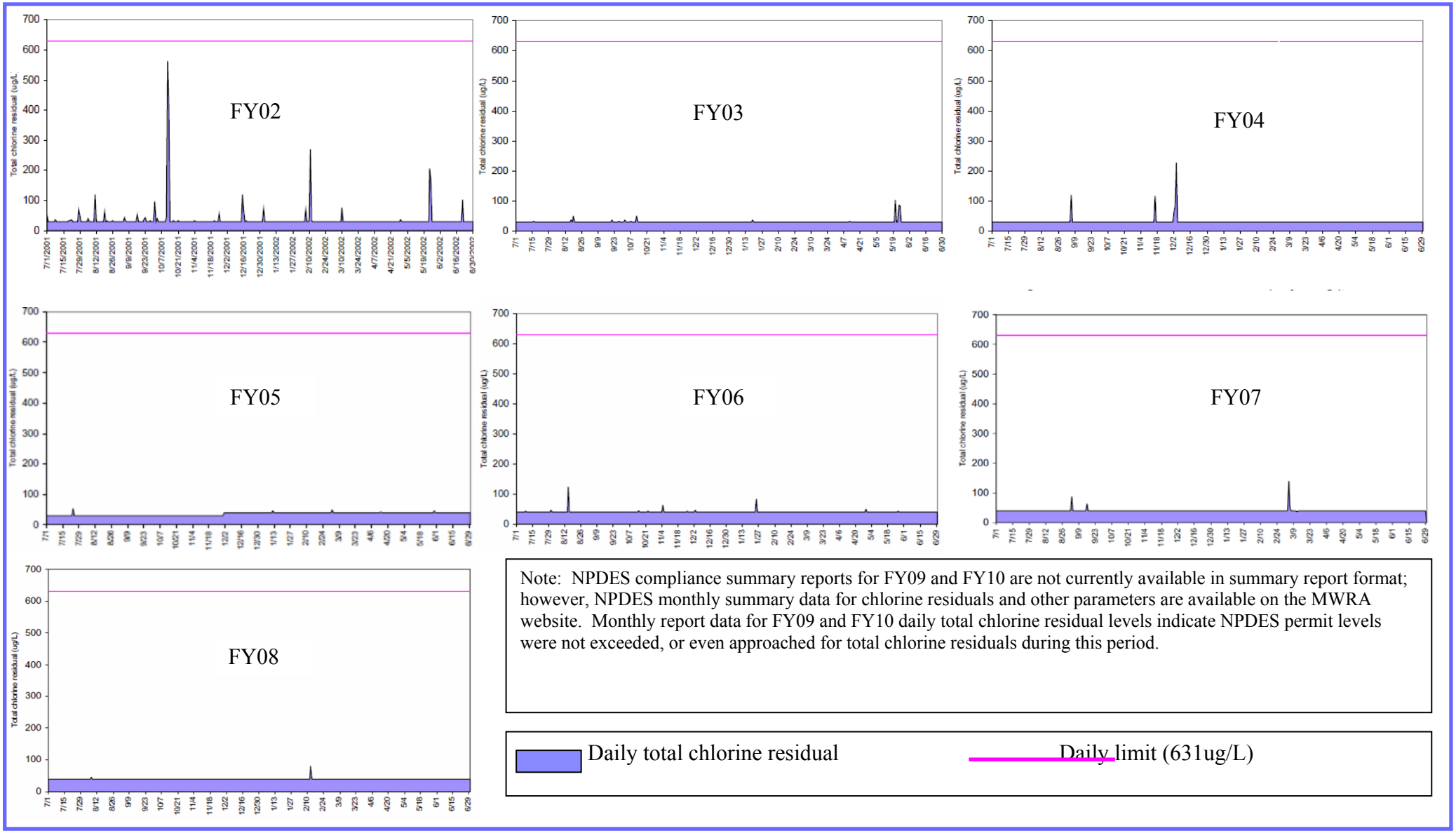

Figure 4: MWRA NPDES compliance summary report data for daily total chlorine residual, FY02 – FY10 (figures copied from MWRA NPDES compliance summary reports, fiscal year 2002 – 2008 and NPDES monthly summary data for FY09 – 10).

Buzzards Bay

No. NBWTF permit requirements for total chlorine residual (TCR) discharge is 67.5 µ/L (ppb) average monthly with a 117 µ/L (ppb) daily maximum limit. Since 2005, chlorine residual levels have not exceeded current NPDES permit limit levels for the Buzzards Bay outfall. (Figures 5 – 6). In addition, chlorine residual levels are measured at the point where the effluent leaves the treatment plant, therefore are conservative since levels continue to drop as the effluent travels the length of the outfall.

The New Bedford plant performs 3 acute toxicity tests during the months of March, June, September, and December: 1) a 7-day chronic and modified acute toxicity test using the inland silverside 2) a 1-hour fertilization test using the sea urchin, and 3) a 48-hour acute test using *Mysid* shrimp. As in Massachusetts Bay, these effluent toxicity tests provide a view of effluent quality, ensuring that the effluent does not adversely affect the environment. A reportable permit violation occurs if a sample of 100% effluent (no dilution) causes greater than 50% mortality in the sample over the duration of the test. Greater than 50% mortality is a reportable permit violation. There have been no reported LC50 violations for *Mysid* shrimp since 2005.

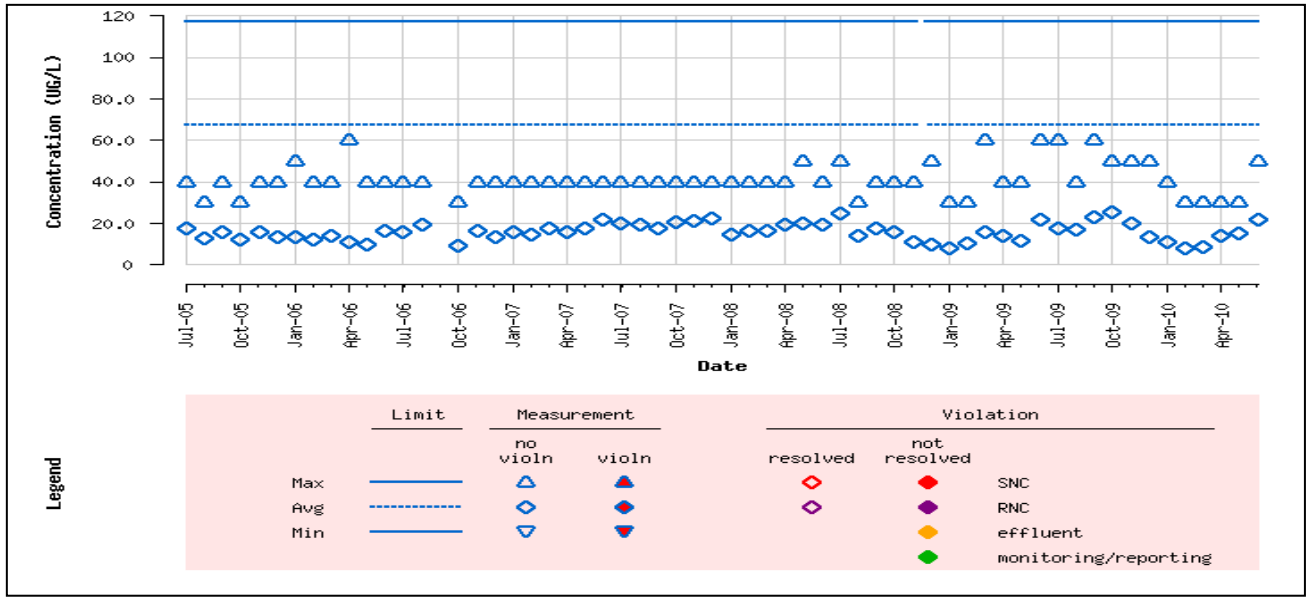

Figure 5: New Bedford Wastewater Treatment Facility, site 1, residual chlorine measurements from July 2005 to June 2010. There have been no violations during this time.

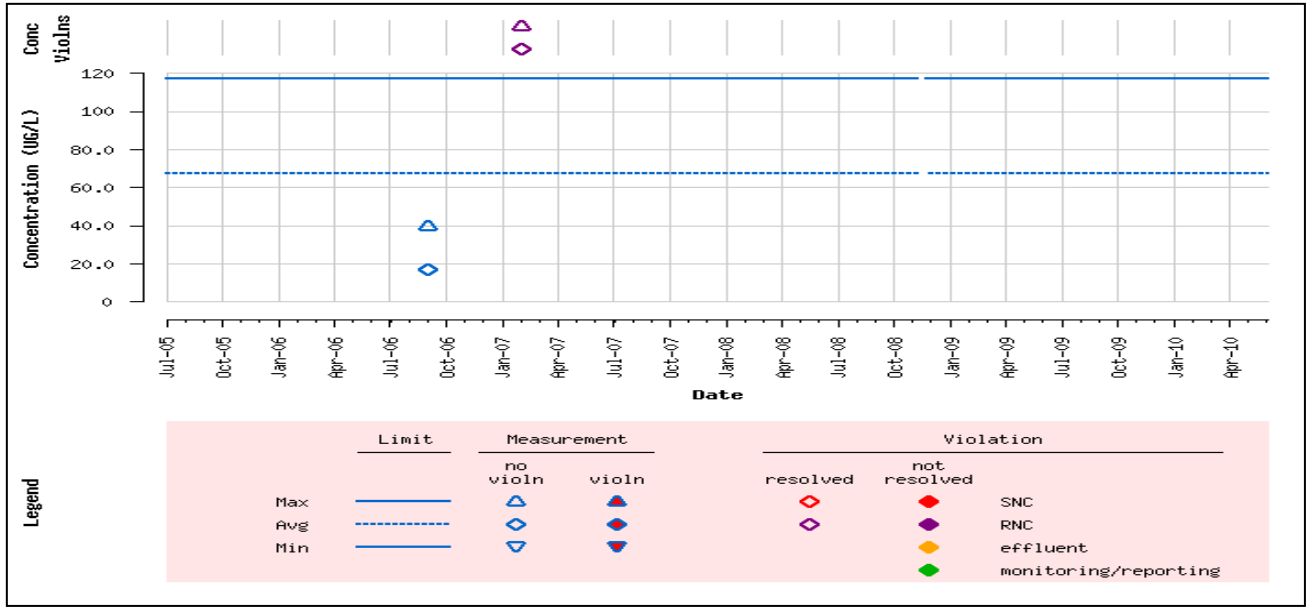

Figure 6: New Bedford Wastewater Treatment Facility, site 2, residual chlorine measurements from July 2005 to June 2010. There was a violation February of 2007, which was resolved.

2. Can chlorine concentration levels around sewage outfalls be consistently high enough to be detectable on the surface by lobstermen during fishing?

Massachusetts Bay

Not likely. The threshold for chlorine detection by humans is 310 ppb in water and 2 ppb in air (1 m^3). Chlorine concentrations above 500 ppb are irritating to the nose, throat, and eyes (EPA statistics from "Toxicology Profile for Chlorine" as reported by the Chlorine Institute 1999). MWRA measures total chlorine residual values in the effluent at the treatment plant on Deer Island to verify that dechlorination has occurred. These readings are reported as the average daily chlorine residual concentration levels from three effluent readings. Since FY02, average daily chlorine residual values are consistently below 100 ppb, with fewer than 10 cases of chlorine residual levels approaching or exceeding 200 ppb during this period (Figure 4). These limits are consistently below detectable thresholds for chlorine in water. Chlorine levels continue to drop as the effluent travels the length of the outfall pipe. Although the end of pipe concentrations are not measured these levels are expected to reduce further as the effluent becomes diluted (Mitchell et al 1998).

Buzzards Bay

Not likely. There is less monitoring available for the outfalls in Buzzards Bay, including the New Bedford outfall. Since permit requirements are similar to those for the Massachusetts Bay outfall, and dechlorination is conducted under permit requirements, it is a safe assumption that chlorinated compounds in concentrations high enough to be either bothersome or detected by humans is unlikely. If these concentrations occur at all, they are very rare.

3. Are chronic effluent discharges damaging habitats near outfalls?

Massachusetts Bay

Not likely. MWRA Outfall benthic monitoring reports are available online dating back to 1992. Data collected for these reports consist of still photograph and video analysis of 23 stations annually. The most recent available report summarizes the status of benthic monitoring data, including information over a nine-year baseline period (1992–2000) and an eight-year post-diversion period (2001–2008) (Maciolek et al. 2009). The report concludes hard bottom communities:

- have not changed substantially with activation of the outfall
- modest increases in sediment drape
- lush epifaunal growth continues to thrive on the diffuser heads
- greater abundance of *Cancer* crabs, cod (*Gadus morhua*), and lobster (*Homarus americanus*) after the outfall went online (Figure 6).

	Baseline					Post-diversion							
	1996*	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Video													
Minutes of video	438	487	439	422	444	448	495	469	454	466	419	440	443
Cancer spp. (rock crab)	6	3	4	15	92	123	168	144	115	67	81	108	12
Gadus morhua (cod)	-	6	12	22	11	41	53	10	52	64	59	40	64
Homarus americanus (lobster)	6	2	11	4	18	21	31	33	12	10	35	36	28
Still Photographs													
Number of photographs	534	622	635	551	635	583	672	661	675	664	666	661	661
Strongylocentrotus droebachiensis	444	339	282	299	157	180	249	90	113	82	145	116	55
Cancer spp. (rock crab)	4	1	4	6	14	44	63	47	16	22	56	49	12
Gadus morhua (cod)	-	-	2	3	-	9	12	-	3	17	5	19	16
Homarus americanus (lobster)	1	-	3	3	5	4	13	6	5	9	19	15	2

Figure 7. Number of individuals of selected species observed during the nearfield hard-bottom surveys, adjusted to include only stations that were surveyed in all 12 years (with the exception of two stations added after 1996). Baseline is data collected before the outfall went online; post-diversion refers to after the outfall went online (figure copied from Maciolek et al. 2009).

Buzzards Bay

Undetermined. There may be available information addressing this concern in Buzzards Bay, but we have not located it yet.

The term "moonscape" has been used to describe seafloor impact in the vicinity of the Massachusetts Bay outfall. One lobsterman reported the area as "looks like an oil spill, and it has been happening for years" (Rose pers comm 2010). Our interpretation of the term is as follows: the seafloor has dramatically less infauna and epifauna relative to the time period before the outfall was built. The term moonscape also suggests a certain amount of cratering but we assume the term is being used loosely to describe a lifeless seafloor instead of cratering. There is no available information to measure the degree of cratering on the seafloor. In general usage, it seems apparent that a reduction in seafloor life is intended in this instance, as opposed to a change in topography.

Summary

Potential impacts from sewage effluent on lobster populations and habitats have been an ongoing concern dating back at least to the early 1990's in Massachusetts. Impacts to lobster populations resulting from the relocation of the MWRA outfall from Boston Harbor to Massachusetts Bay was addressed in 1997. These findings concluded it was highly unlikely chlorine discharging from the new outfall would have any impact on lobster. The Outfall Monitoring Science Advisory Panel (OMSAP) concurred with these findings. NPDES permit and monitoring requirements have become more stringent over time in response to these concerns. Residual chlorine concentrations have decreased because of increased solids removal. Publically available NPDES compliance report summaries clearly indicate substantially lower residual chlorine levels entering the marine environment over the past decade. Both plants are operating well within their permit limits. Effluent toxicity monitoring results indicate no short-term lethal effects on lobsters in the immediate environment surrounding the outfalls. There is no evidence that chlorine levels in effluent are impacting lobster populations. Isolated instances where chlorine levels around the outfalls occur at levels detectable by humans under the appropriate circumstances, and in turn may adversely affect lobsters in the immediate area surrounding the outfall cannot be ruled out. However, these instances would be discrete in time and limited in spatial scale and would have an extremely low probability of having any serious or long-term impact on American lobster populations, or to populations of other commercially important marine finfish or invertebrates. Corroboration of such an occurrence would require specific spatial and temporal information to assess further.

Additional work is required in order to determine if the seafloor around the outfalls could be considered "moonscapes" compared to similar seafloor environments.

	MWRA	**NBWTF**
Are chlorine levels released in sewage effluent responsible for killing lobsters?	**no**	**no**
Can chlorine concentration levels around sewage outfalls be consistently high enough to be detectable on the surface by lobstermen during fishing ?	**not likely**	**not likely**
Are chronic effluent discharges damaging habitats near outfalls?	**not likely**	**undetermined**

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