PESTICIDE LOADING AND SEDIMENT ACCUMULATION IN BAFFIN BAY: ADDRESSING AN IMPORTANT STAKEHOLDER CONCERN REGARDING THE BAY'S HEALTH

by

Jeremy L. Conkle, Zahra Hormoz-Estrabad

Department of Physical & Environmental Sciences
Texas A&M University-Corpus Christi
6300 Ocean Drive
Corpus Christi, TX 78412

Prepared for
Coastal Coordination Council
GLO Contract No. 16-062-000-9106

Texas General Land Office
Austin, TX 78711
29 November 2018

A report funded by a Texas Coastal Management Program grant approved by the Texas Land Commissioner pursuant to National Oceanic and Atmospheric Administration Award No. NA15NOS4190162

Executive Summary

Baffin Bay is a stressed estuary on the Texas Coast that sits at the border between Kleberg and Kenedy Counties and it flows into the Upper Laguna Madre (ULM). The Bay's watershed has a relatively low population density, but there is intensive crop agriculture as well as some livestock. The geographic location of this bay and ULM with their low freshwater inflows make this system a tide and wave-dominated estuary. This means that there are only limited discharges for water to leave the system due to barrier islands. Therefore, during the hot summer months or droughts water in the system will evaporate resulting in fluctuations in salinity that may stress the system. When this stress is coupled with anthropogenic contaminants such as nutrients and pesticides, they may further strain the ecosystem and organismal health. Studies are ongoing to examine the influence of nutrient pollution, but pesticides, particularly current use pesticides have not been measured in Baffin Bay surface waters since 1996-1998. To examine the pesticide concentrations were measured from 2016-2017 at 9 sites in the bay system. Pesticides were present in Baffin Bay water throughout the sampling period, although their concentrations varied. At least 2 pesticides were detected in each sample, with 96% of samples containing between 4-8 pesticides. Concentrations for each compound during the monitoring period vary from non-detect up to 1,080 µg L^{-1}. The three most common pesticides were atrazine, malathion and chlorpyrifos. Their concentrations were the highest closer to sites 1 and 2, which are higher in the watershed and closer to areas of intensive agriculture. The concentrations observed during this study were higher than those previously reported by the USGS from 1996-1998. Based on the effect concentration values found in previously published literature, it is possible that negative impacts could result from these concentrations. However, the work completed here did not address these potential impacts; therefore, future investigations should examine the impact of pesticides found in Baffin Bay directly on relevant species found in this stressed system.

Table of Contents

List of Tables

List of Figures

List of Appendices

Acknowledgments

We would like to thank Dr. Mike Wetz and his lab as well as the citizen scientist volunteers who helped collect water samples. Thank you to Dr. Jennifer Pollack and her lab for their help collecting sediment samples. We would also like to acknowledge the numbers undergraduate researchers that aided in this work over the course of the project: Claire Berger, Elise Rother, Kevin Nguyen, Rebecca Wagner, Josiah Wray, and Kelli Holt. Several masters students also helped with this work: Elijah (Eli) Waddell and Kelly Correia.

Introduction

Texas's Coastal Bend bays are treasured ecosystems, vital to wildlife and the regional economy. Unfortunately, water quality in the upper Laguna Madre (ULM), particularly Baffin Bay, has declined in recent years[1] resulting in algal blooms[2], dead zones[3] and fish kills.[3] Several drivers of these ecosystem problems are under study by Drs. Mike Wetz (water quality monitoring) and Jennifer Pollack (surveys of benthic organisms) at Texas A&M Corpus Christi. However, local stakeholders are increasingly concerned about an important yet unaddressed parameter in these efforts: agricultural pesticide loading and accumulation in Baffin Bay sediments, where the main food source for black drum (Pogonias cromis), the dwarf surf clam (Mulinia lateralis), lives.

The ULM black drum fishery has struggled in recent years. Historically, the ULM accounted for 64% of all annual black drum landings in Texas, but these numbers dropped to 44% in 2012.[4] This decline is tied to black drum catches in Baffin Bay, which once supplied 63 to 75% of black drum landings in the ULM, but dropped to 55 and 46% in 2011 and 2012.[4] Black drum production by body weight also dropped 33% in the bay, and the fish caught looked emaciated and produced "jelly-like fillets," forcing fishermen to discard ~40% of their catch.[4] Additionally, Texas Parks and Wildlife found that 15% of fish were underweight and linked these issues to declines in their main food source, the dwarf surf clam.[4, 5]

The dwarf surf clam is found at salinities ranging from 5 to 80 ppt, allowing it to thrive in the highly variable salinities of Baffin Bay (mean 36.5).[5] However, salinities sometimes reach 60 ppt in Baffin Bay, reaching the higher end of the dwarf surf clams tolerance.[4] A second and potentially compounding stressor facing the dwarf surf clam in Baffin Bay is the accumulation of pesticides in its sedimentary habitat.

Concentrations of pesticides in Baffin Bay sediments were last analyzed in the early 2000s,[6] but only for legacy compounds banned several decades ago. Unknown are the sediment concentrations of current-use compounds, which can be toxic to benthic organisms.[7, 8] The lone survey of "modern" pesticides (USGS 1996-1998) only examined aqueous concentrations. In that survey, 21 compounds were detected in runoff from a small area of the watershed, with loadings >300 lbs for atrazine and diuron in 1997.[9] These two compounds are soluble, but many pesticides are hydrophobic and rapidly partition to sediment, evading detection in water. Thus, previously measured aqueous samples likely underestimated pesticide loading, particularly to bay sediment. Hence, Baffin Bay dwarf surf clams are routinely exposed to unknown pesticides at potentially toxic levels. Pesticide exposure, coupled with stress caused by poor water quality, may have adverse synergistic effects on dwarf surf clam survival. A recent study found that poor water quality increased pesticide toxicity resulting in higher mortality for larval clams.[10] The combination of pesticides, salinity stress, and excess nutrients may decrease dwarf surf clam survival as well as that of higher trophic level organisms that depend on them as a staple food source.

This goal of this research was to quantify pesticide loading and accumulation in Baffin Bay and assess their impacts on the dwarf surf clam and subsequently the economically important black drum. This project fell short of reaching its full goal due to analytical instrumentation complications. However, data for pesticide concentrations in Baffin Bay were determined and are presented below.

Methods

Experimental Design

Water samples in Baffin Bay were collected from 9 sites in Baffin Bay (Figure 1, additional information in Appendix 1), Texas from February 2016 to December 2017 (Appendix 1), although not all sites could be sampled each trip due to time constraints and weather. Grab samples were collected by boat in solvent-rinse 1 L amber bottles, just below the water surface at each site, placed on ice and returned to the lab.

In the lab, samples not processed within 48 hrs were frozen until extraction. With the exception of the first sampling in February 2016, triplicates were taken every collection at site 5.

Sample Extraction

Water samples were extracted using a modified version of USEPA SW-846 method 3510C.[11] Briefly, each 500 mL was added to a 1 L separatory funnel. Next, sample pH was adjusted to <2 using sulfuric acid (1:1; V/V) and 60 mL of methylene chloride was added to the separatory funnel. The funnel was shaken for vigorously for 2 minutes, with pressure inside the funnel being relieved as necessary. The solution was then allowed to settle for at least 10 minutes so that the liquid and organic phase could separate. The organic layer was then decanted through sodium sulfate to dry the samples and collected in a 500 mL round bottom flask. The methylene chloride extraction step was repeated twice, producing an extract volume of 180 mL. Next, the remaining aqueous phase of the sample was adjusted to pH >10 using sodium hydroxide. The methylene chloride extraction and drying with sodium sulfate was then repeated 3x, resulting in a total extraction volume of 360 mL.

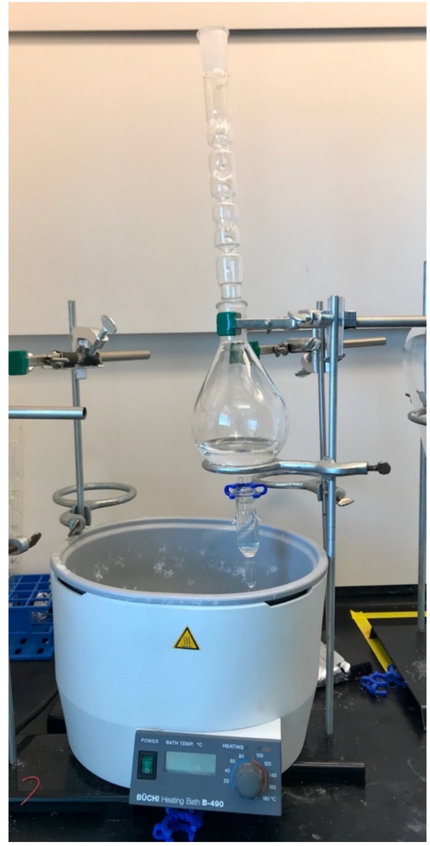


Figure 2. Kudema-Danish Concentrator

The sample extract volume was reduced to ~3 mL using a Kudema-Danish (K-D) concentrator (Figure 2). This final volume was then treated with 1 g of activated copper to remove sulfate, which could interfere with analysis using GC-MS. The extracts were then transferred to a 15 mL concentrator tube and reduced to <0.5 mL under a gentle stream of N_2 gas in a water bath at 40 ˚C using a 12

Figure 1. Water sampling sites in Baffin Bay

port N-Evap system. The final extracts were then transferred to a GC vial and reconstituted to 1 mL. The extraction method recovery for bay water was between 92 and 123% for all compounds except dimethoate. Due to this, all values observed for dimethoate are considered an estimate and any caution should be used interpreting the implications of these values.

Sample Analysis

Samples were analyzed using a Shimadzu GC-2010 Plus paired with a GCMS-QP2020 mass spectrometer. Samples of 1 µL were injected in splitless mode at 250 ˚C. A Shimadzu SH-Rxi-5Sil MS column (30 m × 0.25 mm × 0.25 µm diameter) and helium (99.999%) were used for separation. The column temperature was as follows: 70 ˚C for 2.0 min, ramped to 150 ˚C at 25 ˚C min^{-1}, then raised to 200 ˚C at 3 ˚C min^{-1}, before ramping to 250 ˚C at 8 ˚C min^{-1} and then held for 8.0 min. This resulted in a total run time of 39.87 min. The instrument was run using electron ionization (EI) with selected ion monitoring (SIM) for the target analytes (Table 1). The ion source and interface temperatures were both 250 ˚C. The analyte profile, including retention time, parent ion and confirmation ions, of each target pesticide were determined individually by injecting each compound under the conditions described above. The method was then optimized for simultaneous analysis of the target analytes in Table 1. Compound analysis and quantification were achieved by running a 5-point standard curve (0.08, 0.2, 0.4, 1 and 5 mg L^{-1}). The analytical method detection limit was 0.001 mg L^{-1}.

Table 1. Target pesticide background information and analytical parameters.

Compounds	Type	Class	Retention time (min)	Quantitation Ion(m/z)	Second confirmation Ion (m/z)	Third confirmation Ion(m/z)
Trifluralin	Herbicide	Dinitroaniline	13.740	306	264	248
Dimethoate	Insecticide	Organophosphate	14.997	125	87	93
Simazine	Herbicide	Triazine	15.290	201	186	173
Atrazine	Herbicide	Triazine	15.544	200	173-215	138-58
Chlorpyrifos	Insecticide	Organophosphate	22.150	197	199	314-97
Metolachlor	Herbicide	Chloroacetanilide	21.842	162	238	240
Malathion	Insecticide	Organophosphate	21.657	173	127	125
Bifenthrin	Insecticide	Pyrethroid	30.584	181	166	165-182

Results & Discussion

Delayed Analysis

Method development and analysis using the two GC-MS systems housed at TAMUCC was attempted from 2015-2017. However, we were unable to produce consistently reliable results and the instruments, which are 10-15 yrs old, did not have sufficient sensitivity to detect the target analytes. In 2017 we begin looking for outside instrumentation to run our samples, but the system at Del Mar College was not functioning properly (with no time frame for its repair) and the GC-MS at Texas A&M University-Kingsville was being run at capacity. After Hurricane Harvey, we learned that UTMSI had a GC-MS system that was available and affordable since no funds had been allocated for sample analysis, but we had to wait until it came back online following their recovery. This further delayed our sample analysis and the ability to develop sediment and dwarf surf clam tissue extraction methods. However, it did establish a new collaboration between our lab and Dr. Zhanfei Liu at UTMSI, which has led to further discussions about research potential on the Texas coast. With regards to the instrumentation at TAMUCC, inadequate GC-MS instrumentation will no longer be an issue after spring 2019. Due to the lack of a functioning GC system on our campus, we were awarded an NSF Major Research Instrumentation grant that will support the acquisition of a new GC-MS/MS for our campus.

Precipitation

Daily precipitation data was captured from the NOAA National Centers for Environmental Information for site USC00418081 near Sarita, TX. This data, shown in Figure 3. Precipitation during the study period. Data obtained from NOAA National Centers for Environmental Information. There are 14 rain events near or above 25 mm (~1 in) of rain during the study period. These events cluster in the spring (March-June) and Fall (September-November).

Water

Water samples were collected over a 23-month period from February 2016 to December 2017, with the bulk of sample collection occurring between May 2016 and May 2017 (Appendix 2). A total of 104 water samples were collected (not including triplicates taken at site 5). At least 2 pesticides were detected in each sample, with 96% of samples containing between 4-8 pesticides. Concentrations for each compound during the monitoring period vary from non-detect up to 1,080 µg L^{-1} (malathion; Table 2). Therefore, the target pesticides are consistently found in the water of Baffin Bay throughout the year. However, there are also some trends noticeable for certain compounds.

The three most prevalent compounds (atrazine, malathion, and chlorpyrifos) generally have higher concentrations at sites 1 and 2, which decrease as you move east to sites 3, 4 and 6 (Figure 4). This is logical as sites 1 and 2 are closest to agricultural areas, which are sources of these pesticides. Site 5, which is also higher up in the watershed, has generally lower values than sites 1 and 2. This may be due to less agricultural acreage on nearby lands.

Atrazine is the only compound detected in every sample, with concentrations ranging from 1-385 µg L^{-1} and an average value of 71 ± 81 µg L^{-1}. In the spring of 2016 (March-June), its concentrations were

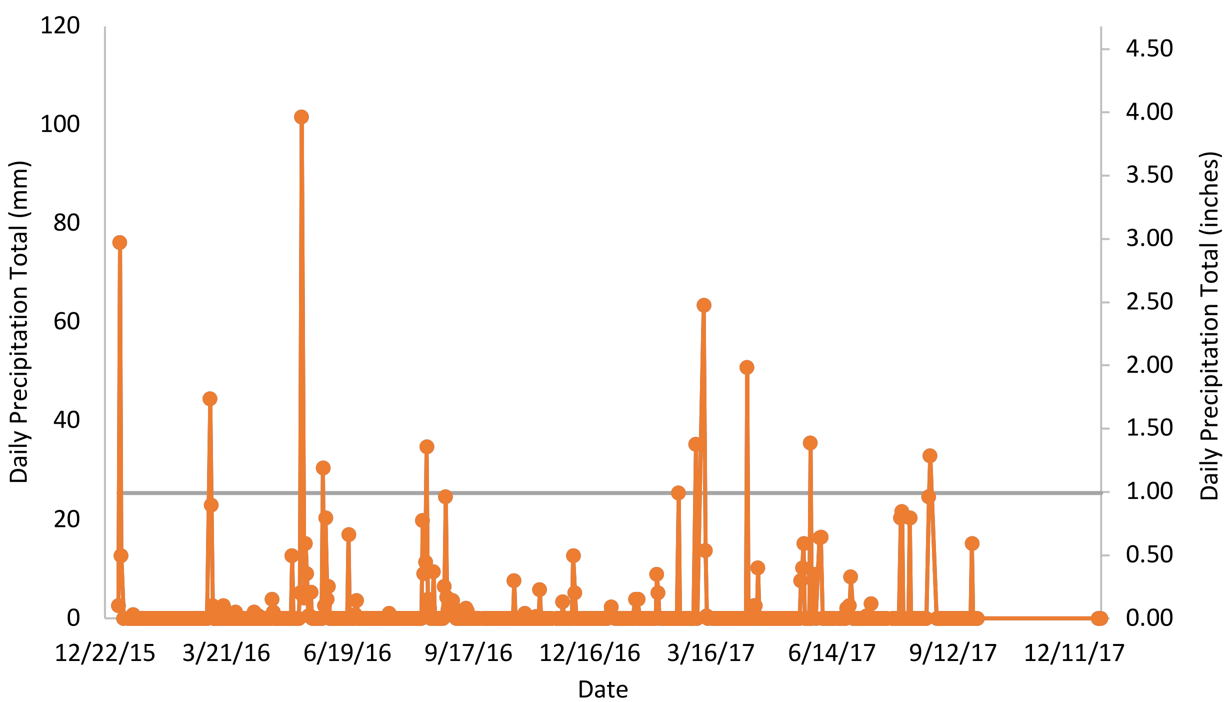


Figure 3. Precipitation during the study period. Data obtained from NOAA National Centers for Environmental Information.

consistently above 100 µg L^{-1}, with 6 of the 12 samples during this period exceeding 200 µg L^{-1}. Generally, the concentrations during the March, May and June 2016 are the greatest at sites 1 and 2 with decreasing values as you move closer to site 8 (Figure 5). Atrazine concentrations, while still elevated during July and August, trend down into the fall and winter 2016 (Figure 5). This spring pulse is not observed in data for April and May of 2017 (Figure 5), despite more rain events with higher precipitation amounts during that period (Figure 3). Atrazine was also detected in Baffin Bay by the USGS in samples collected from 1996-1998.[9] However, their concentrations (0.03 – 47 µg L^{-1}) were much lower than those quantified in 2016-2017 (Table 2).

Table 2. Range and concentrations of target pesticides in water as well as concentrations from a previous USGS study in Baffin Bay.

	Range	**Average ± Standard Deviation**	**USGS (1996-98)**
		Water Concentrations (µg L^{-1})	
Trifluralin	<1 - 114	7 ± 21	<0.02 - 0.21
Dimethoate	<1 - 98	31 ± 21	
Simazine	<1 - 108	3 ± 12	<0.005 - 0.24
Atrazine	1 - 385	71 ± 81	0.03 - 47
Malathion	<1 - 1080	127 ± 159	<0.005 - 0.035
Metolachlor	<1 - 61	3 ± 8	
Chlorpyrifos	<1 - 357	55 ± 67	
Bifenthrin	<1 - 119	5 ± 17	

The USGS study also targeted several of the analytes examined with this study, but only malathion, trifluralin, and simazine were detected. The concentrations in 2016-2017 were orders of magnitude higher than those observed by the USGS in the late 1990s (Table 2). For example, malathion was found at concentrations up to 0.035 µg L^{-1}, while in this study values, when detected, typically ranged from 50-250 µg L^{-1}. Water concentrations for pesticides at each site can be found in Appendix 3. Additional data analysis is planned for the future.

Potential Impacts

This study did not specifically address the potential negative effects of the pesticides observed. However, the presence of pesticides in an aquatic system could lead could affect organismal health. It is important to understand that those impacts would vary by species, pesticide exposure (route, amount and duration) and environmental conditions (temperature, salinity, pH, etc.). It is clear that Baffin Bay has experienced poor water quality in recent years due to nutrient inputs as well as increasing salinity caused by reduced freshwater inflows and droughts.[1] Therefore, in a system already stressed by poor water quality, organisms may be more susceptible to pesticides than under normal conditions.[12-14] For example in a study where juvenile rainbow trout were transitioned from freshwater to a salinity of 16 ppt and exposed to chlorpyrifos at 0.5 or 5 µg L^{-1}, fish had reduced response to predator cues, making them more susceptible to predation.[15]

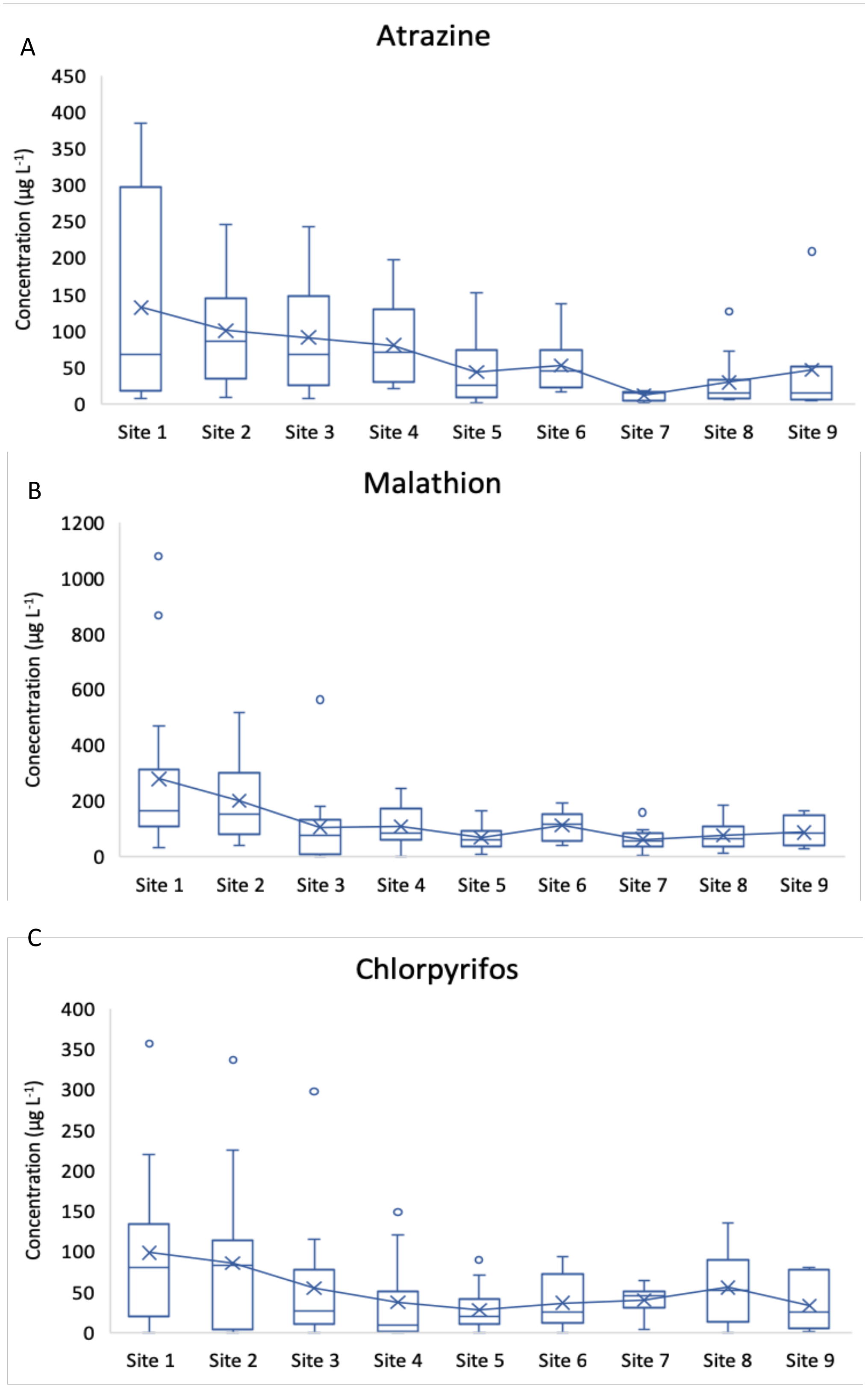


Figure 4. (A) Atrazine, (B) malathion and (C) chlorpyrifos concentrations for all sampling dates at each site. The "X" represents the average value, the top and bottom of the box represent the 75^{th} and 25^{th} percentile, the line across the box is the median value, the top bar is the local maximum, bottom bar the minimum and any points shown outside of the box and whisker represent outlier values.

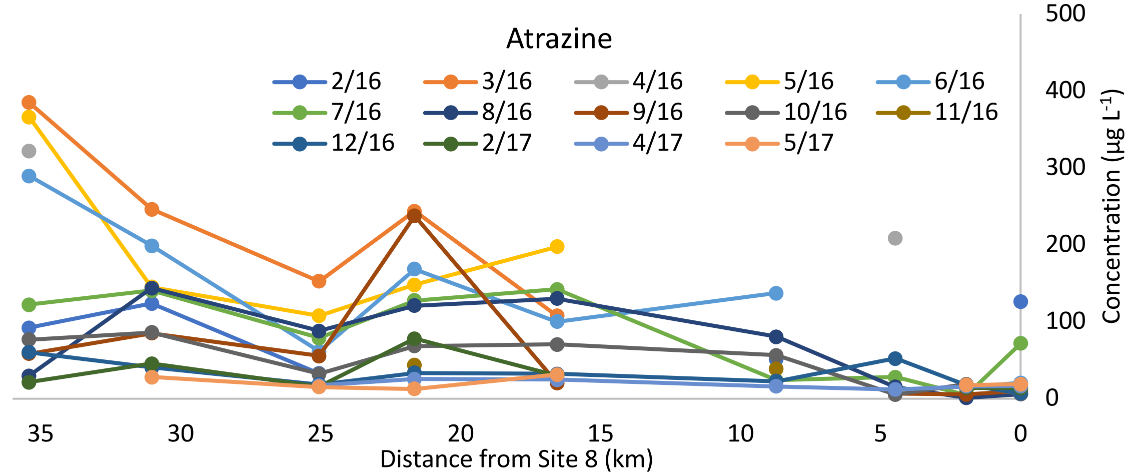


Figure 5. Atrazine concentrations with distance from site 8 for each sampling event.

With atrazine, lethal doses in estuarine and freshwater fish are >1,000 µg L^{-1}, which is well above concentrations observed in this work. However, there are sublethal effects observed in fish (fathead minnows; a freshwater fish), where egg production was significantly reduced at 0.5, 5 and 50 µg L^{-1} which are within the range of values found in this study.

Part of this study's original goal was to assess the presence of pesticides in Baffin Bay to see if there is the potential for them to impact for fish health, specifically the black drum. The data generated on pesticide concentration find some at levels that have been shown to affect various fish. Therefore, it is possible, but further work is necessary to determine if previously observed effects would be observed for species in Baffin Bay.

Outreach

The education and outreach component of this project was slowed due to the lack of data. However, discussions of the ongoing water quality problems and their potential impacts in Baffin Bay were discussed in Dr. Conkle's Wetlands & Water Quality course at TAMUCC in the Spring of 2017 (5 undergraduate and 10 master's students) and 2018 (9 undergraduate and 5 masters students). Slides from these presentations can be found in Appendix 4. Now that data is available, it will be incorporated into local presentations when possible, potentially at a Coastal Issues Forum.

Conclusions

Baffin Bay is a stressed estuary with inputs from runoff as well fluctuating salinities due to high temperatures in the region and varying freshwater flows into the system. This variable environment can be stressful to aquatic organisms. When pesticides are also factored into the system, it can result in additional stress. Pesticides were present in Baffin Bay water throughout the sampling period. Their concentrations varied and spatial trends were observed where concentrations of the three most prevalent pesticides, atrazine, malathion, and chlorpyrifos, were the highest closer to sites 1 and 2. These sites are closer to intensive agriculture in the area. The concentrations observed during this study were higher than those previously reported by the USGS from 1996-1998. Based on effect concentration values found in previously published literature, it is possible that negative impacts could result from these concentrations. However, the work completed here did not address these potential impacts; therefore, future investigations should examine the impact of pesticides found in Baffin Bay directly on relevant species found in this stressed system.

Literature Cited

1. Wetz, M. S.; Cira, E. K.; Sterba-Boatwright, B.; Montagna, P. A.; Palmer, T. A.; Hayes, K. C., Exceptionally high organic nitrogen concentrations in a semi-arid South Texas estuary susceptible to brown tide blooms. *Estuarine Coastal and Shelf Science* **2017,** *188*, 27-37.
2. Buskey, E. J.; Liu, H.; Collumb, C.; Bersano, J. G. F., The decline and recovery of a persistent Texas brown tide algal bloom in the Laguna Madre (Texas, USA). *Estuaries* **2001,** *24*, (3), 337-346.
3. Munson, J., Fish Kill in Baffin Bay has Resident, Scientists Concerned. *KIII TV* 2013.
4. Grubbs, F.; Morris, A.; Nunez, A.; Olsen, Z.; Tolan, J., Emaciated black drum event: Baffin Bay and the upper Laguna Madre. In Division, T. P. a. W.-C. F., Ed. 2013; p 25.
5. Montagna, P. A.; Stockwell, D. A.; Kalke, R. D., Dwarf Surfclam Mulinia-Lateralis (Say, 1822) Populations and Feeding during the Texas Brown Tide Event. *J. Shellfish Res.* **1993,** *12*, (2), 433-442.
6. USEPA, Environmental Monitoring and Assessment Program for Baffin Bay (12110205). In Agency, E. P., Ed. Washington, DC, 2014.
7. Anderson, B.; Phillips, B.; Hunt, J.; Siegler, K.; Voorhees, J.; Smalling, K.; Kuivila, K.; Hamilton, M.; Ranasinghe, J. A.; Tjeerdema, R., Impacts of pesticides in a Central California estuary. *Environ. Monit. Assess.* **2014,** *186*, (3), 1801-1814.
8. Gunasekara, A. S.; Truong, T.; Goh, K. S.; Spurlock, F.; Tjeerdema, R. S., Environmental fate and toxicology of fipronil. *J. Pestic. Sci.* **2007,** *32*, (3), 189-199.
9. Ockerman, D. J.; Petri, B. L., Hydrologic conditions and water quality in an agricultural area in Kleberg and Nueces Counties, Texas 1996-98. In Survey, U. S. G., Ed. 2001; p 54.
10. Garcia, R. N.; Chung, K. W.; Key, P. B.; Burnett, L. E.; Coen, L. D.; DeLorenzo, M. E., Interactive Effects of Mosquito Control Insecticide Toxicity, Hypoxia, and Increased Carbon Dioxide on Larval and Juvenile Eastern Oysters and Hard Clams. *Archives of Environmental Contamination and Toxicology* **2014,** *66*, (3), 450-462.
11. USEPA, SW-846 Test Method 3510C: Separatory Funnel Liquid-Liquid Extraction. In 1996.
12. Arniri, B. M.; Xu, E. G.; Kupsco, A.; Giroux, M.; Hoseinzadeh, M.; Schlenk, D., The effect of chlorpyrifos on salinity acclimation of juvenile rainbow trout (Oncorhynchus mykiss). *Aquatic Toxicology* **2018,** *195*, 97-102.
13. Jesus, T. F.; Rosa, I. C.; Repolho, T.; Lopes, A. R.; Pimentel, M. S.; Almeida-Val, V. M. F.; Coelho, M. M.; Rosa, R., Different ecophysiological responses of freshwater fish to warming and acidification. *Comp. Biochem. Physiol. A-Mol. Integr. Physiol.* **2018,** *216*, 34-41.
14. Schlenk, D.; Lavado, R., Impacts of climate change on hypersaline conditions of estuaries and xenobiotic toxicity. *Aquatic Toxicology* **2011,** *105*, 78-82.
15. Maryoung, L. A.; Blunt, B.; Tierney, K. B.; Schlenk, D., Sublethal toxicity of chlorpyrifos to salmonid olfaction after hypersaline acclimation. *Aquatic Toxicology* **2015,** *161*, 94-101.

Appendices

Appendix 1

Appendix 1. Baffin Bay sampling site coordinates.

Site #	Site Name	N	W
West Group			
1	Drum Point (Cayo del Grullo)	27° 22.076′	97° 42.145′
2	Site 55 (Laguna Salada)	27° 16.115′	97° 43.354′
3	Marker 36	27° 16.635′	97° 37.492′
4	Alazan mouth	27° 16.600′	97° 34.924′
5	Petronilla (Alazan)	27° 21.159′	97° 30.924′
East Group			
6	Marker 14	27°15.937′	97°29.662′
7	South mouth	27° 15.925′	97° 25.179′
8	Middle mouth-Marker 2	27° 16.660′	97° 24.772′
9	North mouth	27° 19.215′	97° 24.595′

Appendix 2

Appendix 2. Sample collection dates and sites sampled. Not all sites could be sampled during each trip due to time constraints and weather. The bold, italicized ***X*** for site 5 indicates triplicate samples were taken.

Sampling Matrix					**Site**					**TOTAL**
Year-Month	1	2	3	4	5	6	7	8	9	
2016-02	X	X			X	X		X		5
2016-03	X	X	X	X	***X***					5
2016-04	X	X								2
2016-05	X	X	X	X	***X***					5
2016-06	X	X	X	X	***X***	X	X	X		8
2016-07	X	X	X	X	***X***	X	X	X	X	9
2016-08	X	X	X	X	***X***	X	X	X	X	9
2016-09	X	X	X	X	***X***		X	X	X	8
2016-10	X	X	X	X	***X***	X	X	X	X	9
2016-11	X	X								2
2016-12	X	X	X	X	***X***	X	X	X	X	9
2017-01			X							1
2017-02	X	X	X	X	***X***		X	X		7
2017-04			X	X	***X***	X	X	X	X	7
2017-05		X	X	X	***X***	X	X	X		7
2017-08			X		***X***					2
2017-09	X	X			***X***					3
2017-10	X	X	X			X				4
2017-11	X									1
2017-12						X				1
TOTAL	15	15	14	11	14	10	9	10	6	104

Appendix 3

Appendix 3. Pesticide concentrations quantified at each site across all the sampling events.

		Water Concentration (µg L-1)							
Site	**Date**	**Trifluralin**	**Dimethoate**	**Simazine**	**Atrazine**	**Malathion**	**Metolachlor**	**Chlorpyrifos**	**Bifenthrin**
1	Feb-16	107.6	90.8	0.0	92.3	866.5	3.1	5.2	1.3
1	Mar-16	20.5	17.3	0.0	384.9	120.3	3.3	172.7	2.2
1	Apr-16	105.7	89.2	0.0	322.0	178.1	1.6	120.3	0.8
1	May-16	25.3	21.3	2.6	366.4	167.1	0.8	52.3	2.3
1	Jun-16	36.9	31.1	0.0	289.7	53.5	0.5	0.6	2.3
1	Jul-16	67.9	57.3	0.0	122.2	258.4	1.6	0.8	0.3
1	Aug-16	33.3	28.1	0.0	29.8	32.4	2.9	25.6	0.4
1	Sep-16	25.1	21.1	0.0	58.3	157.0	3.2	62.4	0.2
1	Oct-16	32.7	27.6	0.0	76.9	123.9	1.1	111.5	0.7
1	Dec-16	42.7	36.0	12.9	60.2	126.4	0.8	121.6	0.8
1	Feb-17	32.3	27.3	23.3	21.3	75.2	12.5	35.9	28.3
1	Sep-17	37.4	31.6	0.0	7.3	185.5	1.1	97.7	0.2
1	Oct-17	114.0	96.2	3.2	11.4	1080.0	5.0	357.1	1.1
1	Nov-17	37.7	31.8	0.1	8.2	470.3	60.8	219.8	1.1
2	Feb-16	0.0	17.9	0.3	123.9	516.9	1.1	6.1	2.4
2	Mar-16	0.0	20.4	17.4	246.3	52.8	9.8	7.1	25.8
2	May-16	0.2	6.0	0.1	145.3	39.7	0.6	0.7	5.4
2	Jun-16	0.0	13.8	0.0	198.6	91.6	0.7	1.4	0.5
2	Jul-16	0.0	81.5	0.0	140.4	513.1	4.9	3.1	2.0
2	Aug-16	0.0	42.8	0.0	143.9	183.1	3.3	85.8	1.1
2	Sep-16	0.0	33.8	0.0	85.3	150.6	2.1	55.5	0.2
2	Oct-16	0.0	98.2	17.7	86.0	81.6	3.9	225.3	2.7
2	Dec-16	0.0	49.6	0.0	40.7	127.7	4.1	83.8	2.1
2	Feb-17	0.0	10.9	0.0	45.7	76.1	2.2	98.8	118.7
2	May-17	0.0	24.7	0.0	28.0	166.4	0.7	130.8	3.2
2	Sep-17	0.0	65.9	0.0	14.7	241.4	5.1	85.5	0.7
2	Oct-17	0.0	43.5	0.1	9.4	358.4	13.8	336.8	0.1

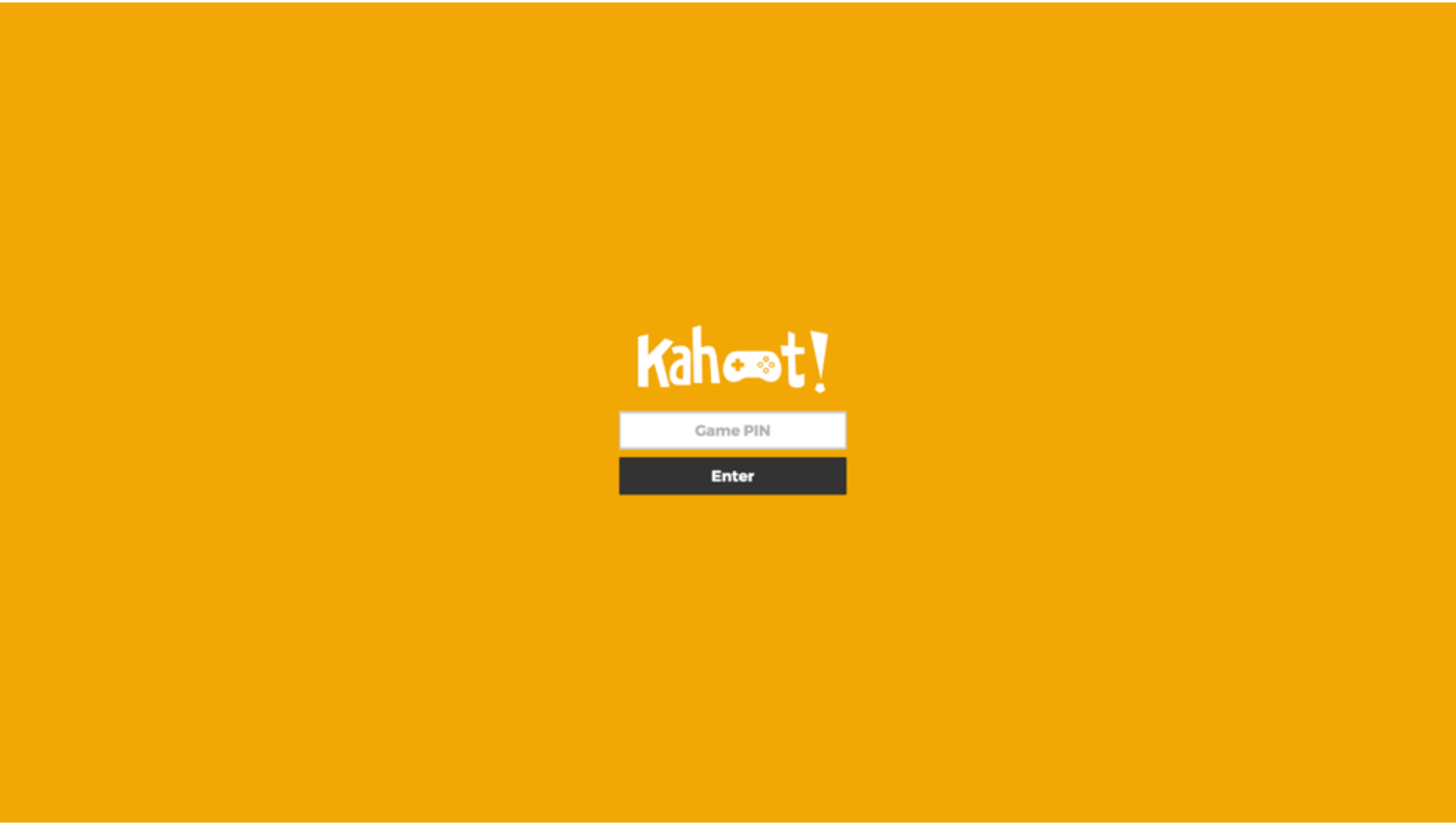
Site	Date	Trifluralin	Dimethoate	Simazine	Atrazine	Malathion	Metolachlor	Chlorpyrifos	Bifenthrin
3	Mar-16	0.2	9.4	1.8	243.8	32.2	2.7	37.3	3.0
3	May-16	0.4	23.4	2.2	148.2	58.4	1.7	0.3	2.2
3	Jun-16	0.0	15.0	0.0	168.4	0.0	0.0	0.0	0.0
3	Jul-16	0.0	37.2	1.5	127.5	73.7	0.7	20.8	0.1
3	Aug-16	0.3	28.8	0.0	121.0	158.9	1.9	77.7	0.4
3	Sep-16	0.0	76.7	108.2	237.7	112.3	45.5	55.0	56.0
3	Oct-16	0.3	19.2	0.0	68.7	88.8	1.9	9.6	1.9
3	Nov-16	0.8	36.5	14.1	43.8	130.5	3.4	115.7	3.3
3	Dec-16	6.1	27.1	10.6	33.7	8.6	6.4	11.9	3.7
3	Jan-17	1.9	18.0	0.6	40.8	4.2	1.2	15.4	3.1
3	Feb-17	0.0	11.7	2.9	78.2	180.0	0.9	10.3	2.0
3	Apr-17	0.0	21.0	4.6	25.7	73.3	0.6	64.8	5.5
3	May-17	0.0	10.5	7.8	12.6	8.1	0.4	26.9	0.4
3	Aug-17	1.9	31.0	0.0	13.1	73.4	2.2	85.5	1.3
3	Oct-17	1.4	43.8	0.0	7.7	563.9	15.4	297.8	1.5
4	Mar-16	0.0	16.7	0.0	107.7	0.0	0.4	1.1	0.3
4	May-16	0.0	0.0	0.0	197.5	137.8	1.6	0.2	1.5
4	Jun-16	3.5	39.7	3.7	100.3	65.2	1.9	3.9	6.2
4	Jul-16	0.2	8.2	0.0	142.4	243.7	3.3	0.6	0.3
4	Aug-16	0.4	4.9	22.5	130.3	63.8	1.3	51.5	0.7
4	Sep-16	0.0	17.2	0.1	20.7	57.3	0.8	9.1	0.7
4	Oct-16	0.6	76.3	0.0	70.8	222.8	3.6	148.9	1.9
4	Dec-16	0.0	27.5	0.0	32.5	87.0	2.6	46.9	3.4
4	Feb-17	0.4	50.2	0.0	30.4	171.0	2.6	23.0	2.0
4	Apr-17	1.0	7.3	0.0	24.7	58.3	0.8	10.1	2.6
4	May-17	1.0	28.4	0.0	31.6	81.8	0.6	121.5	5.0

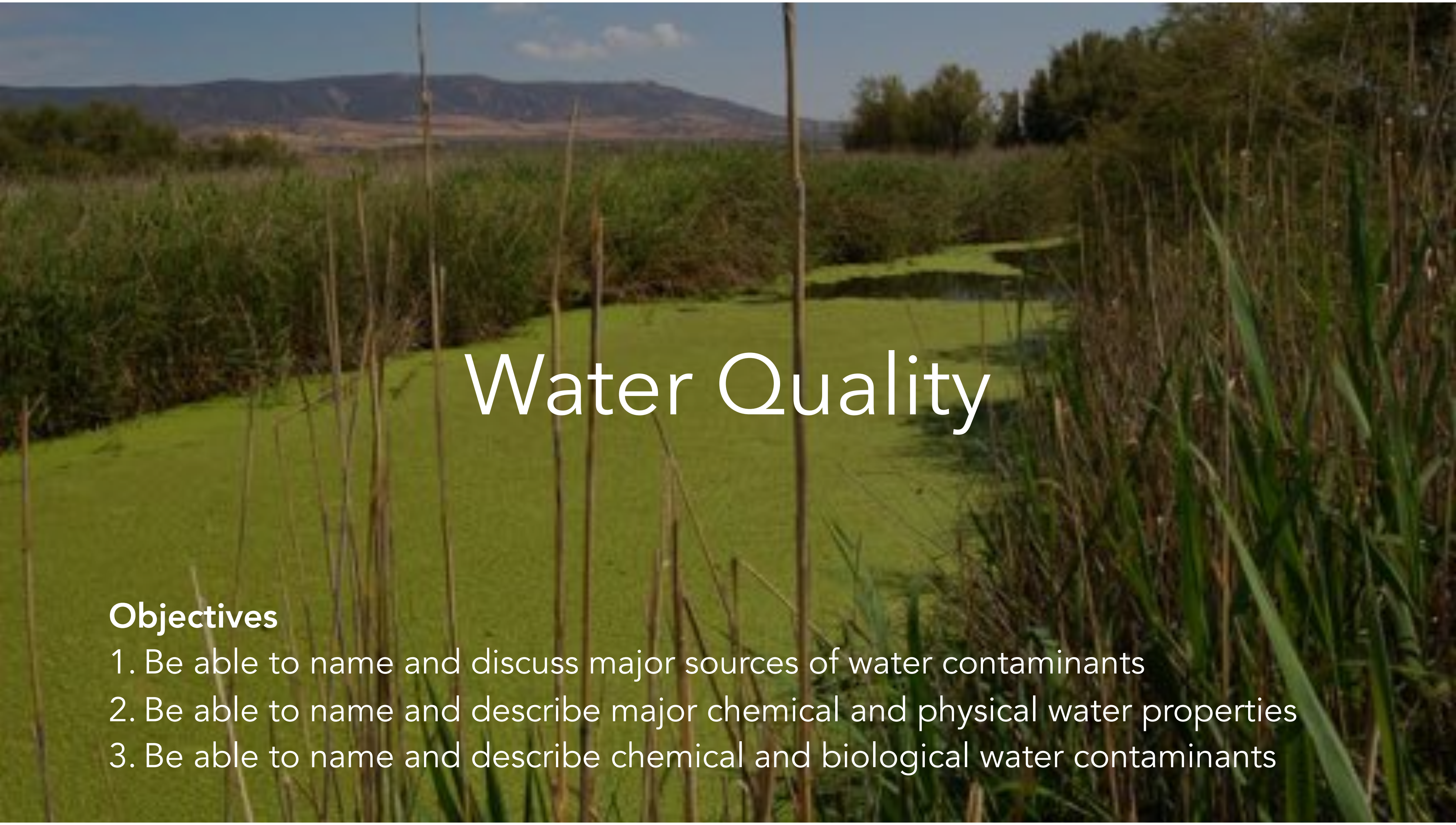
Site	Date	Trifluralin	Dimethoate	Simazine	Atrazine	Malathion	Metolachlor	Chlorpyrifos	Bifenthrin
5	Feb-16	0.0	2.1	0.0	32.7	7.0	0.0	4.2	0.0
5	Mar-16	0.0	45.0	0.3	152.8	29.5	1.1	12.0	0.1
5	May-16	0.1	40.5	0.0	107.8	36.8	0.5	0.3	1.7
5	Jun-16	0.1	8.7	0.0	61.3	20.0	0.2	0.3	0.2
5	Jul-16	0.6	38.4	0.0	79.1	107.7	0.7	18.8	0.0
5	Aug-16	1.4	60.9	1.8	88.0	130.9	0.8	40.8	0.1
5	Sep-16	1.6	34.9	0.0	55.8	95.3	0.5	45.6	0.0
5	Oct-16	0.1	28.0	0.0	32.5	48.3	0.6	16.9	0.1
5	Dec-16	0.1	16.9	0.0	18.7	60.0	0.9	20.7	0.4
5	Feb-17	1.0	30.2	0.0	16.1	80.4	1.2	28.3	0.6
5	Apr-17	1.1	18.4	0.1	17.4	61.0	0.2	18.0	0.5
5	May-17	1.3	21.4	0.0	15.3	56.8	0.2	41.8	4.4
5	Aug-17	1.4	21.6	0.0	8.1	63.0	0.5	37.7	0.1
5	Sep-17	1.3	27.3	0.5	6.0	84.2	0.8	70.7	0.0
5	Oct-17	0.0	17.4	0.0	2.1	162.0	1.8	90.3	0.0
5	Dec-17	0.0	4.9	0.0	7.4	32.9	0.6	10.7	0.3
6	Feb-16	0.2	38.5	0.3	51.2	148.5	0.5	10.5	1.3
6	Jun-16	0.2	46.3	0.0	137.1	133.0	0.2	0.9	0.7
6	Jul-16	0.3	27.8	0.0	23.8	68.2	0.2	31.9	0.1
6	Aug-16	0.2	37.1	0.0	80.5	100.6	0.2	16.4	0.4
6	Oct-16	0.7	40.8	0.0	56.5	154.9	3.0	85.0	1.1
6	Nov-16	0.3	9.0	0.1	38.9	191.1	2.8	94.7	1.5
6	Dec-16	0.1	13.9	0.0	22.6	48.8	0.9	19.8	0.3
6	Apr-17	0.7	1.1	0.0	16.1	38.3	0.2	35.8	6.2

Site	Date	Trifluralin	Dimethoate	Simazine	Atrazine	Malathion	Metolachlor	Chlorpyrifos	Bifenthrin
7	Jun-16	0.1	12.5	0.0	14.7	28.4	0.2	4.8	0.0
7	Jul-16	0.3	44.5	0.0	4.7	2.8	0.8	46.1	0.1
7	Aug-16	1.3	79.1	0.0	1.2	40.4	0.8	24.9	0.2
7	Sep-16	1.4	33.2	0.0	5.7	94.1	1.4	49.3	1.0
7	Oct-16	0.7	61.8	0.0	18.9	55.0	0.8	51.7	3.8
7	Dec-16	0.2	18.2	0.0	17.4	69.3	0.8	42.6	0.4
7	Feb-17	2.0	32.7	3.6	14.3	157.0	5.9	63.9	108.1
7	Apr-17	1.5	9.0	0.0	16.2	57.8	0.4	36.8	1.0
7	May-17	1.0	28.9	0.0	17.6	38.0	0.3	45.7	2.4
8	Feb-16	0.0	5.2	0.0	126.5	34.0	1.2	109.1	2.3
8	Jun-16	0.0	15.0	0.0	20.8	72.1	0.1	0.3	0.2
8	Jul-16	0.0	54.7	0.0	71.9	184.8	1.5	83.9	0.9
8	Aug-16	0.0	47.0	0.0	6.1	30.5	0.5	16.6	0.1
8	Sep-16	0.0	21.9	0.0	10.4	127.5	1.3	57.3	0.9
8	Oct-16	0.0	7.2	5.3	6.1	12.6	0.8	4.0	1.7
8	Dec-16	0.0	24.2	0.0	7.4	90.2	0.4	57.6	0.1
8	Feb-17	0.0	24.5	0.0	13.7	100.9	2.1	48.7	0.8
8	Apr-17	0.0	39.0	0.1	16.5	49.8	0.7	46.4	8.4
8	May-17	0.0	29.8	0.0	19.1	48.3	0.8	136.2	7.9
9	Apr-16	0.0	17.4	40.9	208.9	82.8	0.9	81.1	0.3
9	Jul-16	0.1	28.9	0.0	28.3	147.9	0.6	77.5	0.0
9	Aug-16	3.8	44.6	0.0	15.4	163.4	0.7	5.1	0.0
9	Sep-16	0.5	27.0	0.0	6.7	28.7	0.6	15.6	0.1
9	Oct-16	0.0	19.7	0.0	5.4	40.4	1.3	29.1	0.6
9	Dec-16	0.2	13.5	0.0	52.2	83.4	0.4	1.3	0.1
9	Apr-17	1.0	24.6	0.0	12.0	51.1	0.3	25.2	0.9

Appendix 4

Appendix 4. Lecture slide from Dr. Conkle's Wetlands & Water Quality course for the lecture on Water Quality. Baffin Bay and its water quality problems were discussed on slides 5-1, 5-2, 6, 10 and 17. Also, depending on the conversation during class, Baffin Bay may have been discussed on additional slides in this lecture or other lectures during the course.


Kahoot!
Game PIN
Enter



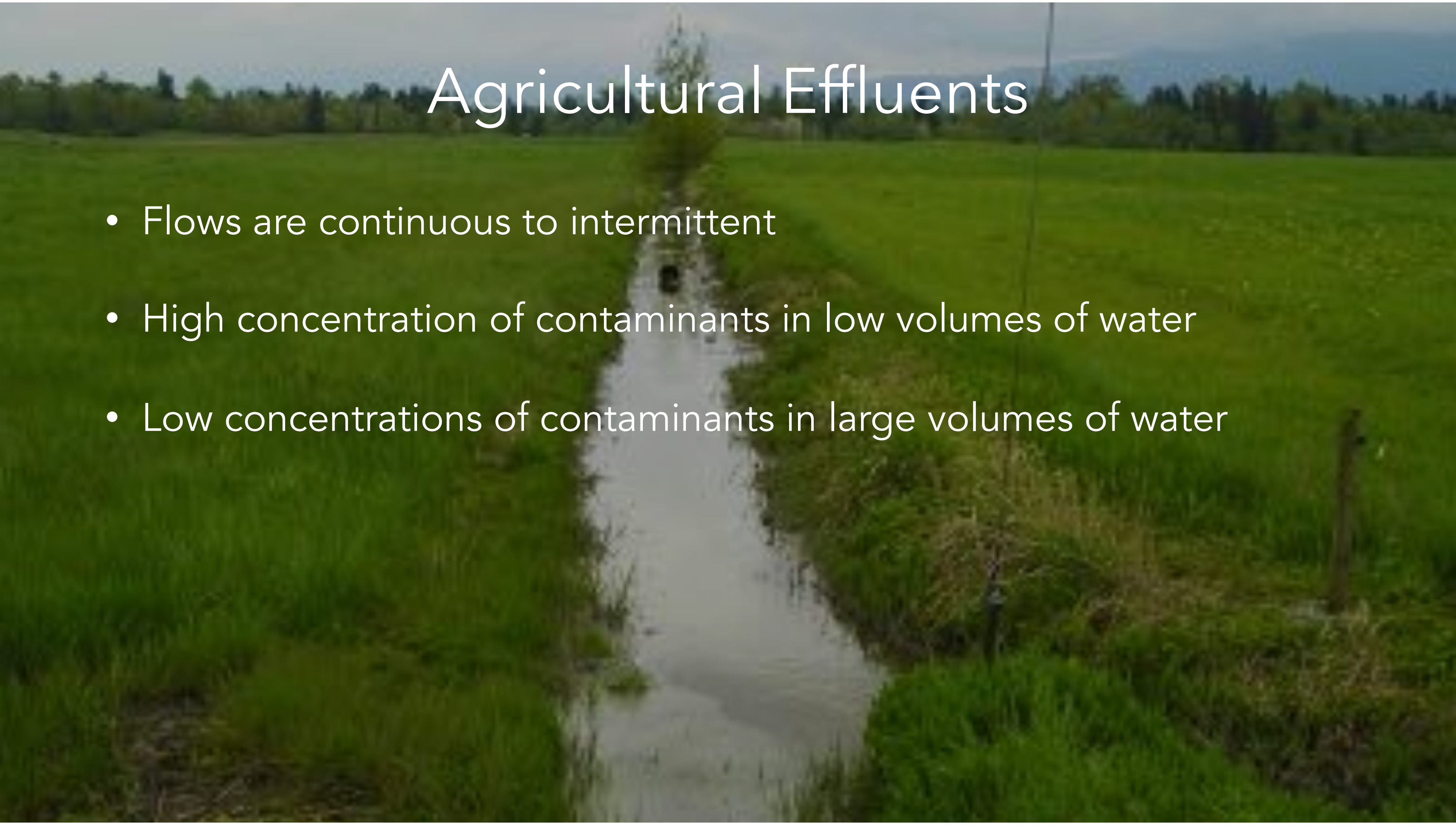
Water Quality

Objectives

1. Be able to name and discuss major sources of water contaminants
2. Be able to name and describe major chemical and physical water properties
3. Be able to name and describe chemical and biological water contaminants

Water Quality

- Contaminant: a substance at a concentration greater than background levels in the environment
- Pollutant: a substance at a concentration greater than background levels in the environment ________________________



Agricultural Effluents

- Flows are continuous to intermittent
- High concentration of contaminants in low volumes of water
- Low concentrations of contaminants in large volumes of water

Baffin Bay, Texas


Baffin Bay, Texas
Intensive Agriculture

Cattle and Dairy Operations


Citrus Industry


Sugarcane

Nurseries/Greenhouses

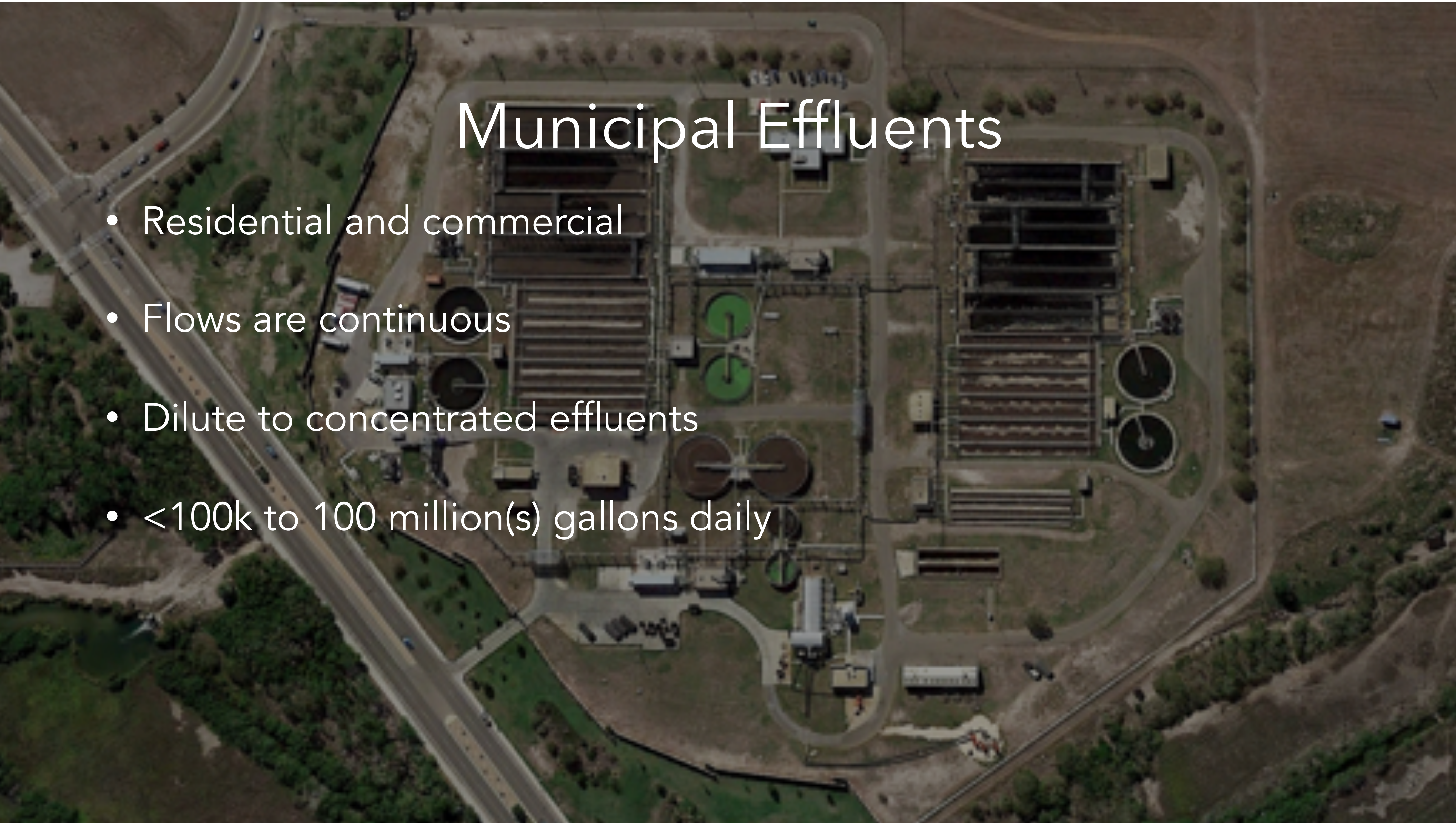
- Small footprint
- Big impact

Stormwaters

- Runoff from urban and rural areas
- Flows are intermittent
- Dilute mixtures of mineral and organic solids, dissolved salts, nutrients, trace metals, and toxic organics

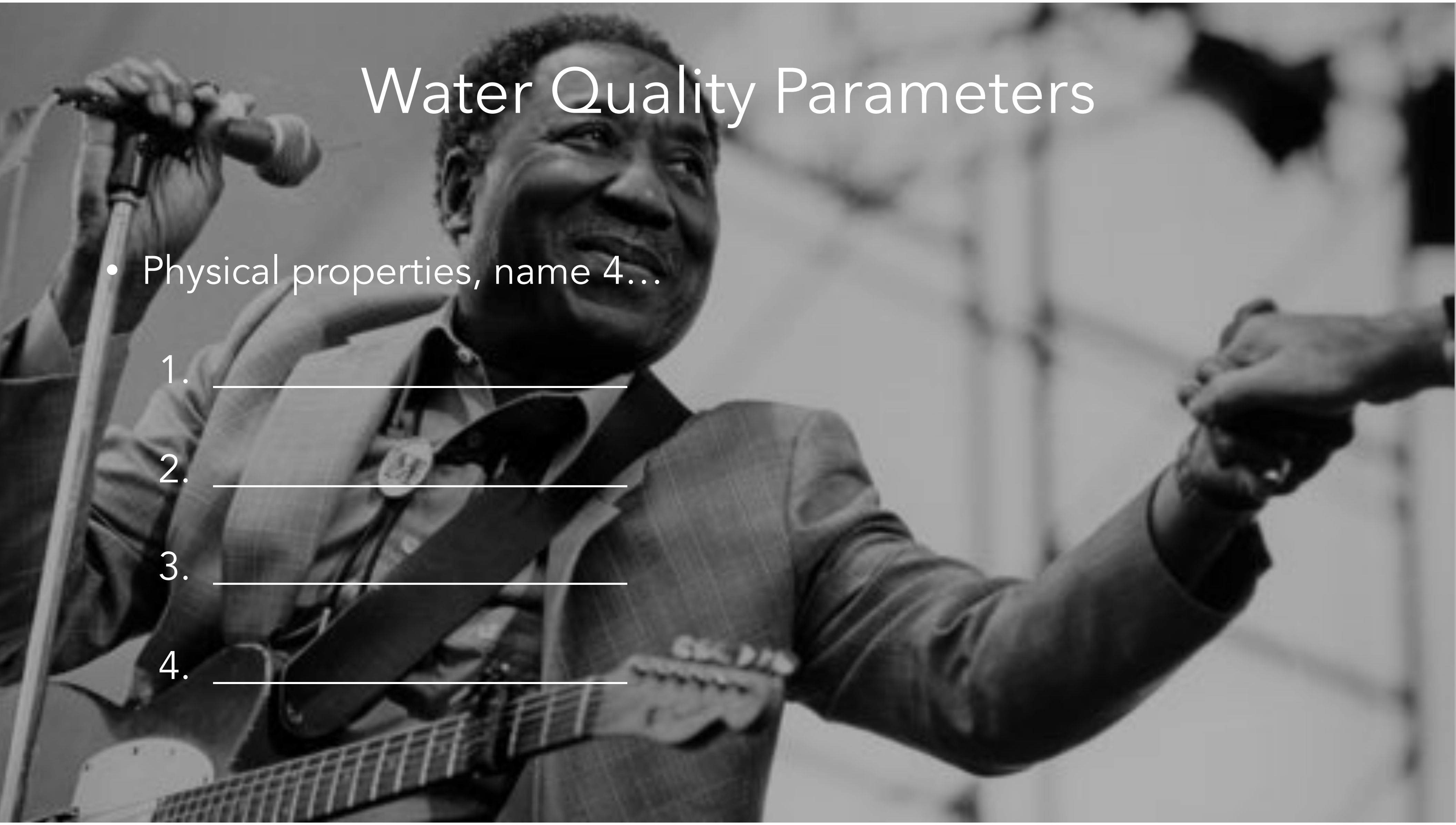
Industrial Effluents

- Industrial processes and leachates
- Flows are continuous to intermittent
- Small flows with high concentration of contaminants
- Concentrated solutions of biodegradable and non-biodegradable compounds



Municipal Effluents

- Residential and commercial
- Flows are continuous
- Dilute to concentrated effluents
- <100k to 100 million(s) gallons daily



Water Quality Parameters

- Physical properties, name 4…

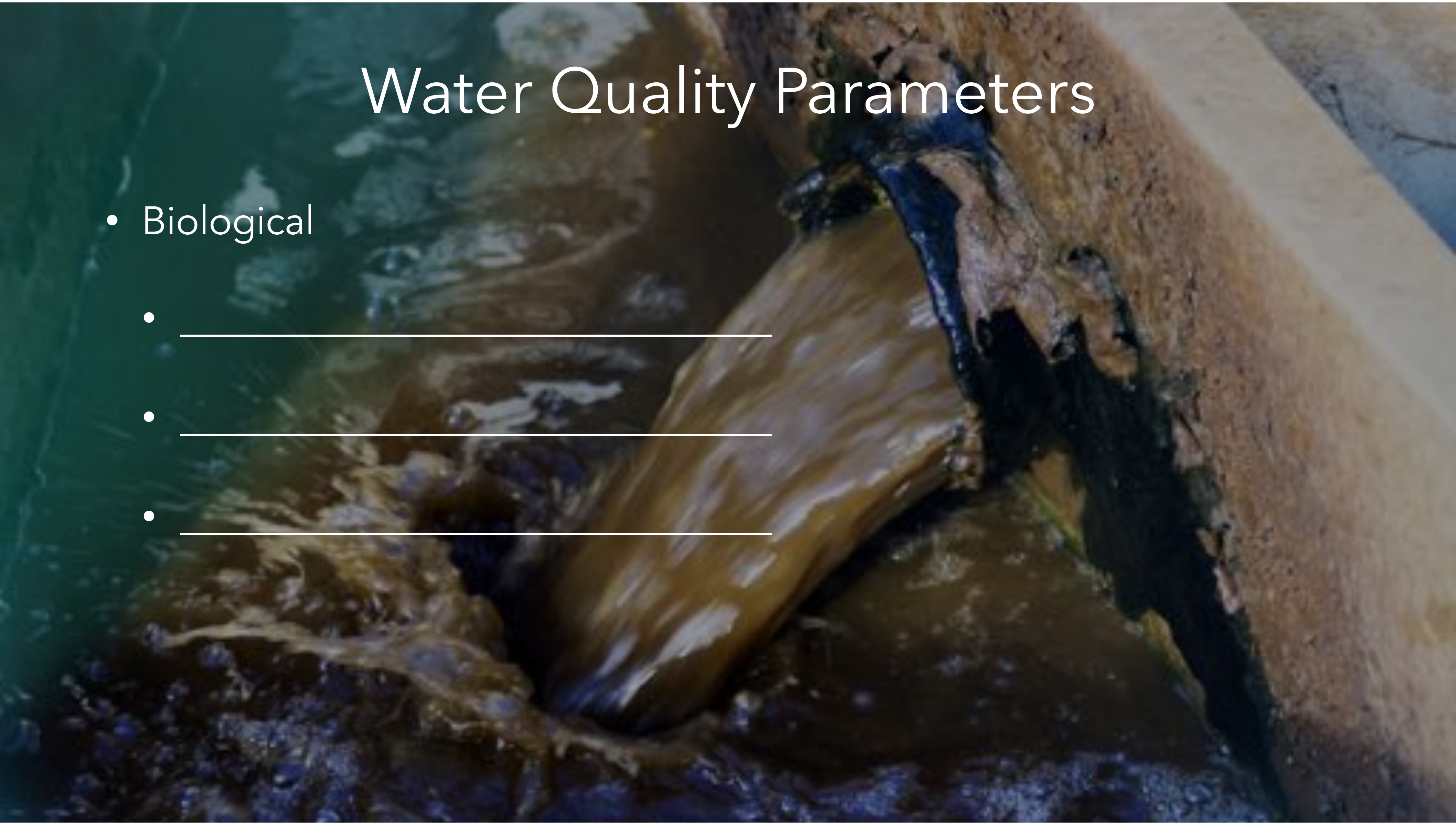
  1. ______________________
  2. ______________________
  3. ______________________
  4. ______________________


Water Quality Parameters
• Chemical properties, name 5…
1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________
5. ___________________________

Water Quality Parameters

- What nutrients cause this?
  - ____________________
    - Forms:
  - ____________________
    - Forms:


Water Quality Parameters
• Metals
• Organics
• Petroleum
• Surfactants
• Food Processing Waste
• Pesticides (Baffin Bay)
• Emerging Contaminants



Water Quality Parameters

- Biological
  - ______________________________
  - ______________________________
  - ______________________________

Water Quality

Objectives Review

1. What are the major sources of water contaminants?
2. Name and discuss 4 chemical and 4 physical water parameters.
3. Name and discuss 6 chemical and 3 biological water contaminants.