Benthic Recovery Monitoring Report

Contract areas: S-AM-1, S-AN-1a, and S-KVK-2

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INTRODUCTION

The U.S. Army Corps of Engineers, New York District (USACE-NYD) has played a major role in the navigation, development and maintenance of water resources in The Port of New York/New Jersey for more than two centuries. The Port is a critical economic component of the New York City Metropolitan region, providing more than 230,000 direct and indirect jobs and $20 billion in economic activities to the States of New York and New Jersey (USACE 2010). However, the Port is located within a naturally shallow estuary, with an average depth of less than 20 feet (USACE 2008). Since the late 19th century, periodic maintenance dredging and improvement of navigation channels has been necessary for the continued use and economic vitality of the Port.

Today, there are more than 200 miles of federally maintained navigation channels within NY/NJ Harbor. To meet current and anticipated shipping needs, including increased containerization using larger Post-Panamax shipping vessels, these existing navigation channels are currently being deepened. The Harbor Deepening Project (HDP), a multi-year program sponsored by USACE and the Port Authority of New York and New Jersey, is aimed at improving navigation in the Harbor while minimizing impacts to the aquatic environment, and incorporating beneficial aspects that seek to improve the environment. Ongoing improvements to the Port since 1999 include the deepening of portions of the Ambrose Channel (from the Narrows to Port Jersey Channel), the Kill Van Kull Channel, Newark Bay Channel, the Arthur Kill Channel, and the Port Jersey Channel.

The impacts of navigation channel dredging on benthic macro-invertebrate and finfish communities residing in the channels have been monitored by USACE-NYD in compliance with the Coastal Zone Management Act (CZMA). This report presents the results of baseline (pre-dredging) and post-dredging benthic macro-invertebrate community surveys conducted within three completed HDP contract areas: S-AM-1 (Ambrose Channel), S-AN-1a (Anchorage Channel), and S-KVK-2 (Kill Van Kull Channel). These three contract areas were the first to be completed under the HDP and were dredged sequentially in June 2008, September 2008, and

March 2007, respectively. Benthic sampling was conducted a little more than one year following dredging in Ambrose Channel and Anchorage Channel and two years following dredging in the Kill Van Kull The results can be used to document impacts to the Harbor's benthic community as a result of channel deepening and provide a timescale for benthic re-colonization.

Background

The benthic community in the Harbor consists of a wide variety of small aquatic invertebrates which live burrowed into or in contact with the bottom, such as worms, mollusks, and amphipods (Pearce 1974). Benthic invertebrate communities play an important role in the Harbor. They are an essential part of the marine food web, they cycle nutrients from the sediment and water column to higher trophic levels, and they modify the substrate through bioturbation and the formation of fecal pellets (Wildish and Kristmanson 1997, Wolff 1983).

Life strategies of marine benthic macro-invertebrates and sediment characteristics of their habitats are tightly coupled (Levinton 1982). The distribution and abundance of benthic invertebrates are influenced by a wide variety of physical parameters, such as substrate, water temperature, dissolved oxygen, pH, salinity, and hydrodynamics, as well as disturbance and pollution (Cristini 1991, Watson and Barnes 2004). Benthic organisms are good indicators of local environmental conditions and anthropogenic disturbance since they live and feed on the sediment and have limited mobility, thus they cannot avoid exposure to contaminants in the sediments (Dauer 1993). Benthic communities generally respond in stages to changes in habitat disturbance. Response stages include an increase (or decease) in abundance; increase (or decrease) in diversity, and a shift to (or from) a pollution -tolerant to pollution-intolerant assemblage (USEPA 2009).

When a benthic community is physically disturbed, specifically through dredging or smothering, the community may re-colonize through natural succession to pre-disturbance conditions within approximately one to five years following the cessation of the disturbance (Blake et al. 1996, Van Dolah et al. 1992). However, recovery may take longer if physical characteristics (e.g. sediment, hydrology, etc.) are changed and different species re-colonize (Schaffner et al. 1996, Van Dolah et al. 1994, Wilber and Stern 1992). The offshore benthic community in the USACE-NYD's Manasquan Inlet study recovered rapidly following sand borrow area dredging in 1997 and 1999; by the spring of 2000 no s tatistically detectable differences were noted between dredged and reference areas in benthic abundance and biomass (USACE 2001).

METHODS

Sample Collection

Pre-construction benthic samples were collected throughout the Harbor in July of 2005 with the exception of the Kill Van Kull Channel, which was sampled in April 2005 due to the dredging schedule. Five samples were taken in the Kill Van Kull Channel, four were taken in the Ambrose Channel, and two were taken in the Anchorage Channel near the S-AN-1a contract area (Figure 1). Note that the station labeled AN-1 in 2005 was located within the Ambrose Channel contract area. Because benthos distribution is not uniform and the areas that were proposed to be dredged were throughout the Harbor, sample locations in 2005 were chosen by sediment types.

In September 2009, five post construction samples were collected in each of the three completed HDP contract areas: S-AM-1 (Ambrose Channel), S-AN-1a (Anchorage Channel), and S-KVK-2 (Kill Van Kull Channel). When available, sampling locations in 2009 were chosen to correspond to previous locations sampled in 2005, otherwise they were chosen based on sediment type to sample as diverse an area as possible (Figure 2a-c). Note that benthic samples from 2005 are designated by the initials of the channel sampled (e.g., Ambrose = AM) followed by a dash and the number sample (e.g. Sample AM-1). Samples from 2009 follow a similar nomenclature but are designated by the contract area (e.g. sample 1 in the S-AN-1a contract area is SAN1a-1).

Benthic samples were collected using a 0.1 m^2 Smith-McIntyre Grab. At each sampling location, one benthic sample was collected and washed onboard the sampling vessel using a 500-µm mesh sieve. Material retained within the sieve was placed into a labeled sample bottle and preserved with 10% buffered Formalin containing Rose Bengal stain for laboratory analysis. For each grab sample, the date, time, location, weather/oceanographic conditions, water depth, and sediment characteristics were recorded.

In the laboratory, organisms were sorted from the remaining debris, identified by taxonomists and enumerated. Identifications were made to the lowest practical identification level when not to the species level. When the number of organisms in a sample was large (>500) sub-sampling was conducted using a sampling tray with 30 grids, each 6 cm x 6 cm. For all samples, organisms in randomly selected grids were counted until the total number of organisms reached 100 or the entire sample was sorted, whichever occurred first." To clarify, for sub-sampling a grid is selected and each grid is completely counted until organism count reaches 100. If count is reached halfway through grid, the grid still is fully sorted so the 100 count could vary.

Data Analysis

The benthic community was assessed through calculation of density, taxa richness, Shannon-Wiener's diversity index, and Evenness from the benthic grab data. To assess the community within each completed contract area, biodiversity indices were calculated from the sum of all samples collected within that area.

Benthic density, or abundance, can be used as an indicator of benthic community health (Becker et al. 1990). Density, the number of organisms per meter squared (organisms/m^2), was calculated for each taxa in each sample collected. Density was based on the total grab area sampled (0.1m^2) and the applicable laboratory split fraction, if the sample was sub-sampled. Density was also calculated for each area as a whole (e.g. Ambrose) by taking the sum of each taxa collected at each station in that area.

Species richness is a measure of the total number of individual taxa collected at a site. In counting the number of taxa present, general taxonomic designations at the generic, familial, and higher taxonomic levels were dropped if there was one valid lower level designation for that group. For example, if Leitoscoloplos sp., Leitoscoloplos fragilis, and Leitoscoloplos robustus were all identified in one sample, then *Leitoscoloplos* sp. was not counted in the total number of taxa. The number of taxa recorded in this example would be two. Species richness was calculated in this matter in order to be as conservative as possible with the number of species present.

The Shannon-Wiener Diversity Index (H') is a widely used species diversity index (Washington 1984). It provides more information about the benthic community structure than taxa richness because it takes into account the relative abundance of each taxa as well as taxa richness (Morin

1999). Comparing between samples, lower values of H′ indicate lower taxa richness and an uneven distribution of abundance among species while higher values indicate higher taxa richness and an even distribution of abundance among taxa. Typically, a healthy benthic macro-invertebrate community would have a relatively high H value. The index is computed as follows:

$$H' = -\sum_{i=1}^{s} (p_i Lnp_i)$$

S is the total number of species per sample (i.e., taxa richness) and p_i is the proportion of total individuals in the i^{th} species. Mathematically, p_i is defined as n_i/N where n_i is the number of individuals of a taxa in a sample and N is the total number of individuals of all taxa in the sample.[1]

Evenness (E) measures the distribution among species within the community by scaling one of the diversity measures relative to its maximal possible value. Evenness can range from 0 to 1. It is computed as follows:

$$E = \frac{H'}{H'_{max}}$$

where H' is the observed diversity (as cited above) and H'_{max} is the natural logarithm of the total number of taxa (S) in the sample (H'_{max}= LnS).

The proportion of benthic organisms characterized as pollution tolerant (i.e., indicators of potentially degraded habitat conditions) and pollution sensitive were also calculated for each sample based on Adams 1998, Llansó et al. 2002, and Weis 1995. Pollution tolerant taxa include: Oligochaeta, Leitoscoloplos sp., Capitellidae, Streblospio benedicti, and Mulinia lateralis. Pollution sensitive taxa include: Diopatra cuprea, Spiophanes bombyx, Cyathura polita, Acteocina canaliculata, Ensis directus, Mercenaria mercenaria, Spisula solidissima, and Tellina agilis.

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[1] For the 2005 Harborwide Benthic Report describing the 2005 sampling results, the Shannon-Wiener diversity index was calculated using Log base 10 (Log10). To remain current with existing benthic community literature, the 2009 diversity was calculated using the natural log (Ln) and the 2005 results were updated using Ln.

RESULTS

Ambrose Channel

Ambrose Channel 2005

A total of 43 taxa were collected in Ambrose Channel grab samples from 2005 (Table 1). These taxa were distributed among the primary phyla: annelids (51%), arthropods (21%), mollusks (16%), and 'other' including Echinodermata, Echiura, and Nemertea (12%) (Table 3). The benthic community in Ambrose Channel during 2005 exhibited a total density of 14,785 organisms/m^2 with mollusks composing the majority collected (88%), followed by annelids (7%) (Table 3). Overall Ambrose Channel diversity was 0.81, ranging from 0.32 to 2.50, and evenness was 0.21 but ranged from 0.12 to 0.86 (Table 4). Blue mussel (Mytilus edulis) dominated the assemblage, accounting for 86% of the total (Table 1). Amphipods (Gammaridae), Polychaetes (Nephtys sp. and Magelona sp.) and the bivalve Tellina agilis (northern dwarf tellin) also contributed to the benthic community in this area. Pollution sensitive taxa were collected in a higher proportion (2%) than pollution tolerant taxa (1%) (Table 4).

Sediment in the three Ambrose samples was composed primarily of sand with some fine sand evident in Sample AM-1 (Table 5). Despite the relative consistency in sediment type across the four sampling stations, densities in Sample AN-1 (12,460 organisms/m^2) were considerably higher than in AM-1 (345 organisms/m^2), AM-2 (160 organisms/m^2) and AM-3 (1,820 organisms/m^2) primarily due to greater density of blue mussel (12,722 organisms/m^2) (Table 1). This contributed to the low diversity and evenness calculated for this location (specifically in sample AN-1). Individual sample densities averaged 3,696 organisms/m^2 (Table 4).

S-AM-1 Contract Area 2009

A total density of 4,110 organisms/m^2 was collected in the S-AM-1 contract area in 2009, distributed among 29 taxa (Table 2). These taxa consisted of annelids (41%), arthropods (35%), mollusks (17%) and 'other', including Echinodermata and Nemertea (7%) (Table 3). The organisms collected among all samples were composed primarily of annelids (74%) and arthropods (18%) (Table 2). Diversity within the contract area ranged from 1.34 to 2.06 with a total diversity of 2.57 which was slightly higher than in 2005 for the Ambrose Channel (Table 4). Evenness within the contract area ranged from 0.61 to 0.99 with a total evenness of 0.76 (Table 4). The majority of the individuals collected were composed of the annelids Magelona sp. and Paraonidae, and the arthropod Parahaustorius sp. No blue mussels were collected in 2009. The proportion of the total assemblage consisting of pollution sensitive taxa (2%) was slightly less than pollution tolerant taxa (5%) collected in 2009 (Table 4).

The sediments collected within the S-AM-1 contract area in 2009 were similar to those collected within the Ambrose Channel in 2005 and were composed of sand and fine sand. The only sample with a noticeable change in sediment type, sample SAM1-2 was composed of clay (Table 5). SAM1-2 was the least dense (230 organisms/m^2), moderate numbers of organisms were collected in samples SAM1-5 and SAM1-3 (710 and 970 organisms/m^2, respectively), and high numbers of organisms were collected in SAM1-1 and SAM1-4 (1,050 and 1,150 organisms/m^2, respectively). Individual sample collections with the S-AM-1 contract area averaged 822 organisms/m^2, which was slightly higher than the 2005 collection average within the Ambrose Channel (Table 4).

Anchorage Channel

Anchorage Channel 2005

Benthic samples collected in Anchorage Channel during 2005 displayed a taxa richness of 34 taxa (Table 1). These taxa were distributed among annelids (53%), arthropods (18%), mollusks (26%) and others, including Nematoda and Nemertea (3%) (Table 3). Overall, the benthic community of the Anchorage Channel exhibited a total density of 2,580 organisms/m^2, a total diversity of 1.83 (ranging from 1.79 to 2.23), and a total evenness (0.51), with both AN-2 and AN-3 exhibiting Evenness values of 0.66 (Table 3). Unlike the Ambrose Channel collections in 2005, blue mussel did not dominate the assemblage in Anchorage Channel, accounting for only 2% of the total in 2005 (Table 1). Amphipods (Ampeliscidae), northern dwarf tellin (Tellina agilis), and the annelid species (Spio setosa) also contributed to the benthic assemblage in this area. Pollution sensitive taxa comprised 21% of the total collection in the area during 2005 while pollution tolerant taxa comprised 17% (Table 4).

Sediment in Anchorage Channel samples AN-2 and AN-3 were composed of silt (Table 5). The benthic assemblage from samples AN-2 and AN-3 exhibited low densities of 1,360 and 1,220 organisms/m^2, respectively (Table 1). The three most common taxa among these two stations were Ampeliscidae (23%), *Tellina agilis* (17%), and *Spio setosa* (16%).

S-AN-1a Contract Area 2009

A total of 28 unique taxa were collected in the S-AN-1a contract area in 2009 (Table 2). Taxa were distributed among annelids (46%), arthropods (32%), mollusks (18%) and other, consisting of Nemertea (4%) (Table 3). The total density for the contract area was 34,563 organisms/m^2 with the highest density occurring in sample SAN1a-1 (14,320 organisms/m^2) and the lowest in sample SAN1a-5 (1,343 organisms/m^2). Average sample density was higher in 2009 (6,913 organisms/m^2) than in 2005 (Table 4). Sample SAN1a-3, the only sample which was located in the same location as a 2005 sample, had a higher density than its corresponding 2005 sample (3,387 organisms/m^2 in 2009 compared to 1,220 organisms/m^2 in 2005), but nearly the same diversity and evenness (Table 4). Diversity for the contract area (1.70) was higher than in 2005 (1.10) and samples ranged from 0.90 to 2.37 in 2009 (Table 4). Evenness for the contract area was also higher in 2009 (0.51 compared to 0.30), with samples ranging from 0.46 to 0.90 (Table 4). Arthropods comprised 53% of the organisms collected while 44% of the total assemblage consisted of annelids (Table 3).

The amphipod Ampelisca abdita and the polychaete family Capitellidae dominated the catch, accounting for 51.7% and 16.9%, respectively, of all the organisms collected during 2009 (Table 2). Pollution tolerant taxa made up 29% of the total catch, while only a few individuals of pollution sensitive taxa were collected (<1% of total catch) during 2009. 74% of the organisms collected in sample SAN1a-3 consisted of pollution tolerant taxa compared to 10% in the corresponding AN-3 sample collected in 2005 (Table 4).

Samples SAN1a-1, SAN1a-2, and SAN1a-3 consisted of silt/clay. Sample SAN1a-4 also consisted of silt/clay with some fine sand present. Sample SAN1a-5 consisted of fine sand and silt (Table 5). Sediments in sample SAN1a-3 changed slightly between years, with 2009 samples containing some clay.

Kill Van Kull Channel

Kill Van Kull Channel 2005

A total of 32 taxa were collected in the five Kill Van Kull grab samples collected in 2005 (Table 1). These taxa were distributed among annelids (44%), arthropods (22%), mollusks (28%) and other (6%) (Table 3). Overall, the benthic community of the Kill Van Kull exhibited a community diversity of 2.20 and evenness of 0.62, a total density of 109,860 organisms/m^2,as well as the highest average density (21,972 organisms/m^2) (Table 4). Nematodes, blue mussel, and polychaetes (predominately Paraonidae, Sabellaridae and Spionidae) were the dominant organisms (Table 1). The dominant annelids were Paraonidae, Sabellaria vulgaris and Streblospio benedicti with densities up to 13,063 organisms/m^2 while the dominant arthropod was amphipods (Aoridae) with densities up to 6,006 organisms/m^2. Blue mussel was the most abundant mollusk with densities up to 13,814 organisms/m^2 (Table 1). Pollution tolerant taxa were found in higher proportions than pollution sensitive taxa at all stations, indicating that moderately degraded habitat may have existed in the Kill Van Kull during 2005 (Table 4).

Sediment types in 2005 consisted of sand, and mud/clay (Table 5). Sample KVK-2 had the highest density of organisms (61,411 organisms/m^2) and consisted of sand (Tables 4 & 5). By comparison, the lowest sample density was found in sample KVK-5 (295 organisms/m^2), which consisted of mud/clay.

S-KVK-2 Contract Area 2009

A total of 32 individual taxa were collected in the S-KVK-2 contract area in 2009, the same as were collected in the channel in 2005 (Table 1). These taxa were distributed primarily among three phyla: annelids (56%), arthropods (22%), mollusks (13%) and other, consisting of Chordata, Cnidaria, and Nematoda (9%) (Table 3). Total density for the contract area in 2009 was 61,831 organisms/m^2 and averaged 12,366 organisms/m^2, which were less than the Kill Van

Kull densities during 2005 (Table 4). Diversity and evenness were nearly the same between 2005 and 2009, with a 2009 diversity of 2.18 (ranging from 1.33 to 2.49), and an evenness of 0.63 (ranging from 0.49 to 0.86) (Table 4). The sample with the lowest diversity and evenness (SKVK2-1) contained the highest density of organisms (29,149 organisms/m^2), mostly due to the large collection of the polychaete Sabellaria vulgaris which accounted for 68% of the total catch (Table 2).

Annelids dominated the total catch during 2009 (64.8% of the total organisms collected), mostly due to Sabellaria vulgaris, and to a lesser extent Scolecolepides viridis and Capitellidae (Table 2). Other taxa accounted for 20.9%, mostly due to large collections of nematodes across all stations (Table 2). Pollution tolerant species accounted for 18% of all organisms collected during 2009 which was twice as many as the percentage collected in 2005 (Table 4). Similar to 2005, pollution sensitive species were nearly absent from all samples collected.

Sediment types in the S-KVK-2 contract area of the Kill Van Kull changed the most dramatically between sampling years, as compared to the other 2 contract areas sampled in Ambrose and Anchorage Channels. In 2005, the sediment consisted of mostly fine grained sediments. In 2009, samples consisted of sand, rock, gravel and cobble. Only sample SKVK2-5 consisted of silt, clay and some sand. The sample with the highest organism density (29,149 organisms/m^2), sample SKVK2-1, contained sand, rock and gravel while the sample with the lowest density, sample SKVK2-4 (3,120 organisms/m^2) was composed of cobble and sand (Tables 4 & 5).

DISCUSSION

Physical modifications associated with urbanization often result in the loss of habitats within estuaries (Squires 1992, Hawkins *et al.* 1992). The Harbor is an example of an estuarine system that is affected by urbanization. However, despite urbanization, the Harbor remains a productive estuary, and supports fairly diverse communities of benthic invertebrates (Iocco et al. 2000, Steimle and Caracciolo-Ward 1989, Woodhead et al. 1999).

The majority of species identified in grab samples collected during the 2005 and 2009 benthic macro-invertebrate surveys were nematodes, annelids (oligochaetes and polychaetes), arthropods, and mollusks (bivalves and gastropods). These taxa are typically found in the Harbor, and vary considerably in occurrence and abundance both seasonally and spatially (BVA 1998, Cerrato et al. 1989, Dean 1975, Iocco et al. 2000, Gandarillas and Brinkhuis 1981).

Figures 3 through 7 display summaries of calculated indices in each area sampled for both the 2005 and 2009 sampling efforts. Average density decreased 78% in the Ambrose Channel, and increased 436% in the Anchorage Channel, but decreased by 44% in the Kill Van Kull. Diversity and evenness increased 217% and 262%, respectively. Diversity and Evenness decreased 7.1 and 5.9%, respectively in Anchorage Channel. Diversity and evenness in the Kill Van Kull remained the same between sampling years (<1% decrease).

Sediment types were generally consistent between sampled years in the Ambrose and Anchorage Channels, but changes occurred in the Kill Van Kull from predominantly fine grained sediments in 2005 to relatively coarse grained sediments (e.g. coarse sand and gravel) in 2009. The exclusion of some species and the establishment of new species which were not previously found in the Kill Van Kull may occur as a result of the shift in sediment type, and the specific habitat needs for many species.

Changes in community composition between sampling years are evident. Blue mussel was the most abundant species collected in the Ambrose and Anchorage Channels in 2005, but was absent in 2009. Sample densities of up to 11,777 organisms/m^2 were recorded in 2005; however, these were the result of the collection of juvenile mussels, not adult mussels, as indicated by laboratory observations. Mussels are typically found in intertidal areas and require a hard substrate to successfully establish a reef, so it is unlikely that these mussels would have established and matured into a successful mussel reef given the absence of hard substrate at this location. Juvenile mussels go through an initial settlement period where they grow in a temporary location to about 1.5 millimeters in shell length. Upon reaching this length, the mussels release from the substrate and are passively carried by currents in bottom waters until they reach an adult mussel reef, where they permanently establish themselves (Newell 1989). The dense accumulations of juvenile blue mussels collected in 2005 were likely in the process of being passively transported by the currents to potential settlement locations in adult mussel beds. If these mussels were to have established in the soft substrate of the channel, it is unlikely that they would have survived since dense accumulations of mussels settled on soft substrate are frequently knocked free during storm events or other disturbances (Seed 1976).

In NY/NJ Harbor, sediment contamination, including synthetic compounds used in herbicide and pesticide production, metals, and petroleum hydrocarbons, has resulted from combined sewer discharges, urban runoff, stormwater runoff, industrial discharges, and maritime and industrial accidents (Bopp et al. 1991, Conner et al. 1979, Long et al. 1995, HEP 1996). The presence and concentrations of these contaminants could influence benthic community composition, species distributions, and species abundance (Stainken 1984, Cristini 1991, Long et al. 1995). Previous studies indicate that density and diversity of benthic organisms are negatively correlated with pollution and silt-clay content throughout the Harbor (Cerrato 1986, Stainken 1984).

Between 2005 and 2009 an increase in pollution tolerant species was observed, specifically in the Anchorage Channel. This increase in pollution tolerant species could be an indication that the resulting habitat following dredging is degraded in the short term, but many pollution tolerant species are also early colonizing species that can capitalize on disturbance.

Benthic sampling was conducted a little more than one year following dredging in Ambrose Channel and Anchorage Channel and two years following dredging in the Kill Van Kull, and as such the benthic communities in those contract areas are likely still in a state of transition.

Newell et al. (1998) describes the process of ecological succession and the re-colonization process of marine macro-benthic communities. Within the first year following disturbance, there is typically rapid re-colonization and population growth by R-selected species, which are opportunistic and reproduce quickly (e.g. Capitellidae and Ampelisca sp.) (Gray and Elliot 2009, Santos and Simon 1980, Tsutsumi 1987). Typically, less than one year after disturbance, the number of species is relatively low, but the number of organisms in the disturbed area is extremely high. At one year post-disturbance a second group of species begin to re-colonize the area. Species richness increases, but the number of organisms decreases. Mollusks such as Tellina and Nucula species usually re-establish during this time frame. After one year post-disturbance, longer-lived and less prolific K-selected species such as Sabellaria sp. also begin to recolonize the area. During this transitional period, a mixture of R-selected colonizers and stable (K-selected) species are present, as was generally observed in each of the sampled contract areas during the 2009 sampling. Eventually, the species composition and density begin to reach pre-disturbance conditions, or resemble a relatively stable community (Pearson and Rosenberg 1978). This community, though perhaps different from the pre-existing community, will nonetheless continue to provide trophic support and material/nutrient processing functions which contribute to maintenance of the estuarine benthos.

The observed difference in the abundance and diversity indices between the 2005 and 2009 samples are likely due to the communities still being in a transitional state. However, it is important to note that seasonal differences likely account for some variation between sampling years. Sampling in early spring and summer during 2005 may have resulted in a lower abundance of macro-invertebrates being collected than would have been collected later in the year such as in 2009 when sampling was conducted during September..

The benthic communities sampled in 2009 may have been different from the baseline conditions established during the 2005 sampling as a result of factors independent of the project, such as urbanization, commercial uses, and changes in water quality brought about by recent improvements to municipal wastewater treatment facilities Harbor-wide However, year-to-year changes in surface water quality alone are unlikely to translate into detectable changes in the benthic community in a historically disturbed, temperate estuary. Estuarine benthic communities are more likely to respond to changes in sediment dynamics, texture, and contaminant concentrations than to surface water quality – faunal assemblages of temperate estuaries are generally quite tolerant of annual fluctuations in water quality parameters such as DO, salinity, turbidity and pH. Prolonged severe hypoxia, on the other hand, would elicit a response, and analysis of long-term water quality records for the study area(s) would identify the occurrence of such events within the contract area(s).

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Table 1. Benthos Density (Organisms/m^2) collected in NY/NJ Harbor Navigation Channels, 2005.

Phylum	Class	Order	Family	GenusSpecies	Ambrose Channel					Anchorage Channel			Kill Van Kull Channel					
					AM-1	AM-2	AM-3	AN-1*	Ambrose	AN-2	AN-3	Anchorage	KVK-1	KVK-2	KVK-3	KVK-4	KVK-5	Kill Van Kull
Annelida	Oligochaeta	---	---	---	5	5	60	0	**70**	20	50	**70**	0	1,502	0	0	0	**1,502**
	Polychaeta	---	---	---	10	0	0	0	**10**	0	0	**0**	0	0	0	0	0	**0**
		Aciculata	Dorvilleidae	*Schistomeringos sp.*	15	0	0	0	**15**	0	0	**0**	0	0	0	0	0	**0**
			Pilargidae	---	5	0	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
		Arenicolidae		---	5	0	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Arenicola	*Arenicola sp.*	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
		Ariciida	Opheliidae	*Ophelia sp.*	0	0	5	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Orbiniidae	---	0	0	0	0	**0**	0	0	**0**	0	300	0	0	0	**300**
				Leitoscoloplos fragilis	0	0	0	0	**0**	0	0	**0**	0	0	0	250	25	**275**
				Leitoscoloplos sp.	0	0	10	7	**17**	150	0	**150**	0	0	0	0	0	**0**
		Canalipalpata	Ampharetidae	*Amage auricula*	0	0	0	0	**0**	15	0	**15**	0	0	0	0	0	**0**
			Sabellidae	*Potamilla neglecta*	0	0	0	15	**15**	0	0	**0**	0	0	0	0	0	**0**
		Capitellida	Capitellidae	---	10	0	0	7	**17**	100	75	**175**	0	0	0	0	0	**0**
			Maldanidae	---	0	0	0	0	**0**	35	0	**35**	0	0	0	0	0	**0**
			Cirratulidae	---	10	0	45	0	**55**	0	10	**10**	0	0	0	0	0	**0**
		Eucinida	Lumbrinereidae	*Lumbrineris sp.*	5	0	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Onuphidae	*Diopatra cuprea*	0	0	0	7	**7**	0	0	**0**	0	0	0	0	0	**0**
		Magelonida	Magelonidae	*Magelona sp.*	5	5	135	0	**145**	0	5	**5**	0	0	0	0	0	**0**
		Phyllodocida	Glyceridae	*Glycera sp.*	0	0	0	130	**130**	35	30	**65**	38	0	225	0	5	**268**
			Nephtyidae	*Nephtys sp.*	80	5	120	67	**272**	10	30	**40**	0	0	0	0	0	**0**
			Nereidae	*Nereis sp.*	0	0	0	0	**0**	0	0	**0**	100	300	75	50	0	**525**
				Nereis succinea	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
			Phyllodocidae	---	0	0	5	0	**5**	0	0	**0**	63	1,502	450	88	5	**2,107**
				Eteone sp.	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
				Phyllodoce sp.	10	0	0	0	**10**	0	0	**0**	0	0	0	0	0	**0**
			Polynoidae	---	0	0	5	7	**12**	0	0	**0**	0	150	0	0	0	**150**
				Lepidonotus sp.	0	5	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Syllidae	---	0	0	20	7	**27**	0	0	**0**	0	150	225	0	10	**385**
		Spionida	Chaetopteriadae	---	0	0	0	0	**0**	10	0	**10**	0	0	0	0	0	**0**
			Paraonidae	---	5	0	0	0	**5**	0	0	**0**	2,326	9,159	3,003	1,463	135	**16,085**
			Paraonidae	*Paraonis sp.*	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
			Sabellariidae	*Sabellaria vulgaris*	0	0	0	0	**0**	0	0	**0**	1,300	13,063	9,459	888	5	**24,715**
			Spionidae	---	5	10	140	22	**177**	5	15	**20**	0	0	0	0	0	**0**
				Polydora ligni	0	0	0	0	**0**	0	0	**0**	125	150	150	75	0	**500**
				Polydora sp.	0	5	5	0	**10**	0	0	**0**	0	0	0	0	0	**0**
				Scolecolepides viridis	0	0	0	0	**0**	0	0	**0**	0	0	75	0	0	**75**
				Spio setosa	0	0	0	0	**0**	0	405	**405**	0	0	0	0	0	**0**
				Spio sp.	0	0	0	30	**30**	20	90	**110**	0	0	0	0	0	**0**
				Spiophanes sp.	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
				Streblospio benedicti	0	0	0	0	**0**	10	0	**10**	125	601	6,231	300	5	**7,262**
		Terebellida	Ampharetidae	---	0	0	0	0	**0**	10	0	**10**	38	0	450	0	0	**488**
			Pectinariidae	*Pectinaria gouldii*	0	0	0	0	**0**	85	0	**85**	138	300	225	2,388	85	**3,136**
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	---	0	0	0	0	**0**	590	0	**590**	0	0	0	0	0	**0**
				Ampelisca abdita	0	0	0	0	**0**	0	0	**0**	0	0	0	25	0	**25**
				Ampelisca sp.	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
			Aoridae	---	0	0	0	0	**0**	0	0	**0**	25	6,006	3,679	0	0	**9,710**
			Gammaridae	---	0	10	215	7	**232**	0	0	**0**	325	450	0	0	0	**775**
				Gammarus sp.	30	0	0	0	**30**	0	0	**0**	0	0	0	0	0	**0**
			Melitidae	*Melita sp.*	0	0	0	0	**0**	0	0	**0**	0	0	150	0	0	**150**
			Phoxocephalidae	---	0	5	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
		Cumacea	Diastylidae	*Diastylis sp.*	0	0	0	0	**0**	0	0	**0**	0	0	150	0	0	**150**
		Decapoda	Cancridae	*Cancer irroratus*	0	0	0	250	**250**	0	0	**0**	0	0	0	0	0	**0**
				Cancer sp.	0	0	5	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Crangonidae	*Crangon septemspinosa*	0	0	15	0	**15**	0	0	**0**	0	0	0	0	0	**0**
			Paguridae	*Pagurus longicarps*	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
				Pagurus sp.	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
			Portunidae	---	0	5	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
				Ovalipes ocellatus	0	0	0	0	**0**	0	5	**5**	0	0	0	0	0	**0**
			Xanthidae	---	0	0	0	0	**0**	0	0	**0**	0	300	0	0	0	**300**
				Panopeus herbstii	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
		Isopoda	Anthuridae	*Cyathura polita*	0	0	0	0	**0**	0	0	**0**	25	0	0	0	0	**25**
			Idoteidae	*Idotea sp.*	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
		Mysidacea	---	---	5	0	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
			Mysidae	*Neomysis americana*	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
	Malacostraca	Decapoda	Portunidae	*Carcinus maenas*	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
		Isopoda	Cirolanidae	*Politolana sp.*	0	15	0	0	**15**	0	0	**0**	0	0	0	0	0	**0**
Chordata	Ascidacea	Pleurogona	Molgulidae	*Molgula manhattensis*	0	0	0	0	**0**	0	0	**0**	0	0	150	25	0	**175**
				Molgula sp.	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
Echinodermata	Echinoidea	---	---	---	0	10	0	0	**10**	0	0	**0**	0	0	0	0	0	**0**
		Clypeasteroida	Echinarachnidae	*Echinarachnius parma*	5	0	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
Echiura	Echiuroinea	Echiuroinea	Sipunculoidea/Echiuroidea	---	0	5	0	0	**5**	0	0	**0**	0	0	0	0	0	**0**
Mollusca	Bivalvia	---	---	---	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
		Eudesmodontida	Pandoridae	*Pandora gouldiana*	0	0	0	0	**0**	10	0	**10**	0	0	0	0	0	**0**
		Myoida	Myidae	*Mya arenaria*	0	0	0	0	**0**	0	0	**0**	0	601	0	0	0	**601**
		Mytioida	Mytilidae	*Mytilus edulis*	5	0	940	11,777	**12,722**	0	50	**50**	3,613	13,814	3,829	75	0	**21,331**
		Nuculoida	Nuculanidae	*Yoldia limatula*	0	0	0	0	**0**	5	0	**5**	0	0	0	0	0	**0**
				Yoldia sp.	0	0	0	0	**0**	0	0	**0**	0	0	0	0	0	**0**
		Veneroida	Mactridae	---	0	10	0	0	**10**	0	0	**0**	0	0	0	0	0	**0**
				Mulinia lateralis	0	0	0	0	**0**	45	0	**45**	225	0	0	75	0	**300**
				Spisula solidissima	0	0	0	0	**0**	30	35	**65**	0	0	0	0	0	**0**
			Solenidae	*Ensis directus*	0	0	5	0	**5**	5	5	**10**	0	0	0	0	0	**0**
				Siliqua costata	25	10	40	0	**75**	0	0	**0**	0	0	0	0	0	**0**
			Tellinidae	*Tellina agilis*	75	55	25	72	**227**	25	410	**435**	0	0	0	0	0	**0**
				Tellina sp.	0	0	0	0	**0**	0	0	**0**	38	0	0	0	0	**38**
			Veneridae	*Mercenaria mercenaria*	0	0	0	0	**0**	15	0	**15**	0	0	0	0	0	**0**
	Gastropoda	---	---	---	0	0	0	0	**0**	0	0	**0**	0	300	0	125	0	**425**
		Archaeogastropoda	Naticidae	---	0	0	0	0	**0**	0	0	**0**	0	150	0	0	0	**150**
				Neverita duplicata	10	0	0	0	**10**	0	0	**0**	0	0	0	0	0	**0**
		Cephalaspidea	Acteonidae	*Rictaxis puntcostriatus*	0	0	0	0	**0**	0	0	**0**	0	150	0	0	0	**150**
			Scaphandridae	*Acteocina canaliculata*	0	0	0	0	**0**	0	0	**0**	0	0	0	25	15	**40**
		Mesogastropoda	Calyptraeidae	*Crepidula fornicata*	0	0	0	0	**0**	0	0	**0**	0	150	0	0	0	**150**
		Neogastropoda	Nassariidae	*Ilyanassa trivittata*	0	0	5	0	**5**	0	5	**5**	0	0	0	25	0	**25**
Nematoda	---	---	---	---	0	0	0	50	**50**	0	0	**0**	1,550	12,312	3,679	19	5	**17,565**
Nemertea	---	---	---	---	20	0	20	0	**40**	95	0	**95**	0	0	0	0	0	**0**
Taxa Richness					**20**	**14**	**19**	**14**	**43**	**28**	**14**	**34**	**16**	**20**	**17**	**15**	**10**	**32**
Total Benthos Density (organisms/m^2)					**345**	**160**	**1,820**	**12,460**	**14,785**	**1,360**	**1,220**	**2,580**	**10,052**	**61,411**	**32,207**	**5,894**	**295**	**109,860**

* Station AN-1 was located within the Ambrose Channel contract area.

Table 2. Benthos Density (Organisms/m^2) collected in NY/NJ Harbor Navigation Channels, 2009.

Phylum	Class	Order	Family	Genus species	Ambrose Channel						Anchorage Channel						Kill Van Kull Channel					
					SAM1-1	SAM1-2	SAM1-3	SAM1-4	SAM1-5	SAM1	SAN1a-1	SAN1a-2	SAN1a-3	SAN1a-4	SAN1a-5	SAN1a	SKVK2-1	SKVK2-2	SKVK2-3	SKVK2-4	SKVK2-5	SKVK2
Annelida	Oligochaeta	---	---	---	0	20	0	150	0	**170**	400	675	400	150	0	**1,625**	601	450	0	0	0	**1,051**
	Polychaeta	Ampharetida	Ampharetidae	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	30	0	**30**
		Archiannelida	Polygordiidae	*Polygordius sp.*	0	0	0	0	0	**0**	0	0	0	0	67	**67**	0	0	0	0	0	**0**
		Ariciida	Orbiniidae	*Leitoscoloplos fragilis*	0	0	0	0	0	**0**	0	0	33	0	0	**33**	0	0	0	30	0	**30**
		Capitellida	Capitellidae	---	0	0	0	0	0	**0**	2,700	1,350	1,600	150	33	**5,834**	2,703	4,054	0	300	900	**7,957**
				Clymenella sp.	0	0	0	0	0	**0**	0	75	100	200	0	**375**	0	0	0	0	0	**0**
		Cirratulida	Cirratulidae	*Cirriformia sp.*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	50	0	0	**50**
		Eunicida	Lumbrinereidae	*Lumbrineris sp.*	0	0	0	17	14	**31**	0	0	0	0	10	**10**	0	0	0	0	0	**0**
			Onuphidae	*Diopatra cuprea*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	10	**10**
		Magelonida	Magelonidae	*Magelona sp.*	540	0	360	50	43	**993**	0	0	0	50	0	**50**	0	0	0	0	0	**0**
		Phyllodocida	Glyceridae	*Glycera sp.*	0	0	10	0	29	**39**	10	375	133	150	33	**702**	300	10	0	0	0	**310**
			Nephtyidae	*Nephtys sp.*	0	0	120	83	100	**303**	0	0	33	0	133	**167**	0	0	0	0	0	**0**
			Nereidae	*Nereis sp.*	0	30	0	0	0	**30**	0	0	0	0	0	**0**	300	0	350	60	75	**785**
			Phyllodocidae	---	0	0	0	0	0	**0**	0	75	0	0	0	**75**	10	150	50	60	75	**345**
			Polynoidae	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	150	0	0	**150**
			Syllidae	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	75	**75**
		Spionida	Paraonidae	---	0	50	0	583	286	**919**	0	0	100	150	217	**467**	0	450	0	0	0	**450**
				Aricidea sp.	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	0	300	**300**
				Aricidea fragilis	0	0	0	67	86	**152**	200	525	233	1,850	217	**3,025**	0	0	0	0	0	**0**
			Sabellidae	*Potamilla sp.*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	200	90	0	**290**
			Sabellaridae	*Sabellaria vulgaris*	0	0	0	0	0	**0**	0	0	0	0	133	**133**	19,820	1,201	1,250	570	225	**23,066**
			Spionidae	---	0	0	140	0	0	**140**	0	0	0	0	17	**17**	0	0	0	0	0	**0**
				Polydora ligni	0	30	0	0	0	**30**	0	0	0	0	0	**0**	0	450	0	210	0	**660**
				Spio sp.	30	0	0	67	14	**111**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
				Streblospio benedicti	0	20	0	17	0	**37**	900	1,125	467	150	17	**2,659**	601	450	50	270	600	**1,971**
				Scolecolepides viridis	0	50	0	0	0	**50**	0	0	0	0	0	**0**	0	0	0	0	2,176	**2,176**
				Spiophanes bombyx	50	0	10	0	0	**60**	0	0	0	50	0	**50**	0	0	0	0	0	**0**
		Terebellida	Pectinariidae	*Pectinaria gouldii*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	300	0	0	30	0	**330**
Arthropoda	Crustacea	Amphipoda	---	---	0	0	10	0	0	**10**	0	0	0	50	17	**67**	1,802	300	150	60	75	**2,387**
			Ampeliscidae	*Ampelisca abdita*	0	0	30	0	0	**30**	10,100	7,652	33	100	0	**17,885**	300	0	0	180	0	**480**
			Aoridae	---	0	0	0	33	0	**33**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
				Unciola sp.	0	0	0	0	0	**0**	0	0	100	0	0	**100**	0	0	0	0	0	**0**
			Caprellidae	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	300	150	0	30	0	**480**
			Corophiidae	*Corophium sp.*	0	0	0	0	0	**0**	0	0	0	0	17	**17**	0	0	200	150	0	**350**
			Lysianassidae	---	0	0	0	0	0	**0**	0	0	0	0	67	**67**	0	0	0	0	0	**0**
			Melitidae	*Melita sp.*	0	0	0	0	0	**0**	0	0	0	0	33	**33**	0	0	0	120	0	**120**
			Gammaridae	*Synchelidium americanum*	0	0	10	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Haustoriidae	*Parahaustorius sp.*	320	0	130	0	0	**450**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Lysianassidae	---	0	0	10	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Stenothoidae	*Parametopella cypris*	10	0	0	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Cancridae	*Cancer irroratus*	0	20	0	0	0	**20**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
		Decapoda	Paguridae	*Pagurus sp.*	0	0	0	0	0	**0**	0	0	33	0	0	**33**	0	0	0	0	0	**0**
				Pagurus longicarps	0	0	0	33	14	**48**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
				Pagurus pollicaris	0	0	0	0	0	**0**	0	0	10	0	0	**10**	0	0	0	0	0	**0**
			Pinnotheridae	*Pinnixa sp.*	0	0	10	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Xanthidae		0	0	0	0	0	**0**	0	0	0	0	0	**0**	300	0	0	0	0	**300**
				Hexapanopeus angustifrons	0	0	0	0	0	**0**	10	0	0	0	0	**10**	0	0	0	0	0	**0**
		Isopoda	Anthuridae	*Cyathura polita*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	300	0	0	0	0	**300**
			Idoteidae	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	0	30	0	**30**
			Idoteidae	*Idotea sp.*	0	0	0	0	0	**0**	0	0	0	0	17	**17**	0	0	0	0	0	**0**
		Stomatopoda	Squillidae	*Squilla empusa*	0	0	0	0	0	**0**	0	0	10	0	0	**10**	0	0	0	0	0	**0**
		Tanaidacea	Leptocheliidae	*Leptochelia savignyi*	40	0	0	0	0	**40**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Chordata	Ascidiacea	Pleurogona	Molgulidae	*Molgula manhattensis*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	700	660	0	**1,360**
Cnidaria	Anthozoa	Actiniaria	---	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	450	0	0	**450**
Echinodermata	Echinoidea	Clypeasteroida	Echinarachnidae	*Echinarachnius parma*	10	0	0	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Mollusca	Bivalvia	---	---	---	0	0	0	0	0	**0**	0	0	0	50	0	**50**	0	0	0	0	0	**0**
		Mytioida	Mytilidae	*Mytilus edulis*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	3,850	60	0	**3,910**
		Nuculoida	Nuculanidae	*Nucula sp.*	0	0	0	0	0	**0**	0	0	33	0	0	**33**	0	0	0	0	0	**0**
		Veneroida	Cardiidae	---	0	0	10	0	0	**10**	0	0	0	0	0	**0**	300	150	0	0	0	**450**
			Mactridae	*Spisula solidissima*	0	0	0	0	10	**10**	0	0	33	0	0	**33**	0	0	0	0	0	**0**
			Petricolidae	*Petricola pholadiformis*	0	10	0	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
			Tellinidae	*Tellina sp.*	30	0	90	33	57	**210**	0	75	0	50	267	**392**	0	0	0	0	0	**0**
	Gastropoda	---	---	---	0	0	10	0	0	**10**	0	0	0	0	0	**0**	0	0	0	0	0	**0**
		Archaeogastropoda	Naticidae	*Neverita duplicata*	0	0	0	0	0	**0**	0	0	0	10	0	**10**	10	0	0	0	0	**10**
		Neogastropoda	Muricidae	*Urosalpinx cinereus*	0	0	0	0	0	**0**	0	0	0	0	0	**0**	0	0	50	0	0	**50**
			Nassariidae	*Ilyanassa trivittata*	0	0	20	17	29	**65**	0	375	33	50	0	**458**	0	0	0	0	0	**0**
Nematoda	---	---	---	---	0	0	0	0	0	**0**	0	0	0	0	0	**0**	1,201	7,658	950	180	1,125	**11,114**
Nemertea	---	---	---	---	20	0	0	0	29	**49**	0	0	0	0	50	**50**	0	0	0	0	0	**0**
Taxa Richness					**9**	**7**	**12**	**11**	**11**	**29**	**7**	**9**	**14**	**11**	**14**	**28**	**15**	**11**	**13**	**18**	**11**	**32**
Total Benthos Density (organisms/m2)					**1,050**	**230**	**970**	**1,150**	**710**	**4,110**	**14,320**	**12,303**	**3,387**	**3,210**	**1,343**	**34,563**	**29,149**	**15,475**	**8,450**	**3,120**	**5,636**	**61,831**

Table 3. True taxa occurrence and total density (organisms/m^2) from each sample collected in NY/NJ Harbor Navigation Channels, 2005 and 2009.

Region	Sampling Year	Sample Name	True Taxa Occurrence								Total Density (organisms/m^2) Occurrence							
			Annelida		Arthropoda		Molluska		Other		Annelida		Arthropoda		Molluska		Other	
			NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Ambrose Channel	2005	AM-1	12	61.9%	2	9.5%	4	19.0%	2	9.5%	170	49.3%	35	10.1%	115	33.3%	25	7.2%
		AM-2	5	35.7%	4	28.6%	3	21.4%	2	14.3%	35	21.9%	35	21.9%	75	46.9%	15	9.4%
		AM-3	9	50.0%	3	16.7%	5	27.8%	1	5.6%	550	30.2%	235	12.9%	1,015	55.8%	20	1.1%
		AN-1	9	64.3%	2	14.3%	2	14.3%	1	7.1%	302	2.4%	257	2.1%	11,850	95.1%	50	0.4%
		Ambrose	**22**	**51.2%**	**9**	**20.9%**	**7**	**16.3%**	**5**	**11.6%**	**1,057**	**7.2%**	**562**	**3.8%**	**13,055**	**88.3%**	**110**	**0.7%**
	2009	SAM1-1	3	33.3%	3	33.3%	1	11.1%	2	22.2%	620	56.4%	420	38.2%	30	2.7%	30	2.7%
		SAM1-2	6	75.0%	1	12.5%	1	12.5%	0	0.0%	200	87.0%	20	8.7%	10	4.3%	0	0.0%
		SAM1-3	4	33.3%	5	41.7%	3	25.0%	0	0.0%	640	65.3%	210	21.4%	130	13.3%	0	0.0%
		SAM1-4	7	63.6%	2	18.2%	2	18.2%	0	0.0%	1,033	89.9%	67	5.8%	50	4.3%	0	0.0%
		SAM1-5	6	54.5%	1	9.1%	3	27.3%	1	9.1%	571	80.5%	14	2.0%	96	13.5%	29	4.0%
		SAM1	**12**	**41.4%**	**10**	**34.5%**	**5**	**17.2%**	**2**	**6.9%**	**3,065**	**73.5%**	**731**	**17.5%**	**316**	**7.6%**	**59**	**1.4%**
Anchorage Channel	2005	AN-2	15	53.6%	5	17.9%	7	25.0%	1	3.6%	515	38.0%	610	45.0%	135	10.0%	95	7.0%
		AN-3	8	57.1%	1	7.1%	5	35.7%	0	0.0%	695	57.7%	5	0.4%	505	41.9%	0	0.0%
		Anchorage	**18**	**52.9%**	**6**	**17.6%**	**9**	**26.5%**	**1**	**2.9%**	**1,210**	**47.3%**	**615**	**24.0%**	**640**	**25.0%**	**95**	**3.7%**
	2009	SAN1a-1	5	71.4%	2	28.6%	0	0.0%	0	0.0%	4,210	29.4%	10,110	70.6%	0	0.0%	0	0.0%
		SAN1a-2	6	66.7%	1	11.1%	2	22.2%	0	0.0%	4,201	34.1%	7,652	62.2%	450	3.7%	0	0.0%
		SAN1a-3	7	50.0%	4	28.6%	3	21.4%	0	0.0%	3,100	91.5%	187	5.5%	100	3.0%	0	0.0%
		SAN1a-4	7	63.6%	1	9.1%	3	27.3%	0	0.0%	2,900	90.3%	150	4.7%	160	5.0%	0	0.0%
		SAN1a-5	8	57.1%	4	28.6%	1	7.1%	1	7.1%	877	65.3%	150	11.2%	267	19.9%	50	3.7%
		SAN1a	**13**	**46.4%**	**9**	**32.1%**	**5**	**17.9%**	**1**	**3.6%**	**15,288**	**44.2%**	**18,249**	**52.8%**	**977**	**2.8%**	**50**	**0.1%**
Kill Van Kull Channel	2005	KVK-1	9	56.3%	3	18.8%	3	18.8%	1	6.3%	4,251	42.3%	375	3.7%	3,876	38.6%	1,550	15.4%
		KVK-2	11	55.0%	3	15.0%	5	25.0%	1	5.0%	27,177	44.3%	6,757	11.0%	15,165	24.7%	12,312	20.0%
		KVK-3	11	64.7%	3	17.6%	1	5.9%	2	11.8%	20,571	63.9%	3,979	12.4%	3,829	11.9%	3,829	11.9%
		KVK-4	8	53.3%	1	6.7%	4	26.7%	2	13.3%	5,501	93.3%	25	0.4%	325	5.5%	44	0.7%
		KVK-5	8	80.0%	0	0.0%	1	10.0%	1	10.0%	275	93.2%	0	0.0%	15	5.1%	5	1.7%
		Kill Van Kull	**14**	**43.8%**	**7**	**21.9%**	**9**	**28.1%**	**2**	**6.3%**	**57,774**	**52.6%**	**11,136**	**10.1%**	**23,210**	**21.1%**	**17,740**	**16.1%**
	2009	SKVK2-1	8	53.3%	4	26.7%	2	13.3%	1	6.7%	24,635	84.5%	3,003	10.3%	310	1.1%	1,201	4.1%
		SKVK2-2	8	72.7%	1	9.1%	1	9.1%	1	9.1%	7,217	46.6%	450	2.9%	150	1.0%	7,658	49.5%
		SKVK2-3	7	53.8%	1	7.7%	2	15.4%	3	23.1%	2,100	24.9%	350	4.1%	3,900	46.2%	2,100	24.9%
		SKVK2-4	10	55.6%	5	27.8%	1	5.6%	2	11.1%	1,650	52.9%	570	18.3%	60	1.9%	840	26.9%
		SKVK2-5	9	81.8%	1	9.1%	0	0.0%	1	9.1%	4,436	78.7%	75	1.3%	0	0.0%	1,125	20.0%
		SKVK2	**18**	**56.3%**	**7**	**21.9%**	**4**	**12.5%**	**3**	**9.4%**	**40,038**	**64.8%**	**4,449**	**7.2%**	**4,420**	**7.1%**	**12,924**	**20.9%**

Table 4. Benthic community true taxa richness, density (organisms/m²), Diversity (H'), and Evenness (E) from each sample collected in NY/NJ Harbor Navigation Channels, 2005 and 2009.

Region	Sampling Year	Sample Name	Taxa Richness	Density (organisms/m^2)	Average Density (organisms/m^2)	Diversity (H')	Evenness (E)	Proportion of Pollution Tolerant Taxa (%)	Proportion of Pollution Sensitive Taxa (%)
Ambrose Channel	2005	AM-1	20	345	--	2.50	0.82	4%	22%
		AM-2	14	160	--	2.32	0.86	3%	34%
		AM-3	19	1,820	--	1.79	0.60	4%	2%
		AN-1	14	12,460	--	0.32	0.12	0%	2%
		Ambrose	**43**	**14,785**	**3,696**	**0.81**	**0.21**	**1%**	**2%**
	2009	SAM1-1	9	1,050	--	1.34	0.61	0%	5%
		SAM1-2	8	230	--	2.06	0.99	20%	0%
		SAM1-3	12	970	--	1.96	0.79	0%	1%
		SAM1-4	11	1,150	--	1.86	0.78	14%	0%
		SAM1-5	11	710	--	1.95	0.81	0%	1%
		SAM1	**29**	**4,110**	**822**	**2.57**	**0.76**	**5%**	**2%**
Anchorage Channel	2005	AN-2	28	1,360	--	2.23	0.66	24%	6%
		AN-3	14	1,220	--	1.79	0.66	10%	37%
		Anchorage	**34**	**2,580**	**1,290**	**1.83**	**0.51**	**17%**	**21%**
	2009	SAN1a-1	7	14,320	--	0.90	0.46	28%	0%
		SAN1a-2	9	12,303	--	1.36	0.59	26%	0%
		SAN1a-3	14	3,387	--	1.86	0.66	74%	1%
		SAN1a-4	11	3,210	--	1.72	0.64	14%	2%
		SAN1a-5	14	1,343	--	2.37	0.84	4%	0%
		SAN1a	**28**	**34,563**	**6,913**	**1.70**	**0.48**	**29%**	**0%**
Kill Van Kull Channel	2005	KVK-1	16	10,052	--	1.79	0.65	3%	1%
		KVK-2	20	61,411	--	2.02	0.66	3%	0%
		KVK-3	17	32,207	--	2.00	0.71	19%	1%
		KVK-4	15	5,894	--	1.74	0.63	11%	0%
		KVK-5	10	295	--	1.54	0.67	10%	2%
		Kill Van Kull	**32**	**109,860**	**21,972**	**2.20**	**0.62**	**9%**	**0%**
	2009	SKVK2-1	15	29,149	--	1.33	0.48	13%	1%
		SKVK2-2	11	15,475	--	1.53	0.61	32%	0%
		SKVK2-3	13	8,450	--	1.82	0.69	1%	0%
		SKVK2-4	18	3,120	--	2.49	0.84	19%	0%
		SKVK2-5	11	5,636	--	1.75	0.73	27%	0%
		SKVK2	**32**	**61,831**	**12,366**	**2.18**	**0.62**	**18%**	**1%**

Table 5: Sediment type of each sample collected from NY/NJ Harbor Navigation Channels, 2005 and 2009.

Region	Sampling Year	Sample Name	Sediment Type
Ambrose Channel	2005	AM-1	sand/fine sand
		AM-2	sand
		AM-3	sand
		AN-1	sand/rock
	2009	SAM1-1	fine sand
		SAM1-2	clay
		SAM1-3	fine sand
		SAM1-4	sand
		SAM1-5	sand
Anchorage Channel	2005	AN-2	silt
		AN-3	silt
	2009	SAN1a-1	silt, clay
		SAN1a-2	silt, clay
		SAN1a-3	silt, clay
		SAN1a-4	fine sand, silt, clay
		SAN1a-5	fine sand, silt
Kill Van Kull Channel	2005	KVK-1	sand/rocks/clay
		KVK-2	sand
		KVK-3	Mussel shells, sand, mud
		KVK-4	mud/clay
		KVK-5	mud/clay
	2009	SKVK2-1	sand, rock, gravel
		SKVK2-2	sand (course/fine), gravel
		SKVK2-3	sand (course/fine), gravel
		SKVK2-4	cobble, sand
		SKVK2-5	silt, clay, some sand

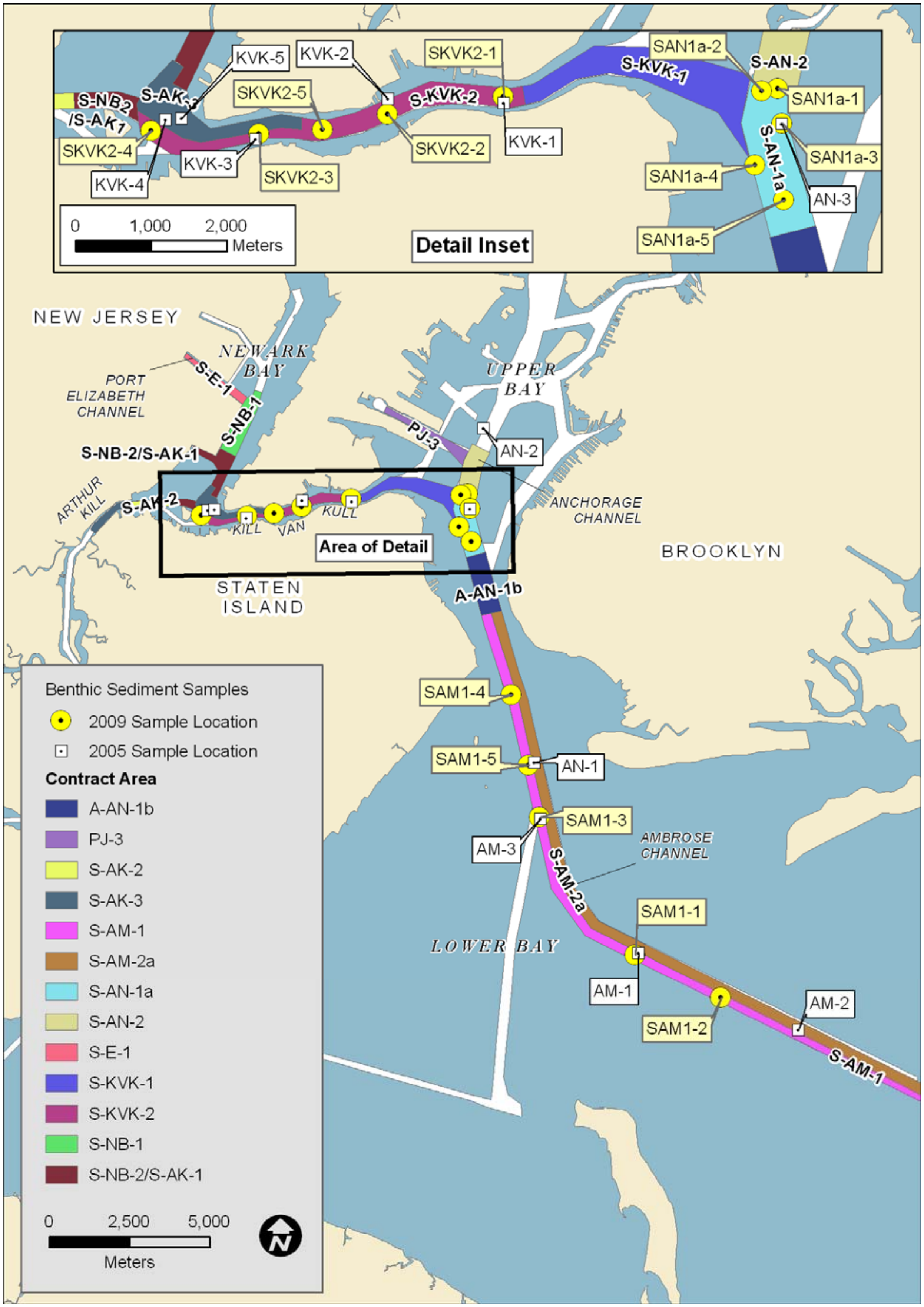

Figure 1: Over view of HDP contract areas and benthic sampling locations in 2005 and 2009

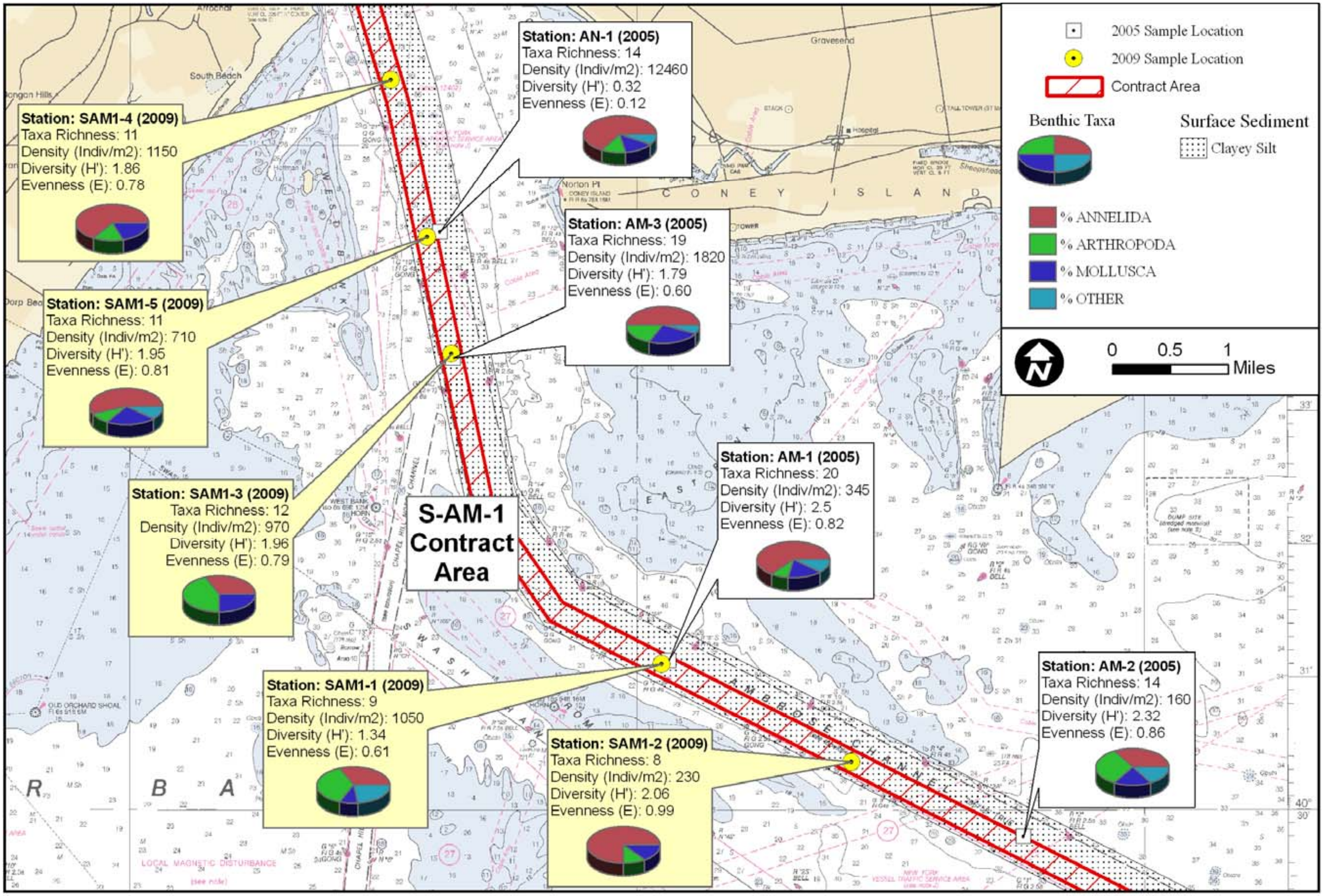

Figure 2a: HDP contract area S-AM-1 (Ambrose Channel) displaying Benthic Taxa and Surface Sediment for 2005 and 2009 sampling locations

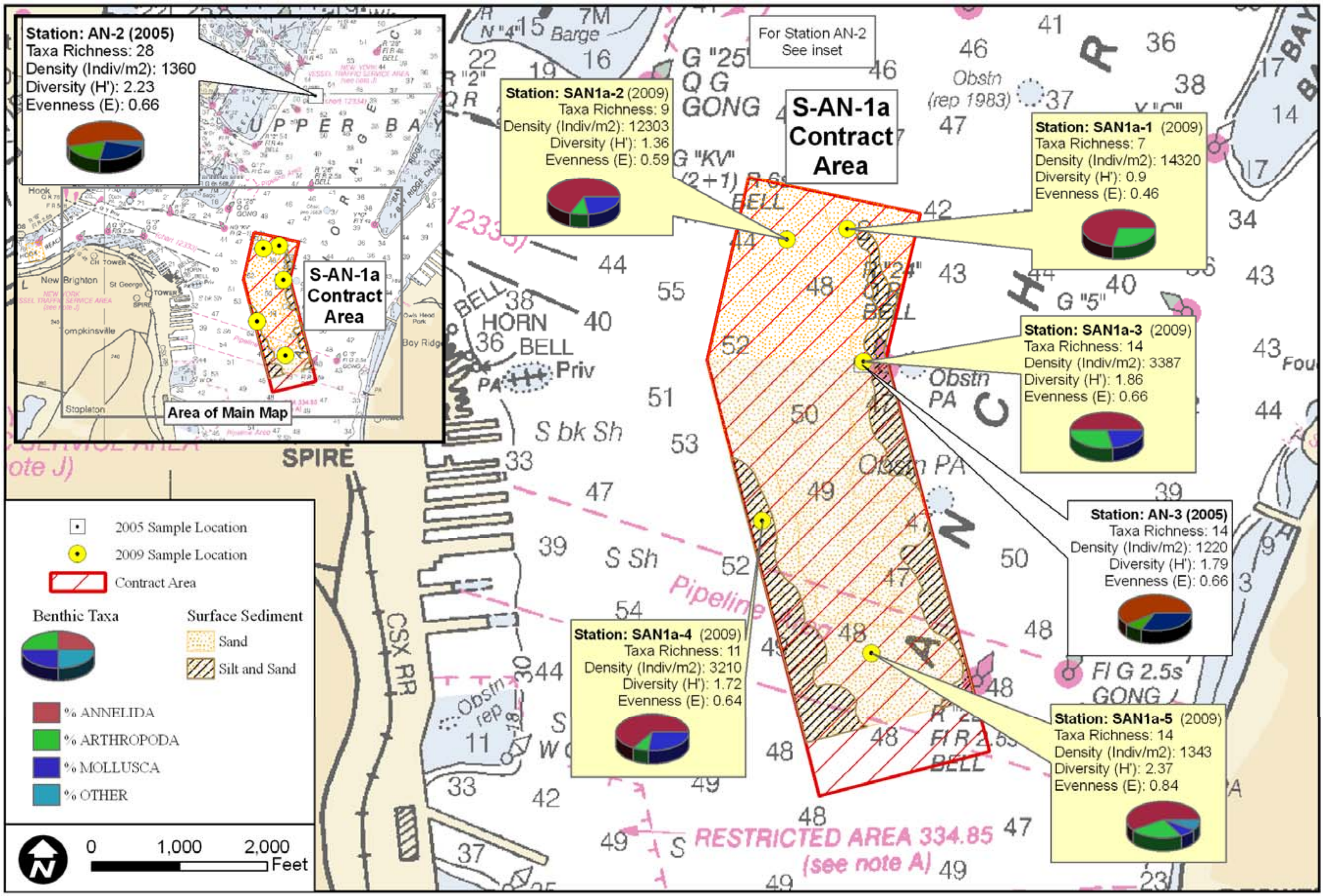

Figure 2b: HDP contract area S-AN-1a (Anchorage Channel) displaying Benthic Taxa and Surface Sediment for 2005 and 2009 sampling locations

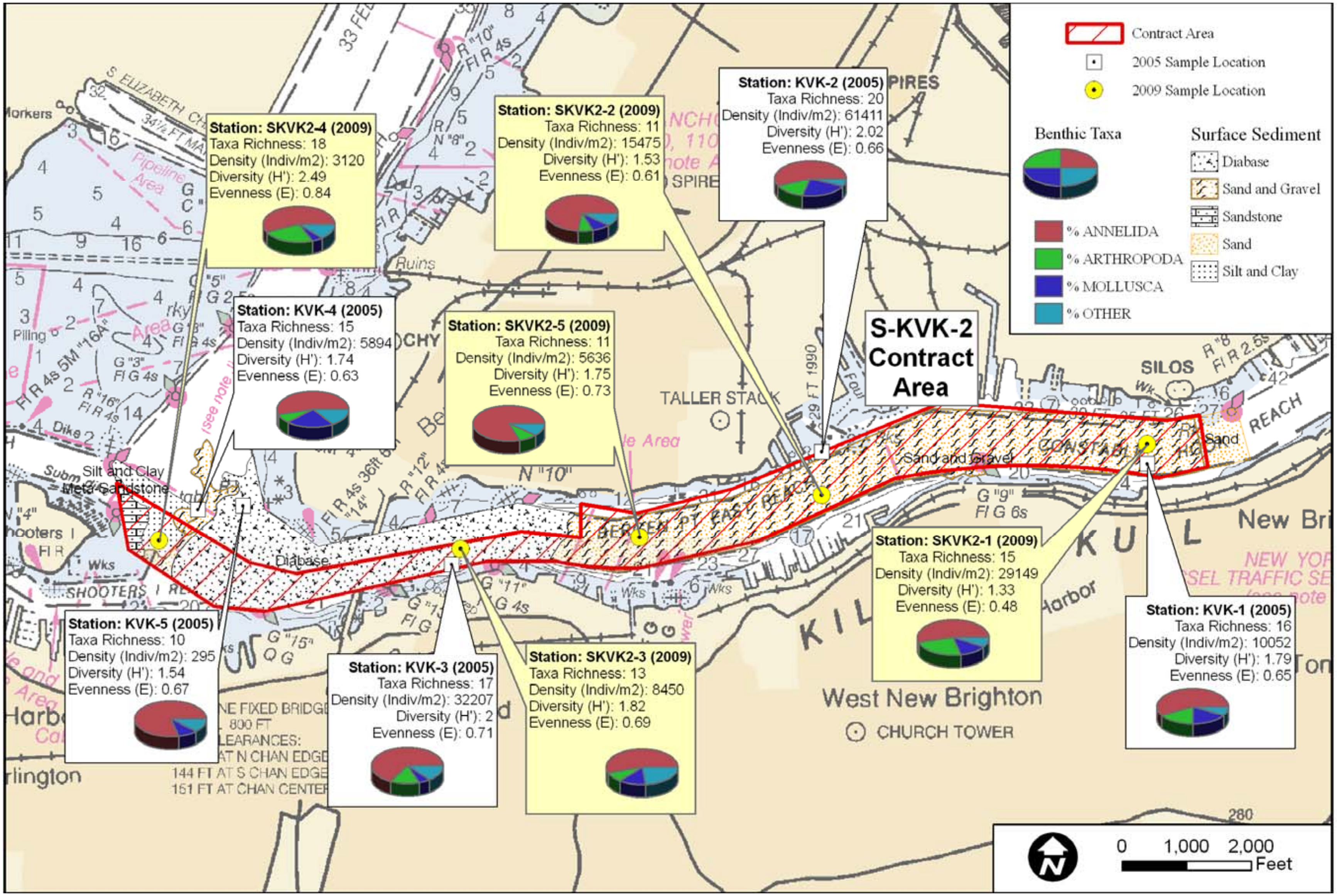

Figure 2c: HDP contract area S-KVK-2 (Kill Van Kull Channel) displaying Benthic Taxa and Surface Sediment for 2005 and 2009 sampling locations

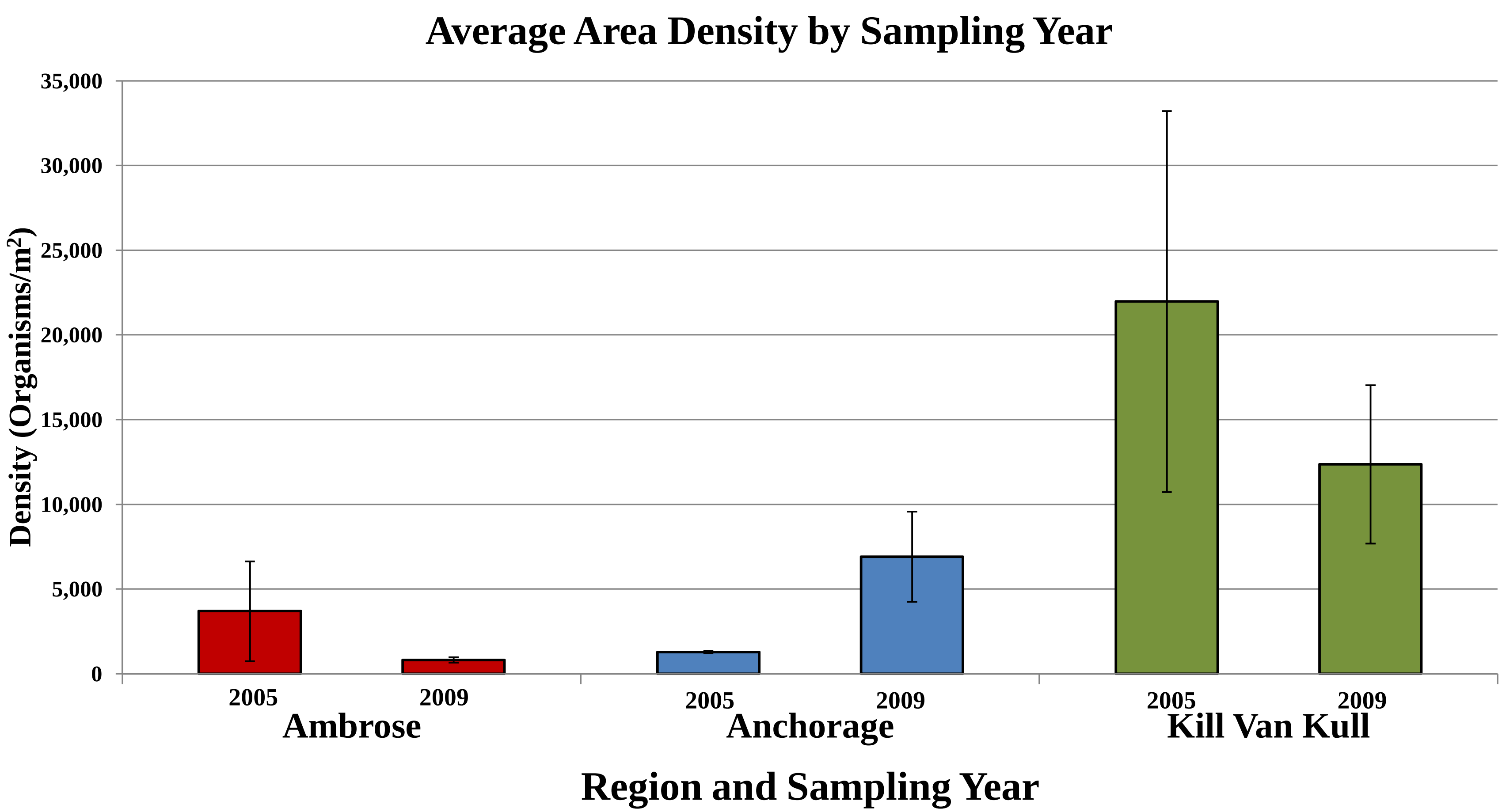

Figure 3: Average Benthic Macroinvertebrate Density ($\bar{x}$ ± 1SE) in Contract areas by Sampling Year

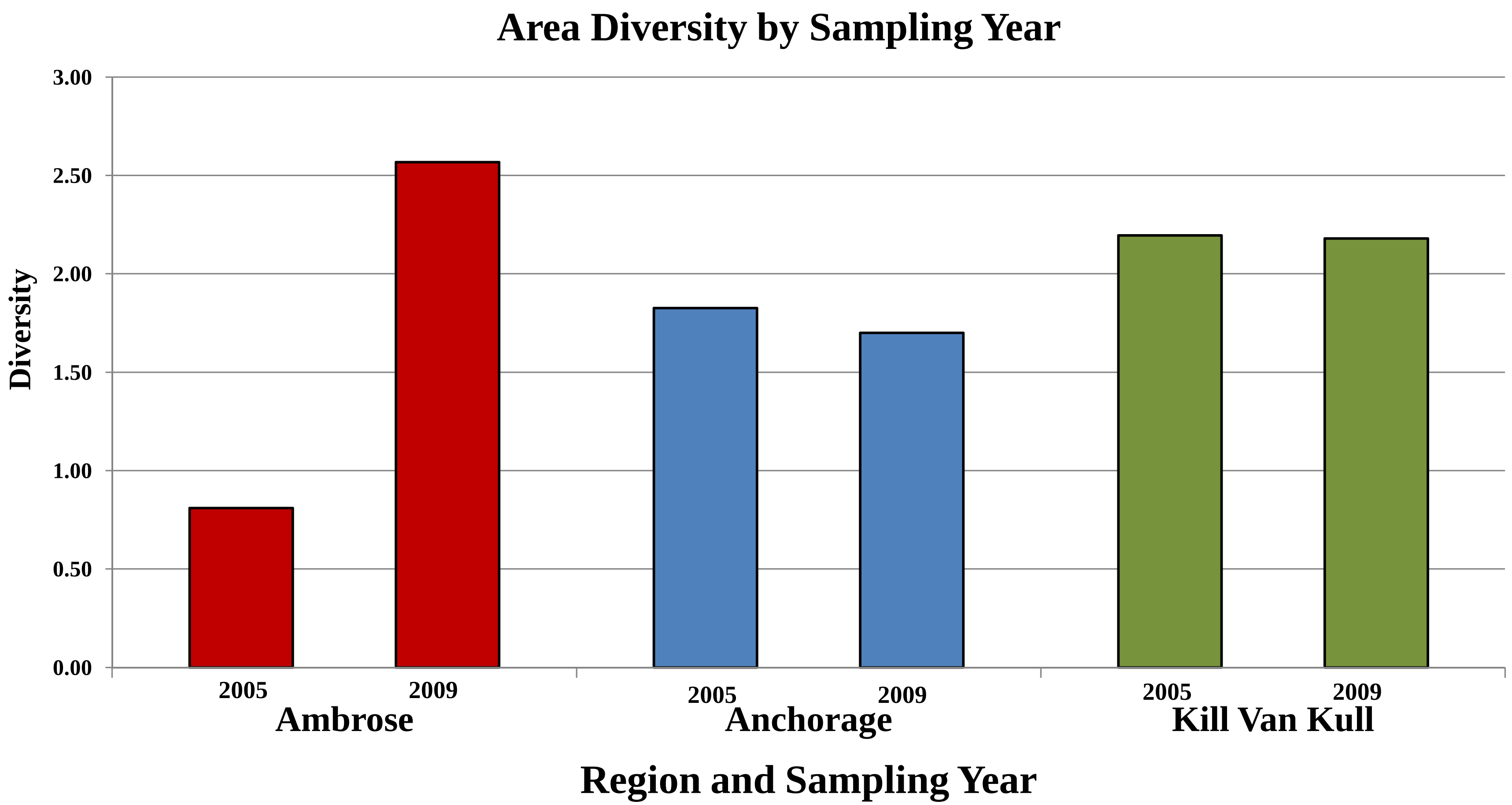

Figure 4: Benthic Macroinvertebrate Community Diversity in Contract Areas by Sampling Year

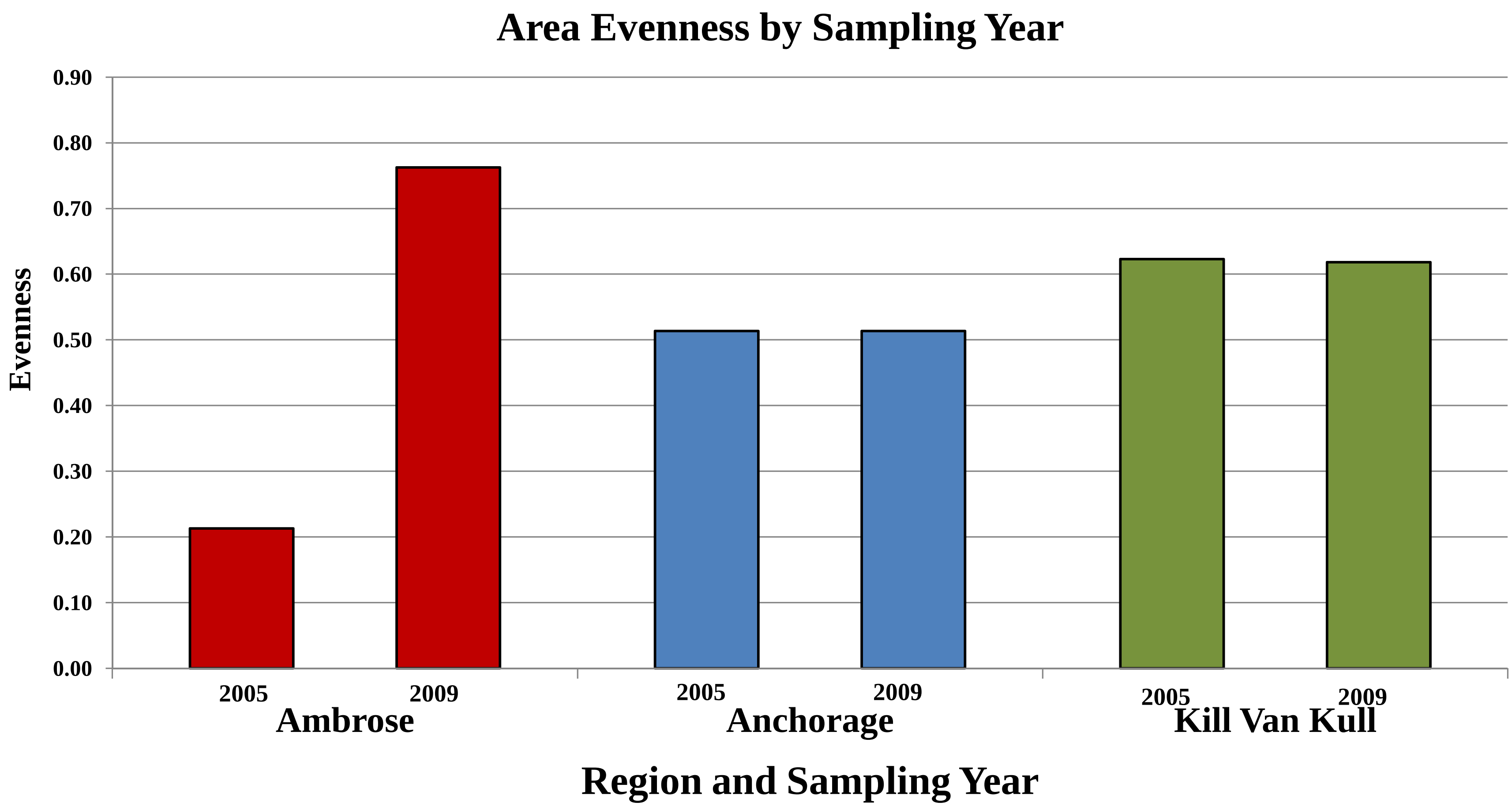

Figure 5: Benthic Macroinvertebrate Community Evenness in Contract Areas by Sampling Year

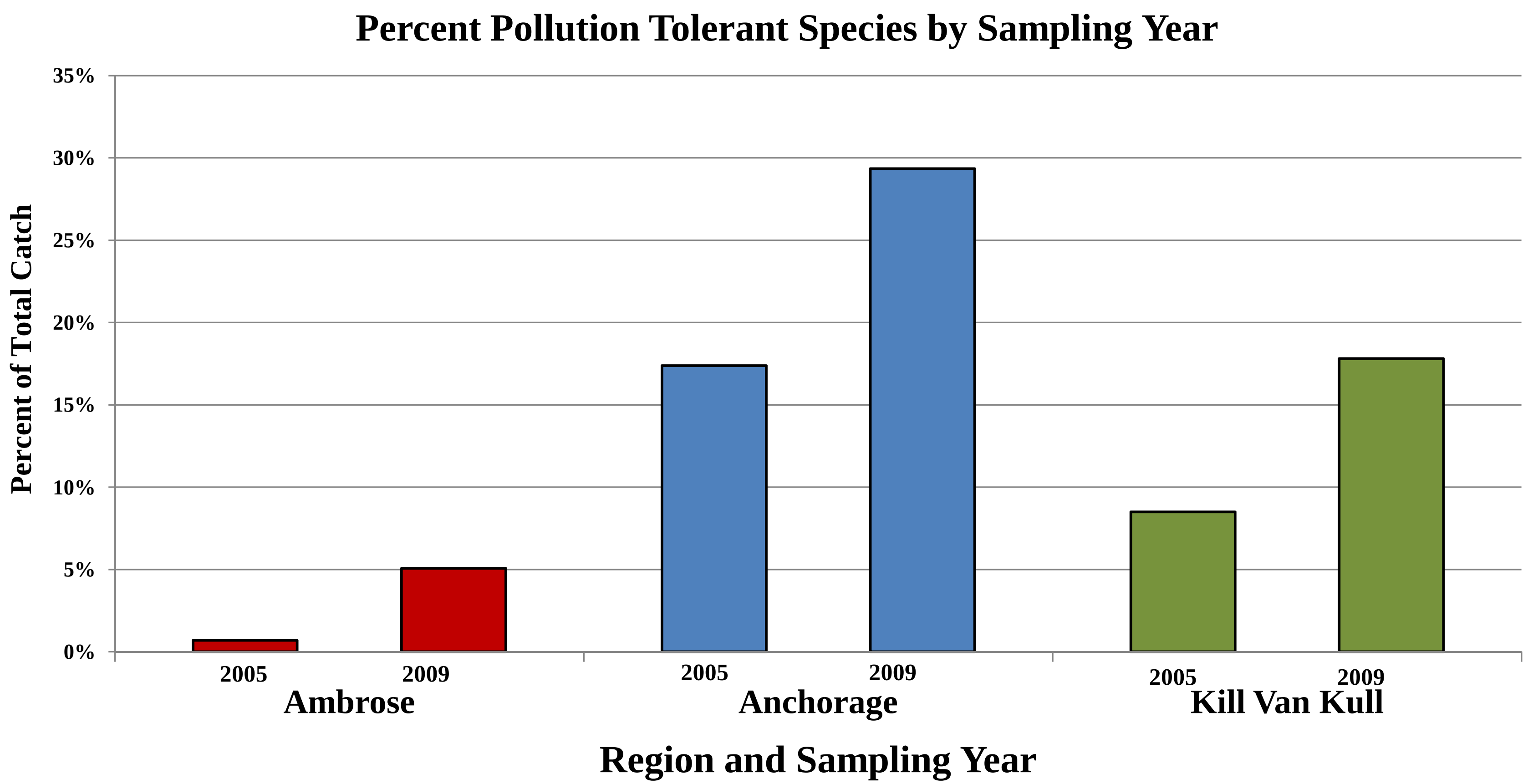

Figure 6: Proportion of Pollution Tolerant Benthic Macroinvertebrates in Contract Areas by Sampling Year

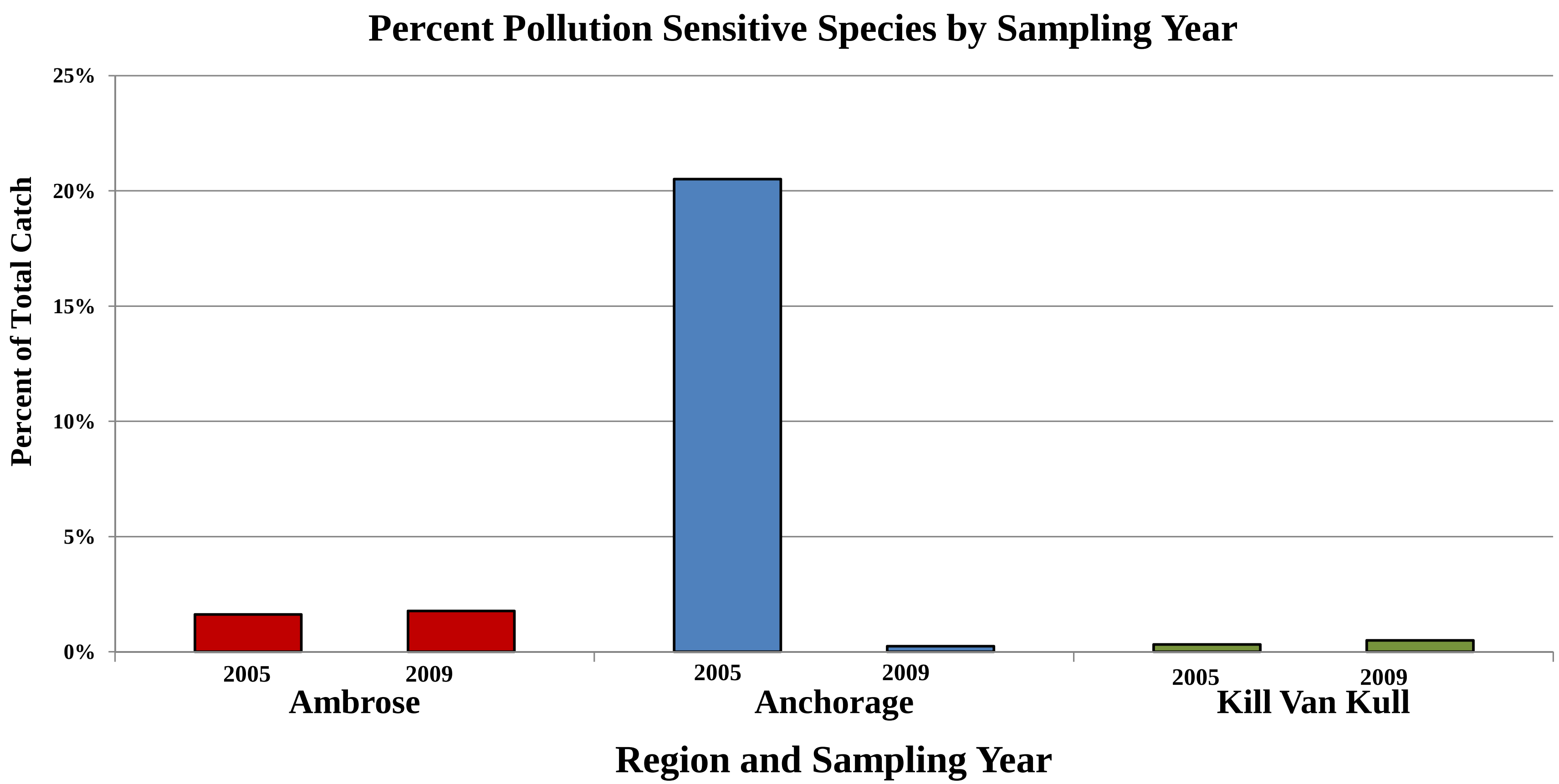

Figure 7: Proportion of Pollution Sensitive Benthic Macroinvertebrates in Contract Areas by Sampling Year