HUMAN IDENTIFICATION FOLLOWING THE WORLD TRADE CENTER DISASTER: ASSESSING MANAGEMENT PRACTICES FOR HIGHLY FRAGMENTED AND COMMINGLED HUMAN REMAINS

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Abstract

This study is a retrospective analysis of major management decisions, particularly those that involved anthropology, made during the World Trade Center human identification project. The objective is to understand why certain decisions were made and to access how those decisions affected the overall identification project from the perspective of increased efficiency, accuracy, and by increasing the number of identifications. Based on these results and insights, a list of recommendations is provided to help mass fatality managers better incorporate anthropological expertise into disaster victim identification projects.

Data used in the study are derived from the complete World Trade Center Human Remains Data Set of 19,970 human remains recovered from Ground Zero and the Staten Island Landfill in combination with qualitative evaluations of management decision made by the author during the World Trade Center identification project from September 11, 2001 through July 2004. Particular emphasis is on subsets of the World Trade Center Human Remains Data Set related to the implementation of anthropological review programs addressing commingled remains and for DNA analysis. Results indicate that the management decision to have anthropologists perform triage in the mortuary, and the decision to implement specific review programs designed to address missed commingling, increased efficiency, accuracy, and identifications.

Evidence indicates that lower limb bones from taphonomically compromised remains more reliably yield successful DNA profiles than the arms, trunk, or skull. Further, the patella and metatarsal bones yield at rates comparable to the femur and tibia and should be preferentially sampled for DNA during mass fatality identification projects. This research holds both empirical and theoretical significance. It provides the first empirically based study comparing DNA yields of different skeletal elements from a mass fatality event. It is also the first to use that information to propose disaster victim identification DNA sampling guidelines. Finally, it presents a framework for other mass fatality managers to follow in presenting critical evaluations of major management decision made during a mass fatality disaster victim identification project. These evaluations will increase the overall collective learning and contribute to future recommendations for other mass fatality managers to follow.

Keywords: mass fatality management; disaster victim identification (DVI); forensic anthropology; commingled remains; human identification; DNA sampling

This dissertation is dedicated

to those who were killed at the World Trade Center on September 11, 2001.

May we continue to learn from their tragic deaths.

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List of Abbreviations

AA	American Airlines
AFIP	Armed Forces Institute of Pathology
AM	Antemortem
AVP	Anthropological Verification Project
BCP	Body Collection Point
CED	Complete Elements Data Set
CIFA	Centre for International Forensic Assistance
CODIS	Combined DNA Index System
CT	Computed Tomography
DM01	Disaster Manhattan 2001
DMORT	Disaster Mortuary Operational Response Team
DNA	Deoxyribonucleic acid
DOH	Department of Health
DPMU	Deployable Portable Mortuary Unit
DQ01	Disaster Queens 2001
DVI	Disaster Victim Identification
ERT	Evidence Response Teams
ESD	Entire Sample Data Set
ESF	Emergency Support Function
FAC	Family Assistance Center
FAR	Final Anthropological Review
FBI	Federal Bureau of Investigation
FDNY	New York Fire Department
FDR Drive	Franklin D. Roosevelt Drive
FEMA	Federal Emergency Management Agency
FEMORS	Florida Emergency Operations Response System
ICS	Incident Command System
ISFG	International Society of Forensic Genetics
ME/C	Medical Examiner/Coroner
MFI	Mass Fatality Incident
MLI	Medicolegal Investigators
MOS	Members of Service
mtDNA	Mitochondrial DNA
NAME	National Association of Medical Examiners
NDMS	National Disaster Medical System
NIJ	National Institute of Justice
NIST	National Institute of Standards and Technology
NJDC	New Jersey Department of Corrections
NRF	National Response Framework
NRP	National Response Plan
NYDC	New York Department of Corrections
NYPD	New York Police Department
OCME	Office of Chief Medical Examiner
PAHO	Pan American Health Organization
PAPD	Port Authority Police Department
PM	Postmortem
PMI	Postmortem Interval
PPE	Personal Protective Equipment
RCMP	Royal Canadian Mounted Police
RD	Resampled Data Set
SD	Split Data Set
SEMS	Standardized Emergency Management System
SILF	Staten Island Landfill
SNP	Single nucleotide polymorphism
STR	Short-tandem repeat
UA	United Airlines
UV	Ultra-violet
VIP	Victim Information Profile
WHO	World Health Organization
WTC	World Trade Center
WTC 1	North Tower (WTC)
WTC 2	South Tower (WTC)
WTCHRD	World Trade Center Human Remains Database
x-ref	cross-referenced

Chapter 1.

Introduction

1.1. Why Identify Victims of Mass Fatality Incidents?

The Pan American Health Organization (PAHO) recognizes "that family members of people missing as a consequence of natural disasters have the right for their loved ones to be recovered, identified, and buried, respecting religious rites and cultural beliefs" (Pan American Health Organization 2004:143). It references a number of international law sources, including treaties such as the Geneva Conventions and principles of humanitarian law relating to the respectful identification and repatriation of enemy dead, as well as human rights conventions that have been interpreted as giving families a right to learn the truth about loved ones who have been "disappeared" (Pan American Health Organization 2004:140-144). This human right, which requires that States make their best effort to identify and repatriate dead following mass fatality incidents (MFIs), is based on the observation that the mental anguish that accompanies not knowing a loved one's fate inflicts continuing mental distress (Pan American Health Organization 2004; Weinstein 2002:143-144). It also recognizes that identifying remains is integral to the process of supplying justice for surviving family members and communities, and is required for legal reasons, such as closing out wills, assigning insurance benefits, and prosecuting crimes (Alonso, et al. 2005; Kahana, Ravioli, et al. 1997; Ludes, et al. 1994). As this right has emerged, we have seen increasing efforts to identify victims, whether they are soldiers lost during wars, victims of war crimes, or acts of terrorism (Cockle, et al. 2005; Corach, et al. 1997; Edson, et al. 2004; Jordan 1999; Skinner and Sterenberg 2005; Stewart 1970; Ubelaker, et al. 1995; Waaler 1972).

Sometimes even victims from natural disasters seek justice through victim identification. This became apparent following the May 2008 earthquake in China where thousands of children died in collapsed schools due to shoddy construction.

1.2. Research Questions

This retrospective study poses several research questions to examine predominantly anthropology-related mass fatality management decisions made during the World Trade Center (WTC) victim identification project. The decisions are evaluated to determine whether they increased the number of identifications and improved the efficiency and accuracy of the identification process. Efficiency is defined in this context as the conservation of both time and resources. The research questions are:

1. Did the major management decisions made during the mortuary operations of the World Trade Center identification project, particularly involving anthropology, affect the identification project? And, if so, how?

2. Did these decisions result in a more or less streamlined identification process?

3. Were the introduced programs effective, as reflected by increased numbers of identifications?

4. What lessons can be learned from the World Trade Center disaster victim identification project and applied to improve future victim identification projects? What factors limit the application of these findings and restrict their generalizibility?

One additional research question regarding current disaster victim identification (DVI) manuals will also be addressed:

5. Do the currently available disaster victim identification manuals adequately address the elements necessary to manage a large-scale DVI project?

Early in the WTC DVI process, the decision-makers decided to have anthropologists direct the triage of remains as they entered the mortuary. Triage has commonly been used to sort out nonhuman remains and commingling during mass fatality mortuary operations. I examine the role of anthropology at triage and the influence of anthropologist-directed triage on the identification project as a whole and on commingling in particular. Anthropologists have recently begun assuming greater decision-making roles during disaster victim identification projects. I will examine three additional programs designed and implemented by anthropologists during the World Trade Center victim identification project—the Anthropological Verification Project (AVP), the Final Anthropological Review (FAR), and a bone Resampling project to determine how these programs influenced the overall DVI project's outcome. I use the database of the 19,970 human remains recovered from the World Trade Center disaster to analyze the specific cases affected by these programs to assess whether the management schemes increased victim identifications. For example, the Anthropological Verification Project was implemented to find cases that were possibly still commingled, even after the initial examination. Potential cases of commingling were then split into many individual cases. I examine the results of the split cases from two perspectives: first, to determine how many new fragments were identified as a result of this program, and second, to ascertain why the commingling was overlooked during the initial mortuary examination.

I also evaluate remains documentation during mortuary examination by assessing the choice of forms used, the placement of information on those forms, and the decisions about what information was to be recorded. Finally, I again use the World Trade Center human remains data set to examine DNA based identifications success rates by skeletal element. The focus of this analysis is to determine which skeletal elements more commonly yield successful DNA profiles. The knowledge gained from these results could increase efficiency in DVI projects by allowing practitioners to first sample the bone elements that are likely to yield the most preserved DNA profiles. The results from this analysis are also presented from a mass fatality management perspective. While certain elements may yield DNA identifications at comparable rates, I will discuss managerial reasons for choosing certain elements over others during a DVI response. I also discuss the limitations of these results and the potential to apply them to other DVI projects with both similar and different characteristics as the World Trade Center disaster.

1.3. Objectives

The organizing questions for this thesis focus on the principles of efficiency, accuracy, and maximization of identifications. My goal in this thesis is to draw from the knowledge gained during the processing of the WTC disaster to establish common principles that can be applied to the management of future incidents. I have several reasons for writing this thesis, but primarily I believe that those of us who managed the WTC victim identification project learned a tremendous amount about identifying large numbers of highly fragmented human remains from a mass fatality event and that this information should be disseminated to those seeking guidance on managing DVI projects. It is my hope that this guidance can help ease the pressure, both scientifically and emotionally, for other DVI managers.

In most DVI projects "responders" are usually deployed on a 2-3 week rotation, but I had the unique experience of working on this project continuously, from September 11, 2001, through July 2004. As the only full-time anthropologist for the New York City Office of Chief Medical Examiner (OCME) at the time, I participated in nearly every aspect of the identification project. On September 11, 2001, I was a part of a team that was sent to the WTC complex, before either tower collapsed, to assess what the OCME should expect in terms of numbers of deceased and condition of remains. I then worked in the WTC mortuary for the following nine months it was in operation. My mortuary responsibilities ranged from triaging remains upon their arrival to the morgue, to examining remains and collecting the postmortem information on the remains. This postmortem information later became the basis of the data set I use for the analyses in this dissertation. As the lead anthropologist, I also oversaw the 33 anthropologists who "rotated" through the WTC identification project (mostly on three-week deployments) at the morgue, Ground Zero, and the Staten Island Landfill (SILF) operation. During this time, I also participated in establishing policies and protocols for DNA sampling, quality control, and remains release procedures. After the mortuary operations closed, I spent the next two years working with the medicolegal investigators (MLI) toward establishing and verifying new identifications, meeting with victims' families to review their case files, and attending family meetings to update victims' families on our progress.

Being involved with key decision-making and policy-implementation, along with my continuing hands-on work on this project, afforded me a rare holistic picture of the WTC DVI project. It allowed me to observe the repercussions of our early decisions, many of which did not emerge for weeks or months. It allowed me to then be part of the team that designed and implemented new programs to remedy these problems. Some new procedures were implemented because of patterns that emerged over time, patterns I likely would not have seen had it not been for my continuous engagement with this project. Working on the WTC DVI project over this long period was a unique experience and the lessons I learned motivated me to write this dissertation.

I also decided to write this thesis to contribute critical and scientific evaluations of these "lessons learned" and management decisions to the DVI literature. The DVI literature currently available is particularly lacking in critical evaluations of management decisions made during DVI projects. Numerous articles detail individual experiences, usually from the perspective of "we did this," but there is little in the way of "we learned this from what we did, and this is how we'd do it differently next time." At the end of this thesis, I provide a list of recommendations, mostly specific to anthropologically related decisions. These recommendations are designed to augment current DVI manuals as policy-makers design or implement their own DVI plans. I believe these recommendations will contribute significantly to filling the current void in the DVI literature.

1.4. Organization

Chapter 2 provides the context for this thesis with a description of the events of September 11, 2001, as they unfolded in New York City. I describe the response at Ground Zero, the Staten Island Landfill operation, and the OCME, and include details on the mortuary process and identifying the missing victims. Chapter 3 is a literature review providing descriptions of victim identification projects from historic disasters and the history of anthropological response to disaster victim identification, information on the growing use of DNA to identify disaster victims, and a review of the literature on managing overall disaster victim identification projects. I also address new areas of research by anthropologists and archaeologists pertaining to disaster victim identification. In Chapter 4, I compare and critically evaluate the currently available manuals, guides, and books on managing disaster victim identification projects. These manuals are evaluated on their overall usability and value in helping jurisdictions design their own guides and whether they include and are able to convey key information necessary for managing a mass fatality human identification project as identified by a panel of experts gathered by the World Health Organization (Tun, et al. 2005). They are also evaluated for their inclusion or otherwise of the role of anthropology in disaster victim identification processes.

Chapter 5 describes management decisions and policies, particularly those involving anthropology, implemented throughout the World Trade Center victim identification project. In this chapter I assess how these decisions seemed to help or hinder the identification project as a whole. Chapter 6 describes the data set used for the analyses presented in Chapters 7 and 8. In Chapter 7, I examine the differences in DNA yield success rates by skeletal element, with particular emphasis on determining which bones would be more appropriate sampling choices for future disaster victim identification projects. Chapter 8 focuses on the results of the management decision to implement the Anthropological Verification Project. The AVP re-evaluated nearly 17,000 cases for instances of commingling. This analysis discusses the factors that motivated the implementation of the AVP and whether this program increased the number of identifications. In Chapter 9, I summarize the major lessons learned from managing anthropologically related aspects of the World Trade Center victim identification project. This chapter provides recommendations for incorporating anthropologists into DVI projects to streamline the identification process and increase identifications. These recommendations will be useful to mass fatality managers and those designing disaster victim identification protocols.

Chapter 2.

Background

2.1. September 11, 2001

Four airplanes were hijacked over the USA on September 11, 2001. One was flown into the Pentagon building in Washington D.C., another crashed in a field in Shanksville, Pennsylvania, and two were flown into the World Trade Center buildings in downtown New York City. This section will cover the events in New York City.

At 7:59 a.m., on September 11, 2001, American Airlines (AA) Flight 11 departed Boston's Logan airport en route to Los Angeles carrying 92 individuals: 2 pilots, 9 flight attendants, and 81 passengers, of whom 5 turned out to be terrorists intent on bringing down the airplane. At 8:14 a.m. air traffic control had their last communication with AA Flight 11. At the same time, United Airlines (UA) Flight 175 departed Boston's Logan Airport, also en route to Los Angeles. This flight carried 65 individuals: 2 pilots, 7 flight attendants, and 56 passengers, of whom 5 were also terrorists intent on crashing the airplane. At 8:42 a.m., air traffic control logged their final radio contact with UA Flight 175. At 8:46 a.m. AA Flight 11 crashed into the North Tower of the World Trade Center complex between the 93rd and 99th floors. Seventeen minutes later, at 9:03 a.m., UA Flight 175 crashed into the South Tower of the World Trade Center complex between the 77th and 85th floors.

UA Flight 175, a Boeing 757 with 10,000 gallons of jet fuel on board, was traveling at approximately 590 mph, 150 mph faster than recommended at such low altitudes. At 9:59 a.m., 56 minutes after it was hit, the South Tower collapsed. The collapse lasted 10 seconds and registered 2.1 on the Richter scale (Marchi and Chastain 2002). Twenty-nine minutes later, at 10:28 a.m., the North Tower imploded in a 10-second collapse, measuring 2.3 on the Richter scale (Marchi and Chastain 2002). A total of 102 minutes separated the first airplane's impact and the second tower's collapse (NCTA 2004).

2.2. The World Trade Center Complex

The World Trade Center complex included seven buildings, most notably WTC 1 and WTC 2, referred to as the North and South Towers, respectively. WTC 3 was a 22-story Marriott Hotel and WTC 4-7 were large office buildings housing a variety of public and private organizations. New York City's Office of Emergency Management and the city's Incident Command Center were headquartered in WTC 7, and a United States Customs Office was located in WTC 6. All seven buildings, comprising over 12 million square feet of rental floor space, were destroyed as a result of the attacks (Marchi and Chastain 2002). WTC 1 and WTC 2 fell on the morning of September 11. WTC 3 suffered severe damage when the South Tower collapsed and fell later that morning. Building 7 collapsed that evening at 5:20 p.m. as a result of fire (Langewiesche 2002). Buildings 4, 5, and 6 suffered irreparable heavy damage and were later intentionally leveled. The ruined World Trade Center Complex covered 17 acres of downtown New York City.

Construction for the WTC complex began in 1966. The buildings were first occupied by early 1970. WTC 1 and WTC 2 were each 110 stories, or approximately 1,350 feet tall, with 10.4 million square feet of office space. On any given day approximately 50,000 people worked in the towers, while another 40,000 passed through in the underground mall connecting the buildings. The National Institute of

Standards and Technology determined that on the morning of September 11, 2001, between 16,000 and 18,000 civilians were in the WTC complex at the time of the first impact (NCTA 2004). In response to lessons learned from the 1993 bombing of the WTC buildings which killed 6 individuals—in particular, their assigning a fire safety director (who supervised a team of deputy fire safety directors) and conducting fire drill trainings at least twice per year—the Port Authority Police Department orchestrated a successful evacuation (NCTA 2004).

2.3. The Casualties

An official total of 2,749 people, from 27 different countries, were killed in the World Trade Center attack on September 11, 2001 (Gill 2005). Of the 2,346 civilians killed (403 additional deaths were first responders entering the buildings) approximately 1,942 are thought to have been at or above the level of impact (Hirsch 2008). Nearly everyone below the impact zone was evacuated safely. Of the people still in the buildings at the time of the collapses, only 18 individuals survived. Sixteen people were rescued from a portion of Stairwell B in the North Tower that was left partially standing after the collapse. Two Port Authority police officers also survived the collapse, but 403 Members of Service (MOS) were killed responding to the attacks that morning: 343 from the New York Fire Department (FDNY), 37 from the Port Authority Police Department (PAPD), and 23 from the New York Police Department (NYPD). Cantor Fitzgerald, a trading company occupying the top floors of WTC 1, lost 658 employees (Langewiesche 2002). Many of the remains recovered in the early days following the disaster were associated with artifacts like uniforms and identification cards. Therefore, knowing which particular organizations lost employees and how many were lost to each organization became important to the identification process.

2.4. The Response at Ground Zero

The disaster response was swift and intense although in the beginning there was no organized structure. The FDNY took the lead role while more than 3,000 unionized construction workers, structural engineers, and civil engineers assisted the NYPD, PAPD, and FDNY personnel at the site. From September 11 through September 29, 2001, the operation was designated a rescue as hope of finding other individuals who had survived the collapse continued. However, no more survivors were found, and after September 29, 2001, the rescue operation officially became a recovery. In late October the City established a "joint command" between the Department of Design and Construction and the uniformed services to manage the "unbuilding" of the site (Langewiesche 2002). Recovery operations at Ground Zero ran 24 hours per day in two 12-hour shifts for over 8 months. An official closing ceremony was held on May 30, 2002, when "The Pit" was finally empty, but excavations around Ground Zero and searches of nearby rooftops continue at the time of this writing in 2009.

2.4.1. Office of Chief Medical Examiner Personnel at Ground Zero

While the FDNY and the OCME were accustomed to working together during day-to-day events requiring the response of both agencies, the FDNY assumed complete authority over Ground Zero leaving the OCME's jurisdictional power limited to the handling of human remains. The OCME permanent presence at Ground Zero was restricted, although many key personnel were granted full access passes for site visits. OCME personnel fulfilled short-term and ongoing needs as they worked at a temporary holding facility within the restricted zone of Ground Zero. Long-term they logged in remains before they were transported to the morgue; short-term they were called to the site as periodic experts to assist recovery workers with specific situations.

The permanent OCME liaison personnel working at the site were not usually in the recovery area but in a temporary facility, called the Body Collection Point (BCP), where the body bags were brought from the site, catalogued, opened, and briefly checked before being transported to the OCME mortuary facility (located approximately 50 blocks north on 1st Avenue and 30th Street in midtown Manhattan) for identification. Initially, the Disaster Mortuary Operational Response Team (DMORT), a Federal-level disaster response team that provided additional personnel for the OCME, provided anthropologists and pathologists to assist the OCME medicolegal investigators at the BCP facility. Their role was to attempt to identify and then segregate possible "Members of Service" or MOS (that is, officers from the FDNY, PAPD, and NYPD) remains from those of civilians. This was accomplished primarily by visual observation of clothing and uniform material associated with the remains (Mackinnon and Mundorff 2006). For example, because firefighters wear bunker gear, if a partial leg within bunker pants was recovered from the site, that set of remains would be flagged as "possible MOS." Often the flagging process was straightforward, as in the case of a nearly complete body still in full uniform and obviously an MOS. But it could also be ambiguous, as was the case with a shard of bone found next to a shred of blue cloth. Since police officers' uniforms are blue, this piece might be flagged as well, although it was not as clear-cut as the previous example.

When remains were flagged as MOS, they were taken out of the routine, civilian transport system to be accorded an honor guard and special transport. MOS remains were immediately placed in an ambulance under police or fire escort that then rushed to the OCME. By contrast, civilian remains were placed in a refrigerated truck at the site that made deliveries to the OCME once it was full. Upon arrival at the OCME the remains were offloaded into another refrigerated holding trailer to await mortuary processing.

Because all the identification work was performed at the medical examiner's office, it quickly became apparent that the expertise of anthropologists and pathologists was unnecessary at the BCP. Duties at the BCP were taken over by a number of MLIs from the OCME who staffed this facility (2 per shift, 12 hour shifts) until recovery operations at Ground Zero closed in late May 2002 (Mackinnon and Mundorff 2006). The MLIs' role at Ground Zero continued to be keeping a log of body bags from the site prior to transport to the OCME. During the login procedure, they also continued to briefly check the remains to flag possible MOS. More important to the personnel back at the OCME, they communicated with mortuary staff, indicating when the remains transport trucks were en route to the OCME. MLIs also provided status reports on excavations at the site, alerting OCME personnel when a large "pocket" of human remains was to be excavated. Periodically, an area of the site would reveal a void that sometimes contained several bodies. Mortuary staff could then prepare for an increased volume of remains. Conversely, MLIs also notified OCME personnel when construction activities in the site slowed recoveries. Many areas within the site were unstable, including the slurry wall that had been erected during the original construction to keep the East River from flooding the foundation. Sometimes recovery activity stopped for days while engineers ensured the site was safe enough for the construction workers to proceed with excavations. These updates allowed mortuary staff to prepare accordingly, either gearing up with more staff or granting them much-needed downtime.

Additionally, experts from the OCME were occasionally summoned to Ground Zero to assist with specific recoveries. For example, when a large pocket of burned bone was discovered, recovery personnel from the NYPD asked for an anthropologist from the OCME to provide guidance on excavating, recognizing, and handling badly burned remains. At the request of the NYPD, the anthropologist assisted in constructing a large water screening system where buckets of remains were initially screened. The debris was then deposited on a large makeshift table within the site. Dozens of members of service surrounded the table and picked through the debris, looking for small fragments of bone or personal effects.

2.5. Excavating Ground Zero

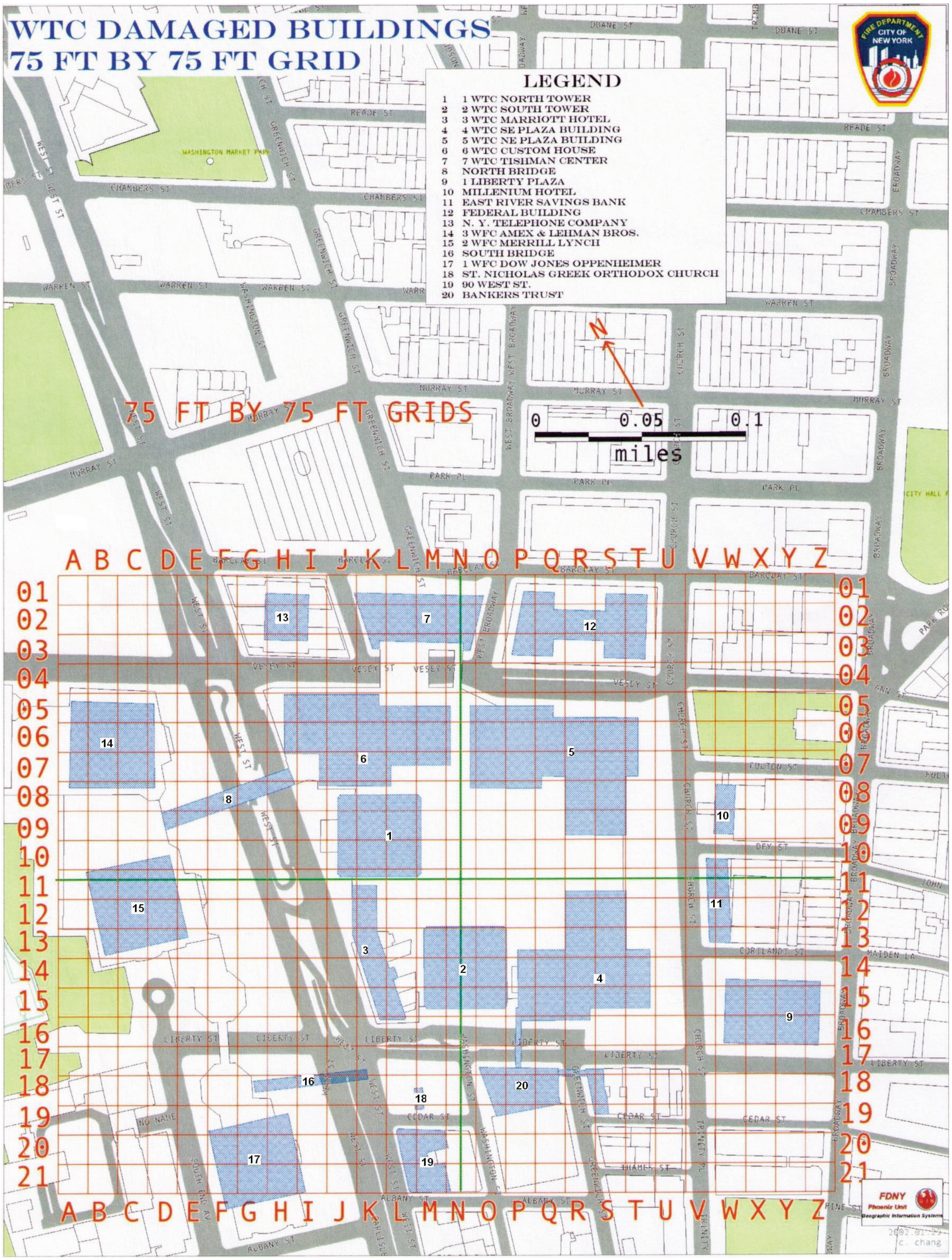
In November 2001, the Mayor's office decided to reduce the number of people working at Ground Zero and to bring in more heavy equipment to do the excavations (Simpson and Stehr 2003). Most of the excavating was then carried out by large diesel excavators with hydraulic arms and grappling claws that could cope with the excessive weight of the debris. This type of heavy machinery was needed because the weight of the debris was too heavy for ordinary truck buckets. The steel used to construct the buildings was the heaviest ever used for construction, each box column weighting 3,100 pounds per foot (Langewiesche 2002). More than 1.7 million tons of steel and debris was eventually removed from the site. Between 2 and 12,000 tons of steel alone were removed daily.

Three "hot spots" burned under the pile until January 2002. They burned at temperatures of up to 1,000°C for 12 weeks and were constantly doused with brackish water from the East River (Biesecker, et al. 2005; Marchi 2004). By this stage most remains were being excavated by the grapplers, which simultaneously tore and mashed the decomposing bodies, causing further destruction and commingling. The grapplers were described as, "gapped tooth claws that could open 8 feet wide, but could also close into an overbite so tight that it could snap twigs" (Langewiesche 2002:182). The aggressive manipulations by heavy machinery, combined with the effects of fires, water, and decomposition over time rendered most of the recovered human remains highly fragmented and unrecognizable. However, a few nearly intact bodies were recovered (less than 200), most prior to the New Year. And, of the relatively few recognizable body parts found, most were either encased in concrete dust from the pulverized building, which dried and mummified the remains, or were far enough from the fires to be "smoked" but not burned.

2.5.1. Spatial Control

Within days of the disaster, the FDNY sectioned the site into a grid system similar to that at an archaeological excavation, although no archaeologists were consulted for this project. The grid was divided into 546 sections (21 x 26) each measuring 75 ft x 75 ft (Figure 1), with x-y axis designations A-Z and 1-21. Body bags were labeled with locator tags indicating from which grid section the remains were recovered (e.g., M-14). Once the grid system was fully established, these grid locator tags were associated with nearly all body bags recovered from Ground Zero. However, depth was not always taken into account on the locator tags (although some had GPS coordinates), and because the initial pile stood over 70 feet above ground surface, eventually to be excavated 70 feet below the surface, this grid information was of only limited use in recording actual recovery location.

Figure 1. The Grid System Established Over the Ground Zero Site



Source. Fire Department, City of New York (2001), used with permission.

2.6. Fresh Kills: The Staten Island Landfill

The downtown financial district of New York City was much too small and congested to efficiently excavate and sort through the debris coming from Ground Zero. Therefore, city officials decided to send the debris to Fresh Kills, a landfill on Staten Island that had been closed and capped for six months. The Fresh Kills landfill is approximately 2,200 acres, 176 of which were set aside for the WTC debris (Langewiesche 2002). Here the debris was sifted for human remains not found during the initial searches at Ground Zero. The first truckload of debris arrived at the Staten Island Landfill (SILF) on the evening of September 11, 2001. In order to minimize dust from the trucks carrying the debris to the landfill and to speed up the transportation process, the old barge system originally used to transport garbage to the landfill was brought back into operation. Each barge could transport between 50 and 100 truckloads, and the 26-mile trip up the channel was significantly faster than the truck route through the city. Most of the debris (1.2 million of the 1.7 million tons) extracted from the site was eventually transported to the SILF by barge (Hirsch 2008).

Before being transported to the SILF, the debris passed through a two-stage inspection (Langewiesche 2002). First, during the initial excavation, recovery personnel (mostly MOS and construction workers) inspected the debris for human remains and collected anything they found. Then, as the debris was piled up at a collection point to be loaded into trucks and then transported to the pier for loading into the barges, it was inspected, a second time (usually using rakes), to recover remains overlooked during the first inspection. Once the debris was received at the SILF it was subject to a third and more rigorous inspection for human remains.

The debris was mostly made up of broken and crushed concrete, asbestos, asphalt millings, rebar, and light steel (structural steel went to a scrap yard in New Jersey), but it also included the day-to-day possessions of the 50,000 people who occupied the Towers before they fell (Langewiesche 2002). At the landfill operation, the debris was lifted by excavators into dump trucks that then created small mounds for the SILF workers to sort through (Photo 1). Metal and large concrete chunks were extracted and the rest of the rubble and debris was scooped into one of four shakers. The shakers removed debris pieces larger than six inches. These were spread out over a field and sifted by hand. Everything smaller than six inches was sent through more sifters that separated the material into three separate debris streams according to size (Langewiesche 2002). The debris was then carried out onto a conveyor belt where MOS scrutinized the material to collect anything resembling human remains, items of evidence, or personal effects (Photo 2). Because this was a police investigation and not just human remains were being collected, police personnel primarily occupied the conveyor belts. However, every possible fragment of human remains collected from the conveyor belts was taken to a tent where forensic anthropologists were stationed.

Photo 1. ***Members of Service Raking Through Piles of Debris at the Staten Island Landfill***

Source. Photo © Rich Press (2001), used with permission.

Approximately 7,000 tons of rubble were processed daily (Marchi and Chastain 2002). Operations at the landfill were split into two 12-hour shifts of up to 700 people each. The workers came from different city, state, and federal agencies and private contracting companies and were under the direction of the NYPD. As at Ground Zero, the OCME's authority extended only to matters directly involving human remains. The anthropologists assigned to the landfill operation were provided by DMORT but supervised by the OCME. Periodically, the OCME staff anthropologist traveled to the landfill to review and assess anthropology-related operations. This generally involved determining if there were sufficient anthropologists onsite and providing the MOS working the conveyor belts with training on recognizing fragmented, burned, and decomposing human remains by showing them actual burned and fragmented bones previously recovered.

Photo 2. Members of Service Monitoring the Conveyor Belts at the Staten Island Landfill Operation

Source. Photo © Rich Press (2001), used with permission.

At least two DMORT anthropologists worked during each shift at the landfill. As mentioned previously, they were stationed in a tent on site where their primary role was to examine items retrieved from the conveyor belts by the MOS to distinguish human from nonhuman remains (Warren, et al. 2003). A number of restaurants and catering services had been located in the WTC complex, contributing an unexpected amount of nonhuman remains to the debris. Anthropological expertise was important to quickly sort and discard this material and anthropologists worked at this location from early September 2001 through the New Year. Early January 2002, DMORT no longer provided anthropologists to staff the landfill operation and all recovered presumptive human remains were instead sent directly to the OCME, where an anthropologist sorted nonhuman fragments during the triage process.

NYPD personnel logged all remains recovered at the SILF site. Each set of remains was then individually bagged and secured with an evidence tag, which also indicated the remains' recovery as being "landfill," then photographed before being transported to the OCME. Because each body part was separately bagged, the incidence of commingled remains from the landfill operation was negligible. Recovered evidence and personal effects not directly associated with a set of remains were sent to the NYPD evidence unit.

In August, 2002, the landfill operation began winding down. The last piece of rubble from Ground Zero was delivered to the landfill on June 28, 2002, although some piles already at the landfill had still to be processed. At this stage, NYPD personnel noticed that the rooftops of buildings nearby the landfill had garbage, including bones, on them. When barges originally carried New York City garbage to the landfill, birds would pluck food items off and carry them away, depositing them on nearby rooftops. On the basis of this historical fact, searches were conducted on the rooftops and the bones were transported to the OCME for examination, although the assumption was that there would be no WTC association. Because the first assemblage consisted of ten industrial garbage bags filled with thousands of bones, all of which were determined to be nonhuman (Photo 3), OCME personnel decided it would be more efficient instead to periodically send an anthropologist to the landfill before transporting any more undetermined remains. No human remains were ever found with the unassociated nonhuman fragments from the rooftops, but the inspection was important to rule out the possibility that human remains had also been "stolen" off the barges by birds.

Photo 3. Contents of One of the Ten Bags of Nonhuman Bones Collected from Rooftops at the Staten Island Landfill

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.

The landfill operation closed in late August 2002. Anything that could be recycled, was, including more than 1,300 vehicles destroyed in the disaster. The remaining material was buried.

2.7. The Medical Examiner's Office

As the disaster unfolded, the OCME began organizing an independent response at the OCME mortuary. In accordance with existing plans, almost immediately on September 11 two refrigerated tractor-trailer truck units were placed outside the OCME building to store remains. A disaster of this magnitude would quickly overwhelm normal refrigeration capacity, the latter being needed to maintain daily morgue operations. Eventually, 24 tractor-trailer trucks stored the body parts until a stand-alone long-term storage refrigeration unit was purchased nearly 3 years later.

Finding space for hundreds of additional personnel and room to process the remains was also an initial concern. By the afternoon of September 11, the NYPD had closed 30th Street between 1st Ave and Franklin D. Roosevelt Drive (FDR) to all vehicular and pedestrian traffic. This area began filling with trailers and tents to house hundreds of volunteers, law enforcement personnel, and others who would support the identification efforts over the next several years. Instead of using the morgue where routine autopsies were conducted, OCME management decided to construct independent facilities for processing WTC victim remains. This temporary facility was built within the mortuary receiving bay and had semi-permanent tents attached to expand the structure onto 30th Street. Trucks and ambulances could then pull up to the temporary morgue receiving bay where remains could be off-loaded for immediate processing.

The temporary morgue had one table for the triage station, one table for post-triage cases waiting for examination, and six processing stations (Photo 4). Each processing station consisted of a gurney as the examination table for the remains and an equipment cart. The cart contained additional personal protective equipment as well as scalpels and blades, a Stryker saw and decontamination solution, extra bags and writing implements, tools for scraping dirt off remains, water and sponges for cleaning remains, and other items needed to conduct a full examination. The rest of the forensic subspecialties were located within the mortuary building to be closer to the permanent equipment such as x-ray machines. WTC remains were radiographed in the x-ray room used to x-ray daily autopsy cases. Dental examinations and dental x-rays were conducted in the previously designated dental exam room where the equipment was located. The OCME mortuary facility also has a second autopsy room, normally reserved for autopsying decomposing cases, which was transformed into the fingerprint room for the duration of the WTC project.

Photo 4. Examination Tables Set Up in Assembly Line Fashion in Temporary Mortuary

Source. Office of Chief Medical Examiner, New York City (2001), used with permission.

As in many previous disaster identification projects, instead of being autopsied, the remains were processed through an assembly line of forensic subspecialties (Busuttil, et al. 2000; Hooft, et al. 1989; Jensen 1999; Levinson and Granot 2002; Morlang 1986; Randall 1991; Sloan 1995; Wagner and Froede 1993). This configuration created a streamlined process whereby the remains could be sorted, examined, and sent to the next forensic station where additional analysis was conducted. For example, an amputated hand would be examined by the fingerprint station but not by the dental station. This arrangement proved advantageous in several ways. Not only were there relatively few intact bodies that could warrant an autopsy, but the cause and manner of the victims' deaths were not in question. Nearly all victims were certified as "blunt force trauma, homicide." This configuration also allowed facilities managers to keep WTC remains separate from the normal daily OCME caseload.

2.7.1. Mortuary Personnel

The assembly-line-type procedure was constructed to process the remains quickly and efficiently in the temporary mortuary. The flow of the remains through the system was smooth, with few incidents of bottlenecking with personnel, paperwork, or remains. NYPD, FDNY, PAPD, and Federal Bureau of Investigation (FBI) personnel were present at most stations to contribute their identification experience. FBI agents from the Evidence Response Teams (ERT), who are trained to perform excavations of human remains, were deployed to the OCME along with dozens of NYPD officers, including over 40 who moonlighted as funeral directors. Their familiarity with dealing with deceased victims and handling human remains made them a relatively easy fit for the mortuary work. FBI agents assisted at the first station—triage—to identify and seize possible evidence as the body bags were opened. PAPD and NYPD officers served in diverse roles. Officers assisted at the triage table and examination tables, and served as scribes for the medical examiners; crime scene officers photographed the cases; and evidence technicians collected and catalogued the personal effects associated with remains. New York and New Jersey Department of Corrections officers (NYDC, NJDC) transferred the remains from delivery trucks to the refrigerated trailers onsite at the OCME. They also unloaded the remains from the trailers to gurneys for processing in the mortuary. NYDC and NJDC personnel were also used as “escorts” for the remains as they went through the identification assembly line. Each escort remained with a single case and its file through the mortuary at all times, thereby ensuring a chain of custody. The FDNY were present to keep track of the remains that were presumed to be those of firemen, which was usually determined by clothing associated with the remains. Student volunteers from nearby medical schools also assisted in the mortuary (Goldstein 2005). These medical students served as scribes, taking notes for medical examiners as they processed the human remains. Fingerprinting experts from the NYPD and FBI handled the fingerprinting station and OCME consulting forensic odontologists augmented by DMORT forensic odontologists performed the dental examinations. Finally, DMORT also provided additional mortuary personnel, whose wide-ranging duties included serving as scribes and escorts, anthropologists for the triage table, and providing manpower for restocking supplies or transferring remains from the site trucks into the onsite refrigerators. However, only OCME forensic pathologists performed the examinations on the remains since only they were empowered to sign death certificates.

2.7.2. Remains Processing

Many forensic science subspecialties participated in this multidisciplinary endeavor, including forensic pathologists, anthropologists, odontologists, radiologists, radiographers, fingerprint experts, DNA specialists, evidence technicians, medicolegal investigators, photographers, morgue technicians, medical scribes, computer and information technology specialists, records personnel, and ancillary office staff.

The medical examiner's office received human remains several times a day. Remains were held in a preprocessing refrigerated trailer outside the temporary morgue until they were analyzed. Once inside the mortuary, the attending anthropologist, who was generally assisted by officers from the NYPD, PAPD, and FBI, first received the remains at the triage station for initial assessment. From the triage station, remains were placed on a holding table to await the medical examiner's examination, where the contents of each body bag were subsequently assigned a case number, documented, photographed, and sampled for DNA analysis. Depending upon which parts of the body were present—and whether there were any identifying features, personal effects, or evidence associated with the remains—each case was then taken by an escort to specialists in odontology, radiology, fingerprints, and evidence collection for further examination (Mackinnon and Mundorff 2006). Anthropologic analysis was primarily limited to the triage station and will be discussed in further detail in Chapter 5. Following these examinations, the remains were returned for storage to refrigerated trailers, situated in an area on 30th Street called Memorial Park, to await identification, release to funeral homes, and return to families.

2.7.3. Antemortem Information Gathering

While postmortem (PM) information on the remains was being gathered in the mortuary, the NYPD was collecting antemortem (AM) information about the missing victims. Both sets of data are necessary to begin matching information and making identifications. Within hours of the attack, the NYPD established collection points throughout the city to begin gathering missing person reports and antemortem material on the victims. Many workers in the WTC complex commuted into the city; therefore, police agencies outside the city also collected missing person reports from families in their communities and forwarded this information to the NYPD. Within weeks of the attack, the City of New York consolidated this process and established a single Family Assistance Center (FAC) at Pier 94 on the west side of Manhattan.

The antemortem information was gathered on a DMORT seven-page questionnaire, the Victim Identification Profile (VIP), that could be filled out by friends, co-workers, or family members of presumed missing individuals. This form records details of the missing person such as name, race, sex, eye color, weight, height, scars, tattoos, piercing, surgery, and any other physical characteristics that might individualize someone. It also records what victims were wearing and carrying when they disappeared, including jewelry, watches, cell phones, and purses, and where they were when they were last seen or spoken to. In addition, medical records and other items useful in victim identification, such as dental records, family DNA exemplars, victim's DNA (taken from a razor or toothbrush for example), and photographs, were collected.

At the FAC, NYPD personnel collected the personal reference and kinship samples and performed interviews with victims' families to collect data for the VIP forms. Hundreds of DMORT volunteers logged thousands of hours to complete the data entry for thousands of these VIP forms. Months later, OCME staff including forensic biologists and medicolegal investigators organized a second round of antemortem information collection to ensure direct items had been collected for every possible victim or indirect reference samples had been collected from every possible family member who wanted to donate a DNA sample (Hennessey 2002). This second round of information collection was also initiated because unfortunately, one-sixth of the initial information collected had to be corrected because of missing data, incorrectly recorded data, improper kinship sampling, or data entry errors (Hennessey 2002).

2.7.3.1. Who Was Missing?

Determining who to collect information on, or more specifically, determining who was missing, was a challenge because of the magnitude and characteristics of the disaster. The NYPD was initially responsible for collecting the antemortem information, but the OCME was responsible for establishing the official missing persons list. Therefore, the VIP forms filled out by family members or co-workers at Pier 94 were necessary not only to begin making matches for identifications, but also to start the long process of finalizing the missing persons list. However, because there were no restrictions on who could fill out this form, multiple forms were often created for the same missing person, meaning a single individual could be listed as missing many times. Some VIPs created by different reporters for the same missing person contained conflicting information for the birth year or even different spellings of the person's name (Hennessey 2002). In other cases, some victims did actually share the same first, middle, and last names. At one point there were over 60,000 official missing person reports in the system (Ribowsky and Shachtman 2007). Consolidating the redundant reports was challenging but essential to establish an official missing persons list.

The WTC incident is considered to have an “open population” because there was no immediate list of the victims. By contrast, an incident involving an airplane crash, where there is a manifest listing the passengers, is considered a “closed population.” The distinction between the two is important to mass fatality managers (van den Bos 1980). Open population disasters are more challenging with respect to collecting antemortem information; without a list of the victims there is no easy way to determine from whom and from where to collect the antemortem data. The WTC complex was not only a massive office space, it was also open to the public, had a mass transit hub beneath it, and was a major tourist destination. These factors added to the lengthy process of compiling a final list of victims.

As seen in previous disasters with open populations, the predicted number of fatalities fluctuated greatly in the first few weeks and there was a significant overestimation of the number of dead (Brondolo 2004; De Valck 2006; Jordan 1999; Simpson and Stehr 2003; Sweet 2006). Fatality estimates on September 11, 2001, ranged up to 20,000 people from 88 countries, though that number dropped quickly (Gill 2005). A month after the event, however, the estimated number of deceased remained above 6,000. It took three years to finalize the number of victims.

During the antemortem and postmortem data collection process, the OCME developed a computer database that would store and allow for the easy matching and retrieval of pertinent ante- and postmortem data. Most of the VIP forms had been entered into the system during the first few months following the disaster, but a few new forms were still added over the next two years. This database was a work in progress and took a few years to complete, but the information entered into it meant matches were made throughout the process.

Chapter 3.

Literature Review

3.1. Introduction

> How are dead bodies treated when they are absolutely or relatively many in number, unanticipated and unexpected in their appearance, concentrated rather than dispersed in their location, and where the response to death and the existing professional social organization for dealing with dead bodies cannot follow the usual path for that community? [Blanshan and Quarantelli 1981:3].

This literature review addresses several issues related to mass fatality management. In particular, it will focus on the history of anthropological contributions to the management of mass fatality incidents. The next section will review new areas of anthropological research specific to DVI. The research investigates new applications of Computed Tomography (CT) to DVI and the application of forensic archaeology techniques to disaster scenes. The emergence of DNA technology in DVI will also be covered. Finally, the existing literature on managing overall identification efforts following a mass fatality incident will be reviewed.

The death of an individual is momentous when it occurs within our immediate circle, but is routine for the myriad public agencies that handle and account for death every day. Our public agencies are generally well equipped to deal with routine, individual deaths, but most lack the resources, both logistical and theoretical, to prepare for the possibility of mass death. Some medical examiner/coroner (ME/C) offices do develop their own disaster plans but prior to September 11, 2001, these had been limited to incidents on the scale of a passenger airplane crash (Biesecker, et al. 2005; Gilliland, et al. 1986; McCarty, et al. 1987; Mittleman, et al. 2000; Morlang 1986; Scanlon

1998). New York City's OCME was one of the ME/C that had a disaster plan in place, but it did not cover the use of DNA, which turned out to be responsible for more than half the identifications following the WTC disaster (Gill 2005; Hirsch and Shaler 2002).

Significant benefit has been found in not only planning for, but practicing mock disasters as well (Bedore 2008; Pretty, et al. 2001; Pretty, et al. 2002; Sledzik and Kauffman 2008). Planning and preparing for disasters is unequivocally cheaper, both economically and socially, than being caught off guard and having to conjure up an impromptu management plan (Eyre 2002; McCarty, et al. 1987; Morlang 1986), but what happens when the number of dead is beyond anything ever envisaged by the plans in place? Unplanned events, unexpected numbers of victims, and the problems associated with finding, collecting, removing, and identifying the dead can force disaster management personnel to improvise on their existing plans (Blanshan and Quarantelli 1981).

What mass fatality incidents have in common is what separates them from the regular, individual daily deaths handled by the medical examiner/coroner system; that is, the scale or the sheer number of dead, long and often complicated body recoveries often involving buried remains, and burned or fragmented remains that complicate identification. Those responsible for the recovery and identification of the victims frequently have a reactive response instead of a planned proactive response to the incident because either the disaster is beyond the scope of the plan they have in place or through inexperience. Furthermore, depending on the scale of the disaster, many tasks may require the assistance of workers not professionally trained to deal with dead bodies (Blanshan and Quarantelli 1981). These factors affect the relative success of any mass disaster recovery and identification project.

3.2. Historic Disasters

Medical examiners, coroners, scientists, dentists, sociologists, funeral directors, police, radiologists, anthropologists, and other responders have been writing about their experiences of recovering and identifying deceased disaster victims for nearly a century (Ballantyne 1997; Brannon and Kessler 1999; Filippi 2007; Hinkes 1989; Hoffman and Oliver-Smith 2002; Nye, et al. 1996; Palmer 2001; Paul 1984; Pine 1969; Reals and Cowan 1979; Robb 1999; Sledzik and Kauffman 2008; van den Bos 1980; Woodward 1982). In fact, a 1917 ship explosion in Halifax, Canada, that killed over 1,400 individuals was one of the first disasters to spur recovery workers to compile reflective and descriptive books detailing their personal experiences of identifying the victims (Deacon 1917; Foster 1917; Tooke 1918).

Most of these writings are story-like narratives that simply describe the disaster without providing any insight into the key decision-makers and their decisions. For example, much of the information about the Halifax disaster is found in the autobiography of a young schoolboy who lived near the local school that was used as a makeshift mortuary (Scanlon 1998). In 1998, Joseph Scanlon, a disaster communications researcher in Canada, used this autobiography along with other material to publish the first article examining “how the bodies were handled” after the 1917 Halifax explosion. He concluded that this “incident changed the way bodies were dealt with” (Scanlon 1998:302).

Scanlon surmised that there was no formal response, describing it instead as ad hoc and illustrating his assessment with stories of regular citizens recovering and moving dead bodies, some to places as far away from the scene as 60 miles. Some bodies were moved to funeral homes, hospitals, or even collection points, and others were dumped in ditches or left to pile up. Only when the bodies began to pile up did the army decided to step in and help with the handling of the deceased. A school was used as a mortuary and the army personnel assisted in cleaning, documenting, and numbering the dead bodies, although the civilians remained in control of the process (Scanlon 1998). Detailed descriptions of the dead were published in local newspapers to assist in identification and families would visit the mortuary to review the written descriptions of the dead. If any descriptions resembled their missing loved one, they viewed the body to make the identification. Many bodies could not be identified, but the respect showed to the dead was evident as these unidentified were buried in numbered individual graves and not simply in one mass grave (Scanlon 1998).

Historically, the U.S. has been fortunate to have suffered relatively few high-death-toll events. One of the most notable mass death incidents is the 1906 San Francisco earthquake and fire. The city became caught up in dealing with the living, displaced, and ruined infrastructure and the dead seemed to simply disappear. The literature on the incident is silent on how the city dealt with the dead. For decades the official death toll from the San Francisco earthquake was less than 500. However, in the mid-1980s, Gladys Hansen, a museum curator, began reviewing the official death records and coroner reports. These records listed numbers only, no names, but as Hansen carefully worked through the scant information and low tally, she eventually concluded that the official number count was wrong (Hansen 1987; Hansen and Condon 1989). After years of Hansen's persistent research, the death toll from that disaster now stands at over 3,000, and is most probably even higher. But what these figures do not tell us is what the city learned from the high number of deceased victims, and how they dealt with these dead bodies. This too was never documented.

Other significant disasters such as large fires and explosions have also claimed great numbers of lives (Davis 2002). For example, the worst harbor explosion in U.S. history, the 1947 explosion of the French ship *Grandcamp*, destroyed over one-third of Texas City, Texas, and killed 752 individuals (Davis 2002). In this incident, most bodies were either blown into small unidentifiable fragments or completely destroyed during the ensuing extreme fires (Davis 2002). The small fragments were collected by locals and taken to a makeshift morgue in a nearby abandoned garage, although little could be done to identify these fragments at that time (Stephens 1993). And again, as with the San Francisco earthquake, there is no documentation or discussion about how the dead were recovered, identified, certified, or disposed of, let alone what lessons were learned from dealing with the deceased victims of this disaster. Smaller incidents, such as airplane crashes, fires and floods, and even a few terrorist events, with victim tallies in the dozens or low hundreds, are more often noted throughout North America (Charney and Wilber 1984; Clark, et al. 1989; Jordan 1999; McCarty, et al. 1987; Randall 1991; Ubelaker, et al. 1995; Vosswinkel, et al. 1999). Many of these disaster victim identification projects following mass fatality events have gone undocumented in the scientific literature, although more recent events are now being more thoroughly documented.

There are several recent works in the academic literature on victim identification projects following mass fatality incidents, but most of them are anecdotal writings that describe only the role of specific practitioners (such as pathologists, radiologists or odontologists) within the overall identification process and they can have little technical value (Brannon and Kessler 1999). Such articles often lack a critical analysis of the specialists' skills used and of how these skills fit within the greater identification scheme. Further, writings on the specific role of the forensic anthropologist in DVI have been limited until very recently, although there appears to be a correlation between the increased responsibility of anthropologists during DVI projects and the amount of new literature detailing this work. However, most of what is available is still limited to “what we did” as opposed to “what we learned” or “how can we apply this knowledge” next time. More importantly, the literature on how to *manage* these massive and complicated identification efforts is rare.

3.3. History of Anthropology in Disaster Victim Identification

3.3.1. The Earliest Contribution

Around midnight on June 17, 1896, the British ship *Drummond Castle* crashed off the coast of Ushant, France, and sank in about three minutes. Only 3 of the 252 individuals on board survived. Within days of the disaster, locals had scoured the coastlines and recovered 53 bodies. Famed anthropologist Alphonse Bertillon, known for his work in identifying criminals through photographs and anthropometric measurements, was asked by government officials to travel to Ushant to photograph and document for identification purposes the victims of the shipwreck (Rhodes 1968). Despite knowing that there would be little comparative material to use and that his identification techniques were based on his experience with the criminal population, Bertillon traveled to the scene with a photographer to document the remains. He measured, photographed, and recorded every detail possible, including approximate age, sex, scars, and anomalies such as “harelip” or “diminutive stature for a male”. Personal effects were also catalogued in detail. Letters and engraved jewelry likely contributed toward the 10 identifications that were made from Bertillon’s 27 official descriptions, although there are no official surviving records detailing his work there (Rhodes 1968). However, one individual was likely identified based on Bertillon’s descriptions alone (Rhodes 1968). Nellie Peachey was described as "Woman about 30. Height 6 feet. Features strongly marked of masculine type. Nose very arched. Upper lip with scar like a hair-lip [*sic*] extending from base of nose to middle of lip. Abundant chestnut hair" (Rhodes 1968:136). With no labeled personal effects to help single her out, her unique physical description must have contributed to her identification.

Bertillon's describing the physical remains of these shipwreck victims to aid identification is quite possibly the earliest known account of an anthropologist participating in a disaster victim identification process. He was not working with a team of specialists performing autopsies to determine cause of death, but was called upon specifically because of his expertise in using anthropometrics and photography to identify criminals. Sadly, there is little in the way of records that detail his work with the *Drummond Castle* victims in Ushant.

3.3.2. The Twentieth Century

Most of the earliest accounts by forensic anthropologists document their contributions as part of a team identifying war dead, largely from World War II, the Korean War, and the Vietnam War (Sledzik 2009). Following a seminar held at the Smithsonian Institute in 1968, anthropologist T. D. Stewart edited the book, *Personal Identification in Mass Disasters* (Stewart 1970). Although many of the chapters in this book do not directly relate to mass disaster victim identification, the book does contain some of the earliest contributions by anthropologists and pathologists detailing their various roles in identifying disaster and war victims, including A.K. Mant's chapter "Identification Involving Atrocities" (Mant 1970).

3.3.2.1. Mant

Mant believed that war is the greatest mass disaster of all and that the severe destruction to which the victims of war are subjected often creates special identification problems (Mant 1970). Mant and his colleagues were responsible for identifying airplane crash victims and individual murder victims often buried in unmarked graves. The remains recovered from airplane crashes were often so severely fragmented that the investigating was limited to determining the number of victims. Mant details two important lessons learned from his experiences, lessons that are often relearned and repeated throughout the literature for the next 39 years. First, dental records are generally only reliable for identification when they are accurate and complete. Mant and colleagues often found dental records lacking and this frequently frustrated their efforts at identification. Second, mistakes made during exhumations cannot be fixed later; properly trained personnel are essential for successful identification (Mant 1970).

3.3.2.2. Waaler

In his 1972 article *Personal Identification in Mass Disasters*, the Norwegian forensic pathologist E. Waaler details his work identifying victims from two separate disasters. The first, in 1944, was an explosion of dynamite on a boat moored adjacent to the city that subsequently burned many nearby buildings, killing 93 individuals. The second incident was a fire in a tourist hotel in 1959, killing 24 (Waaler 1972). In his article, Waaler highlights the differences between the two identification projects. In particular he notes whether forensic experts were present at the scene from the beginning of the disaster and the consequences that follow from having a scene controlled by non-experts. Interestingly, this continues to be a recurring theme in today's disaster victim identification literature.

In his comparison of the two incidents, Waaler stresses that the rapid response to the 1944 explosion, which was primarily to locate and rescue potential live victims, later caused identification problems of the deceased because no site provenience or any other location information was recorded as the bodies were recovered. By contrast, after the 1959 hotel fire, Waaler, and his team of a police inspector and a forensic odontologist evaluated the scene before any bodies were recovered. They adopted archaeological excavation techniques, including the use of spoons and small spades for digging, which allowed them to gather critical information that was later used to help identify victims.

By using these archaeological techniques, the preserved context of the hotel fire allowed Waaler to use evidence in association with the bodies or their locations to help identify many of the victims. In fact, the place of discovery for many of the bodies was integral to their identification. Waaler stated that many identification problems encountered after the 1944 explosion could have been avoided if better documentation procedures had been used at the scene (Waaler 1972). Because the 1944 scene was not accurately documented, the identification team had to reconstruct scene information to determine the exact locations of victims and associated evidence, which wasted time.

Waaler goes on to explain in detail many of the creative ways in which they managed to conclusively identify their victims from both incidents. For example, many identifications were confirmed by traditional methods such as ID cards, clothing, and jewelry, but some were also made from matching the location of remains (burned remains found in documented hotel rooms) with the location of coins from the missing person's country of origin. One woman from a group where only one woman had not given birth was identified from evidence of "childlessness." Waaler, with help from the anthropologist and radiologist, identified seven individuals from the hotel fire by a process of elimination, and one by a process of exclusion. Interestingly, this article is one of the earliest to highlight the use of anthropologists in disaster identifications. Anthropology consultants were called in to measure bones and estimate probable age, sex, height, and weight. The biological information was then used during the process of elimination to identify the final hotel fire victims (Waaler 1972).

Waaler concludes his article by justifying the importance of victim identification work for both the legal system and victims' families. He states that victims' families often traveled great distances to provide and receive information on their missing loved ones and then repatriate their remains. For him, the extensive identification work is important not only because of the families' "legal right to receive clear evidence" of the death, but also because "sentimental reasons speak heavily against careless summary methods" such as mass burials of unidentified remains (Waaler 1972:626).

3.3.2.3. Charney

In the mid-1970s anthropological participation in disaster victim identification began to reappear in the literature. In 1976, Michael Charney, a recently retired physical anthropologist from Colorado State University, assisted the Larimer County Coroners office in the aftermath of a massive flood in the Big Thompson Canyon near his home in Colorado (Byers 1998). Not only did he coordinate the identification efforts, he also used his skills as an osteologist to assist in identifying the 139 victims (Charney and Wilber 1984). Charney subsequently called for the development of a national team of forensic experts who could help with disaster identifications nationally (Charney and Wilber 1984).

3.3.2.4. Hinkes

Madeleine Hinkes, a forensic anthropologist working for the U.S. Army Central Identification Laboratory identifying U.S. war casualties, helped identify the dead following a military aircraft crash in 1985 (Hinkes 1989). At the time, forensic anthropologists were called in to assist only when the forensic pathologists and dentists could not identify the last few sets of remains, in this case nearly three weeks after the airplane crash (Hinkes 1989). Hinkes used her anthropological skills to provide biological profiles on these remains, which contributed to their identifications, but her techniques were also used to re-examine already identified remains and correct anatomic inventories and resolve issues of commingling (Hinkes 1989). As a result of this experience, Hinkes wrote the article “The Role of Forensic Anthropology in Mass Disaster Resolution” where she called for anthropologists to be included in mass fatality identification projects from the beginning, stating that anthropologists are “accustomed to looking at bone – incomplete, fragmentary, burned, with or without soft tissue – as few others are” (Hinkes 1989:A62). She goes on to detail how anthropologists could assist in mass disaster situations beyond providing biological profiles by reassociating fragments, determining the minimum number of individuals, sorting commingling, and identifying nonhuman remains (Hinkes 1989).

3.3.2.5. Stratton and Beattie

In 1986, two Canadian anthropologists, Stratton and Beattie, were called by the Alberta Medical Examiner’s Office to assist with identifications following a train collision in Hinton, Alberta, that killed 23 individuals. Stratton and Beattie describe the incident, discuss their role in identifying 10 of the 23 victims during the subsequent identification project, and offer lessons learned in a book chapter titled “Mass Disasters: Comments and Discussion Regarding the Hinton Train Collision of 1986" (Stratton and Beattie 1999). They describe a recovery operation rendered complicated by extreme burning, mangled trains, and sulfur from an open hopper car. They credit the Royal Canadian Mounted Police (RCMP) and the Alberta OCME personnel for good site documentation and recovery, including the use of archaeological excavation techniques and conveyor belts with screens (Stratton and Beattie 1999). However, anthropologists were not included at the site during the recovery process. Consequently, the anthropologists in the morgue, who needed to use the provenience of remains and associated artifacts as a method of elimination in the identification process, now had to recreate a mock disaster scene by using photographs from the site (Stratton and Beattie 1999).

The article predominantly describes the anthropologists' contributions toward identifying these 10 individuals, while other mortuary operations such as the documentation, autopsies, and identifications of the other 13 individuals are not mentioned. Stratton and Beattie describe their methods of identification for these ten individuals, seven of whom were identified based on location, artifacts, and non-metric skeletal characteristics because their bodies were burned so extensively. In fact, one set of calcined female remains, which had the same biological profile as that of two other missing women, was identified based on an associated earring and camera that the victim was known to carry, all of which had been found in an adjacent grid. The authors do not mention whether the other women were known to *not* carry a similar camera, or whether such inquiries had been made. An important skill brought by the anthropologists was their ability to sort out many fragments of nonhuman material, much of which was burned and melted insulation, resembling the thousands of recovered calcined bone fragments (Stratton and Beattie 1999).

While anthropologists made an important contribution to the identification of the Hinton victims, like Hinkes' experience they were only incorporated into the identification project for cases where pathology and odontology could not first provide identifications; they were not integrated into the entire mortuary operation. Furthermore, despite the RCMP and OCME's decision to use archaeological techniques, they were also not included at the site during the recovery operation. The major lesson these authors reinforce is similar to that described by Mant, Hinkes, and Waaler: anthropologists must be at the site to assist in recovery (Hinkes 1989; Mant 1970; Stratton and Beattie 1999; Waaler 1972).

3.3.2.6. Waco

In 1993, several anthropologists were called upon to assist in the search, recovery, documentation, and identification of the victims from the Branch Davidian compound incident in Waco, Texas. The expertise of forensic anthropologists and archaeologists at this disaster scene, with badly burned and fragmented remains, proved invaluable for recovering information that contributed to the overall success of the victim identification project (Ubelaker, et al. 1995). Not only did anthropologists prove important during remains recovery, they also proved adept at sorting, documenting, and analyzing the fragmented, decomposed, and burned remains (Owsley, et al. 1995). In fact, the techniques of the forensic anthropologists helped age and subsequently identify many of the juvenile victims (Houck, et al. 1996).

3.3.3. Disaster Mortuary Operational Response Team

In 1992, shortly before the Waco incident, the Disaster Mortuary Operational Response Team (DMORT) had been created as a component of the National Disaster

Medical System (NDMS) within the Office of Emergency Preparedness, a division of the U.S. federal government (Sledzik 1996). DMORT is a federally supported team of mortuary personnel and forensic experts, including pathologists, radiologists, odontologists, anthropologists, and funeral directors. It provides mandatory training opportunities for its volunteers, many of whom have responded to multiple disasters over the years (Saul and Saul 2003). It also has two fully operational deployable portable mortuary units (DPMU) that can be transported to jurisdictions lacking the resources to handle a large disaster or to disaster scenes in remote places such as the crash of Flight 93 in Shanksville, Pennsylvania, on September 11, 2001. In addition to its personnel and DPMUs, DMORT has developed and made available antemortem and postmortem collection forms as well as a computer database system to enter the data, search the data, and assist in establishing identifications. DMORT personnel are drawn from across the U.S. and will respond to disasters nation-wide.

Some of the earlier incidents DMORT has responded to include the recovery and identification of bodies from the Hardin Cemetery flood in 1993, a second cemetery flood in Albany, Georgia, in 1994, the bombing of the Oklahoma City Federal Alfred P. Murrah Building in 1995, the 1997 crashes of Korean Airlines 801 in Guam and Comair Flight 7232 in Michigan, the 1999 Egypt Air Flight 990 crash, and the Alaska Air Flight 261 crash in 2000 (Filippi 2007; London, et al. 2003; Saul and Saul 2003; Sledzik 1996; Sledzik and Kauffman 2008; Sledzik and Willcox 2003). DMORT's creation recalls the vision propounded by Charney nearly ten years earlier. Although funeral directors initially dominated the command structure and personnel of DMORT, dozens of anthropologists now serve as team members and team leaders. This gradual change in focus has shifted DMORT's role in disaster assistance more toward identification and away from a funeral director's expertise of body preparation and repatriation. It also recently led to the fulfillment of Hinkes's appeal for anthropologists to be included not only at the recovery site, but also in the mortuary from the beginning of the identification process.

3.3.4. 9/11 and Beyond

The role of anthropologists in DVI has shifted noticeably in the past several years, and this has been particularly evident within the DMORT system. Anthropologists have begun to take on larger policy and management positions in disaster recovery efforts both at the scene and in the mortuary. They managed aspects of DVI in Shanksville, Pennsylvania, after the crash of Flight 93 on September 11, 2001, for example (Dirkmaat and Miller 2003; Sledzik, et al. 2003), and after the victim identification there, anthropologists were responsible for drafting new DVI mortuary protocols (London, et al. 2003). DMORT anthropologists also played key roles at the Tri-State Crematory incident in Noble, Georgia, and in the aftermath of Hurricane Katrina in Louisiana (Fulginiti, et al. 2006; Steadman, et al. 2008). Following the Tri-State crematory incident, forensic anthropologist Hugh Berryman took a lead consulting position during the legal trial, which involved differentiating negligence from misconduct by analysis of the remains (Berryman and Berryman 2007). In all these relatively recent disasters anthropologists served as mortuary managers, team leaders, and experts responsible for contributions beyond the traditional physical anthropological techniques of developing biological profiles of unknowns.

Outside of DMORT, anthropologists were also managing aspects of the DVI process following the events on September 11, 2001, at the Pentagon and in New York City (Mackinnon and Mundorff 2006; Mundorff 2003; Rodriguez 2003; Wiersema, et al. 2003). During the identification of the World Trade Center victims, anthropologists assumed a variety of leadership positions including managing daily mortuary operations and developing new anthropological methods for dealing with unprecedented levels of commingled human remains (Budimlija, et al. 2003; Mackinnon and Mundorff 2006; Mundorff 2008). Anthropologists worked alongside managers in forensic biology to establish new DNA sampling strategies and to develop quality control and quality assurance protocols to prevent misidentifications (Mundorff, et al. 2008). This was also true for the identification of the Pentagon victims. An anthropologist played a lead role in the mortuary operations and as part of the reconciliation team (Rodriguez 2003).

Despite the growing importance of anthropologists in DVI, however, their research contributions, both retrospective as well as prospective, have been limited until recently. Conversely, there is a growing trend to write about the role of anthropologists in mass disaster situations by anthropologists who have not participated or exaggerated their limited roles in DVI projects. Their contributions are not actually reflective of the role of anthropologists in mass disasters (Kimmerle and Doying 2007) and some can be particularly misleading (Gould 2002).

3.3.5. The Bali Bombings

Australian anthropologists participated in DVI work after two bombing incidents in Bali, Indonesia, both in 2004 (Briggs and Buck 2009). The first incident was a nightclub bombing where almost half the victims were Australian. The Australian government formed a multi-agency support team that included police personnel, Australian Security and Foreign Affairs personnel, and forensic specialists (Lain, et al. 2003) to deploy to Bali. The anthropologists’ role in this DVI investigation was limited to assisting pathologists and odontologists during mortuary examinations (Briggs and Buck 2009). Specifically, they were tasked with sorting out commingling and determining the minimum number of individuals from fragmented remains, but they also participated in describing the remains, and their skills were particularly useful with fragmented remains. They assessed remains for biological details such as sex, age, or ancestry and examined them for the presence of anomalies or characteristics that might individualize the victim for identification (Briggs and Buck 2009), but they were not included at the disaster scene to assist in recognizing and collecting fragmented and burned human remains. They were also not included in the reconciliation phase, when a multidisciplinary team including pathologists, odontologists, DNA experts, and police personnel reviewed the antemortem and postmortem information to confirm identifications (Briggs and Buck 2009).

In the second Bali incident, 12 people were killed during a bombing outside the Australian embassy (Briggs and Buck 2009). An Australian DVI team was again deployed to Indonesia to assist the local authorities with the investigation and again, the team included an anthropologist. However, this time the anthropologist assisted in identifying and recording remains at the scene (Briggs and Buck 2009). The anthropologist also assisted in the mortuary with the examination of remains. In fact, when two sets of remains with similar biological profiles were still unidentified, the anthropologist tried to establish a preliminary identification by using stature to differentiate the two (Briggs and Buck 2009). Ultimately, this is not a scientifically accepted method of identification, and the identities were eventually confirmed with DNA, but the anthropologist's assessment was correct. The authors believe that because of their contributions during these two DVI responses, "The value of having a forensic anthropologist on the DVI teams is now widely recognized in Australia" (Briggs and Buck 2009:414-415).

3.3.6. The Boxing Day Tsunami

Sue Black, an anthropologist in the UK, provides valuable background information on how the massive DVI project unfolded after the Boxing Day tsunami in Thailand (Black 2009). However, contrary to her chapter title "Disaster Archaeology: Tsunami," little anthropology took place during the initial weeks and months following the event she details. This is especially notable as the tsunami followed closely on the heels of the second Bali bombing and, of the nearly 30 Interpol member countries that sent DVI teams to work in collaboration with the Thai government, the Australian DVI team assumed the lead role (Black 2009). According to Black, the discipline of anthropology "remained largely marginalized throughout the entire proceedings" (Black 2009:404). A few anthropologists served a minimal role assisting pathologists and odontologists in the general recording of data during mortuary operations, but anthropological techniques of determining age, sex, ancestry, and more to assist in developing a biological profile were not employed. And like the 2002 Bali DVI project, anthropologists were not included as part of the reconciliation of antemortem and postmortem data because anthropology is not part of the primary identification disciplines (dental, fingerprint and DNA) in an Interpol mediated response.

Black's experience of seeing anthropologists marginalized during a DVI project to which she felt they could significantly contribute proved worthwhile. The Boxing Day tsunami spurred the UK government to develop a more organized DVI capability (Black 2009), which resulted in anthropologists as core instructors for the DVI member training program and part of the deployable DVI team (Black 2009). So, while anthropology did not play a key role in Thailand, its conspicuous absence significantly changed the participation of anthropologists in DVI teams in the UK.

It should be noted that this literature review describing the roles anthropologists have played during identification projects following mass fatality events is limited to what is available in the public literature. Anthropologists have responded to and been influential in many more disasters than are chronicled here, but they have not published on their experiences. For example, anthropologists were an integral part of the DVI project following the 2005 subway bombings in London, UK (Mackinnon 2007). Although they were not included at the scene to assist with identifying and collecting human remains, they were present in the mortuary from the start. Anthropologists worked alongside pathologists, odontologists, and radiologists. They sorted out cases of commingling, identified and described bone fragments for the postmortem information collections, and contributed to developing policy for DNA sampling (Mackinnon 2007). In fact, having worked closely with the Counter Terrorist Unit of the Metropolitan Police during this DVI project, anthropologists were later included as instructors during their training exercises (Mackinnon 2007).

3.4. New Areas of Research in DVI

3.4.1. Computed Tomography and DVI

Anthropologists, researching alongside radiologists and odontologists, have recently begun contributing to the literature with new methods aimed at improving disaster victim response and identification. Computed tomography's (CT) application in DVI is just one new approach and its advantages and limitations are discussed in three articles (Blau, et al. 2008; Rutty, et al. 2007; Sidler, et al. 2007) that each focus on a different aspect of how the CT scanner can improve disaster victim identifications.

3.4.1.1. Blau and Colleagues

Blau and colleagues applied CT technology to a small airplane crash from 2007. They CT-scanned all human remains in their body bags before they were removed for examination and had an anthropologist review these CT scans during the process. They explained that having an anthropologist monitor the CT scanner was essentially a noninvasive method of removing the soft tissue to visualize the bone fragments (Blau, et al. 2008). This saved significant time because practitioners did not have to remove soft tissue. Blau and colleagues believe that the CT scanner also allowed practitioners to more easily identify commingling and to reassociate fragmented remains, thus reducing the number of fragments that required DNA testing (Blau, et al. 2008).

3.4.1.2. Sidler and Colleagues

Sidler and colleagues conclude in their article that the use of multislice CT in DVI might be both a valuable tool for screening remains and also a means of permanently recording physical details of each body or body part. CT scans easily and objectively capture and record physical characteristics such as the size and shape of a nose or the angle of a forehead. These types of physical descriptions comprise nearly 60% of the information recorded in Section D of the Interpol DVI postmortem forms (Sidler, et al. 2007), the most commonly used antemortem and postmortem DVI information collection forms in Europe and other Interpol member countries (Cattaneo, et al. 2006). Capturing the information on a CT scan not only digitally stores the visual information permanently, but also allows the information to be retrieved and reviewed by other scientists without re-examining the actual remains. They also suggest the possibility of using CT scans as a noninvasive virtual autopsy for DVI victims (Sidler, et al. 2007).

3.4.1.3. Rutty and Colleagues

Rutty and colleagues employed a mobile multi-detector computed tomography (MDCT) machine during a DVI response to a car crash that killed six individuals and resulted in commingled disrupted remains (Rutty, et al. 2007). Following this incident, the authors proposed the use of a mobile MDCT at all disaster mortuaries to replace the more commonly used fluoroscope, plain x-ray, and dental x-ray machines. They state that the MDCT "offers superior, faster, contamination free examinations of both bodies and body parts, which can be electronically stored as a permanent record" (Rutty, et al. 2007:1349). The bodies could be scanned by the MDCT in 15 minutes versus 1 hour for the traditional radiography, and the team could visualize tissue, bone, and foreign objects such as cigarette lighters on the scan, as well as fractures not detected during regular autopsy. Investigators could also use the MDCT scans to correctly identify the cause of death for all the victims involved in this disaster. At the end of the article, the authors introduce the standard operating procedures they developed for using an MDCT in a DVI response (Rutty, et al. 2007).

3.4.2. Developing Indices for Addressing Commingling

In their 2008 chapter addressing commingling from mass fatality incidents, Kontanis and Sledzik propose an innovative process to maximize identifications in situations involving fragmented remains (Kontanis and Sledzik 2008). They use a "fragmentation index," the ratio of recovered remains to the number of decedents, to describe differential fragmentation levels found at different types of incidents (Kontanis and Sledzik 2008). The "fragmentation index" is followed by the "probative index system," which could be invaluable for any disaster incident and particularly for those with fragmented remains. The probative index is defined as "a system that allows triage personnel to systematically and objectively classify human remains according to their identification potential or investigative value" (Kontanis and Sledzik 2008:325). Sorting remains with a high probative index, like hands with potential fingerprints, or remains with dental attributes, allows them to be prioritized and processed through the mortuary first. This in turn speeds up potential early and straightforward identifications. This system can be modified according to the characteristics of both the disaster and the recovered remains. A probative index will be particularly useful in incidents with closed populations like airplane crashes. In closed population incidents the goal of the identification project is frequently 100% victim identification as opposed to 100% remains identification, which is more common for open population incidents. Because the vast majority of identifications are typically established from fingerprint and dental comparisons, applying the probative index means the pieces most likely to yield fingerprint and dental identifications can be sorted out and processed first, allowing those identifications to proceed quickly. Following those preliminary identifications, fewer fragments would have to be identified through other means such as DNA because presumably many victims will already have been identified through fingerprint and dental comparison. Using the probative index, anthropologists would then triage the rest of the unidentified remains to determine which were in good enough condition and likely to yield new identifications, and to send them on for DNA testing. This method reduces the number of DNA tests and aids 100% victim identification in the quickest manner possible.

3.5. Applying Forensic Archaeology to the Disaster Scene

In 1985, B. Sigler-Eisenberg described forensic archaeology as "the application of archaeology to forensic investigations" and argued that customary "archaeological training is different from forensic archaeological training" (Sigler-Eisenberg 1985:653). Although the field of forensic archaeology was still in its infancy at the time, and its application to mass fatality scenes was not even mentioned, practicing forensic anthropologists already had a foundational understanding that proper excavations of human remains from a crime scene allows for easier and more accurate forensic analysis of the remains once they reach the laboratory (Morse, et al. 1983; Skinner and Lazenby 1983; Ubelaker 1978). As Mant (1970) initially demonstrated, and others have subsequently confirmed, problems arise when remains are excavated under less than optimal conditions (Sigler-Eisenberg 1985; Stratton and Beattie 1999; Waaler 1972), and this is particularly true when remains are excavated from a disaster scene. Sigler-Eisenberg explains that other work conducted at a crime scene is highly structured and carried out by experienced, trained personnel. She argues that the standards for the process of recovering human remains should be equally demanding. Police specialists do not possess the extensive field experience or skills of forensic archaeologists yet often they are carrying out these responsibilities at a disaster scene. For example, when 913 bodies were found at the Jonestown Colony in Guyana, South America, U.S. troops separated family groups who had died together without identifying or mapping their group locations first, in turn destroying valuable identifying information (Eckert 1980).

However, it is no longer standard practice for police personnel alone to recover the victim remains from mass fatality incidents (Sledzik, et al. 2009). Forensic anthropologists and forensic archaeologists are becoming more integral to the recovery process. In the twenty-first century, forensic archaeologists have advanced mass fatality recovery theory and techniques by applying forensic archaeological methods to the disaster scene. Forensic archaeologists know how to protect remains from recovery damage, preserve contextual evidence by photography and mapping in situ, and maximize recovery of both human and evidentiary items from either buried or surface recoveries (Sigler-Eisenberg 1985). Although archaeological techniques have been employed at military aircraft accidents and human rights investigations for many years there has been relatively little research into applying those techniques to large mass fatality incidents (Blau and Skinner 2005; Dirkmaat, et al. 2005; Holland and Mann 1996; Hunter, et al. 2001; Skinner 1987; Skinner, et al. 2003).

The field of forensic archaeology itself is relatively new, as is its application at disaster scenes (Blau 2003; Dirkmaat, et al. 2005; Dirkmaat, et al. 2001; Hunter, et al. 2001). Both Blau and Dirkmaat emphasize the importance of having forensic archaeological experts at disaster scenes. According to these authors, the forensic archaeologists' familiarity with systematic search techniques and their use of archaeological field methods for recovery and excavation ensure that recovery-induced commingling, contamination, and postmortem damage are minimized. Much as Sigler-Eisenberg argues that using forensic archaeologists at crime scenes enhances the reliability of remains and evidence recovery, having anthropologists present at mass fatality scenes to apply anthropological methods also increases the collection of human remains and associated evidence, which can then be valuable during the identification process (Blau 2003; Park, et al. 2009; Stratton and Beattie 1999; Waaler 1972).

Following the 2003 Daegu subway disaster in Korea, the anthropology division of the Korea Disaster Mortuary Operational Response Team (KDMORT) "argued that forensic anthropology expertise during the recovery could contribute significantly to the identification of victims in mass disasters and that the charred body parts and completely cremated bones could potentially be link [*sic*] to specific individuals" (Park, et al. 2009:513). The remains were left in situ until they could be photographed, mapped, and properly excavated. The recovery team used articulations and other anthropological examinations at the scene to link charred and cremated bones on site rather than waiting for DNA to match the fragments (Park, et al. 2009). The authors credit the success of this DVI project to the team's meticulous recovery of a disaster scene that had not been compromised by nonmedical personnel (Park, et al. 2009). They also reiterate the early opinions of Mant and Waaler, and more recently of forensic archaeologists, that "once remains are disturbed or removed, they can never be returned to their original condition" (Park, et al. 2009:518).

3.6. Emergence of DNA in DVI

The advancement of DNA techniques, particularly with small compromised specimens, has changed the standards and practices in human identification following mass fatality incidents. It has done that by adding a second layer of scientific verification to anatomical observations and associations. For example, in 1963, pathologists identifying victims from an airplane crash predominantly used fingerprint and dental matches for identifications. However, after all identifications were complete, body parts identifiable only to anatomical part and basic biological profile, were assigned to identified individuals based on their proximity at the scene and which parts they were missing (Fisher, et al. 1965). Today's DVI standards, particularly with the advancement of DNA techniques, would not allow for identifications based on associations, only on scientific certainty.

DNA has become an increasingly common tool for personal identifications following disasters since the early 1990s. The 1993 incident in Waco, Texas, was one of the earliest incidents to use DNA to assist with identifications (Clayton, Whitaker, Fisher, et al. 1995; Clayton, Whitaker and Maguire 1995). Before then, most disaster victim identification projects still relied predominantly on visual identification, dental matching, and fingerprint matching (Filippi 2007; Gilliland, et al. 1986; Jensen 1999; Leclair, et al. 2007; Morlang 1986). DNA techniques improved quickly, but the approach was adopted slowly, and usually only as a last resort, and most remains continued to be identified by other means (Corach, et al. 1995; Goodwin, et al. 1999; Ludes, et al. 1994; Piccinini, et al. 2004). The 1996 Spitsbergen air crash DVI used DNA to identify 139 of 141 victims, but only because of a lack of antemortem dental and fingerprint records (Leclair, et al. 2004; Olaisen, et al. 1997). In 1998, Swissair Flight 111 crashed off the coast of Nova Scotia, killing all 229 people on board. During mortuary operations, the remains were put into one of four categories: visually identifiable, identifiable part, large but unidentifiable, and small but unidentifiable (Robb 1999). Of the estimated 15,000 fragments of human remains recovered, between 1,277 and 1,370 were deemed suitable for DNA testing (Leclair, et al. 2004; Robb 1999). This ratio, particularly at that time in history, was common for a closed population incident. DNA alone identified 88 individuals and contributed to another 218 identifications, with a total of 228 (out of 229) unique profiles.

Nearly two years after the Swissair incident DNA was used for the first time in history as the sole method to identify all the victims from a single mass fatality incident. Using predominantly cardiac blood, 155 victims of the 2000 Kaprun cable car disaster were successfully identified by DNA (Meyer 2003). The forensic scientists managing the identification project used DNA exclusively to identify the victims because of a previous success in identifying 11 highly burnt yet mostly intact bodies from a tunnel incident (Meyer 2003). DNA was also the best option for the Kaprun incident because many of the victims were too badly burned for fingerprint identification. Additionally, the victims came from many different countries and the management team believed that the DNA analyses could be completed before dental records were available (Labovich, et al.

2003). The Kaprun victims were all positively identified within 19 days. This project represented the beginning of a change in the management of mass disaster identification projects. For the first time, DNA was used as the single method for quick personal identification, rather than being a last resort or a method of reassociating fragmented remains.

However, using *only* DNA to identify mass fatality victims remained an anomaly. DNA analysis was still relatively new although it was increasingly being applied to identify and reassociate fragmented remains from disasters. It was quickly becoming the primary means of identifying previously unidentifiable fragments that would otherwise have been deemed "unidentifiable" and grouped with common tissue (Sledzik and Kauffman 2008). Since the mid-1990s, many airplane crash incidents, terrorists attacks, and human rights violations investigations have increased their numbers of identified fragments by using DNA to reassociate parts (Ballantyne 1997; Goodwin, et al. 1999; Hsu, et al. 1999; Kahana, Ravioli, et al. 1997; Leclair 2004; Parsons, et al. 2007).

The use of DNA to identify multiple victims following incidents with little fragmentation or decomposition was also increasing. Although not as commonly used as muscle or bone, blood can still be sampled for DNA when remains are recovered quickly. For example, in 2000, DNA identified most of the victims following a train crash incident in Oslo in which a total of 19 individuals were killed (Hoff-Olsen, et al. 2003). The bodies were recovered and autopsied within four days. Eighteen victims had biological reference material available, and those 18 victims were identified using DNA (Hoff-Olsen, et al. 2003).

Since the events of September 11, 2001, and the 2004 Boxing Day tsunami, it has become apparent that DNA has moved from being an anomalous method or method of last resort to a primary means of identifying mass fatality victims. Indeed, forensic biologists leading the DNA work for mass fatality incidents have become managers of major portions of identification projects and have published extensively on their efforts (Alonso, et al. 2005; Ballantyne 1997; Biesecker, et al. 2005; Brenner and Weir 2003; Budowle, et al. 2005; Butler 2005; Clayton, Whitaker, Fisher, et al. 1995; Clayton, Whitaker and Maguire 1995; Corach, et al. 1995; Deng, et al. 2005; Goodwin, et al. 1999; Holland, et al. 2003; Leclair 2004; Leclair, et al. 2004; Prinz, et al. 2007; Shaler 2005; Whitaker, et al. 1995; Whittaker and Macdonald 1989). Highlighting this shift, the recent publication of the DNA Commission of the International Society of Forensic Genetics' (ISFG) article "Recommendations regarding the role of forensic genetics for disaster victim identification (DVI)" (Prinz, et al. 2007) is particularly interesting to those who use DNA to identify disaster victims. This article, written by an international group of leaders in human forensic identification, details the group's recommendations regarding the role of DNA in mass disaster identifications (Prinz, et al. 2007). Specifically, the group lists 12 recommendations that:

> are intended to provide guidance on establishing preparedness for the forensic genetics laboratory, on collecting and storing ante-mortem and post-mortem samples suitable for DNA analysis, on DNA extraction and genetic typing strategies, on data management, and on issues related to the biostatistical interpretation and reporting of results [Prinz, et al. 2007:3]

when using DNA to identify victims of mass disasters. The authors in no way advocate for DNA to be used as the sole identification tool, citing that dental and fingerprint matching are often quicker methods. They summarize their recommendations by reminding the reader that an interdisciplinary approach, using multiple modalities of identification, will increase the confidence level for all identifications (Prinz, et al. 2007).

3.7. Managing Disaster Victim Identification Projects

Overall evaluations of managing disaster victim identification projects are uncommon although there are a few for specific subspecialties (Labovich, et al. 2003; McEntire 2004; Patterson 2006; Warnick 2002). While some “lessons learned” have been published, too often they have been primarily a platform for members of a single scientific subspecialty to boast about their successful identification rates (Brannon and Kessler 1999; Brannon and Morlang 2004; Harcke, et al. 2002; Kahana, Ravioli, et al. 1997; Kieser, et al. 2006; Mundorff 2003; Nye, et al. 1996; Poisson, et al. 2003; Sledzik, et al. 2009; Suzuki, et al. 1981; Warren, et al. 2000). Critical and self-reflective analysis is comparatively rare, and what is available are often short summaries explaining “how it was done” with little information on how the critical decisions were made, who made these decisions, and what lessons were learned from mistakes or particular choices. Other publications described as overall victim identification management evaluations actually only address small aspects of the overall DVI project and, not the project as a whole.

One notable exception is a 1986 article detailing the identification of the Delta 191 crash victims from the medical examiners’ perspective. At the end of their article the authors include an appendix that addresses many aspects of managing a mass fatality incident beyond the mortuary work. The list is in question format, forcing the reader to think about different aspects of managing a mass fatality incident, and so most of the questions do not provide answers. Topics covered include administrative issues—who will have emergency purchasing authority for supplies and how to find extra forensic specialists in your area, for example (Gilliland, et al. 1986)— and communication issues—do you have someone on staff who can interpret the order of “Oriental names” and who will answer the telephone (Gilliland, et al. 1986). Security issues and questions around the location of the morgue work are also addressed. This list of questions and thought-provoking statements is comprehensive for its time; the team had quite obviously taken their experience and translated it into a set of helpful lessons from which future mass fatality managers could learn.

Another notable exception is a brief article, described as a “critical review,” by Prieto and colleagues, following the 2004 Madrid terrorist train bombings that killed 191 individuals (Prieto, et al. 2007). Their stated reason for publishing their article was “an obligation to the scientific community to make our experience known to our colleagues, as only in this way can we evaluate our successes and errors with the purpose of learning from them for the benefit of others who have to face … similar situations…” (Prieto, et al. 2007:518). In their article, they address how and why decisions were made and the repercussions of these decisions. For example, the authors discuss a problem they encountered during postmortem information collection. Even though the Interpol DVI forms were available, “the lack of instructions…and the absence of a clear chain of command” (Prieto, et al. 2007:519) resulted in the forms not being used. This in turn resulted in nonstandardized and arbitrary information collection based on what each pathologist believed was interesting. Ultimately the information was incomplete and imprecise (Prieto, et al. 2007). Other jurisdictions could learn from these experiences, mistakes, and lessons, and plan accordingly. If the Interpol DVI forms are used by a particular agency, for example, this information could help them address the associated instructions and command structure before an incident occurs.

Brief overviews of the few available publications on managing mass disaster identification projects, along with their contributions to the literature, are provided below.

3.7.1. The Gander Crash

In 1989, Clark et al. published an article in *Aviation, Space, and Environmental Medicine* detailing their experience identifying the victims from the Arrow Air Flight 1285, an airplane carrying 248 U.S. army personnel, that crashed in Gander, Newfoundland, in 1985 (Clark, et al. 1989). (This was the incident that prompted anthropologist Madeleine Hinkes (1989) to highlight forensic anthropology and call for anthropologists to be included from the outset of the identification process.) Cooperation between the U.S. and Canadian governments meant the remains were transported to the U.S. Air Force mortuary facility at Dover Air Force Base in Delaware for identification. The time lag allowed for Clark and colleagues at the Armed Forces Institute of Pathology (AFIP) to plan for and arrange the facility into a series of ten workstations (Clark, et al. 1989). All the remains passed through every station for identification.

Clark and his colleagues' experience prompted them to create and publish the "Armed Forces Institute of Pathology Mass Disaster Operations Plan" with the intention that it could be modified for use during other disasters (Clark, et al. 1989). This comprehensive plan lists the types of teams and specific team members required for a successful identification project along with each team member's individual responsibilities. Even forensic anthropologists are listed as team members; they are to provide technical assistance to the forensic pathologist. The inclusion of anthropologists here could be due to Hinkes's valuable contributions during that particular project. The plan describes the procedures to follow at the incident command center, the disaster site, and the mortuary. The mortuary section provides information on the ten workstations used during this specific identification project and which included "in processing," where remains are assigned a number, as well as finger printing, dental exam, radiology, and pathology. Approximately two-thirds of the victims from this incident were identified through dental records (Clark, et al. 1989). Communication is clearly important, and the penultimate procedure described states that the Commander will hold meetings with key personnel at the end of every day to review the day's identifications and address any problems that arose (Clark, et al. 1989). Although it may seem obvious with hindsight, this kind of insight—that is, holding daily briefings with your team leaders—is invaluable to future disaster victim identification managers and has been incorporated into current DVI protocols such as those developed by Interpol.

3.7.2. ValuJet 592

In May 1996, ValuJet Flight 592 crashed in the Everglades of Miami-Dade County, Florida, killing all 110 on board. The fragmentation was severe. Over 4,000 pieces of human remains, comprising a mere 25% of the estimated weight of the passengers, were recovered (Mittleman, et al. 2000). Of those, 119 fragments were eventually identified, representing 70 victims of whom 50% were identified by fingerprints (Mittleman, et al. 2000). Several key members of the identification management team compiled their experiences and lessons learned into a book, *The Crash of ValuJet 592: A Forensic Approach to Severe Body Fragmentation* (Mittleman, et al. 2000).

This book provides a comprehensive review of the team's recovery and identification process and shares the information learned from their experience for others to modify and use during future incidents. The book is concise, only 60 pages long, but it provides valuable insight. It begins with information specific to this incident, including conversations from the flight recorded before the crash, information about the crash itself, and information about the investigation into the fire and aircraft damage. A detailed section about the recovery of human remains and how the unique environment of the Everglades complicated and dictated the techniques used to recover the remains follows this. The next section covers the general departmental operations and reads like a diary, listing news conferences, how and where buildings were chosen as Family Assistance Centers, and which city or federal agency was in control of what aspect of the project. The next two sections explain the mortuary and identification process. Their numbering system, how remains were triaged to maximize identifications, and the examination procedures are all detailed. Approximately 300 tissue samples were frozen for potential DNA analysis, but DNA analyses were not initiated because of “the thousands of fragments from so many individuals creating an insurmountable logistical and technical behemoth” (Mittleman, et al. 2000:49). A DNA sample was also stored from each of the 70 identified individuals in the event of a paternity issue or challenge to the identification (Mittleman, et al. 2000).

At the book’s conclusion, the authors include “Comments,” listing what they believe are the 13 most important lessons for future forensic practitioners managing mass disaster victim identification projects. These wide-ranging lessons include using an initial triage system to direct the most identifiable fragments toward further studies (similar to the system later described by Kontanis and Sledzik [2008]), retrieving fingerprints from personal effects if no fingerprint card exists for a victim, issuing presumptive death certificates without remains, and suggesting writing letters to family members of the victims as a tool for communication (Mittleman, et al. 2000). They also provide an appendix with sample forms and copies of the communications that they sent to family members as the project unfolded, including letters used to inform families of their ongoing progress, the list of “Options of Disposition” they provided to next of kin, and the different procedures used to notify next of kin when identifications were established. Lesson 13, the final lesson, emphasizes that despite the level of detail in their extensive disaster plan, the operation’s success lay in the staff’s ability to “be flexible and improvise appropriate actions to unique circumstances" (Mittleman, et al. 2000:54). This book makes an important contribution to the literature on mass fatality management and should be regarded both as essential reading for anyone preparing to manage a mass fatality incident and as a template for all those who write about their experiences after an incident.

This disaster, like the previous one described by Clark and colleagues, was a closed population incident. The management and identification teams know the number and names of the victims quickly, which allows them to access antemortem records and begin the identification process. Incidents with open populations, such as the Boxing Day tsunami or the World Trade Center disaster, are fundamentally different. Open population mass fatality incidents present challenges that must be dealt with by the management and identification teams before identifications can begin, such as simply compiling a list of missing persons.

3.7.3. The Boxing Day Tsunami

To date, the largest international mass fatality identification operation was in Phuket, Thailand, in response to the 2004 Boxing Day tsunami. Estimated deaths in Sri Lanka (35,399) and Indonesia (165,708) were significantly higher than in Thailand (8,345). However, nearly 50% of the victims in Thailand were not locals but Westerners on vacation (Hirsch, et al. 2005; Morgan, et al. 2006b). Therefore, approximately 30 countries, most of which had lost nationals in the event, deployed DVI teams to assist the Thai government with victim identification. These DVI teams and associated resources were not sent to either Sri Lanka or Indonesia, where the majority of victims were buried, unidentified, in mass graves (Morgan, et al. 2006b).

This event has received significant scholarly attention. Articles published on the forensic response fall into the two usual categories discussed above, first-hand accounts providing the perspective of individual forensic specialists and broader perspectives laying out specific management principles (Cockle, et al. 2005; De Valck 2006; Deng, et al. 2005; Kieser, et al. 2006; Kvaal 2006; Tyrrell, et al. 2006; Westen, et al. 2008). However, to date there is no comprehensive publication detailing all aspects of the disaster victim identification project. There are many possible reasons for this void in the literature, but the most likely is that not enough time has passed for these texts to be written. ValuJet crashed in 1996 but the book detailing the management of the identification project was not published until 2000. The tsunami struck Thailand in December 2004, and in December 2006 investigators were still working on identifying the remaining victims.

A number of separate, short management articles on the project have been published (Morgan, et al. 2006b; Patterson 2006; Sribanditmongkol, et al. 2005) but they are limited in scope and detail. They mostly describe the events and the initial response with little summary, analysis, or advice for future practitioners on how to manage these projects. For example, when describing the search and recovery process in their article, the authors do not provide any information on the length of the search operation or details on search techniques, but simply state, “The recovery of dead bodies was conducted by the local government, military and volunteer rescue teams from charity foundations” (Sribanditmongkol, et al. 2005:3). However, this article was published within months of the event, when significant numbers of victims had yet to be identified, and it should not be compared to the ValuJet publication. Its purpose could only have been to describe the tsunami disaster victim management decisions from the first few months without a retrospective analysis on what worked and what they would do differently with hindsight.

An interesting article by Morgan and colleagues compares mass fatality management of the dead in Thailand, Indonesia, and Sri Lanka after the Boxing Day tsunami (Morgan, et al. 2006b). They examine “body recovery and storage, identification, disposal of human remains, and health risks from dead bodies” (Morgan, et al. 2006b:809) and their overall findings are not surprising. Refrigeration was not available or did not arrive soon enough to slow decomposition, so visual identification was not possible within two days of the incident. Additionally, none of the countries had a national or local mass fatality plan or the forensic capacity for an identification project of this magnitude (Morgan, et al. 2006b). The authors conclude that “Mass fatality management following natural disasters needs to be informed by further field research and supported by a network of regional and international forensic institutes and agencies” (Morgan, et al. 2006b:809). Perhaps this statement should be extended to include man-made disasters, accidents and acts of terrorism.

3.8. The World Health Organization Conference

In May 2005, the World Health Organization (WHO) arranged a conference, “Health Aspects of the Tsunami Disaster in Asia,” where a panel of experts discussed the forensic aspects of disaster fatality management (Tun, et al. 2005). The experts on the panel had previous experience managing the World Trade Center victim identifications or were currently managing the identification of the tsunami victims in Thailand. They discussed four major factors that need to be considered when managing a mass fatality incident: “1) the existence of a manifest; 2) the condition of the remains; 3) the rate of recovery of the remains; and 4) the number of victims” (Tun, et al.

2005:455). They also paid particular attention to the importance of resource allocation. Their discussions were eventually published, adding practical and applied management ideas to the mass fatality management literature.

The next chapter will review existing manuals, books, and guides that provide direction on DVI management processes following a mass fatality incident. These manuals will be critiqued according to the specific criteria, outlined by the WHO panel of DVI experts.

Chapter 4.

Comparison of Management Manuals, Guides, and Books

The recent trend in mass fatality management literature has been for groups of experts to come together and publish a manual under the umbrella of a governmental organization. These manuals usually contain general identification guidelines as well as personnel and equipment lists that could be modified to fit the needs of a particular incident or a particular agency's mass fatality plan (Bedore 2008; DMORT 2002; Interpol 1997; National Association of Medical Examiners 2002; National Institute of Justice 2005; Pan American Health Organization 2004, Morgan, et al. 2006a). These manuals are genuinely helpful and contain crucial information for mass fatality managers to consider. The following section will review the content, organization, and origin of these manuals, with particular emphasis on determining whether they address minimally the four major factors outlined by the WHO panel. The four major factors for a mass fatality manager to consider are "1) the existence of a manifest; 2) the condition of the remains; 3) the rate of recovery of the remains; and 4) the number of victims" (Tun, et al. 2005:455). Each manual's consideration of the role of anthropologists during the DVI process will also be reviewed.

4.1. Interpol

One of the first disaster operations manuals was Interpol's *Disaster Victim Identification Guide*, which was originally created in 1984 and then updated in 1997 and 2008. The Interpol Standing Committee on Disaster Victim Identification continuously updates this manual in response to its member teams' DVI experiences of responding to disasters. Interpol makes the most recent, non-finalized draft of the DVI guide available online. The guide provides victim identification procedures that are designed to be compatible across international boundaries as the guide and its corresponding computer program are available to all 187 member countries. This comprehensive guide provides detailed procedures for establishing a Family Assistance Center and a mortuary, and for collecting antemortem and postmortem information. The corresponding computer program, PlassData DVI System International v.3, mirrors the AM/PM information collection forms and is used to store information, compare data, and direct forensic specialists to make identifications.

The Interpol DVI guide is the most comprehensive mass fatality management tool available for use in the aftermath of a disaster. Because it has been used frequently over the years—the Interpol forms are the most frequently used DVI forms in Europe (Cattaneo, et al. 2006)—the procedures have been thoroughly tested and proven reliable (De Valck 2005, 2006; Gilchrist 1992; Kieser, et al. 2006; Kvaal 2006; Lain, et al. 2003; Lunetta, et al. 2003; Moody and Busuttil 1994; Prieto, et al. 2007; Soomer, et al. 2000). The guide is structured in a manner that makes it both accessible and straightforward. It is available online in four languages.

The most recent Interpol DVI guide clearly addresses the four major themes outlined by the WHO panel within its first five pages. It clearly notes the important distinction between an open versus a closed population, stating that antemortem data is more easily attainable from closed populations because the number and names of the victims are known (Interpol 2008). Early in chapter 2, “Disaster Management,” the authors also stress the importance of determining the scope of a disaster by sending out an advance team. This team can assist in the preliminary assessments of the condition and number of the dead and can provide an evaluation of the estimated duration of the

DVI process (Interpol 2008). The authors of this guide demonstrate a clear understanding of how to approach and manage fatality incidents from the onset.

However, anthropologists seem to be underutilized in the Interpol DVI process. The 1984 and 1997 Interpol DVI guides do not mention using the skills of anthropologists during disaster scene processing or the identification process. The most recent version, available online, does periodically mention anthropologists, but only as playing very limited roles. They are not mentioned as team members who can contribute at the disaster scene. For example, when discussing the collection of human remains from the disaster scene, the DVI guide recommends that police personnel should be made responsible; if necessary, they can call on experts such as odontologists or pathologists (not mentioning anthropologists) to "recognize and differentiate human tissue as needed" (Interpol 2008:9).

During mortuary operations, anthropologists do not have their own station for anthropological evaluation and act only as consultants to the other forensic specialists. For example, in the radiology section it is noted that a forensic anthropologist "can ask and assist [*sic*] in positioning of radiological views to estimate age, detect unique skeletal features and for AM/PM comparisons" (Interpol 2008:30). Notably, anthropologists are not empowered to do this routinely, but are only consulted on a case-by-case basis at the discretion of the forensic pathologist. Anthropologists are also not recognized as part of the reconciliation team, a multidisciplinary group of forensic scientists who evaluate all contributing data before validating a new identification. The manual includes a section that discusses the use of DNA, particularly where remains are contaminated or fragmented. This section addresses the need to sort out, where possible, nonhuman remains before sampling for DNA. However, even this task is not deemed suitable work for an anthropologist. Instead, "Pre-sorting and exclusion of samples that do not originate from a human source are the responsibility of a somatologist or an appropriately trained forensic pathologist" (Interpol 2008:35).

Forensic anthropologists and forensic archaeologists worldwide have been presenting strong arguments for their assuming more responsibility at the disaster scene and in the mortuary (Blau 2003; Dirkmaat, et al. 2005; Sledzik 2009), but their capacity to assist in a DVI project seems to be ignored by the Interpol guide authors. Despite its exclusion of anthropologists, the Interpol guide is the best organized, and most detailed and comprehensive guide available for those working on large-scale disaster victim identification projects or for those seeking information on how to manage disaster victim identification projects.

4.2. United States

In comparison with the unitary and centralized approach of the Interpol-affiliated countries, approaches within the United States tend to be more diverse and decentralized. In recent years, several new manuals have been promulgated within the United States in direct response to the events of 9/11 and, to a lesser extent, the publication of the revised *National Response Framework* (NRF). The Federal Emergency Management Agency (FEMA) recently published an updated version of the *National Response Plan* (NRP), re-titled the *National Response Framework* (FEMA 2008b). According to FEMA:

> The *National Response Framework* presents the guiding principles that enable all response partners to prepare for and provide a unified national response to disasters and emergencies—from the smallest incident to the largest catastrophe. The *Framework* establishes a comprehensive, national, all-hazards approach to domestic incident response. [FEMA 2008a]

The major difference between the new NRF and the previous NRP is the inclusion of a small section addressing how to deal with dead bodies.

A series of 15 Emergency Support Function (ESF) annexes are appended to the NRF. ESF #8 addresses Public Health and Medical Services. Page seven of the ESF #8 contains the following paragraph addressing the federal government's anticipated role in mass fatality management.

> ESF #8, when requested by State, tribal, or local officials, in coordination with its partner organizations, will assist the jurisdictional medico-legal authority and law enforcement agencies in the tracking and documenting of human remains and associated personal effects; reducing the hazard presented by chemically, biologically, or radiologically contaminated human remains (when indicated and possible); establishing temporary morgue facilities; determining the cause and manner of death; collecting antemortem data in a compassionate and culturally competent fashion from authorized individuals; performing postmortem data collection and documentation; identifying human remains using scientific means (e.g., dental, pathology, anthropology, fingerprints, and, as indicated, DNA samples); and preparing, processing, and returning human remains and personal effects to the authorized person(s) when possible; and providing technical assistance and consultation on fatality management and mortuary affairs. In the event that caskets are displaced, ESF #8 assists in identifying the human remains, recasketing, and reburial in public cemeteries [FEMA 2008b:95].

Responding to the NRF and the events of 9/11, DVI management guides have been updated or developed in the U.S. by the National Association of Medical Examiners (NAME), the National Institute of Justice (NIJ), and the Florida Emergency Mortuary Operations Response System (FEMORS) (Bedore 2008; National Association of Medical Examiners 2002; National Institute of Justice 2005). The FEMORS system is similar to DMORT, but its focus is on responding to disasters in Florida only. DVI managers in North America are also familiar with the book *Mass Fatality and Casualty Incidents: A Field Guide* (Jensen 1999). All of these documents will be reviewed below.

4.2.1. National Association of Medical Examiners

The National Association of Medical Examiners has drafted a *Mass Fatality Plan* manual that is available for download on from their website or the DMORT website (National Association of Medical Examiners 2002). The target audience for this manual is predominantly medical examiners and coroners developing their own DVI plan. The manual is in outline format, providing extensive lists but with little in the way of detail, explanation, or guidance on identification procedures. It refers the reader in several places to the DMORT website for further information.

This manual is designed as a guide for a medical examiner/coroner's office to use during a small-scale disaster or in conjunction with DMORT personnel for an incident that overwhelms the agency. The major topics covered include the role and responsibilities of the medical examiner at the disaster scene, in the mortuary, and at the Family Assistance Center. The processes of establishing an identification and death certification are also outlined, and an extensive resource list is provided. All this, in 18 pages, is followed by 30 pages of forms, including logs for each mortuary station and a copy of the DMORT antemortem and postmortem information collection forms. Although lacking in any specific detail about the process of managing disaster victim identifications, the NAME manual is well organized, allowing for easy reading, and provides a good overall guide to what the medical examiner/coroner should expect in a disaster. The resource list is impressive, ranging from chairs, to toe tags, to media liaisons, as well as a list of potential mortuary personnel.

The authors of the NAME *Mass Fatality Plan* address three of the four major themes outlined by the WHO panel, which contributes to the usefulness of this document. For example, they state in the introduction that an evaluation team, consisting of at least a medical examiner/coroner, the operations director, and the chief of investigations, should go to the scene to evaluate, among other issues, the number of fatalities, the condition of the remains, and the relative difficulty of the recovery operations (National Association of Medical Examiners 2002). However, the guide does not address how an open or closed population can affect victim identification projects.

Anthropologists are well incorporated in the DVI process throughout the NAME manual. Not only do the authors call for a stand-alone anthropology/morphology station in the mortuary, they also list anthropologists as personnel in the section that describes long-term site operations (National Association of Medical Examiners 2002). In comparison with the Interpol DVI postmortem data collection forms, which contain no areas specifically for anthropological examination, the DMORT forms appended to the NAME manual provide a separate Anthropology Examination Form. In addition, anthropological analysis appears on the Morphology Examination Form-Fragmented Remains and the Station Tracking Form. Anthropologists are clearly incorporated into all aspects of the DVI process in the NAME *Mass Fatality Plan* manual.

4.2.1.1. Flight 93 Morgue Protocols

The NAME manual is broad in scope and addresses the disaster scene, the Family Assistance Center, and overall mortuary procedures. Another manual, *Flight 93 Morgue Protocols*, published by DMORT Region III (DMORT 2002), is more narrowly focused and is designed to supplement the *NAME Mass Fatality Plan*. These protocols complement the *NAME Mass Fatality Plan* by providing specific details for mortuary operations that are not included in the NAME guide. They were developed “to document the morgue operations for the United Airlines Flight 93 response” (DMORT 2002:1) following the events in Shanksville, Pennsylvania, on September 11, 2001, and to be modified for use during other disaster mortuary operations.

The *Flight 93 Morgue Protocols* contain details omitted from the NAME manual, specifically individual mortuary protocols outlining triage, remains admitting, radiology, photography, anthropology (including cleaning a specimen), pathology, DNA sampling, file QA/QC, and even sanitation. Antemortem and postmortem dental protocols are also addressed. Interestingly, while the Interpol guide focuses heavily on the pathologist's role in the mortuary, the pathology section in the *Flight 93 Morgue Protocols* is the shortest of any of the forensic specialties. This manual also provides detailed information on DNA sampling, including the equipment needed to establish the DNA station in the morgue and the Armed Forces DNA Identification Laboratory (AFDIL) guidelines for tissue sample selection (DMORT 2002).

4.2.2. The National Institute of Justice

The NIJ manual, *Mass Fatality Incidents: A Guide for Human Forensic Identification*, was designed to assist medical examiners/coroners in creating or updating the strategy their jurisdiction would adopt in conducting identifications in the wake of any mass fatality (National Institute of Justice 2005). Like the NAME manual, this guide covers the initial response, and the arrival at and processing of the scene, identification, disposition, personal effects, and record-keeping. Additionally, the appendix lists resources, URLs, and organizational flow charts. However, this guide's organization and structure are poor and it is therefore more difficult to follow than either the Interpol or NAME guides. For example, the first section of the chapter addressing the identification of human remains begins by discussing the medical examiner's role for both the project as a whole and within the mortuary process. A section titled "Administration/Morgue

Operations," addressing the mortuary set-up, follows. The discussion on setting up a mortuary, and describing administrative duties in a mortuary, would have been more logically placed *before* the section describing the specific role of the pathologist *in* the mortuary. The next section returns to individual forensic stations in the morgue such as anthropology, DNA, and fingerprint. The overall effect of this bouncing around significantly disrupts the flow and therefore the usefulness of the information presented.

Each section of the NIJ manual is organized by paragraphs labeled "principle," "procedure," and "summary." Some sections lacked sufficient detail to fill each labeled section and so these sections became very repetitive as the authors adhered to the strict format. Also, redundancy of information throughout the manual is a significant problem. The same or similar concepts were discussed in several sections and it was often unclear whether these were distinct concepts or whether the same idea was being repeated. For example, establishing a numbering system and assigning a case number were mentioned in at least three sections; once when discussing the scene and twice in the discussion about the mortuary (National Institute of Justice 2005). In the mortuary section under "Establish Work Station Flow," the reader is instructed to assign a case number. Further down, the reader is directed to "establishing and/or [*sic*] maintain a…numbering system," this time below the heading "Other Considerations" (National Institute of Justice 2005:20). Both sets of instructions already follow the chapter on "Arriving at the Scene," where the reader is directed to "Implement a simple, consistent, and expandable numbering system for remains, personal effects, and evidence" (National Institute of Justice 2005:8). It is not clear if the scene number is carried over to the mortuary or if the mortuary number is a supplementary numbering system. This would obviously have important implications if the guide were used to help establish mortuary procedures during an incident.

One of the main problems with this guide is the way the material is presented. Rather than making suggestions or fostering critical approaches, the authors adopt a conclusory tone and issue statements and directives that appear to allow little room for deviation in the face of a disaster's unique characteristics. They also assume the reader understands the specifics of terms used, even where some words carry deep and complex meanings. For example, whereas the *Flight 93 Morgue Protocols* discuss in detail what exactly happens during triage, this guide simply states "conduct triage" and leaves it to the reader to decide who conducts triage and what it entails.

There is a problem with the flow and organization as well, which is exacerbated by uneven contributions in scope and depth between the different disciplines. For example, the dental and fingerprint authors discuss in their individual sections how to collect both antemortem and postmortem information and how to make matches between the two sets of data. The radiology and anthropology sections only discuss postmortem information collection; antemortem data collection for these fields is discussed in a separate general section on antemortem information collection. Either method of presenting the information would be acceptable if used consistently, but the fragmented approach of the guide damages its usability.

The DNA section is comprehensive and lists important questions that the mass fatality manager should consider before beginning identification work. These questions include whether to test every fragment and whether to set a minimum size for testable samples. The reader is also given a list of preferred samples, ranging from blood to bone. However, despite the usefulness of the information, the organization and flow are a problem. For example, in the appendix, DNA sampling is addressed for a second time, separate from the DNA section in the main document. The appendix includes a list of suggested elements for DNA sampling in order of their relative anticipated DNA yield rates. The list suggests the technician sample blood, then muscle, cortical bone, teeth, and then anything else (National Institute of Justice 2005). But there is no obvious guidance on when or why the sampler should switch from sampling muscle to bone or bone to teeth. Pedagogically, it might have been better for the authors to provide some background information on DNA degradation between various sample types in mass disasters. This would allow DVI planners to better anticipate the need to switch between sample types to continue maximizing yield rates as DNA degrades over time. Moreover, it would have been more effective to include all the DNA information in the DNA section, and not to split it between the main document and the appendix.

Overall, this guide is not well organized. It is difficult to follow and limited in its information. This may be the result of trying to please too many people with one single document. The Planning Panel and Scientific Working Group tasked with authoring this manual had 49 members, and the list of organizations and individuals who reviewed the document numbers 332. All this for just over 50 pages of content. The guide also fails to comprehensively cover the key topics outlined by the WHO panel. While section 1 is titled "Initial Response Considerations," and the first part of that section is headed "Determine the Scope of the Incident," only one of the four WHO issues is mentioned, "how many fatalities are involved." The condition of the remains (fragmentary or whole), open versus closed population, and rate of recovery are not mentioned in this section and are barely alluded to in the rest of the document.

Anthropologists' skills, however, are well recognized throughout this guide. The authors suggest that an anthropologist be present at the scene and during the mortuary examination. Anthropologists are recognized as having "specialized training, education, and experience in the recovery, sorting, and analysis of human and nonhuman remains, especially those that are burned, commingled, and traumatically fragmented" (National

Institute of Justice 2005:23). In fact, these skills are the exact ones listed by Hinkes, nearly 20 years earlier, when she argued for the inclusion of forensic anthropologists in DVI (Hinkes 1989). However, the high profile of anthropologists in this guide is not altogether surprising as six members on the Planning Panel and Scientific Working Group were anthropologists who obviously recognized and appreciated anthropologists' contributions to the process.

4.2.3. The Florida Emergency Mortuary Operations Response System

The Florida Emergency Operations Response System was modeled after the federal DMORT system and "developed in conjunction with the Florida Department of Health (DOH) to provide a state-wide fatality management resource when an incident of such proportion occurs as to overwhelm local resources" (Bedore 2008:13). Members of FEMORS provide assistance and technical support for recovery, mortuary operations, and identification of deceased victims to local medical examiners. FEMORS also maintains a basic deployable portable morgue unit that contains enough equipment and supplies to operate for the first 72 hours of a disaster. FEMORS team members, like DMORT team members, are required to participate in training exercises to maintain their deployable status. In addition, all team members use the FEMORS *Field Operations Guide* (FOG) during their training so they are all comfortable with the format and procedures and their feedback is then used to modify and update the FEMORS procedures and manual. "The FEMORS Field Operations Guide (FOG) was developed to assist FEMORS personnel during training and while on mission assignment" (Bedore 2008:13). The current version of the FOG, the 2008 fourth edition, has recently been revised following testing of the manual during training operations.

The manual is massive, 324 pages, although the last 82 pages are forms and flowcharts. The manual's overall format is appropriate for a training manual but it is probably too bulky for an operational guide to be used during an event. For example, the second section is devoted to lists of information, some of it superfluous, such as the FEMORS membership application process, lists of position names, their state pay grade, state hourly salaries, and team uniform criteria. This information would probably be more appropriate in a member's introduction manual or as an annex to this manual. However, some of the information in this section is pertinent to anyone deploying to a disaster scene. A list of what each person should have in their personal "go kit," descriptions of duties and minimal requirements for each position classification within the FEMORS system, and even what to do in case of a vehicle accident while deployed, are all spelled out in this section.

FEMORS has adopted the Incident Command System (ICS) into their operating plans as required by the federal government for all programs receiving federal funds (Bedore 2007). The ICS system was designed in California in the 1990s to coordinate resources, personnel, and the overall management structure during disaster operations (Jensen 1999). The next section of the FEMORS FOG provides an overview of the ICS system as well as a helpful terminology list. A brief operational overview section then describes the responsibilities of each team unit and where that unit fits into the overall operation. This is followed by more detailed operational overviews for each branch of the operation, including "Search and Recovery", "Mortuary Operations", and the "Victim Information Center". The last operational overview is the "Morgue Identification Center", where identifications are made and verified by a multidisciplinary team reviewing the antemortem and postmortem paperwork.

Individual morgue teams are described in the chapter “Mortuary Operations Overview,” with a list in outline format that includes minimal staffing, equipment, and basic job descriptions of the mortuary personnel. The same information is provided for radiology, pathology, anthropology, fingerprint, DNA collection, and odontology. The information is general enough to be adapted to different disaster characteristics. However, some of the information is not detailed enough. For example, the authors list an anthropology kit, but there is no corresponding list of what it should contain (Bedore 2008). Other mortuary teams, including the embalming and photography teams, are also described in insufficient detail. Furthermore, although each team is described individually, the reader does not get a clear picture of how the teams work together or how the mortuary process works as a whole. Instead, this must be inferred by the descriptions of the individual teams and the order in which they appear. Possibly a little more narrative as to how a mortuary assembly line flows during a DVI operation could supplement the outline and list format of the information.

The last major section provides a page on each team member’s position along with his or her individual “operational” checklist. Each position description lists its classification within the FEMORS system and the expected duties for that position. The duties are further broken down into three operational checklists, splitting up the disaster mobilization into what is expected of that team member “Upon Activation” and “On-Site,” and for “Deactivation.” The detail provided in this section is comprehensive and clearly establishes expectations for each team member’s position.

The appendix includes everything that did not fit into the previous chapters, including the FEMORS code of conduct, supply requisition procedures, search and rescue protocols, numbering protocols, x-ray and photography, information on proper personal protective equipment (PPE), and even guidelines for jaw resection policy and embalming. Additional issues addressed in the appendix include records management, next-of-kin notification procedures, and even the policy on decontaminating body storage trailers. All these policies and protocols are in list or outline format with little explanation and no obvious organization.

Overall, the FEMORS FOG is extremely comprehensive in the material it covers and is fairly straightforward to follow. The table of contents is detailed enough to allow the reader to find any topic within the manual. However, even though the manual is comprehensive and easy to follow, it does not adequately describe the flow of the mortuary operations. Each subspecialty is listed individually, complete with job descriptions, but how it all comes together is not made clear. The reader does not get a big picture idea of mortuary operations, but instead sees each unit as an individual operation.

It is also clear that the authors have failed to address several of the four major themes outlined by the WHO panel. For example, this manual does not include an initial disaster assessment list as contained in the Interpol and NAME guides. However, the reason for this oversight, which is repeated numerous times throughout the manual, is that for overall command and control of the disaster, "the Medical Examiner is responsible for the fatality management operations" (Bedore 2008:182). The FEMORS personnel are to support the medical examiner; they are not the decision-makers. Therefore, while some sections briefly touch upon the four major themes, such as the need to consider the number of dead when deciding on the size of the mortuary, or evaluating remains during triage as to whether they are whole or fragmentary, the information is buried and not addressed explicitly. Despite this, this manual was obviously written by experts in the field of fatality management. Small jurisdictions will most probably rely on the FEMORS system not only for their deployable portable morgue, but also for the personnel and expertise to guide them in the DVI process. Most small ME/C offices will have significantly less training and background in fatality management than the FOG authors or team members and will not know to assess these four important themes early in a mass fatality situation. Therefore, although the medical examiner is ultimately the overall manager, the authors should have known to include the importance of evaluating a disaster specifically for the number of victims, an open or closed population, the condition of the remains, and the overall rate of recovery during an initial assessment.

The section describing the role of anthropology comes under "Morgue Forensic Group Teams" in the chapter "Operational Overview-Morgue Operation." The anthropologist's role as described is wide-ranging and overlap with other specialties. Anthropologists may assist in four different areas:

> …documentation at the incident site and associated material (separate Team), assisting with the initial documentation and sorting of human remains in the morgue Pathology triage, evaluation of body x-rays for adequacy and identifying features, and providing comprehensive forensic anthropological documentation of human remains in the morgue [Bedore 2008:52].

This comprehensive anthropological documentation in the morgue includes performing all the techniques used for developing a biological profile as well as evaluating pathology and antemortem trauma.

4.2.4. The Private Sector

Unlike the other manuals and guides reviewed in this chapter, *Mass Fatality and Casualty Incidents: A Field Guide* (Jensen 1999) was written by a single author. This book draws on the author's experiences of managing disasters for both the military and private sectors. It is comprehensive in scope, easy to understand, and a good foundational book for any agency manager interested in learning about important factors to consider as they develop their own mass fatality plan. It is also the only one of the group that was written before September 11, 2001.

According to the author, this guide was designed to provide the responder with a tool to be used before, during, and after a mass fatality incident (Jensen 1999). Unlike the other manuals again, this guide reads like a book. There are a few sections in outline or list format, but for the most part the book is written in paragraph form making it difficult to find information quickly. Jensen begins with a brief introduction of common terms and their definitions. This serves the reader well as it grounds the rest of the book in an accessible vocabulary. Chapter one begins with the history and definition of the ICS system, the same management system described in the FEMORS guide. However, this book also mentions another management system known as the Standardized Emergency Management System (SEMS). The SEMS is a similar system to ICS and Jensen believes it should be implemented along with the ICS for the best results (Jensen 1999). The ICS section is followed by a brief outline of an overall disaster operation: from medical examiner activities, to media operations and logistical support. This outline serves as a table of contents for the rest of the book.

Chapter two, “Incident Overview—A Quick Look,” is a brief overview of the basics from notifying the medical examiner of the disaster through the identification process, release of remains, and development of a final incident report. This chapter provides key questions that should be asked during the first 12 hours following a disaster and then illustrates what might happen during the next 12–24 hours and 24–36 hours. It provides an idea of the sequence of events as they would unfold during a mass fatality incident and is general enough to be applied to events with quite different characteristics. The two subsequent chapters provide important background information that should be internalized within an agency as it develops its pre-incident disaster plan. These chapters deal with PPE and how professionals who work in this field cope with mass fatalities. Again, it is important that individuals who develop mass fatality plans understand these issues before an incident occurs.

The next two chapters provide much of the sought-after information mass fatality planners are looking for on topics such as victim identification, search and recovery operations, and morgue operations. Personal anecdotes and "author's notes" that provide insight based on actual mass fatalities are scattered throughout this book. For example, in "Search Overview," the author notes that speedy search and quick recovery "may actually result in longer identification time, loss of valuable information, and a lack of complete reports" (Jensen 1999:67). This has been a recurring theme throughout my literature review chapter, as the earliest to the most recent writers on mass fatality incidents have tended to note the connection between hasty or improper recoveries and difficult identifications (Hinkes 1989; Sledzik, et al. 2009; Stratton and Beattie 1999; Waaler 1972). The remainder of the search and recovery chapter provides information on the different types of search and recoveries that can be performed. Building collapse, ground recovery, and water recovery are all noted, as well as many different types of grid and mapping approaches for the different types of recoveries. Lastly, this section also addresses numbering, and advocates the simplest method: case numbers beginning with the year of the incident followed by a dash and then sequential numbers for each separate fragment (Jensen 1999).

The chapter on morgue operations begins with key factors to consider when looking for a facility and establishing a mortuary, but quickly becomes rather vague and disjointed. The discussion on establishing morgue operations simply asserts the need to establish a station to receive the remains. There is no indication of the type of personnel needed or requirements of personnel for this station. The next directive is to place the remains in a refrigerated holding container if the mortuary is not yet operational, or to assign an escort to move the remains to the next appropriate station. At this point, the discussion turns to administrative issues including a brief paragraph on antemortem information collection. It then jumps back to mortuary work with sections on personal effects, fingerprints, x-ray, odontology, anthropology, and autopsy.

There are two problems with the chapter "Morgue Operations." The first is the overall organization of the information. The description of the administrative issues interrupts the description of the mortuary operations. The second is the description of the organization of the mortuary stations. In Jensen's mortuary stations, the autopsy exam is conducted last. In most other recent mass fatality morgues, the pathologist examines the remains before they go on to fingerprint, dental, anthropology examination, or DNA collection. It is during the autopsy examination that the medical examiner decides which of those forensic identification specialists should examine the remains, usually based on what remains are present. The other reason for this is fairly straightforward. When forensic subspecialists examine remains, those remains are often subjected to destructive analysis. Jensen's section on fingerprinting discusses amputation and the anthropology section mentions the removal of soft tissue to expose the bone. These destructive analyses should be performed only after the overall examination or autopsy. Lastly, there is no station listed for DNA collection although it is mentioned as an option for identification. This omission can probably be attributed to the age of the book, as DNA did not play a significant role in the DVI process prior to 2000.

The rest of the book covers topics such as collecting and documenting personal effects, the needs of a Family Assistance Center, and working with the media. There is no chapter dedicated to collecting antemortem information or establishing an identification, and these omissions create a major void. However, three of the four major themes outlined by the WHO panel are well covered throughout the book. The only missing theme was a discussion of the difference between an open and closed population. Additionally, anthropologists are well represented. Jensen recognized anthropologists' expertise by recommending that they be present at the disaster site, and that they run their own station in the morgue operations.

Overall, this book would be useful for any jurisdiction looking to develop their own mass fatality plan as it provides general guidance on many aspects of a mass fatality incident. Jensen's most valuable contribution is his attempt to equip the novice planner with the critical analysis skills to problem-solve the DVI process. However, the book is noticeably dated. Published in 1999, it refers to taking Polaroid pictures, which are no longer available, and barely addresses the role of DNA. An updated version, including a more detailed section on collecting antemortem information and establishing an identification, and discussion of some twenty-first-century technology, could make this book invaluable. This book would be helpful to read before a disaster, as part of an agency's predisaster planning, rather than being used like the Interpol Guide during a disaster.

4.3. The Pan American Health Organization and the World Health Organization

The Pan American Health Organization collaborated with the World Health Organization to publish two manuals on disaster victim identification management, *Management of Dead Bodies after Disasters: A Field Manual for First Responders* edited by Morgan, Tidball-Binz and Van Alphen and *Management of Dead Bodies in Disaster Situations* (Pan American Health Organization 2004, Morgan, et al. 2006a). These documents share similar ideas, but differ greatly in their detail and presentation. *Management of Dead Bodies after Disasters: A Field Manual for First Responders* is an extremely basic manual designed for use during a disaster situation, while *Management of Dead Bodies in Disaster Situations* is a detailed book explaining the overall management processes for large-scale identification projects and many other aspects of identifying dead bodies from disasters.

4.3.1. Management of Dead Bodies after Disasters: A Field Manual for First Responders

This PAHO field manual is written for practitioners in areas with limited access to resources for dealing with large numbers of dead bodies, or where these resources are better applied to helping the living. While acknowledging that the management of dead bodies can be one of the most difficult aspects of disaster response, and understanding that the participation of nonspecialists can influence the success of the identification project, the manual states that it "focuses on practical recommendations for non-specialists" (Morgan, et al. 2006a:1) because often the "immediate management of human remains is done by local organizations and communities" (Morgan, et al. 2006a:1). It goes on to state on the first page, "This manual has two broad aims: first to promote the proper and dignified management of dead bodies, and second, to maximize their identification" (Morgan, et al. 2006a:1). Unlike the NAME and Interpol manuals, this manual is not designed for medical examiners, coroners, or forensic specialists. It does not provide in-depth detail on conducting complicated identification projects, and there is little discussion on how to deal with fragmented remains beyond not matching body parts in the field. Instead, it provides the foundational information and processes needed for nonforensic specialists to identify relatively whole bodies following a natural disaster.

The manual lists minimal yet essential steps for establishing an identification: assign a number, label the remains, photograph the remains, record the details, and secure the remains. The photography section is the most detailed. Storage and disposal of remains, media communication, and support for families are also briefly discussed. An annex provides basic forms that could be used to document the remains. The forms are to be filled in by hand and do not have a corresponding searchable database like the DMORT or Interpol forms. However, they are adequate for documenting bodies. This manual is straightforward and provides basic information on recovery, documentation, identification, and final disposition that can be used to identify victims of a mass fatality in a region with little infrastructure or monetary/forensic support.

Despite its many strengths, however, this PAHO manual does not adequately address the four major themes outlined by the WHO panel. The condition of the remains (whole versus fragmented), assessing the number of victims and how that affects the identification project, and the presence or absence of a manifest are not mentioned. The rate of recovery and personnel at the recovery site are discussed and the authors acknowledge that some disasters will have short recoveries while others may be lengthy (Morgan, et al. 2006a). This manual does not try to be something it is not, and it achieves its stated goals, properly managing and identifying dead bodies (Morgan, et al. 2006a). There is no mention of anthropology or anthropologists in this manual, but the introduction clearly states that it is to be used by nonspecialists.

4.3.2. Management of Dead Bodies in Disaster Situations

The second document created by the PAHO, *Management of Dead Bodies in Disaster Situations,* is very comprehensive. In fact, this manual reads more like a book and was developed as a tool to help authorities understand the steps required to organize a large identification project and prepare them for what to expect as that project unfolds. This manual should be read thoroughly by planners before they design their disaster plan; it is not a field guide to be used during a disaster. This excellent resource suggests that agencies should have extensive preplanning—for example, agreements with institutions to provide expert forensic personnel or with companies to provide essentials such as generators or refrigerated trucks—in place and that they should hold trainings and simulations.

While emphasizing that each disaster teaches us something new, this manual stresses three basic activities that are constants for any disaster situation. First, rescue and treat the survivors, then repair and maintain basic services, and finally begin the recovery and management of the dead bodies (Pan American Health Organization 2004). While this manual often refers the reader to the Interpol DVI guide for additional details on mortuary work, comprehensive sections explain different specialties used in forensic identifications, including the role of anthropologists, and there is a detailed DNA section. The anthropology section covers many different procedures in which an anthropologist may be expected to participate, from differentiating human from nonhuman remains, to sorting commingled remains, developing biological profiles, or conducting trauma analysis. The wide-ranging skill set of the anthropologist is clearly recognized in this manual. The DNA section is more detailed than that of the other guides and manuals, and the historical background and process of DNA identifications are both explained. But, more important to DVI DNA identifications, this manual not only suggests what tissue to sample but also distinguishes what tissue to sample in different taphonomic situations. Sampling strategies are outlined for well-preserved bodies, charred corpses, decomposed or skeletonized corpses, and embalmed corpses (Pan

American Health Organization 2004); information on embalming and other forms of body disposal is also supplied.

Beyond the actual identification work, the manual provides other helpful information that can be useful for an agency creating an individualized disaster plan. Lists of personnel and their corresponding duties, and important resources are provided. A comprehensive preplanning section covers a variety of topics including what type of PPE is needed, how the media and religion can play a role in a DVI project, and the advantages of providing cooks to help prepare meals for those working on the disaster. Other important considerations include using medical doctors in the mortuary if no forensic specialists are available.

The next sections in the manual address the socio-cultural aspects of disasters, different aspects of dealing with grief, health considerations, and myths that follow disasters such as epidemics. The importance of the psychological care of survivors and first responders is also touched upon. The authors devote additional extensive coverage to the international right to identifications in different scenarios (times of war, war crimes, and disasters). This is followed by case studies that provide concrete examples of ideas and scenarios discussed in the manual. The manual finishes with a list of recommendations, a list of myths versus reality, and an extensive glossary.

Chapter two, “Medicolegal Work in Major Disasters,” has a subsection “Operations Coordination,” and this is where the WHO’s major themes are addressed. There is a list of ten ideas for the person designated to manage the fatalities to consider immediately following an event. These ten ideas include 1) determining the number of fatalities, 2) estimating the time needed to recover the remains, and 3) determining the condition of the remains (Pan American Health Organization 2004:33-34). The last

WHO topic, acknowledging if there is a manifest or not, is covered in that same chapter but under the subsection "DNA Identification." Here it is stated that before beginning the identification process, the type of population must be classified, followed directly by definitions of both open and closed populations (Pan American Health Organization 2004).

These key themes are not simply listed once and never addressed again. They are expanded upon throughout this manual. This manual covers the WHO major ideas thoroughly and serves as a comprehensive and valuable resource for any agency or jurisdiction drawing up plans for managing a large-scale mass fatality incident.

4.4. Summary

There are few resources available for those seeking information on how to develop their own disaster victim identification protocol or for those seeking to use an existing one. The Interpol guide is the only one comprehensive enough in scope and complete with forms and directions that could be used directly during a disaster. It also clearly addresses all four of the WHO panel themes. Its major weakness is the absence of anthropologists in the DVI process. Anthropologists have much to contribute toward improving DVI endeavors, so their exclusion constitutes a major oversight (Blau 2003; Kontanis and Sledzik 2008; Martrille, et al. 2006; Sledzik 2009). The guide developed by the National Association of Medical Examiners is straightforward and easy to use, and also covers three of the four themes outlined by the WHO panel. It too comes complete with forms developed by DMORT, but is not as easy to follow as the Interpol guide which spells out all the steps to follow in an easier format. The NIJ manual is difficult to follow, lacks clear organization, and does not address the major WHO themes. The FEMORS guide is comprehensive in scope, complete with forms as well, but also includes much extraneous information that would make it difficult to use during a disaster. It also does not clearly address the WHO themes. The Field Guide by the Pan American Health Organization is a well-organized, basic guide designed for community organizers and nonforensic specialists when resources are scarce and bodies are intact. Although the WHO themes are not addressed, the guide fulfills its stated purpose. The Jensen book and the more comprehensive Pan American Health Organization guide are both designed to provide a solid foundation on how to manage a disaster victim identification project as well as what questions to ask when designing an individualized protocol. Both are essential for any agency that wants to develop its own plan. The Jensen book is somewhat dated in its presentation and does not completely cover all the WHO themes but it provides crucial information and good case examples. The PAHO guide is impressively thorough, clearly covers the WHO themes, and discusses every aspect of managing an incident involving a large loss of life. This manual is well written and is invaluable to anyone working in the field of DVI management.

Chapter 5.

Major Management Decisions for the World Trade Center Victim Identification Project

The distinctiveness of each disaster raises new questions for fatality management teams. Usually, vital disaster characteristics such as the number of fatalities, the challenges associated with searching for and recovering victims, and the role of DNA in the identification efforts are known before the identification work proceeds (Sledzik and Kauffman 2008). These variables guide the design of the mortuary and identification process, which is tailored to meet each disaster's unique characteristics. However, the managers of the World Trade Center disaster response were forced to begin the identifications before they had enough information to answer any of these shaping questions. The result was a dynamic management approach as major policy decisions were open to constant re-evaluation in response to new information. A team of managers composed of OCME medicolegal investigators, forensic biologists, and mortuary personnel, including an anthropologist and a medical examiner, primarily made these decisions. The medicolegal investigators worked with the victims' antemortem information and next of kin, the forensic biologists processed and analyzed the DNA samples, and the anthropologist/medical examiners handled the human remains processed through the mortuary.

This section will evaluate several major management decisions. Some key decisions reviewed in this chapter include: 1) the decision to have anthropologists direct triage; 2) the decision to use the OCME standard autopsy form, instead of a disaster-specific form; 3) the process of determining what information should be collected from each set of human remains; and 4) the decision to implement internal review programs such as the File Review, Resampling, the Anthropological Verification Project, and the Final Anthropological Review. The results and discussion on each of the management decisions will mostly follow their presentation. However, results of the statistical analyses of two internal review programs will be discussed in Chapters 7 and 8.

5.1. Anthropologist-Directed Triage

The *Oxford English Dictionary* defines triage as “the actions of assorting according to quality”, “to pick, cull” (Oxford English Dictionary 1961:Ti-Tz 334). It is the assessment of the degree of urgency in order to assign the order of treatment. The term “triage” was commonly used in the early 1700s to describe the sorting of wool in degrees of fineness and quality and in the 1800s to describe the sorting of coffee (Oxford English Dictionary 1961). The U.S. military first applied the term to sick and injured people during World War I. In a book about his experiences working in an evacuation hospital during World War I, F.A. Pottle describes the military’s use of the term triage as a “sorting station” where the “the wounded were carefully sorted out according to the seriousness and urgency of their injuries” thus ensuring the most critically injured were treated first (Pottle 1929:140). Similarly, as applied in this dissertation triage encompasses the first assessment of human remains received, at the “triage sorting station” in the OCME mortuary once they had been recovered and transported from either Ground Zero or the Staten Island Landfill.

Triage is often the first station in a disaster mortuary, especially in incidents with highly fragmented remains (Mittleman, et al. 2000). A pathologist or an anthropologist commonly directs triage, depending on the type of disaster and the condition of the remains. The WTC mortuary initially had a forensic pathologist staff the triage station but within days of the disaster the management team determined that an anthropologist should direct triage. Two main considerations motivated this change. First, only medical examiners were allowed to complete death certification forms and it was important to free them to work the examination tables (Mundorff 2008). A second consideration was the condition of the remains. Of the 2,749 victims, fewer than 200 whole bodies were recovered. In fact, most of the remains were unrecognizable due to crushing, fragmentation, and decomposition. Early on some identifiable body parts, such as a hand, a toe, or an organ, were recovered, but this quickly changed. As time passed decomposition increased and most remains were simply bones with adherent soft tissue obscuring anatomic landmarks, making element classification difficult. An anthropologist with a deeper knowledge of osteological detail could use the boney landmarks to provide precise anatomical bone identification, whether or not soft tissue was present.

5.1.1. Triage Considerations

Every disaster is unique, and each incident's individual characteristics will determine triage team composition, how it functions, and where it is integrated into the identification process. Characteristics directly influencing the triage process include the number of deceased, degree of fragmentation, and taphonomy of recovered remains (Alonso, et al. 2005; Mundorff 2008; Rodriguez 2005). It is well recognized that site characteristics, recovery-induced commingling, trauma inflicted by digging activities, and improper and unscientific recovery techniques complicate mortuary analysis (Egana, et al. 2005; Sledzik and Kontanis 2005; Tuller, et al. 2005). These were some of the problems recognized and addressed at the WTC triage station (Mundorff 2008).

Actions performed during a triage examination can also differ greatly depending on event characteristics (Kontanis and Sledzik 2008), but the central feature in any mass fatality triage situation involves sorting, or culling material useful in identification from material that is not. The triage team is empowered to sort out commingling, identify and discard nonhuman remains, rearticulate or reassociate disparate pieces within a body bag, and anatomically identify fragments for later examination. Because an in-depth understanding of human skeletal anatomy drives all these activities, triage of fragmented remains is most effective when directed by a physical anthropologist (Byrd and Adams 2003).

5.1.2. WTC Triage Process

The triage process used during the World Trade Center mortuary operations was designed by the OCME staff anthropologist and evolved over time. As mentioned previously, the triage station was first in the mortuary assembly line established to examine and document the remains. The triage team usually consisted of an anthropologist and up to four assistants, depending on the flow of the remains from Ground Zero. The assistants were often NYPD, FBI, medical students, or other personnel from the OCME. The anthropologist performed all assessments at the triage station; the assistants provided support, such as labeling and opening and closing bags to help accelerate the process.

The process began as follows: a body bag was removed from the refrigerated truck outside the mortuary and brought to the triage table. Before they opened a body bag, the triage team attempted to locate the grid recovery tag. Then an anthropologist opened the bag to assess the contents. Bags from Ground Zero contained a wide variety of material, ranging from single whole bodies, to fragmented body parts mixed together, to dozens of small red biohazard bags each filled with fragments of human remains. Additionally, building material, personal effects, and nonhuman remains were intermingled in these bags (Mundorff 2008).

Each bag was examined to eliminate nonhuman remains and to detect commingling. Commingling was defined as any unassociated or unattached parts within the same body bag. Body bags delivered from Ground Zero generally contained the remains of more than one individual. Individual body bags could contain dozens of small, discrete pieces of human remains along with large torsos or other recognizable body parts. Where fragmented remains appeared to originate from the same individual, but were not physically attached or could not be fit together with anatomic certainty, they were separated. For example, if ten skull fragments were collected in the same recovery bag and six of these fragments could be fit together but the remaining four could not, the remaining four skull fragments would each be bagged separately, while the matched six would be grouped and bagged together as a single case. Even if the remaining four appeared consistent with the acceptably grouped fragments in size and other characteristics and did not overlap anatomically with the other six, they still would not be associated. This ensured that a DNA sample would be taken from every fragment that might possibly represent a separate individual. Therefore, every fragment of human remains that was not attached to another by hard or soft tissue, or did not fit together, was segregated. When such parts were found, they were removed separately, passed to an assistant, and individually bagged.

Each of these bags became its own case. A case was a single set of human remains that was individually processed for identification, and could be as small as a 1-inch bone fragment or as large as an entire body (Mundorff 2008). These new cases were also labeled with the accompanying grid location of their originating body bag, indicating that the remains were recovered from Ground Zero. Anthropologists performing triage also provided short anatomical descriptions of the contents in the bag if necessary. The bags were then placed on another table to await medical examiner processing.

The remains recovered from the Staten Island Landfill operation were individually bagged directly from the conveyor belt and therefore did not require an in-depth triage examination in the mortuary to sort commingling (Mundorff 2008). Instead, they were examined to eliminate nonhuman remains and the bag was labeled SILF, to show that the remains were recovered from the landfill. The majority of the remains recovered from the landfill were dry bone fragments so the bags were also anatomically labeled to indicate which bone and side the fragment represented.

While this was the basic triage protocol, its practice actually evolved over time. As mortuary personnel learned about the extent of the devastation to the human remains, complicated by necessary destructive excavation procedures at Ground Zero, they came to believe far more commingling might be present than had been initially recognized or anticipated (Mundorff 2003). Consequently, more rigorous triage standards and examination techniques had been introduced after the first few weeks of recovery. Essentially, cases that “appeared” not to be commingled (essentially whole bodies or large body parts), that sometimes bypassed triage in favor of quick processing for potential identifications, were no longer allowed to bypass triage. Instead, every case was rigorously examined by an anthropologist to separate grouped remains and dissect out small, embedded bone fragments.

5.1.3. Results from Anthropologist Directed Triage

5.1.3.1. Nonhuman Remains

Having a forensic anthropologist triage each bag prior to assigning the remains a case number and commencing processing was one of the most significant decisions made during the WTC identification project. The anthropologist's ability to sort out and discard nonhuman remains was immediately beneficial because many restaurants and catering services were destroyed in the WTC complex and so thousands of nonhuman remains were recovered. Sorting these fragments from the overall sample saved precious time, energy, and resources. Each discarded fragment of nonhuman remains meant avoiding another examination and another costly and time-consuming DNA test. It should be noted, however, that the anthropologists working the triage station were directed to be cautious and conservative in deciding what was not human. Only clearly nonhuman remains, recognizable as animal or building material, were discarded. Any ambiguous remains, for example, a bone shaft fragment without any identifiable landmarks, were processed as human.

A review of the human remains recovered from the landfill operation illustrates the time saved in discarding nonhuman bones. From September 12, 2001, through December 31, 2001, a DMORT anthropologist attended the landfill operations to discard nonhuman remains recovered by the members of service who were monitoring the conveyor belts. During this time, the only remains that were submitted to the OCME for processing from the SILF were either clearly human or indeterminate. After December 31, 2001, DMORT no longer provided an anthropologist for the landfill operation. As a result, all subsequent fragments recovered from the landfill operation were submitted to the OCME without preliminary examination. Without an anthropologist at the landfill to discard the nonhuman remains, thousands more remains were sent to the OCME.

A comparison of the total number of NYPD evidence vouchers for cases submitted to the OCME from the landfill and the number of cases recorded by the OCME as being recovered from the landfill reveals just how many nonhuman remains anthropologists discarded during triage. The NYPD has documented that it submitted almost 5,000 separate cases, represented by individual evidence vouchers, from the landfill operations (New York State Museum 2002). The OCME has fewer than 2,500 cases documented as recovered from the landfill. The difference between these two numbers represents the nonhuman remains, which were documented by the NYPD at the landfill but discarded once they reached the OCME and therefore did not receive official case numbers. Since an anthropologist was discarding nonhuman remains at the landfill operation through December 31, 2001, most of these 2,500 nonhuman cases sent to the OCME and subsequently discarded were likely sent after there was no longer an anthropologist sorting them at the SIFL.

Conducting an anthropological analysis of the remains during triage at the OCME allowed for the nonhuman material to be identified and discarded before assigning the human remains a case number and sending them to examination. This eliminated nearly 2,500 nonhuman cases and resulted in significant savings in time and money for DNA testing. However, had an anthropologist been present at the landfill operation following January 1, 2002, to perform this initial examination, nearly half the cases submitted to the OCME would have been discarded before transport. This would have saved the NYPD the time of photographing, logging in, tagging, and transporting nearly 2,500 fragments that were subsequently discarded at the mortuary.

5.1.3.2. Type 1 and Type 2 Commingling

Triage anthropologists also addressed the significant problem of extensive commingling as they examined each body bag. During triage, every piece of human remains that was not anatomically attached to another by hard or soft tissue, or that could not be fit together, was separated.

The triage process addressed both recovery-induced (Type 1) and disaster-induced (Type 2) commingling. Type 1 commingling refers to remains collected together in one bag, but not attached to each other (Mundorff 2008). Therefore, the commingling occurred in the collection or recovery of the remains. The potential for this type of commingling has long been recognized, and most recovery operations are equipped to cope with it (Blau, et al. 2008; Fernando and Vanezis 1998; Goodman and Edelson 2002; Hooft, et al. 1989; Sloan 1995). An experienced practitioner can easily detect Type 1 commingling by examining the remains to see which pieces are actually attached to each other. When the remains are not attached, the triage team dissociates them. However, another type of commingling, more severe and difficult to recognize, was also common in remains recovered from the WTC site. Type 2 commingling, which is disaster-induced, was caused by the extreme destructive and explosive nature of the building collapses. The explosive force that blew over fire trucks and peeled stone facades from buildings also disintegrated human bodies, turning bones into flying shrapnel that became embedded in soft tissue from other individuals. The tidal wave of debris that carried human remains blocks away, depositing them in some cases on top of buildings, also fused soft tissue to bone fragments from multiple individuals so completely that the remains appeared to be from the same individual (Mundorff 2008). Type 2 commingling is less easily recognized than Type 1 commingling and is much more difficult to sort out during the triage process because it is more than just a matter of recognizing unattached parts; it is about teasing apart remains that appear to be one.

5.1.3.2.1. Site Formation Processes Contributing to Commingling

Site formation processes and transformation of the site over time determined the remains condition that also contributed to the commingling problem, particularly Type 2. These processes, some cultural in nature, include the events that initially formed the site, manipulation of the site for excavation, and site transformations over time from factors such as decomposition (Schiffer 1987). In the World Trade Center disaster, these processes included both primary and secondary events (Mundorff 2008).

The complex "archaeological site" was created by a multiplicity of primary events set in motion on September 11, 2001. These include the impact of the two airplanes and subsequent explosions from the jet fuel, the collapse of the South Tower, the collapse of the North Tower 29 minutes later *through* the debris of the South Tower, and the destruction of five additional commercial buildings into the debris pile over the next few days. Additionally, fires that started that day burned for almost three months. Often, one or more of these factors is present at a disaster, but rarely, if ever, have they all occurred at one disaster site (Sledzik and Rodriguez 2002). Multiple events combined into the process that determined the shape and condition and commingled state of the remains, in turn determining the methods used during triage and identification (Mundorff 2008).

Secondary events also affected the remains composition and their commingled condition upon arrival at the medical examiner's office. Secondary events include everything that was done to or occurred at the site in response to the events of September 11, 2001: the brackish water applied to those fires, decomposition over the eight-month excavation, and extensive site manipulation with dozens of bulldozers and grappler machines. The site consisted largely of 5,000-pound steel beams mixed with chunks of concrete making a manual deconstruction impossible. Large pieces of machinery, including grapplers and cranes, were brought in to assist. In order to place these cranes close enough to “the pile,” it was first necessary to create platforms for them, which involved bulldozing and compacting sections of the site. Additionally, as the site was excavated below ground level, a ramp was built to allow excavation equipment to move in and out of “the pit.” The material bulldozed for these constructions came from the pile itself. When these platforms and roads were later excavated, human remains were recovered from the debris (Mundorff 2008). Even the way the grappler machines tore into the debris pile with their metal teeth to grab up the debris and carry it to the waiting trucks would destroy, pull apart, and commingle any friable remains mixed within the building material. Although it was mostly unavoidable, this manipulation of decomposing and already fragmented human remains caused further destruction and commingling.

The methods and techniques used to recover remains further complicated triage and identification, and are also characterized as secondary events. Excavations by untrained personnel or performed in an unscientific manner affect the recovery process and cause further commingling (Egana, et al. 2005; Sigler-Eisenberg 1985; Sledzik and Kontanis 2005; Tuller, et al. 2005). FDNY personnel performed the bulk of the recovery and excavation of the human remains from Ground Zero. These individuals are not trained in techniques of forensic archaeology, excavation of human remains, identification or recognition of human remains (especially fragmented ones), or site formation processes and their lack of training complicated the recovery process and allowed for significant additional Type 1 (recovery-induced) commingling. Instead of consigning each piece of remains to a single bag, FDNY personnel filled body bags with potentially unrelated body parts before sending them on to the medical examiner's office. FDNY also lacked knowledge of and training on techniques for properly excavating a body found nearly intact but buried in debris, especially bodies in an advanced state of decomposition. Once decomposed, the slightest movement or disturbance easily dissociates body parts (Mundorff 2008). These issues can be mitigated with a deeper knowledge of human anatomy and the application of forensic archaeological techniques (Blau and Skinner 2005; Sigler-Eisenberg 1985; Skinner and Sterenberg 2005).

5.1.3.2.2. Reconstruction Commingling

Reconstruction of remains at the site by the recovery personnel also complicated triage in the mortuary. Reconstruction commingling typically occurred when human remains were found near empty or partially empty pieces of clothing. Recovery personnel would place the remains into the clothing in an attempt to make it look like the remains had been discovered inside the clothing. For the most part, this happened only with FDNY clothing. For example, FDNY personnel found an empty monogrammed fire department bunker jacket during the excavations and placed the nearest human remains inside the jacket before transporting it to the medical examiner's office. It seems that in placing these remains in the bunker gear, FDNY hoped the identification would be accomplished faster and that the family would receive "more" of their loved one, because the remains were in a jacket with a name on it. When the remains arrived at the mortuary, however, anthropologists immediately detected these reconstructions, which were often quite obvious, during triage. In one instance, leg bones had been placed in a jacket sleeve. In another instance, an examination of what appeared to be the nearly complete body of a fireman, fully clothed in bunker gear, revealed two left feet in boots neatly tucked into the bunker pants (Mundorff 2008).

Although these reconstruction activities were driven by understandable grief and the urge to identify MOS fallen, they changed triage procedures in the mortuary. The triage team began to examine more closely, and often separate into multiple cases, body parts found within clothing (Mundorff 2008). This likely split apart cases that could have remained intact and also separated remains from labeled clothing that could have been used as presumptive information toward identification. All this, in turn, slowed the identification process because the triage team could no longer trust remains in labeled bunker gear recovered by FDNY personnel. It is important to remember that any piece of falsely identified remains might be the only piece by which to identify another individual.

Therefore, it was important to have an anthropologist direct the triage station. Not only could anthropologists sort out nonhuman remains before case numbers were assigned, saving time and money, they were also best prepared to resolve both types of extensive commingling and to identify potentially hidden reconstructions within clothing. As will be discussed later, a few of the bodies or body parts that bypassed the triage processes were later determined to be commingled, causing problems when these cases were identified to just one person.

5.2. Documenting the Remains

Those involved in the WTC human identification project quickly realized that its success depended on the ability to gather, maintain, and retrieve information. The case file for each body part would be the foundation of the WTC operation. But the first, albeit least appreciated, step was to come up with a numbering system to track each case of human remains and its corresponding file, DNA sample, and other associated items.

5.2.1. *Numbering Cases*

After triage, the remains were assigned a case number and then a proper examination was performed. Choosing a numbering scheme to track the cases can be a controversial process (Jensen 1999; Pan American Health Organization 2004; Skinner and Sterenberg 2005). For example, should numbers be randomly assigned, can letters be used along with numbers, should there be subnumbers? The OCME decided to adapt the system used to track regular autopsy cases but make it unique to this disaster (Brondolo 2004). "DM01-," representing Disaster Manhattan 2001, would prefix each case number, which would then appear as DM01-00001, DM01-00002, etc. The numbers would begin at one and continue consecutively until the last case had received a number, with an established potential for 99,999 cases (a random number chosen because it was high enough that the OCME did not expect to exceed it). Each case file contained a printed strip of bar-coded stickers, generated by the OCME, with the same case number on it. Therefore, when a number was assigned to a case, that same number would be affixed to not only the human remains, but also the corresponding case file (on every piece of paper in the file), on the tube containing the DNA sample removed from the remains, and on any other evidence or personal effects associated with that case.

This numbering approach had several advantages. First, consecutive numbers are easy to understand. Second, consecutive numbers imply a logical order and a "date" of recovery and processing; cases with higher numbers were received and processed later than cases with lower numbers. Cases with consecutive numbers could therefore generally be assumed to have been processed around the same date, which often implied the remains were found near each other. Third, not mixing numbers and letters, or using subnumbers, simplified the numbering scheme, thus reducing the opportunity for clerical mistakes. Finally, although the numbering format was the same one used to number daily autopsies, the prefix “DM01-” designated the remains as from the WTC disaster. The electronically printed stickers with bar codes significantly reduced the incidence of transcription errors and increased the tracking potential.

This simple numbering system worked so effectively that it was implemented a second time, two months later, for the crash of AA Flight 587 in Queens, New York. The only difference was that the Queens disaster used the prefix designation “DQ01-” for Disaster Queens 2001, as opposed to “DM01-” and the case file was red.

5.2.2. The Forms

Every single case had its own case file. Because a consecutive numbering system was used, blank case files were put together outside the mortuary, boxed in numeric order, and then brought to the mortuary ready to be assigned to a set of remains. Each cream-colored manila file initially contained two forms, an Intake Form (Appendix A) and a two-page standard New York City OCME autopsy form titled Report of External Examination (Appendix B), plus, as mentioned above, an extra strip of computer-generated stickers bearing the case number and bar-coding.

5.2.2.1. The Intake Form

The Intake Form is essentially a case tracking form. Its top portion has space to record the case number, name, age, race, sex (with an option for unknown), and DNA sample. However, choices for DNA sample are limited to blood, muscle, or other. There is also a place to record whether the remains are a whole body, a partial body, or a fragment (though no standard is provided as to when a partial body becomes a fragment). Next is the tracking section, which provides a list where the medical examiner can check off which other stations they would like the case to be sent to, including photo, evidence/property, x-ray, dental, and three lines for other. To the right of each station option are lines for the station technician to check, indicating that the case was processed, and to provide their initials. Finally, a box designated "disposition/storage" recorded where (that is, in which trailer) the remains were stored, followed by a line for the MLI's and medical examiner's signatures and the date of examination.

5.2.2.2. The External Examination Form

The Report of External Examination form, more commonly referred to as an External Examination form, is the standard OCME form used during an external autopsy. An external autopsy is just that, a visual documentation of the deceased based on what can be seen externally. The body is not cut. On this form there is space to record the decedent's name (which in the case of the WTC disaster was always unknown) and the case number, followed by a line to describe the development/nourishment/overall appearance of the remains. The next line records height in feet and inches, weight in pounds, skin color, sex, race, and age. This is followed by two lines to describe rigor mortis, livor mortis, temperature, and other postmortem changes. The rest of the form is dedicated to providing space to document brief physical descriptions about the decedent such as hair texture, color, and length in inches, presence of moustache/beard (also length in inches), eyes, oral cavity and teeth, torso (anterior and posterior), extremities (upper and lower), genitalia, scars, tattoos, and therapeutic procedures. A blank area comprising nearly half the form, and labeled "Other, Including Injuries" is for additional remarks. Again a line is provided at the bottom for the name of the medical examiner, and the date and time of the exam. The back of the form has a typical front and back diagram of a naked person. This is commonly used during autopsy to illustrate where injuries are on a body or to make other relevant indications. The next section will highlight specific problems with the choice of using these two forms.

5.2.2.3. Using the Forms for the WTC Remains

Information on and descriptions of WTC cases were generally recorded in one of two ways. First, remains representing more than a simple bone or tissue fragment were recorded on the External Examination form. Because all the remains were unidentified, the name, age, race, and often sex were left blank. In fact, most of the top area of that form was usually left blank. Instead, the description of the remains was written within the "Other, Including Injuries" space. Additionally, the diagrams on the back of the form were often used to illustrate specifically what part was present by circling it, or what part was missing by crossing it off. The cases that used the External Examination form would also often use the Intake form to indicate which other forensic stations would need to examine the remains. For example, if the remain was an arm, the description of the arm would be written on the External Examination form and the Intake form would likely have one of the boxes for "Other" checked off and "fingerprint" written in. This would indicate to the escort responsible for that set of remains that it needed to be examined by the fingerprint station.

Remains that were simply a bone or tissue fragment were documented in one of two ways. They were either described on the External Examination form in the same manner as above or, in some cases, medical examiners would only use the Intake Form. In these instances, the ME would use the blank space for Disposition/Storage and write either "bone" or "ST" (indicating soft tissue). This would save significant time as there was really nothing else to document about those types of cases. It was generally not a problem to record these small bone or tissue fragments; the problems with using these forms arose when the case represented anything more than a bone or tissue fragment because of the limitations of the forms' design and the inconsistent formats the pathologists used to record the data.

5.3. What to Document and Where to Document It

Information describing each set of remains was documented on the forms in the case file. But, as mentioned earlier, the forms used were not specific to this disaster and therefore the information they captured was limited. In time, as protocols changed, other forms, which will be discussed later, were added to the file. No set form would have proven adequate to the task. At the outset of the recovery efforts no one knew for sure what information would be pertinent to the identification process. In fact, since the WTC identification project, the OCME, NYC, has invested significant time and money into developing new dynamic, disaster-specific recording forms that could be modified and also mirror the computer program where the information is entered. This subsection will discuss several pieces of information including how, where, and what to record as the descriptions of the remains, the DNA sample, recovery locations, and cross-reference numbers, and how the mortuary team attempted to incorporate such pieces of information onto the forms and into the identification process and final review process.

5.3.1. Recording the Description of the Remains

There was no consistency around what details were recorded or how the remains were described by the different medical examiners. The External Examination form had a blank spot for the description, but asked no specific questions such as side or size, so information written in this field varied considerably depending on who performed the examination. For example, a case consisting of a right leg could be described in many different ways: “a leg,” “a right leg,” or “a right leg from mid-shaft femur and including complete foot.” Also, because the reverse of the form had a diagram of a body, medical examiners sometimes wrote nothing on the front of the form and simply circled the portion of the body represented on the picture.

Sometimes the written descriptions would be as vague as “bone fragment,” even if the fragments were anatomically recognizable. This lack of detail was particularly troublesome for larger body parts such as torsos. When a case is described simply as a “torso,” those reviewing the paperwork cannot determine if this body part included limbs or a part of a limb or even a head. Cases described only as torso, or similar lack of detail, were particularly problematic once they received an identification and other fragments were already identified to the same individual. If the case description lacked specific detail about what was present and what was missing, and there was no photograph, or the photograph did not help clarify, there would be no way to determine if additional pieces identified to the primary body part were duplicate body parts wrongly identified to the same individual, or if they did indeed anatomically “belong.” (The lack of detail and other missing information was rectified during a program called the Anthropological Verification Project, which will be discussed later in this chapter.)

The inconsistency of descriptions and the lack of standardized forms made it impossible to standardize information in the database. Two identical cases could be described and entered into the database differently; for example, two right legs. If one was originally recorded as “right leg,” that was how the information was transcribed into the database. If the other was described as “lower limb, right,” that was how it was entered into the database. This lack of standardization makes searches nearly impossible.

Photography was also used sporadically as supplemental information for documenting the remains. Each case could theoretically have three sets of photographs taken: one Polaroid by OCME personnel and another standard photo by the NYPD team working alongside the ME. However, not every case had both or even one photograph taken during examination. While most identifiable large body parts were photographed, most unidentifiable fragments were not. Additionally, the photos taken by the NYPD were not readily available to the OCME. They had to be requested, and were difficult to sort through as they were often unclear. During the preservation process, for final storage in the memorial of the unclaimed and unidentified remains, every case still curated at the OCME was eventually photographed; some for the third time, some for the first.

5.3.2. DNA Sample Recording

The limitations of the two forms made the detailed recording of DNA sample characteristics problematic. Although the Intake Form included a space to record what was sampled for DNA, this choice, as noted above, was limited to muscle, blood, or "other." The "other" category was usually chosen to designate "bone," but it could also designate other types of DNA samples including cartilage and organs. The form would have been much more useful if it had required and included space to record which specific bone element had been sampled, or from where the muscle had been sampled. Because the form did not elicit this information, it was generally not captured. Although it probably did not affect individual identifications too significantly, this information would have been useful for shaping sampling policies. For example, if patterns showing specific bone elements consistently yielding or not yielding DNA profiles emerged, that information could have been passed along to the medical examiners who were choosing the DNA samples. This will be examined further in the chapter retrospectively analyzing which elements more consistently yielded usable DNA.

5.3.3. Tracking the DNA Sample from Small Remains: The Story of a Sticker

While the torsos and large body parts often lacked important detail in their descriptions, the smallest remains were also ambiguously recorded on these forms and further measures were implemented to help keep track of them. As the recovery process continued at Ground Zero and the SILF, fewer large body parts and torsos were recovered. Beyond the initial trauma to the remains from the primary disaster events, this was likely due to disarticulation as a result of decomposition and disruption by heavy machinery. Many small fragments of human remains continued to be recovered from both the site and the landfill, some of them so small, one inch or smaller, that DNA samples could not be cut from the remains as per usual sampling protocols. Instead, the entire case was sent to the DNA laboratory for testing. Since no part of that case would subsequently be curated at OCME until DNA testing was complete, these cases had to be tracked differently from the others (where only the DNA sample was sent to the laboratory and the case itself remained at the OCME).

In early October 2001, one of the medical examiners who frequently worked the overnight shift noted that the information indicating that a case was so small it was entirely sampled for DNA was not being captured accurately in the case file. Through the procurement department she requested that a sticker and a hand stamp reading “Entire Sample DNA” be created to mark all items and associated paperwork for those cases. The “Entire Sample DNA” sticker was affixed to any DNA sample tube or bag for which the sample represented the entire case (Photo 5). The case file was also stamped “Entire Sample DNA” on the outside of the file folder and on each page of the associated paperwork inside the file, all of which was later transcribed into the computer database. Approximately 5,300 cases in the database are labeled as “Entire Sample.” Since this labeling scheme was not implemented until after approximately 5,000 cases had been processed, some small samples escaped this labeling. However, as most of the cases processed early on were fairly large the number of unlabeled cases must be relatively few. Furthermore, the Anthropological Verification Project, a secondary review of unidentified cases (to be discussed later), uncovered very few of these early cases that should have been designated “Entire Sample DNA,” and of those, many were labeled retroactively.

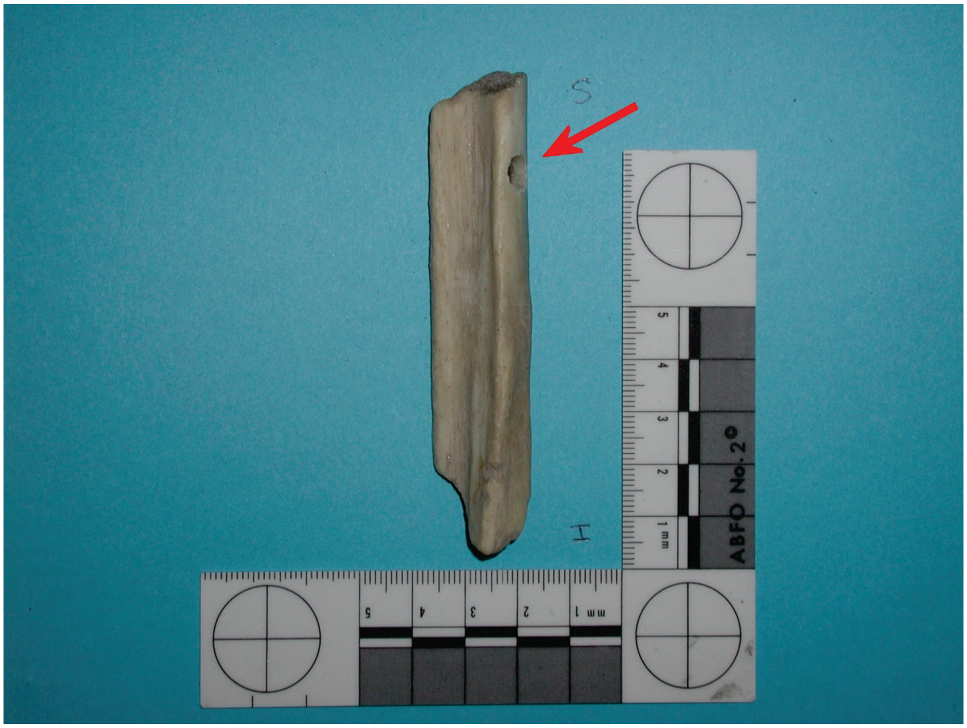
Photo 5. Example of Stickers with Label “Entire Sample DNA” Used on DNA Sample Tubes for Cases Submitted in their Entirerty for DNA Testing

Source. Office of Chief Medical Examiner, New York City (2001), used with permission.

Flagging a case as “Entire Sample” had several advantages. First, the paperwork designation alerted the medicolegal investigators to track the sample and to verify that it had been returned from the DNA laboratory before a family was notified if the sample became identified. By contrast, standard cases were released to the family immediately upon identification, while the corresponding DNA sample would be returned to and permanently curated at the OCME. However, if the case was entirely sampled for DNA testing, no part of it was at the OCME until the DNA sample had been returned from the laboratory. If the case became identified before the sample was returned, there would be nothing to release to the family. Marking the paperwork allowed investigators to track “Entire Samples” and ensure their return before a family was notified.

The “Entire Sample” designation also alerted lab technicians to avoid using the entire sample so that some portion might be returned after DNA testing if possible (Photo 6). Fortunately, most cases that were entirely sampled for DNA were not entirely consumed during testing. Of the approximately 5,300 “Entire Sample” cases, only about 100 of them were entirely consumed. When an entire sample was completely consumed during the DNA testing, there were no remains left to present to the family. However, this circumstance primarily involved victims who had other remains identified to them. If an identification is established by a single fragment of bone which is then entirely consumed during DNA testing, the family can received the remaining extract from the DNA test.

Photo 6. ***Right Fibula Fragment Entirely Submitted for DNA***



Note. Red arrow points at hole drilled from which DNA was actually sampled. Source.Office of Chief Medical Examiner, New York City (2002), used with permission.

5.3.4. Recording but Not Testing Calcined Remains

Other decisions regarding what information to record in the case file from each set of human remains were based on the nature of the disaster. Within days of the disaster, a mayoral mandate required DNA testing of every fragment of recovered human remains (Hirsch 2008). This ensured that every attempt would be made to identify all the possible victims, no matter how small their remains. Because of the extreme destruction and prolonged fires, it seemed likely that many victims' remains would not be recovered. By testing every fragment of bone and tissue, the City of New York could be certain that best efforts had been made to identify all victims in the likelihood that a victim might be represented only by a single small bone or tissue fragment, as indeed was the case many times.

However, despite this mandate to test every piece of remains, it was decided to discontinue testing “completely calcined” remains. This became an issue in early October 2001 when the first “hot spot” in Ground Zero was excavated. Although dozens of fires burned throughout the disaster site for many days, Ground Zero had three long-term hot spots that burned continuously at temperatures upwards of 1000°C for three months (FEMA 2002). At the time of excavation, it was decided that charred, burned, or even partially calcined remains would be sampled for DNA, but the fragments that were completely calcined would not be sampled.

When the calcined remains were first encountered, the director of forensic biology in consultation with the anthropologist sent a memo to the pathologists working the exam tables instructing them to sample burned remains preferentially by color. They were instructed to first look for an unburned section of bone, then brown bone, then blackened bone, and lastly white bone. Classifications based on the condition of remains have been used successfully to categorize burned bone (Correia and Beattie 2002).

Remains that are “completely” calcined are by definition burned to the point where no recoverable DNA is left in the bone; everything organic has been burned out. Testing these fragments would have been a waste of resources. Of the completely calcined remains that were tested (before the policy of not testing them was implemented), none yielded any usable DNA. Since thousands of tiny calcined bone fragments were recovered, testing them all would have increased the overall number of samples for processing without yielding additional identifications.

Large plastic bags full of burned and calcined remains were transported from Ground Zero to the mortuary where they were opened and the contents examined at the triage station. Anthropologists visually inspecting the burned fragments would determine the degree of calcination. Remains that showed evidence of charring or burning were sent through the system to be DNA-sampled in a spot that showed the least amount of burning. Remains that were partially, but not completely, calcined were also sent through the system with a note to sample the remains as far from the calcination as possible.

Once the completely calcined remains were sorted from the rest of the cases, they were grouped together in buckets based on recovery location and labeled as "commingled calcined remains" (Photo 7). Although the remains received a case number, and details were recorded, usually the only information that could be gleaned from these groups of calcined remains was the minimum number of individuals that they represented.

Photo 7. Bucket of Commingled Calcined Bones

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.

In one instance, an identification of calcined remains was possible because a metal prosthesis embedded in a tibia fragment had survived and could be matched to antemortem records (Photo 8). However, because the hundreds of other calcined bone fragments recovered along with that identification represented at least three individuals (as determined by mandibular fragments) the rest of the fragments could not be associated with the identified tibia (Photo 9).

Photo 8. Example of Calcined Tibia Identified by Prosthetic Pin Embedded in Bone

Source. Office of Chief Medical Examiner, New York City (2002), used with permission..

Photo 9. Three Mandibles Used to Determine Minimum Number of Individuals from Commingled Calcined Remains

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.

5.3.5. Location of Recovery

Staff did not discuss recording whether the remains were recovered from the site or the landfill before the mortuary process began. And again, because they used regular autopsy External Examination forms, they had nowhere to record the recovery location or the specific grid location as this is not information associated with regular autopsies. As previously described, recovery workers implemented a grid system and attempted to label every body bag with a grid designation indicating from where the remains inside had been recovered. Eventually some medical examiners and scribes began recording this information in a corner of either the Intake or the External Examination form, but this practice was sporadic for the first 5,000 cases. And when it was recorded it was not written consistently in the same spot or in the same format, or even on the same form, meaning the information was often missed during data entry.

This discrepancy in the documentation procedure resulted from several factors. First, management meetings to review mortuary procedures were held every morning, but no one offered a formal decision on whether or not to record the grid details, so some medical examiners did and others did not. Second, there was little early communication on this subject between the operations at the disaster site and the mortuary, so although the grid system was implemented within days of the disaster, the importance of recording this information was not conveyed to the mortuary personnel. In early October 2001, less than a month after the disaster but after a few thousand cases had been processed through the mortuary, all personnel were eventually instructed to record the grid location. Consequently, most of the first 5,000 cases list no recovery location, and the few that do list only "site" or "landfill," rarely a specific grid location.

The problem was compounded by body bags that sometimes arrived from Ground Zero without an associated grid location, or with a grid location that had become illegible by the time the remains were transported to the OCME. When a body bag contained multiple remains but possessed no legible grid number, none of the remains inside were assigned a grid location. Therefore, even after the decision to record grid locations for all remains, many cases were processed without that information. Approximately 12,575 cases list a specific location in the database. A total of 10,189 have grid designations and about 2,396 are from the landfill. The rest of the 7,395 cases list the default location as "site" only.

How valid was the recorded grid information? And was the time used to keep track of these grid locations justified? The emergency service agencies handling the recovery operations established the coordination grid for Ground Zero. Recovery locations, usually written as a letter and a number (e.g., M-14), were then recorded on tags attached to the body bags. If this grid locator was attached to a bag, that locator followed all remains associated with that body bag. While some grid locator tags had GPS coordinates on them, many did not and of those that did, often this information was not transferred during triage. Therefore, depth was not accounted for on these tags and a fragment found on the surface of Grid M-14 as well as a fragment found at the bottom of the “pit” in Grid M-14 both received the same grid location designation, even though there may have been up to 140 feet in depth between the two fragments. Although locater tags indicated from which 75 ft x 75 ft section of Ground Zero the human remains had been recovered, the accuracy and therefore usefulness of that information is debatable. Bulldozing and road construction to assist excavations caused human remains to be moved and deposited outside their originally deposited location. Yet, the grid they were eventually recovered from was the grid designation they received. Triage personnel invested substantial time and effort in transferring these grid locators to all the bags that were subsequently split out of a single body bag for that information to be included in each case file (Mundorff 2008). The data entry personnel, who searched for and then entered this information into the database, invested additional time. Whether this process was a good use of time and energy is debatable as the information gathered was unreliable, but it most probably did not compromise identifications in any way.

Next of kin often zeroed in on the recorded grid locations when reviewing case files with medical examiner personnel. There seemed to be an overwhelming need to know where victims’ remains had been found, compared to where their office was located, to help understand what might have happened to them during the event. However, when victims had many remains recovered from many disparate grid locations, a false sense of what might have happened to the victim could have been conveyed to the next of kin. Those grid locations could represent where the remains were deposited because of the events of the disaster or because of site manipulation required during recovery and excavations.

5.3.6. *Cross-Referencing*

As mentioned earlier, the triage station was the first stop for the human remains upon arrival at the morgue. Here the remains in a single body bag might be separated into dozens of individual cases if they were not anatomically attached or clearly associated. It was also here that cases became cross-referenced (x-ref). Cross-references were created in two circumstances. First, when anatomic characteristics led the triage anthropologist to believe that remains were likely from the same individual but the remains were not actually attached, those remains were separated into individual bags with each bag being designated a separate case. For example, if during triage the anthropologist found a right first, second, and third rib not attached by soft tissue in the same recovery bag, these would be cross-referenced because they probably belonged to the same individual. Sets of cross-referenced cases were grouped together to be processed consecutively (Photo 10) and each was designated as “x-ref with”…and [the primary case number] in the paperwork. This designation was written in the paperwork of all cases believed to be from the same individual and cross-referenced together. A total of 3,631 cases had a cross-reference designation in their file. This information was intended to be used later to help associate fragments that were believed to belong to the same individual to whom they were cross-referenced.

Photo 10. Cross-Referenced Cases Grouped Together into Bins to Be Consecutively Processed Together

Source. Photo © Rich Press (2001), used with permission.

The second reason for cross-referencing mostly involved presumptive FDNY remains. FDNY officials often insisted that all fragments found in association with firefighter remains be cross-referenced with those remains. These cases were often processed under the "supervision" of a fire marshal who had also been present at the site during the excavation of the remains. These remains were usually cross-referenced even if the triage anthropologist determined that they could not possibly be from the same individual (e.g., duplicate parts).

As with the problem of where to put the grid location, there was no specific spot on either form where the medical examiner could indicate if the case was cross-referenced. Therefore, when a cross-reference was documented for a series of cases, it could either be listed on the Intake Form or the External Examination form. It was frequently written in a corner of either form, but sometimes it was simply listed wherever there was room, such as in the box for Disposition/Storage. This lack of standardization meant some cross-references were missed during the initial data entry of the case files. And, as with the recording of the grid information, it is questionable whether or not the significant time that went into the cross-referencing practice was worth the investment. To date, the cross-referencing data has not been used to help reassociate disparate remains or as a means to bolster partial DNA identifications.

5.4. Form Limitations

As illustrated above, both forms had significant limitations not only in the information they solicited during examination, but also in their design for recording information. One of their main problems was where to document information. The OCME management decided against creating a new form to document the disaster remains and opted to use the External Examination form because it is traditionally used to document bodies that are not going to receive autopsies and the WTC remains were not going to receive autopsies. However, because External Examination form is also generally used for complete bodies, they have no category to accurately document fragmented remains. Even the body diagram on the back of the External Examination form was of limited use once the remains were predominantly skeletonized. A diagram of a skeleton would have been more appropriate to capture information about specific bones.

Furthermore, information recorded from a regular autopsy on an External Examination form will generally be dictated by the medical examiner and then transcribed into a report format. This ensures that the correct information is recorded. The information on the WTC form was transcribed by hand into a database created specifically for the WTC disaster. If the information captured on the forms was unreadable to the data entry personnel, or if they could not find a corresponding place in the database for the information, they ignored it. A specific form, mirroring the separate fields on the database screen, should have been created to avoid discrepancies between what was written on the External Examination form and what was entered into the database. Later in the identification process it became apparent that significant information from the case files had not been transcribed into the database and those discrepancies were impeding identifications. This problem was addressed during the File Review Project, discussed next.

5.5. File Review Project

Ensuring that the correct information from the examination is captured in the case file is only part of the data management process; it is also crucial to ensure that the information recorded in the case file is correctly transcribed into the database. As mentioned above, this did not always happen. Therefore, in early 2004, the OCME anthropologist initiated a File Review project to address the discrepancies between the case files and the database information (Sledzik, et al. 2009). Several anthropologists were hired to review and re-enter the information for each of the nearly 20,000 case files in the database. A cursory comparison of some files with their corresponding database entry revealed that the most frequently omitted information was in the description of the remains, such as anatomical detail, with difficult spellings or ME shorthand. It appeared that the personnel who input the initial data entry, and were unfamiliar with osteological terminology, had left out words when they were unsure of their meaning. Also, because of the lack of consistent use and standardized placement, details such as grid location or cross-references were commonly missed during data entry.

Although this was a file management issue, anthropologists were chosen for this project because of their knowledge of anatomy and osteological terminology (Sledzik, et al. 2009). They were also already familiar with the recording forms because they had served as scribes for the medical examiners during the initial examinations and during the Anthropological Verification Project. The added details and confidence in the accuracy of the database information were later important for the Final Anthropological Review process (to be discussed later), as well as during meetings with individual family members. While the results were not quantified, it appeared that many records reviewed during the File Review project indeed contained errors. This is not uncommon, particularly during data collection from mass fatality events. This phenomenon, highlighting the most common points of data error, has been well explained in a recent chapter on MFI data management (Hennessey 2008).

5.6. Internal Review Programs

The OCME anthropologist eventually initiated four separate review programs aimed at increasing efficiency and accuracy in remains examination, recording of information in the case file and the database, and DNA sampling. One, the File Review project, was discussed above. This next section will address the remaining three: the AVP, the FAR, and a project to resample remains that initially had not yielded sufficient DNA.

5.6.1. Two Programs Re-addressing Commingling and Contamination

Medical examiner personnel were initially caught off guard by the degree of destruction and fragmentation to the recovered human remains. They had no theoretical schema to comprehend the injuries a human body suffers in the collapse of a 110-story building. Even the sheer number of fragmented pieces of human remains—nearly 20,000—was overwhelming. Moreover, the sense of urgency at the beginning of the disaster response was so intense that triage was sometimes bypassed altogether to speed bodies through identification. Larger body parts that bypassed triage in favor of quick identification generally possessed standard identifiers such as fingerprints or dental attributions (Mundorff 2008).

Medical examiner personnel came to appreciate the true force of the disaster and the extent of the commingling within the first few weeks. Anthropologists and pathologists then came to understand that small bone fragments were likely embedded in the tissue of body parts that had bypassed triage and that some cases of commingling, particularly Type 2 commingling, might initially have gone undetected. The policy of DNA-testing each piece of remains made it imperative to retrieve these small fragments and so a secondary review of all the remains was initiated (Mundorff 2008).

One particular “defining case” spurred the forensic anthropologist, along with other key personnel on the Disaster Identification Team including the Director of Forensic Biology, the Director of Investigations, the Assistant Director of Investigations, and the Chief Medical Examiner, to address the need for more rigorous quality control procedures for unidentified remains and before the final release of identified remains. This case led to significant procedural changes and the creation of two crucial programs aimed at mitigating commingling problems: the Anthropological Verification Project (AVP), which focused its efforts on unidentified cases, and a Final Anthropological Review (FAR) program, which focused its efforts on identified cases. The results of the AVP are discussed in Chapter 8.

5.6.1.1. The Defining Case: The Birth of the AVP and FAR Programs

After a disaster such as the WTC, deciding when to have a funeral and bury the remains can be agonizing. Families had been informed that because of the extreme fragmentation and the ongoing identification process, it was likely that victims' remains would continue to be identified days, weeks, months, or even years later. Many families were forced to wait as they balanced their desire for a timely funeral against the desire to bury as much of the decedent's remains as possible. Families often waited until a "significant amount" of remains had been identified before they decided to claim a loved one's remains. It was therefore not uncommon for families to respond to an identification notification with a request that OCME personnel provide them with an estimate of the percentage of remains recovered for that victim (Mundorff, et al. 2008).

In May 2002, the OCME notified a particular family that their loved one's remains had been identified. In this particular case, the forensic anthropologist had examined the remains in collaboration with a medicolegal investigator, at the family's request, to determine the percentage of the victim's body that had been identified. The victim's remains had been excavated from Ground Zero fairly early in the recovery process and were stored in a refrigerated unit for months pending identification. The case consisted of two major portions: the top portion of a torso down to the fourth lumbar vertebrae, and the lower portion of a torso, from the sacrum down to the feet. There was no fifth lumbar, which could have articulated the two halves together. At the time it was not clear whether these two portions had been previously connected by skin or soft tissue, and had become separated over time due to decomposition, or whether they had never been physically attached, but were grouped together because they were assumed to be from the same individual at the time of recovery. It was not unusual for two discrete portions of remains to be held together by skin only. For example, although a portion of hip might be attached to a foot by skin, all the connecting leg bones and other soft tissue in between might be absent. In this case, the original medical examiner's notes stated that the body was in two portions (both of which were sampled for DNA), but made no mention of whether or not the remains were connected by skin or soft tissue. Of the two DNA samples taken at the time of the original examination, one was used to identify the remains, while the other sample failed to yield viable DNA (Mundorff, et al. 2008).

During the interval between this body‘s recovery and its identification, mortuary personnel had learned a great deal about the extent of the devastation at the disaster site. Complicated excavation procedures at Ground Zero combined with enormous fragmentation of the human remains produced far more commingling than had been initially recognized or anticipated (Mundorff 2003). Consequently, more rigorous triage standards and examination techniques had been introduced after the first few weeks of recovery. However, this particular body had been processed through the mortuary during the earliest stages of examination and had not been subjected to these more rigorous standards (Mackinnon and Mundorff 2006). The second examination revealed that these two pieces were not, or were no longer, attached by tissue, and possibly would not have been grouped together under the more rigorous triage and examination standards. The anthropologist and the medicolegal investigator recommended that the identification be postponed until both body portions had been retested for DNA. Subsequent DNA analysis confirmed the identification on the top portion of the torso, but revealed that the bottom portion belonged to a previously unidentified individual (Mundorff, et al. 2008).

5.6.2. Anthropological Verification Project

The Anthropological Verification Project was deemed necessary in order to address cases, such as the one described above, which had not been properly triaged prior to the first examination. The AVP was also intended to address the enormous commingling and cross-contamination problems and to increase the accuracy of the documentation in the case files. The process detected and corrected instances of commingling that were missed in the initial investigation (Budimlija, et al. 2003; Mackinnon and Mundorff 2006; Mundorff 2008).

In late May 2002, three anthropologists were hired to review all the unidentified human remains to ensure that there was no remaining evidence of commingling within each body bag. Each anthropologist, along with a scribe (an anthropology student proficient in osteology), worked as an independent team re-examining, one by one, 16,969 cases (3,001 cases had already been released prior to beginning the AVP). The first step of the AVP confirmed that the case number and associated tag and body bag numbers matched the accompanying paperwork. Next, the team verified the storage manifests to ensure that the body parts were accurately logged and matched their recorded location in the database. All the existing paperwork associated with each case was reassessed, verified, and cross-checked against the physical remains (Mackinnon and Mundorff 2006). A detailed reinventory of the case was then produced on a separate AVP form titled "WTC Supplemental Anthropology Examination," which was added to the original case file (Appendix C).

This process also provided an opportunity to add any additional pertinent information and anatomical detail that may not have been recorded when the case was originally processed through the temporary morgue. For example, while a file might describe a “partial right humerus,” a review of the remains during AVP might reveal that the humerus was specifically from the mid-shaft to the distal end. The additional detail was added to the AVP form in the case file and subsequently into the database (Mackinnon and Mundorff 2006).

Equally, if the team determined that there were fragments associated with a case that were not contiguous or did not appear to belong, the fragments were removed, new cases were created, and all the remains were resampled for DNA. The process of removing unattached fragments from a case and creating new cases is referred to as “splitting” (Mackinnon and Mundorff 2006). Of the 19,970 cases created during the WTC investigation, 16,969 were processed through the AVP; 75 cases were split, yielding 293 new cases (not including the defining case). Twenty-six of the 75 cases were commingled. This resulted in 38 new individuals being identified from the individual with whom they were commingled and provided 87 additional identified links with previously identified remains. The analysis and results of the splits as an outcome of the AVP, as well as the success or failure of the management decision to implement the Anthropological Verification Project, are discussed in Chapter 8.

5.6.3. Final Anthropological Review

While the AVP re-examined unidentified remains, the Final Anthropological Review program focused its efforts on identified remains *before* the identification was ratified and the remains were released to the families. Essentially the FAR was a final verification of identification. At the height of the identification efforts, the OCME identified dozens of victims’ body parts per day. After the first 28 weeks or thereabouts, when the classic methods for identification such as dental comparison and fingerprint matching had been exhausted, most of the new identifications—many of which involved numerous cases per individual—were made using DNA. Each identified case was finalized according to an established routine. First, the DNA lab matched a reference sample or kinship pedigree to human remains and sent this standard “DNA match report” to the medicolegal investigators in the identification unit. Two MLIs then investigated the case details further, verifying, among other information, whether any cases had been previously identified to the victim or if this was a new identification. They were also responsible for verifying all data in the case file, including the victim’s antemortem information. In the early months of the recovery and identification effort, the process simply stopped at this point and the identified remains were released to the family. However, in order to catch potential errors like the one illustrated in the defining case, the management team determined that the process should include a final quality control measure and, in May 2002, the FAR was added as a final step (Mundorff, et al. 2008).

The anthropologist and Assistant Director of Investigations developed a new form for the FAR, the “Anthropology Worksheet,” to be filled in for each potential new identified case. This form listed the case number, the name of the attending medical examiner who originally examined the remains, the date of recovery, a brief description of the remains and what was sampled for DNA (bone, muscle, tooth, etc.), the date of identification, and the means of identification (Appendix D). If identified fragments were linked to a previously identified individual, this information was included on the FAR form. The form also indicated if the previously identified fragments were still housed at the OCME and could be re-examined, or if they had already been released to a funeral home. Every time a new case or aggregate of cases were identified, the medicolegal investigator or Assistant Director of Investigations reviewing the new DNA match filled out this form for the anthropologist to review (Mundorff, et al. 2008).

After the form had been generated, the anthropologist reviewed it, looking for any inconsistencies that could indicate a problem with the identification. Potential problems were then flagged on the FAR form before the final examination of the case. Consider the circumstances in the following situation. First, the individual in question already had multiple body parts identified, including a partial right foot. Next, a new case was linked to that same individual and the paperwork indicated that this new case was also a partial foot, but the original examination lacked detailed information about whether it was a right or left foot. In this example, the paperwork would be flagged so that during final examination the anthropologist could determine if this new case was an additional fragment of the previously identified partial right foot, if it was a left foot fragment, or if it was a duplicate body part (one of the same anatomical elements as the previously identified partial right foot such as an additional metatarsal) thus indicating a problem with the identification (Budimlija, et al. 2003; Mundorff, et al. 2008).

Once the paperwork had been reviewed and any potential problem cases flagged, the anthropologist re-examined the human remains. Both the newly identified cases and the previously identified cases that were still curated at the OCME went through a final examination. In situations where fragments had been previously identified and already released to funeral homes, the anthropologist relied on the information from the original case file recorded on the FAR form (which became more accurate as more cases went through the AVP) and photographs. During the final examination, the team initially confirmed that the case number on the outside of the body bag matched the case number and remains inside the bag. Once this was confirmed, the anthropologist looked for inconsistencies between the physical remains and the paperwork, duplicated elements, and any other discrepancies. This stage included confirming that the victim's biological profile matched the remains. For example, if the victim identified was a female, did the remains appear to be from a female of approximately the same age (Mundorff, et al. 2008)? The identification was placed on hold if there were any disagreements between the documentation and the remains being evaluated. Duplication of body parts, conflict between the biological profiles, or any other questions regarding the validity of the identification were all grounds for further investigation.

The Special Projects Group (an interdisciplinary team of forensic biologists and anthropologists) investigated these problems until any remaining questions had been answered (Budimlija, et al. 2003; Mundorff, et al. 2008). Their investigation often included an examination of the chain of custody and antemortem information collected to establish the identification, review of the postmortem information on the case, and resampling and retesting DNA. Taken as a whole, these quality control measures revealed overwhelming accuracy within the system; very few problems were found (Budimlija, et al. 2003; Mundorff, et al. 2008). Additionally, as the concurrent AVP examined unidentified cases, and those cases became identified, fewer problems were detected during the FAR.

The FAR resolved unanticipated errors created by, for example, mislabeling and sampling problems in the mortuary, DNA contamination from commingling, transcription errors, and data entry mistakes (Budimlija, et al. 2003; Mundorff, et al. 2008). Contaminated DNA samples from DVI projects are not uncommon (Lessig, et al. 2006) and one of FAR's most significant contributions was to address quality assurance in this area. It detected identification problems stemming from a flawed procedure in a DNA vendor laboratory, which caused contamination and therefore misidentifications.

The extreme fragmentation of the remains meant that multiple cases were frequently linked by DNA to the same individual. It was common for dozens of fragments to be identified to a single individual and in one instance 176 fragments were identified to one person (Mundorff, et al. 2008). Although the number of identified fragments per individual complicated the FAR, a pattern of DNA misidentifications still emerged after anthropologists noticed that a handful of DNA identifications did not make anthropological sense. They did not make sense for a variety of reasons, including duplication of body parts (two left feet identified to the same individual) or calcined remains that could not possibly have yielded DNA profiles (before calcined remains were no longer tested). One obvious instance of a misidentification was when two distal femora fragments (one right and one left) were identified to the same individual, even though their very different sizes clearly indicated that one belonged to a female and the other belonged to a male (Budimlija, et al. 2003; Mundorff, et al. 2008).

The DNA analyst responsible for quality assurance was concurrently investigating this problem. He determined that cross-contamination had occurred during the high-throughput DNA-testing process at a vendor laboratory. Although most of the potentially affected samples were detected during the routine DNA investigation before the DNA lab reported them out as an identification, several cases were detected during the FAR. The discovery of problems during the FAR such as this contamination issue, prevented the release of misidentifications, validating the implementation of the FAR as a final check of remains to catch such mistakes. The FAR showed the importance of using traditional anthropological techniques to confirm DNA identifications, particularly from DVI projects with extreme fragmentation, commingling, and potentially contamination.

5.6.4. Resampling

The final management program initiated by the anthropologist was a DNA resampling campaign. As mentioned previously, although the decision to test every piece of human remains was made early in the identification process, what portion of the case to sample and how to record that sampling was not clear. During the first few days following the disaster, blood and muscle were primarily sampled from each case. When blood was no longer viable due to decomposition, muscle alone was sampled if it was available, but within a few weeks the muscle tissue began to decompose. This left practitioners with no clear idea about what to sample. Some medical examiners continued to sample muscle (if it still looked pink and healthy), some took bone instead, and some took muscle and bone together. Since the DNA extraction process had not been fully established, and the DNA matching software was not yet fully developed, there was no way of knowing at the time that the muscle samples were no longer yielding viable DNA and that bone should be preferentially sampled. However, as the software came online and more DNA test were reported back from the labs, those involved could have noticed a clear pattern of when muscle stopped yielding viable DNA by examining the DNA identifications by sample type and date.

By August 2002, it had become obvious to the anthropologists performing the AVP that many cases that should have been identified by DNA, such as large torsos, had not. After looking into the problem further, the Director of the DNA laboratory realized that many of the remains not identified by DNA had only had muscle sampled, and so under the direction of the anthropologist, the anthropology team also performing the AVP implemented a DNA resampling campaign. They began by selecting a group of cases based on their potential to yield new identifications, primarily the largest remains still curated at the OCME. Then, if possible, they resampled only bone. A new

Resampling form, the "WTC Resampling Supplemental," was used, meaning the specific bone element could now be recorded instead of the designation of "bone" only (Appendix E). This was done specifically to track which elements consistently yielded more viable DNA. A total of 641 cases were resampled, 611 of which were bone. Of the 641 resampled cases, 444 (69%) were subsequently identified by this second sample and of those, 434 were from bone samples. It is clear that while the original muscle samples for these cases were too degraded to yield DNA, bone from the same cases was still viable as 98% of the identified resampled cases tested bone instead of muscle. The data set created by these 641 resampled cases will be used for the study examining DNA yields by skeletal element with the results presented in Chapter 7.

5.7. Limitations and Errors of Omission

Financial considerations may limit the generalizibility of some of these management decisions to future mass fatality events. The WTC identification project was fairly unique in enjoying essentially unlimited access to funding. Decision makers did not have to hesitate in deciding to DNA test every fragment. Unlimited resources also enabled hiring additional anthropologists for the AVP and the File Review projects. However, other incidents may be severely constrained by budget considerations. As noted by the WHO panel on mass fatality management, resources must be a consideration for any manager making significant decisions during a DVI project (Tun, et al. 2005). Under such conditions, managers will be forced to prioritize according to what are likely to be the most cost effective practices.

The WTC project also had the luxury of maintaining management continuity through much of the project. Although the OCME did lose a few managers before the project ended, most were involved for years. By contrast, many incidents are staffed with volunteers who rotate through for several weeks at a time. These short deployments only allow personnel to observe a small window of the overall project. What often looks like a successful decision within the first 3 weeks can look much different 3 months, 6 months, or 12 months later. Having DVI personnel who stick with the process over the longer term builds a depth of understanding of that particular project and of the long-term DVI process in general that may be absent in incidents where personnel rotate in and out quickly.

While the focus of this chapter was to examine management decisions made during the WTC DVI project, there are errors of omission that might have proved beneficial to the overall project. First, forensic anthropologists should have been present at the recovery site. In retrospect, it would have been advantageous to have an anthropologist work alongside each pathologist at the examination table during the mortuary phase. They could have compiled a more detailed description of the remains during the initial examination, particularly the fragmented ones. Next, photographic documentation is vital, though often cases were not photographed during the initial examination (this later became a problem if questions arose about a case that had already been identified and released). Additionally, there are some questions that cannot effectively be answered due to a lack of detailed documentation. For example, while we know the FAR was successful because it discovered misidentifications due to DNA contamination, mislabeling, and transcription errors, we are unable to determine how many misidentifications the FAR corrected. As part of the FAR, each problem case was dealt with individually and no overall record keeping was compiled.

Finally, planners did not approach the WTC project with the idea that it would be subjected to the type of post hoc analysis conducted in this thesis. Had that been a concern, there would have been more thorough documentation of the *process*.

However, DVI managers ought to be responsible for putting systems in place to generate knowledge to contribute to the collective learning process at the conclusion of a project. It is important to establish systems that track efficiency and accuracy along the way to measure projects' outcomes (both successes and failures). By happenstance, there were enough data for this dissertation, but the lesson for future MFI managers is to ensure there is enough documentation, from the beginning, for complete evaluation of the DVI process.

Chapter 6.

WTC Empirical Data Set for Quantitative Analyses

6.1. Data Set and Variables

The analyses in the next two chapters will utilize the database of recovered human remains from the World Trade Center disaster. The complete data set, referred to as the World Trade Center Human Remains Data Set (WTCHRD), consists of 19,970 cases of which 10,927 have been identified. The OCME personnel defined a “case” before 9/11 as a single set of human remains, which could represent anything from an intact body to a small shard of bone or piece of soft tissue. All the human remains recorded in this data set were recovered from either Ground Zero or the Staten Island Landfill operation. Remains were officially recovered from Ground Zero beginning on September 11, 2001, through May 25, 2002. However, after the excavations at Ground Zero finished, a few small fragments of human remains were subsequently recovered from areas around Ground Zero and submitted to the OCME for identification. This is reflected in the WTCHRD data set by approximately 59 cases that have Dates of Recovery listed after the site had been closed. Specifically, 18 cases were found in 2002 after the closing date, 31 cases were discovered in 2003, and 10 cases in 2005. Although human remains have been recovered from building rooftops surrounding Ground Zero during 2006–2008, the data set used for this dissertation only includes cases found and DNA tested before the end of September 2005 (Table 1).

Table 1. Identification Statistics used for this Dissertation as of September 2005

Missing Victims	2,749
Victims Identified	1,598
Remains Recovered	19,970
Remains Identified	10,927

6.1.1. Variables

Multiple variables were recorded for each case during the original mortuary analysis. Not all the information originally recorded for each case was used in this dissertation; some variables were modified from their original format to include additional information or to modify the information to allow it to be searched more easily. Of the original variables recorded, the following were used during the analyses in this dissertation.

DM01-#: This is the unique number assigned to each case. *DM01-* stands for Disaster Manhattan 2001 and is followed by a consecutive number beginning at -00001.

Identified: This is recorded as either yes or no. Yes indicates that the case has been officially identified.

Description: This is the anatomical description of a case (single set of remains). The recording format of the descriptions was modified slightly to allow for easier searches of the material. I tried to make the descriptions as consistent in format as possible. For example, if three different descriptions read “left distal humerus,” “humerus, distal left,” and “distal left humerus,” they were all changed to read “humerus, distal left.” Extraneous words were removed, particularly at the beginning of the descriptions. For example, “these remains consist of a torso, including…” became simply “torso, including….” Other changes included elaborating on shorthand or shortened versions. Sometimes soft tissue was entered in as "ST," "soft tissue," or "tissue." These variations were all changed to read "soft tissue." However, it is important to note that the descriptions were never modified to change their meaning, their wording was simply modified to make it more searchable in Excel and consistent with the other cases.

Recovery Location: This is the location of recovery for each case. The variable is recorded as Site (for Ground Zero) or Landfill. When the location was not known (or not recorded on the paperwork), the original OCME database defaulted to Site.

Grid: The *Grid* variable is correlated with the *Recovery Location* variable. If the case was recovered at Ground Zero and a *Grid* location was designated during recovery and subsequently recorded during examination, that designation was recorded as a letter followed by a number e.g., M-12. However, not all cases recovered from the site have a *Grid* designation.

Date Recovered: This is the date when the case was recovered from either the site or the landfill and processed through the mortuary (cases were rarely not processed through the mortuary on the same day they were received). The date is recorded as MM/DD/YY.

Anthropology Review: This is recorded as either yes or no. *Anthropology Review* indicates that the case had gone through the Anthropological Verification Project (AVP). The AVP did not begin until May 2002, and some identified cases had already been released to funeral homes for burial by that point, so not every case went through this process. A total of 16,969 cases went through the AVP review.

Chart Review: This is recorded as either yes or no. This indicates whether or not the case file was reviewed during the File Review Project.

DNA Sample 1: This variable records what was initially sampled for DNA from a case. On the Intake Form this was recorded as “blood,” “muscle,” or “other.” However, if “other” was checked, sometimes the pathologist included a brief description of what was actually sampled, and this information was then captured during data entry in the comments section. Therefore, for this database the choices for *DNA Sample 1* were expanded to include these additional descriptions. The choices for *DNA Sample* are: blood, bone, muscle, fat, cartilage, hair, organ, periosteum, scalp, tooth, skin, scrapings, swab, none, unknown, other, clothing, charred muscle, charred bone, and combinations of the above.

DNA Sample Size: This recorded the portion or size of the DNA sample taken from the case. This variable was recorded as either: Partial, Entire Sample, Entire Sample-Consumed, or none. Partial indicated that a DNA sample had been sawn or cut from the case, usually bone or soft tissue. Entire Sample indicated that the case was so small that a DNA sample could not be cut and the entire case had to be submitted for DNA testing. These cases usually fit into a 50 ml conical sampling tube. Entire Sample-Consumed indicated that not only was the entire sample submitted for DNA testing, but also that the entire sample was then *consumed* in testing. These differences were recorded to properly track Entire Sample cases since that was all there was of those particular cases. *DNA Sample Size* listed as Partial and Entire Sample indicate that there are remains of the case still tangible while Entire Sample-Consumed indicates that nothing but extraction product is left. These cases cannot be resampled and there is nothing but extract to release to the next of kin.

DNA Resample: This is recorded as either yes or no. This field indicates whether a case was resampled. During the original data entry, resampling information was recorded in the *Description* field. During my initial review of the database, I highlighted resampled cases in red to separate and indicate their status. Later, I added the field *DNA Resample* to be able to sort resampled cases into their own subset for use during analysis. If a case was resampled, the specific element that was resampled was also listed in the *Description* field.

Cross-Referenced: This is recorded as either yes or no. This field indicates whether a case was cross-referenced to another case (or to multiple cases) during the mortuary analysis. During the original data entry, cross-referencing information was recorded in the *Description* field. During my initial review of the database, I highlighted cross-referenced cases in blue to separate them and indicate their status. Later, I added the field *Cross-Referenced*. If a case was cross-referenced, the corresponding cross-referenced cases were listed in the *Description* field.

Split: This is recorded as either yes or no. This field indicates whether a case was split during the AVP process. During the original data entry, split information was sometimes recorded in the *Description* field and sometimes recorded in a separate spreadsheet. After tracking down all the split cases not recorded in the database, and then reviewing those recorded in the database, I highlighted split cases in green to separate them and indicate their status. Later, I added the field *Split* to sort split cases into their own subset for use during analysis. If a case was split, the information detailing the primary case and the cases that were subsequently split out from the primary were recorded in the case *Description* field.

6.1.1.1. Additional Variables Recorded for Identified Cases

Some variables could only be recorded if the case was identified. These were:

Sex: This is the sex of the identified victim and is listed as male or female.

Anthropology Approved: This is recorded as either yes or no. Yes indicates that an identified case was reviewed during the Final Anthropological Review for quality control assurances before the identification was finalized. Not all identified cases went through the FAR because the program was not implemented until May 2002.

ID Modality: This is the initial modality used to identify the case. The choices include anthropology, body x-ray, dental, DNA, fingerprint, personal effects, viewed, and other.

ID Date: This is the date of the initial (primary) identification for that case. The date is recorded as MM/DD/YY.

ID Modality 2: Many cases have been identified by multiple modalities (e.g., a partial body with teeth and hands could be identified by dental matching, fingerprint matching, and DNA). Multiple modes of identification were always added to the database. Many cases were initially identified by more traditional (and quick) methods such as dental or fingerprint matching, and were subsequently identified by DNA months or years later. The choices are the same as in the initial *ID Modality* variable; however, fewer records have an *ID Modality 2* recorded.

ID Date 2: This is the date of the second identification for the case. The date is recorded as MM/DD/YY.

ID Modality 3: This is the same as *ID Modality 2*, but it is the third time the case has been identified. The choices are again the same as in the initial *ID Modality* variable, but even fewer records have an *ID Modality 3* recorded.

ID Date 3: This is the date of the third identification for that case. The date is recorded as MM/DD/YY.

ID Modality 4: This is the same as *ID Modality 3*, but it is the fourth time the case has been identified. The choices are again the same as in the initial *ID Modality* variable; however there are even fewer records with an *ID Modality 4* recorded.

ID Date 4: This is the date of the fourth identification for that fragment. The date is recorded as MM/DD/YY.

6.1.2. Other Changes to the Variables

As previously mentioned, a few of the variables have been modified from their original format to allow for analysis and consistency. Often this involved collapsing data. For example, the variable *ID Modality* initially had many more choices than currently listed. However, identification means such as a tattoo, ring, photo ID, clothing, and cast have been collapsed into the category “personal effects.” Similarly, victims who died in the hospital were grouped under the category “viewed.” The variable *DNA Sample* also collapsed together some options. For example, included with “muscle” were DNA samples originally listed as tissue, soft tissue, connective tissue, oral mucosa, fibrous tissue, testicular tissue, subcutaneous tissue, trachea, penis, and tendon. Adipocere was grouped with “fat,” marrow was grouped with “bone,” dura was grouped with “periosteum,” and lung, spinal chord, bowel, liver, pancreas, small intestines, kidney, intestines, GI tract, stomach, spleen, and brain were grouped with “organ.” Hair samples were not processed for DNA, and so *DNA Sample* choices that included hair *along with* another choice were reduced to the non-hair sample because this was how the samples were treated in the laboratory. For example, if the sample was originally listed as "bone and hair," it became "bone only" because in the lab the two items would be separated and only the bone would be processed. This was true unless the hair was attached to the sample, such as "scalp with hair."

All the information pertaining to each case should have been captured in the case file and subsequently entered into the database, but this did not always happen. Instances in which known information was left out of the database, but where the information could be accurately gleaned from other places, was added to the system. For example, if case DM01-100 was split into five new cases, DM01-19990 through DM01-19994, but the split information was only listed with the original case (DM01-100), then the information would be added to the other cases as well.

Information that was not captured during the original or subsequent analysis and that could not be gleaned from other sources was omitted. For example, most of the first 5,000 cases do not have a *Grid* listed. This is probably due to a breakdown in communication between site managers and mortuary mangers and was addressed in the management decisions section of this dissertation. Other variables that may have blank fields include *DNA Sample Size*, again mostly in the first 5,000 cases that were processed before that information was recorded in the mortuary. The concept of submitting a case in its entirety for DNA testing came about after the first few weeks of processing, and so the need to track these samples and label them "Entire Sample" did not arise at the start of the mortuary operations. As a result, some of the first few thousand cases were "Entire Sample" for DNA, but were not labeled as such. Again, this was addressed in the management decisions section of this dissertation. Lastly, as mentioned briefly in the Variables section, some case information was recorded in a "comments field" or within the *Description* field that needed to be teased out for future analyses. Three new fields were created for such information, *Cross-referenced*, *DNA Resampled*, and *Split*.

6.1.3. Subdata Sets

6.1.3.1. The Resampled, Entire Sample, and Complete Elements Data Sets

For the purposes of performing different analyses in this dissertation, the WTCHRD was divided into smaller subsets of data. Although briefly described here, each of these subdata sets will be described in detail in their corresponding analysis chapter. The first subdata set is the Complete Elements Data Set (CED), which is used to analyze success rates of DNA identification by different skeletal elements. This data set is actually two small data sets combined. Within the WTCHRD, cases that had a *DNA Sample Size* listed as "Entire Sample" or "Entire Sample-Consumed" were selected and grouped as the Entire Sample Data Set (ESD). Cases that had been *Resampled* were selected to comprise the Resampled Data Set (RD). By choosing these two variables, subsets were created in which the specific skeletal elements tested for DNA were known. Combining the ESD and the RD formed the CED, which comprised 5,305 cases. Also, an additional field that was not part of the original WTCHRD was added to the CED database. Some of the statistical analyses using the CED data examined identifications based on where, specifically, the victim was located at the time of the disaster. The three categories were airplane passenger, WTC civilian—indicating they were most likely at or above the level of impact, and firefighter—indicating they were likely below the level of impact.

6.1.3.2. The Split Data Set

The next subset created for analysis purpose is the Split Data Set (SD). The Split Data Set is used to determine the benefits and drawbacks of implementing the AVP. This management program was initiated to address commingling and incomplete data in the case files, and to increase identifications. A total of 16,969 cases were re-examined, additional details were recorded on the AVP form, cases that were perceived to still have commingled remains were split, and new cases were created. All the primary cases and newly created cases were documented in the database as split cases. Therefore, all cases recorded as being split, as well as any of the cases that were split from primary cases, are included in the subset Split Data Set. The entire SD comprises 368 cases: 75 primary cases and 293 cases that were split from those primary cases.

Chapter 7.

DNA Recovery Rates of Different Bone Elements

Forensic scientists who process mass fatality incidents have long relied on fingerprints and dental comparisons as their principal means of identifying victims, but in the aftermath of recent events such as the terrorist attacks on September 11, 2001, the 2004 Boxing Day tsunami, and Hurricane Katrina in 2005, DNA identification began to emerge as a credible alternative. It is now the predominant form of identification following incidents with severe fragmentation. However, there are currently no standards for selecting the skeletal elements that most consistently yield DNA for identification (National Institute of Justice 2005). The choice becomes more complicated if the victim's remains are fragmented or have been compromised by taphonomic factors such as fire, water, or decomposition.

The purpose of the analysis in this chapter is to create empirically based standards for bone sampling in mass fatality incidents. It is clear that certain bones yield more reliable DNA sequences than do other elements. From the results presented in this chapter, we should be able to determine a set of scientifically based standards and practices for DNA sampling that can be generalized to meet the needs of future mass fatality incidents.

In this chapter, a subset of the World Trade Center Human Remains Database is used to examine DNA identification rates between different skeletal elements by sex, victim location, recovery month, and recovery location. I expect to find that the victim's sex, the recovery location, and the recovery month do not significantly influence the DNA identification rates of specific bones. Further, as illustrated in previous studies examining mitochondrial DNA yields from specific skeletal elements, I expect certain elements, such as long bones, to yield identifications at higher rates than flat bones such as the skull or scapula. Similarly, as seen in these other comparable studies, I expect weight-bearing limbs to yield the highest overall identification rates (Edson, et al. 2004; Leney 2006; Milos, et al. 2007). Finally, I expect the results to show which elements are most likely to be useful to sample for mass fatality events involving severe taphonomic conditions. A close examination of the cases from the WTC disaster and the overall success rates of different skeletal elements should produce a list of recommendations about the most successful and efficient DNA sampling strategies. The recommendations can then be applied or adapted in the case of other mass fatalities and will be useful for policy-makers and managers faced with making the initial decisions about bone sampling for DNA-based identifications following a disaster.

7.1. Literature Review

Since the early 1990s DNA has played both major and minor roles in identifying victims of mass fatality incidents (MFIs) (Ballantyne 1997; Clayton, Whitaker and Maguire 1995; Corach, et al. 1995; Fernando and Vanezis 1998; Goodwin, et al. 1999; Hsu, et al. 1999; Kahana, Freund, et al. 1997; Leclair, et al. 1999; Ludes, et al. 1994; Olaisen, et al. 1997). The literature describing MFIs discusses whether or not bone, soft tissue, or tooth samples produce enough extractable DNA to permit identification. The ability to extract usable DNA from these tissues is generally presented in terms of success or failure, where failure is commonly attributed to “degraded samples.” However, few studies discuss specifically what tissues or elements were used and how the decision of what to sample was established.

Few MFIs occur in environments that favor DNA preservation, such as freezing temperatures (Ludes, et al. 1994), and even fewer scenes can be processed before decomposition, which contributes to the degradation of DNA, begins. Iwamura et al. (2005:33) state that “little has been known about the extent to which nuclear DNA remains inside the osteocyte lacuna of mineralized matrix and to what extent degradation of nuclear DNA occurs during post-mortem.” While the relationship between DNA degradation rates and the environment in which the sample was exposed is still not fully understood, there are some common themes in the literature. Many different environmental and taphonomic factors influence the degradation of DNA, including temperature, humidity, ultraviolet (UV) light, postmortem interval (PMI), soil microbes, fire, water, mold, and storage conditions (Arismendi, et al. 2004; Burger, et al. 1999; Collins, et al. 2002; Edson, et al. 2004; Graw, et al. 2000; Grupe, et al. 1993; Hochmeister, et al. 1991; Imaizumi, et al. 2004; Iwamura, et al. 2005; Paabo, et al. 2004; Pfeiffer, et al. 1999; Steadman, et al. 2006; Ye, et al. 2004). Some studies have ranked these environmental influences according to severity, with high temperatures and water submersion listed among the most destructive (Collins, et al. 2002; Gotherstrom, et al. 2002; Hochmeister, et al. 1991; Iwamura, et al. 2005; Steadman, et al. 2006).

Along with environmental insults, the postmortem interval of human remains and its relationship to DNA preservation is controversial. In one study, Bar et al. determined that “generally the amount of degraded DNA correlated directly with the duration of the postmortem period” (Bar, et al. 1988:59). However, that study was limited to DNA retrieved from soft tissue, revealing that liver and kidney tissue show rapid degradation while brain tissue shows slow degradation. Further studies examining the relationship between postmortem interval and DNA preservation in bone specimens have found no correlation between the two (Burger, et al. 1999; Evison, et al. 1997; Leney 2006;

Parsons and Weedn 1997). DNA research has demonstrated that bone preserves DNA better than soft tissue does as the structure of bone acts as a physical barrier to external influences (Graw, et al. 2000; Hochmeister, et al. 1991; Imaizumi, et al. 2004; Ye, et al. 2004).

Because it has been established that bone preserves DNA better than soft tissue does, the next logical step for mass fatality management is to determine which specific bones better preserve DNA under less than optimal circumstances. Although rare, it has been mentioned in the literature that DNA from different elements may deteriorate at different rates (Imaizumi, et al. 2004; Perry, et al. 1988). Perry et al. examined degradation of DNA in ribs and the postmortem interval, and found that "when degradation of DNA in clavicle bone was compared with the DNA degradation in a rib bone from the same individual, the clavicle bone DNA seemed to be degraded more slowly" (Perry, et al. 1988:152). Alonso et al. examined the influence of microbial DNA on human DNA extracted from 8- to 50-year-old bone and tooth samples and found that "the quality of DNA obtained from long bones is higher than that extracted from skull or ribs" (Alonso, et al. 2001:265). Parsons and Weedn also agree that DNA is much more reliably extracted from compact bone than spongy bone, such as rib trabecular bone. They believe the more rapid degradation in spongy bone is due to its having a higher moisture content than cortical bone (Parsons and Weedn 1997).

7.1.1. Recent Studies Examining DNA Yield by Skeletal Element

A recent study by Edson et al. examined the rate of successful mitochondrial DNA (mtDNA) extraction from different degraded skeletal elements. During a three-year period, over 1,000 samples were examined to "determine if there was a general trend among success rates versus specimen type" (Edson, et al. 2004:76). The samples comprised remains of U.S. service members and civilians missing in past military conflicts around the world and were recovered from a variety of conditions including having been buried, frozen, and submerged in salt water. The findings from this study both confirm and challenge some of the anecdotal statements found in earlier studies. They argue,

> Of the long bones, the weight-bearing bones, such as femora and tibiae, were the best specimen types. Metatarsals are also weight-bearing bones, but at initial glance they appear to be inadequate specimens by size alone. However, approximately 80% of the metatarsals tested produced reportable results. Ribs were also highly successful, although a larger number of specimens is needed…Cranial fragments are the most difficult of the samples tested from which to obtain quality sequence data [Edson, et al. 2004:76].

Due to the small sample size, certain bones such as metacarpals and patellae were not included in the study and the authors suggest that careful sample selection is more efficient for identification projects. Time and resources on future resampling and retesting can be minimized through more careful selection of elements for DNA sampling. This hypothesis could be applied to sampling human remains from mass fatalities to ensure the highest number of usable nuclear DNA results.

Another recent study by Leney (2006), designed to provide guidance in choosing the best sample for mtDNA testing of archaeological remains, concluded that sample weight along with skeletal element were the most important factors in maximizing successful outcomes. He also concluded that postmortem interval was not an important determinant of success or failure, although climate from where the remains were found was strongly correlated. Samples recovered from temperate environments that were older than samples recovered from tropical environments produced more successful yields. While heat and moisture are detrimental to DNA preservation, arid environments promote DNA preservation by retarding the biological activity that degrades DNA (Leney 2006).

Sample mass was another integral factor in producing successful yields. Leney determined that “the larger the sample, the greater the probability that it will be successful, particularly up to around 7g” (Leney 2006:40). However, this result was mitigated by element choice as well, not just mass. For example, a comparison of femora and humeri samples of the same weight revealed that the femur was successful 92.5% of the time while humeri were only successful 75% of the time. Taking into account mass and element choice, femora and tibia were the most successful, followed closely by the os coxa, first metatarsal, and mandible. Excluding the mandible, the four most successful elements were in the lower limb or the os coxa. The arm bones followed the leg bones in success rates and the axial skeleton followed the arm bones, and similar to Edson et al (2004), the cranial bones showed the lowest rates.

Leney believes that the dense cortical bone along with the forces of locomotion and stresses of bearing static body weight make the leg bones the most successful for DNA extraction (Leney 2006). He proposed two hypotheses to explain the higher mtDNA identification success rates of non-weight-bearing bones such as the mandible. The first is that bone density, as an adaptation to the stresses of mastication critical to maintaining cortical mass and density, may be responsible. Second, areas of reworked bone, predominantly from muscle attachments, may be particularly good sources of DNA. This second hypothesis helps explain the high success rate of the os coxae, since the iliac crest (which is where his samples were from) is an area where the muscle attachments are constantly reworking and remodeling the bone. Unfortunately, certain bones such as patellae were not included in his sample; therefore the hypothesis of reworked cortical bone as a good source of DNA could not be tested for all such bones.

Although the last two studies examined the mtDNA success rates of different elements, Leney argues that these results can be generalized to include nuclear DNA testing (Leney 2006).

In 2007, Milos et al. published their findings on the relationship of nuclear DNA success rates of different skeletal elements and postmortem interval in remains from mass graves in the former Yugoslavia. The skeletal samples used in their study originated from different geographical locations between 1992 and 1999, and the DNA tests were performed between 8 and 15 years postmortem; therefore, DNA preservation was highly variable (Milos, et al. 2007). Again, their results were similar to those of the previous two studies, with dense cortical bone of weight-bearing leg bones yielding the best results (Milos, et al. 2007). It is important to note that this study did not test all skeletal elements; for example, patellae were not tested, and metatarsals are only represented in two of the three sites. Additionally, they show a clear correlation between postmortem interval and DNA success rates. For example, the success rate of the femur varied from 92% to 83% for comparisons of the 1999 and 1992 samples, respectively (Milos, et al. 2007). The authors indicate that their sampling protocols should be used not only for mass grave identifications, but also for disaster victim identification. They suggest that the densest compact bones (midshaft femur) and teeth are the best choices for DNA sampling in both scenarios. However, this may not be true for mass fatality events. Their samples were more analogous to archaeological remains (e.g., buried for years), while samples from MFIs are often more similar to fresh autopsy samples. This study did not examine fleshed or partially fleshed remains, which are typical of mass fatality incidents. Because the samples show a correlation between postmortem interval and yield rate, more complete remains with intact soft tissues are a better proxy for generating results for mass fatality incidents.

7.1.2. *Mass Fatality DNA Sampling Protocols*

Despite a growing trend toward DNA-based identification following mass disasters, there are few detailed guidelines for sampling biological remains for DNA analysis in the mass fatality literature. DNA sampling protocols used in recent mass fatality incidents vary and are often tailored to the unique circumstances of the disaster (Mundorff, et al. 2009). For example, muscle tissue and rib bone were sampled from the 1995 Branch Davidian victims in Waco, Texas (Butler 2005); femora were sampled from victims of the 2002 Bali nightclub bombings (Briggs and Buck 2009); ribs and teeth were initially sampled from victims of the 2004 tsunami in Phuket, Thailand (Cockle, et al. 2005; Lessig, et al. 2006); and the anterior tibial midshaft was sampled for the 2005 victims of Hurricane Katrina (Boyer 2006). Even though the increase in DNA based identifications is primarily used with fragmented remains that do not possess more easily identifying characteristics such as fingerprints or dental, it is clear from incidents such as Hurricane Katrina and the Boxing Day tsunami that DNA is also being used to identify nearly complete, yet decomposing bodies.

To address disparities in sampling strategies, agencies have begun issuing guidelines and recommendations for DNA sampling. The National Institute of Justice recently developed its *Mass Fatality Incidents: A Guide for Forensic Human Identification* (National Institute of Justice 2005) which addresses sampling methods. This guide provides general sampling guidelines, stating that “the sampler obtains one of the following, listed in order of preference”: deep skeletal muscle, cortical bone, canine tooth, or other portion of soft or hard tissue (National Institute of Justice 2005:61). In 2007, the DNA Commission of the International Society of Forensic Genetics (ISFG) published “Recommendations Regarding the Role of Forensic Genetics for Disaster Victims Identification (DVI)” (Prinz, et al. 2007). Of the 12 recommendations, the third one addresses postmortem sampling, again confirming a preference for dense cortical bone, particularly from weight-bearing leg bones (Prinz, et al. 2007). However, neither guideline details specifically which bone to sample in order to maximize the success of a DNA profile, particularly if there are fragmented remains and a weight bearing leg bone is not an option. These existing guidelines offer only very broad recommendations and do not specify which bones are most likely to consistently produce DNA profiles under adverse taphonomic conditions (Mundorff, et al. 2009).

Therefore, the purpose of this analysis is to examine the differences in DNA identification rates between skeletal elements with the intention of establishing sampling criteria for mass fatality DNA identification projects.

7.2. Materials and Methods

I examine two subsets of human remains from the complete WTCHRD data set of 19,970 (as of September 22, 2005) previously described in Chapter 6. I also examine the results of these combined subsets, referred to as the Complete Elements Data Set. The two smaller subsets will be referred to as the Resampled Data Set and the Entire Sample Data Set. Specifically, within the variable *DNA Sample Size*, cases that were listed as “Entire Sample” or “Entire Sample, Consumed” comprise the ESD. Secondly, within the *Resampled* variable, cases that had been resampled comprise the RD. These two variables were used to select the cases for the CED because they are the only variables that consistently recorded the specific bone sampled for DNA. In most cases from the WTCHRD only limited information was recorded about which bones were sampled for DNA. More often than not, only “bone” or “muscle” was listed. A case description of, for example, “right leg present from mid-shaft femur to complete foot,” “bone sampled for DNA,” does not reveal from which element the sample was taken (e.g., femur, tibia, fibula, or foot element). There are a few cases in which more specific information such as blood, skin, hair, tooth, cartilage, or fat was recorded but this was rare.

7.2.1. Entire Sample Cases

Cases that were listed as “Entire Sample” for DNA represented small fragments of a single bone, entirely submitted to DNA. In order to qualify as “Entire Sample” for DNA, the case must have been so small that a DNA sample could not have been cut from it. These represented samples that fit into a 50 ml conical sample tube. Therefore, if a case was listed as “Entire Sample,” the description of that element in the case file allowed for retrospective categorization by skeletal element, and the bone that had been sampled could be identified. For example, if a case description from an “Entire Sample” was “tibia shaft fragment,” it can be safely assumed that tibia was the element sampled for DNA even if simply “bone” was listed as the DNA sample.

7.2.2. Resampled Cases

The second data set that contributed to the CED represented those cases that were “Resampled.” Cases were resampled if the first attempt at DNA extraction failed to yield a full DNA profile. An initial resampling attempt commenced in August 2002 after Ground Zero and the Staten Island Landfill operations had been closed and the OCME was no longer receiving new cases. The anthropologist (Mundorff) and the Director of Forensic Biology decided to limit the number of resampled cases to avoid overloading the DNA laboratory; therefore, not every failed case was resampled. Cases were typically selected by size, with the largest unidentified cases targeted as most likely to yield a new identification, as opposed to identifying additional links to previously identified individuals. Because these cases were being revisited after their initial examination, a more comprehensive form was developed. The Resampling form included a description of which bone was resampled for DNA. Thus, each resampled case records a description of the specific bone that was sampled, allowing for retrospective analysis of identification success rates by skeletal element. The anthropologist performing most of the resampling selected the element to be resampled based on macroscopic preservation. Characteristics preferred for resampling included intact bones encased within soft tissue, long bones, and unburned bones. If there were no intact bones, the most intact element was selected.

After initial analysis of the two data sets separately (RD and ESD), and to facilitate certain statistical comparisons and create more robust sample sizes for the different skeletal elements, the ESD and RD are combined to create the CED. Although sample grouping may introduce potential sources of bias, I will show in the results section that there are few statistically significant differences in DNA identification rates between the two data sets.

7.2.3. Variables

All the data sets are subsets of the WTCHRD and therefore the variables, which included the *DM Number*, the *Date of Recovery*, the *Location of Recovery,* and the *Description* are the same as previously described. The *Date of Recovery* is divided into months, with the final month including any case recovered after September 1, 2002. *Location of Recovery* indicates whether the case was recovered at the Staten Island Landfill or Ground Zero. The *Description* of the case records the specific element sampled for DNA. Metacarpals and metatarsals were initially recorded as 1 through 5 if known, but were combined for analysis as metacarpals and metatarsals, respectively.

Phalanges were recorded as either hand or foot, if known, but did not specify proximal, middle, or distal because this information was often not recorded in individual case descriptions in the WTCHRD. Similarly, because detailed information was lacking and the sample was small, carpals or tarsals were not identified to the specific element but were grouped as carpals and tarsals. All vertebral types are grouped together because vertebrae were not always recorded specifically as cervical, thoracic, or lumbar. Finally, specific information for each element, such as right, left, proximal, mid-shaft, and distal, was not recorded due to a lack of specific information from the WTCHRD. For the purpose of this study, the *Description* variable was also collapsed into different *Body Part Groups* to allow for further evaluation:

- Head: skull, maxilla, mandible (not including teeth)
- Trunk: clavicle, scapula, rib, sternum, vertebrae, sacrum, pelvis
- Arm: humerus, radius, ulna, carpals, metacarpals, hand phalanges
- Leg: femur, patella, tibia, fibula, tarsals, metatarsals, foot phalanges
- Other, Bone Only: unidentified bone fragments, unidentified long bone fragments
- Other, Not Bone: cartilage, skin, soft tissue

The variables *Resampled* and *Sample Size* were also recorded. For the purposes of this CED analysis, if a case was listed as both “Resampled” and “Entire Sample,” the case was only considered as “Entire Sample.” The variable *Resampled* indicates some choice in selecting the element from the original case to be resampled for DNA analysis, and an “Entire Sample” case indicates no choice. Because the majority of the cases in the CED are recorded as “Entire Sample” it can be assumed that most of these cases are small fragments. Certain elements such as metacarpals, metatarsals, and phalanges, even when intact, were small enough to fit entirely into the DNA collection tube, but most other elements, unless fragmented, could not. The final information recorded whether or not the case yielded a DNA identification. If the case was identified, the sex and location (specifically whether victim was aboard American Airlines Flight 11, United Airlines Flight 175, or represented a firefighter or civilian in the WTC towers) were also recorded.

7.2.3.1. Excluded Cases

All analyses excluded hair samples from the WTCHRD. At the time of this analysis, hair samples had not yet been tested for DNA. Similarly, all cases recorded as completely calcined were also eliminated from the CED because they were not DNA-tested. When a bone is completely calcined, the organic component of the bone has by definition been destroyed, and therefore DNA would not be present in these remains. However, the term calcined was only used when the *entire* bone was completely calcined. If some portions of a case were calcined and other portions were charred, the case would still have been sampled and therefore included in this analysis. Additionally, teeth were removed from the data sets because teeth were not processed for DNA at the same time as the bones and it is unclear if all the teeth had been processed at the time of this analysis. Therefore, cases described as "mandible and tooth" and "maxilla and tooth" were removed along with "tooth," because it could not be determined with certainty whether the DNA sample tested was from the bone or tooth.

All cases (excluding hair, teeth, and calcined bone) were initially analyzed for summary data and descriptive statistics (Table 2). However, since the hypothesis is to evaluate whether different bone elements yielded different success rates of identification, non-bone cases such as skin, cartilage, and soft tissue were eventually removed from the final data sets. Soft tissues were identified at a lower rate than bone elements and therefore would skew the meaningful results if included with bone elements. Cartilage, however, while not a bone tissue, had an identification rate similar to that of bones and will be presented separately.

Table 2. Summary of Identification Statistics from Total Complete Elements Data Set

Element	Total Count	Number ID	Percent ID
Mandible and Tooth	12	10	83
Foot Phalanx	25	20	80
Patella	83	66	80
Maxilla	9	7	78
Carpal	12	9	75
Cartilage	43	31	72
Metatarsal	257	184	72
Femur	143	102	71
Tibia	125	88	70
Mandible	46	30	65
Rib	1301	838	64
Phalanx Unknown	19	12	63
Pelvis	62	39	63
Bone	473	294	62
Vertebra	72	44	61
Humerus	110	67	61
Ulna	87	53	61
Fibula	159	96	60
Radius	120	72	60
Sacrum	27	16	59
Manubrium	7	4	57
Hand Phalanx	83	47	57
Scapula	92	50	54
Clavicle	97	52	54
Tarsal	37	19	51
Long Bone	401	198	49
Skin	47	23	49
Skull	494	232	47
Metacarpal	211	93	44
Soft Tissue	554	179	32
Tooth	94	15	16
Maxilla and Tooth	3	0	0
Total	5305	2990	

7.2.4. Identification Criteria

In the complete WTCHRD, a single case can be identified by multiple scientific modalities. For example, a hand might have been recovered and initially identified through fingerprints although a DNA sample would have also been taken at the time of examination. A month later, a muscle sample submitted from the same hand might also yield a full DNA profile. In this instance, the OCME considered fingerprinting to be the primary (first) identification means, with DNA as the secondary means of identification. The highest number of different identification modalities recorded for a single case is four, and this only occurred once. Since this study focuses on which elements best yield DNA identifications, only DNA identifications are considered here. Not having DNA listed as an identification modality implies the fragment tested did not yield a full profile. Therefore, for the purposes of this study, an element is considered identified only if it has been identified through DNA. It does not matter here whether the DNA identification is the primary, secondary, or tertiary means of identification.

7.2.4.1. DNA Identification Criteria

As of September 2005, WTC samples were subjected to short-tandem repeat (STR) DNA analysis using the standard loci of the Combined DNA Index System (CODIS) (Biesecker, et al. 2005; Budowle, et al. 1998) and the additional two Penta loci from the Powerplex 16 commercial kit (PromegaCorporation 2008), mitochondrial DNA sequencing of the HVI and HVII regions (Sullivan, et al. 1992), and single nucleotide polymorphisms (SNP) analysis (Shaler 2005). The population frequencies for all available STR and SNP profiles and available mitotypes were calculated and multiplied together to obtain a final frequency, which was then compared to a set minimum threshold requirement for identification. This threshold was determined to achieve a standard of less than 1 chance in 1,000,000 that a misidentification would result from a fortuitous match in a population estimated at the time to be 5,000 victims, regardless of the number of markers that produced genetic data (Cash, et al. 2003). As the number of victims was lowered from 5,000 to 2,749, this value was also lowered to 2 x 10^9, 2 x 10^8, and 4 x 10^9, for males, females, and profiles with no amelogenin results, respectively. Samples were subsequently identified by direct comparison to a victim exemplar type and/or through kinship analysis using family reference types (Mundorff, et al. 2009).

For the purposes of this analysis, only bone testing is considered here. Bone was tested at a different DNA laboratory than muscle. The laboratory performing the bone tests followed strict protocols, first scraping off any soft tissue, then bleaching the bone, which was then drilled for bone dust. This procedure insured only bone was tested and that muscle was not included in the sample. And, as with regular forensic casework, there were multiple extensive quality control checks implemented to ensure reliability. These QC checks included testing with multiple kits analyzing overlapping loci. Cases that failed the QC checks were not reported out as identified but instead further tested and investigated (Mundorff, et al. 2009).

7.2.4.2. Statistical Analyses

Chi-square and Fisher's Exact tests (when expected cell counts were less than five) were used to evaluate the relationship between DNA identification rate by recovery month and between skeletal elements in the RD and ESD. Phi Coefficient (2 x 2 comparisons) and Cramer's V (>2 x 2 comparisons) were used to examine the strength of association for statistically significant comparisons between variables with large or unequal sample sizes. In many cases, multiple bone fragments were linked to a single individual through DNA. Thus, comparisons of DNA identification rates focus on the variation between different skeletal elements instead of between individual victims. For the variables of sex of victim and victim type (which comprise only positively identified victims for which sex and victim type are known), frequencies are compared to determine whether DNA-based identifications of bone fragments in the RD and ESD occurred in the same proportion as in the complete WTCHRD and in the total missing victim population (Mundorff, et al. 2009). Probability values at $p \leq .05$ were considered statistically significant. The results are presented initially for each subset (RD and ESD) followed by the CED (combined RD and ESD).

7.3. Results

7.3.1. Resampled Data Set

As previously mentioned, the RD comprises cases from the complete WTCHRD that had been resampled (n = 641). The identification results for the total RD are presented in Table 3. Further analysis examining individual element success rates do not include all the cases reported here. Non-bone cases such as soft tissue and teeth were removed from the data set for subsequent analysis. Additionally, cases in which the exact element sampled for DNA could not be determined, such as "long bone indeterminate" or "bone indeterminate," were excluded. Finally, in order to facilitate statistical analysis between elements, cases with sample sizes of 15 or fewer were also removed from the analysis. Therefore, due to their small sample sizes, carpal (n=1), manubrium (n=1), hand phalanx (n=2), foot phalanx (n=1), ulna (n=13), maxilla (n=9), scapula (n=12), tarsal (n=6), and sacrum (n=3) are not included in the statistical analyses for the RD. However, it is worth pointing out that the success rates of the ulna and maxilla are 100% and 78%, respectively. Although the sample sizes are not large enough to reliably evaluate identification rates, it is interesting to note that these two elements initially have high DNA success rates. The resulting data set comprises 537 cases, and is used for subsequent analysis. Identification results are presented in Table 4.

Table 3. Summary of Identification Statistics from Total Resampled Data Set

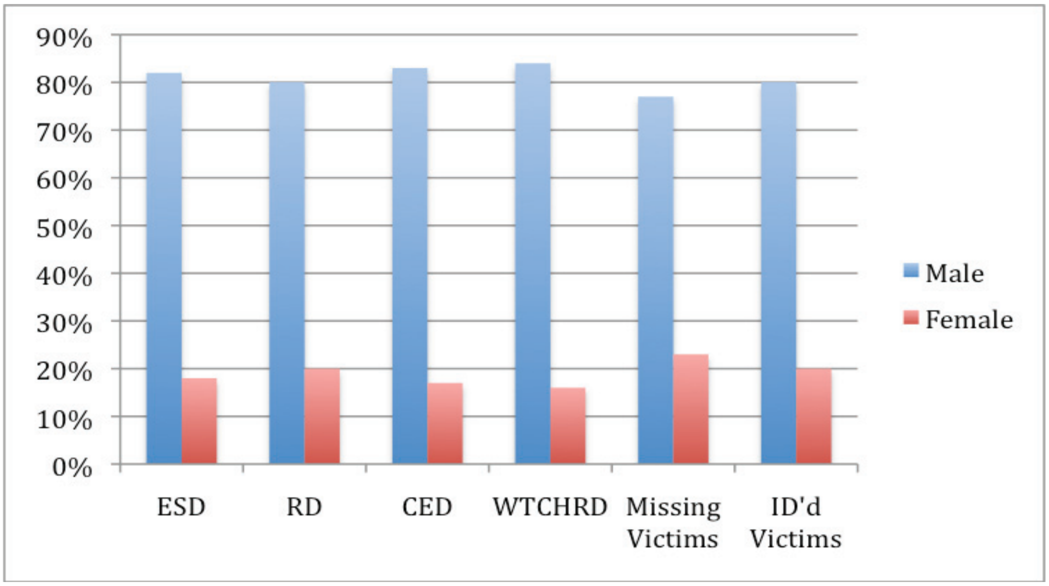
Element	Total Count	Number ID	Percent ID
Carpal	1	1	100
Foot Phalanx	1	1	100
Ulna	13	13	100
Metatarsal	42	36	86
Patella	78	63	81
Maxilla	9	7	78
Tibia	43	33	77
Metacarpal	21	16	76
Pelvis	19	14	74
Femur	66	47	71
Rib	45	32	71
Bone	17	12	71
Mandible	26	18	69
Radius	25	17	68
Long Bone	9	6	67
Mandible and Tooth	3	2	67
Sacrum	3	2	67
Scapula	12	8	67
Fibula	38	25	66
Humerus	60	39	65
Vertebra	18	11	61
Clavicle	19	11	58
Hand Phalanx	2	1	50
Tooth	8	4	50
Skull	37	18	49
Soft tissue	15	5	33
Tarsal	6	2	33
Manubrium	1	0	0
Skin	4	0	0
Total	641	444	

Table 4. Identification Statistics of Cases from Resampled Data Set Used for Subsequent Analyses

Element	Total Count	Number ID'd	Percent ID
Metatarsal	42	36	86
Patella	78	63	81
Tibia	43	33	77
Metacarpal	21	16	76
Pelvis	19	14	74
Femur	66	47	71
Rib	45	32	71
Mandible	26	18	69
Radius	25	17	68
Fibula	38	25	66
Humerus	60	39	65
Vertebra	18	11	61
Clavicle	19	11	58
Skull	37	18	49
Total	537	380	

Certain variables must first be ruled out as influencing factors before individual element success rates can be examined. A chi-square test was computed to evaluate the relationship between recovery location (site or landfill) and DNA success rate. The results indicate no significant association (χ^2 = 1.745, 1 df, p=0.187). Additionally, the sex of the victim was examined against the identification rates to see if there were differences between male and female identification success rates. A total of 2,749 victims were reported missing, 2,122 (77%) males and 627 (23%) females. Of the 2,749 victims, 1,598 have been identified, 1,272 (80%) of whom are males and 326 (20%) females. Within the RD, 80% of the identified cases are from males and 20% are from females, nearly identical to the total victim-to-sex ratio as well as the identified male-to-female ratio (Figure 2, Table 9). Therefore, it is assumed that sex can be ruled out as an influencing factor in victim identification rates.

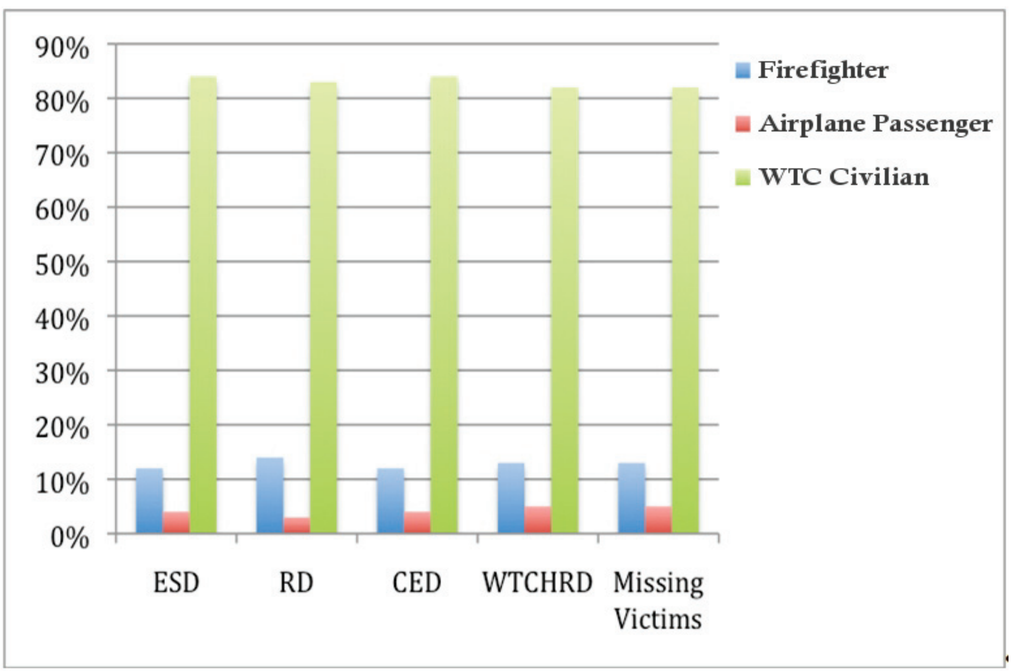
Figure 2. Bar Chart Comparing the Sex Ratio of Identified Remains in the Entire Sample Data Set (ESD), the Resampled Data Set (RD), the Complete Elements Data Set (CED), the Entire World Trade Center Human Remains Data Set (WTCHRD), and the List of WTC Missing and Identified Victims



Recovery month also appears to have no significant influence on DNA yield rates. Monthly fluctuations in identifications simply reflect recovery circumstances such as differences in the number of concentrations of human remains discovered at different times. Additionally, the process of sending samples to the contracting laboratory for DNA testing may also skew *Recovery Month*. Sometimes samples remained at the OCME for days, weeks, or even months before they were submitted for DNA testing. This was due to a variety of managerial reasons including payment contracts, the development of shipping protocols, and database and LIMS development for tracking samples before they were shipped. Finally, *Victim Location* was examined as an influencing factor on identification success rates. Of the 2,749 missing victims, 12.5%

(343) were firefighters, 5% (147) were airplane passengers, and 82.5% (2,269) were civilians in the WTC. As mentioned previously 1,598 of the 2,749 victims have been identified. The breakdown of identified victims by location (firefighter, airplane, or civilian) within the WTCHRD mimics the missing ratios at 13% firefighter, 5% airplane, and 82% civilian. From the RD, the breakdown of identified victims is also nearly identical: 14% firefighter, 3% airplane, and 83% civilian (Figure 3, Table 10). Therefore, the data suggest that the *Victim Location* variable is not a significant influencing factor on DNA-based identification rates.

Figure 3. Bar Chart Comparing the Percentage of Identified Remains by Victim Type in the Entire Sample Data Set (EDS), Resampled Data Set (RD), Complete Elements Data Set (CED), the Entire World Trade Center Human Remains Data Set (WTCHRD), and the Missing Victims



Having ruled out *Recovery Location, Sex*, *Recovery Month,* and *Victim Location* as significant influencing factors in identification success rates, the next variable to consider is the specific element sampled. For the following tests, analyses will be restricted to the modified RD described previously, using bone only where the specific element sampled is known (excluding "long bones, indeterminate," etc.) and where the sample number of cases is greater than 15. A complete table of the 537 cases used in these analyses is presented in Table 4 in descending order of successful identification rates. Metatarsal (n=42) is ranked first followed by patella (n=78), with success rates of 86% and 81% respectively. Tibia, metacarpal, pelvis, femur, and rib all have success rates within 70% to 79% followed by mandible, radius, fibula, humerus, and vertebra that range from 60% to 69%. Clavicle and skull show identification rates at 58% and 49%, respectively. When elements are grouped into the *Body Part Groups* category previously mentioned, success rates break down as follows: leg 76%, arm 68%, trunk 67%, and head 57%. A chi-square test was computed to evaluate whether a significant statistical association exists between the *Body Part Groups* and DNA identification rates. The results indicate that *Body Part Groups* do have a significant difference with regard to identification (χ^2 = 10.746, 3 df, p=.013). Clearly the lower limb shows much better success rates than other areas of the body, with metatarsal, patella, tibia, and femur showing the highest rates.

7.3.2. Entire Sample Data Set

As previously mentioned, the ESD comprises a total of 4,664 cases from the complete WTCHRD where the variable *DNA Sample Size* is listed as "Entire Sample" or "Entire Sample, Consumed." The identification results for the total ESD are presented in Table 5. Further analysis examining individual element success rates will not include all the cases reported here. Non-bone cases such as skin, soft tissue, and teeth were removed from the data set for subsequent analysis.

Table 5. ***Summary of Identification Statistics from Total Entire Sample Data Set***

Element	Total Count	Number ID	Percent ID
Mandible and Tooth	9	8	89
Foot Phalanx	24	19	79
Carpal	11	8	73
Cartilage	43	31	72
Femur	77	55	71
Metatarsal	215	148	69
Tibia	82	55	67
Manubrium	6	4	67
Rib	1256	806	64
Phalanx Unknown	19	12	63
Bone	456	282	62
Vertebra	54	33	61
Mandible	20	12	60
Patella	5	3	60
Fibula	121	71	59
Sacrum	24	14	58
Pelvis	43	25	58
Radius	95	55	58
Hand Phalanx	81	46	57
Humerus	50	28	56
Tarsal	31	17	55
Ulna	74	40	54
Skin	43	23	54
Clavicle	78	41	53
Scapula	80	42	53
Long Bone	392	192	49
Skull	457	214	47
Metacarpal	190	77	41
Soft Tissue	539	174	32
Tooth	86	11	13
Maxilla and Tooth	3	0	0
Total	4664	2546	

However, it is worth noting that costal cartilage (n=43) yielded DNA identifications at a rate of 72%. Cartilage is clearly superior to other soft tissues tested, especially if the soft tissue is significantly decomposed. However, cartilage was not included with the results of the bones tested because it has different material properties, which may skew the *Body Part Group* "Trunk" success rates. Additionally, since the purpose of this analysis is to determine which elements yield better than others, cases in which the exact element sampled for DNA could not be determined, such as "phalanx indeterminate" or "bone indeterminate," were also removed from further analysis.

Finally, in order to facilitate statistical analysis between elements, cases with sample sizes of 15 or fewer were also removed from the analysis. Therefore, due to their small sample sizes, carpal (n=11), manubrium (n=6), and patella (n=5) are not included in the statistical analyses for the ESD. The resulting data set comprises 3,052 cases, which are used for subsequent analysis. Identification results are presented in Table 6.

Table 6. Identification Statistics of Cases from Entire Sample Data Set Used for Subsequent Analysis

Element	Total Count	Number ID	Percent ID
Foot Phalanx	24	19	79
Femur	77	55	71
Metatarsal	215	148	69
Tibia	82	55	67
Rib	1256	806	64
Vertebra	54	33	61
Mandible	20	12	60
Fibula	121	71	59
Sacrum	24	14	58
Pelvis	43	25	58
Radius	95	55	58
Hand Phalanx	81	46	57
Humerus	50	28	56
Tarsal	31	17	55
Ulna	74	40	54
Clavicle	78	41	53
Scapula	80	42	53
Skull	457	214	47
Metacarpal	190	77	41
Total	3052	1798	

To examine individual element success rates, other variables must first be ruled out as influencing factors. A chi-square test was run to evaluate the association of *Recovery Location* (site or landfill) and DNA identification rate. The results indicate that *Recovery Location* does not influence identification (χ^2 = 1.520, 1 df, p=0.218). Additionally, the *Sex* of the victim and the identification rates were examined for differences between male and female identification success rates. As previously mentioned, there are a total of 2,749 victims reported missing, 2,122 (77%) males and 627 (23%) females. And of the 2,749 victims, 1,598 have been identified, 1,272 (80%) of whom are males and 326 (20%) are females. Within the ESD, 83% of the identified cases are from males and 17% are from females, close to the total victim-to-sex ratio and closer to the identified male-to-female ratio (Figure 2, Table 9). Therefore, it is assumed that *Sex* can be ruled out as an influencing factor in victim identification rates. *Recovery Month* also appears to have no significant influence on DNA yield rates. As mentioned in the previous section, identifications fluctuate from month to month, reflecting the recovery circumstances. Additionally, the process in which samples were sent to the contracting laboratory for DNA testing may also skew *Recovery Month*.

Finally, *Victim Location* was examined as an influencing factor affecting identification success rates. Of the total 2,749 missing victims, 12.5% (343) were firefighters, 5% (147) were airplane victims, and 82.5% (2,269) were civilians in the WTC. As mentioned previously 1,598 of the 2,749 victims have been identified. The breakdown of identified victims by location (airplane passenger, firefighter, or civilian in the tower) within the WTCHRD mimics the missing ratios at 5% airplane, 13% firefighter, and 82% civilian. From the Entire Sampled Data Set, the breakdown of identified victims is nearly identical, 4% airplane, 12% firefighter, and 84% civilian (Figure 3, Table 10).

Therefore, it is determined that the *Victim Location* variable has no significant influence on identification rates.

Having ruled out *Recovery Location, Sex*, *Recovery Month,* and *Victim Location* as significant influencing factors in identification success rates, the next variable to consider is the specific element sampled. For the following tests, analyses are restricted to the modified ESD previously described, using bone only where the specific element sampled is known (excluding “long bones, indeterminate,” etc.). A table of the 3,052 cases used in the following analyses is presented in Table 6 in descending order of successful identification rates. Foot phalanx scored the highest at 79% identified, followed by femur at 70%. Metatarsal, tibia, rib, vertebra, and mandible all score in the 60th percentile while fibula, sacrum, pelvis, radius, hand phalanx, humerus, tarsal, ulna, clavicle, and scapula score in the 50th percentile. Finally, skull and metacarpal score the lowest, with both in the 40th percentile. When elements are grouped into the *Body Part Groups* category previously mentioned, success rates break down as follows: Leg = 66%, Trunk = 63%, Arm = 51%, and Head = 47%. A chi-square test was computed to evaluate statistical differences between the *Body Part Groups* and identification rate. The results indicate that *Body Part Groups* shows a significant association with DNA identification rate ($\chi^2 = 62.828$, 3 df, p=0.000). Clearly, the lower limb shows much better success rates than do other areas of the body, with foot phalanx, femur, metatarsal, and tibia ranked as the top four most successful elements.

7.3.3. Comparing Results between Resampled and Entire Sample Data Sets

Although the Resampled Data Set and ESD have vastly different sample sizes (n=537 vs. n=3,052, respectively) their identification statistics are surprisingly similar.

For example, identification ratios between males and females are similar in both groups, as are the identification ratios of *Victim Location* (firefighter, airplane, and WTC civilian). Neither data set had identification rates influenced by the variables *Recovery Location, Victim Location, Sex,* or *Recovery Month.* However, the two data sets do have some differences. Most noticeably, the majority of the elements showed higher rates of full DNA profile recovery in the RD than in the ESD. Overall, the humerus, radius, rib, pelvis, tibia, fibula, metatarsal, and metacarpal are all more successful in the RD, and no elements performed worse in the RD than in the ESD. This points to an underlying difference between the two data sets that may account for these minor differences (for example, resampling allows some choice in which element is picked to be resampled, therefore the best preserved specimen is usually chosen). These minor differences support a repeat analysis of the combined data sets, presented below.

To quantify these results, each bone element was compared against itself between the two data sets. The results of the individual chi-square tests are presented in Table 7. Although the majority of the elements in the RD outperformed the same elements in the ESD, the table reveals that 15 of the 18 elements show no statistically significant difference in identification rates between the two data sets. However, three elements show a significant difference between the two data sets: the metatarsal, the metacarpal, and the ulna. Based on the Phi and Cramer's V values in all three cases, discrepancies in sample size appear to influence these results. Looking at these specific three elements individually, what other factors besides sample size may account for the differences between the two data sets? In all three cases, the elements performed markedly better in the RD. There are two possible explanations for this. First, resampled cases are more likely to represent more intact bones than are Entire Sample cases. Elements that are intact hinder the introduction of outside contaminants, and most probably represent larger sample sizes than fragmented bones, both of which are known to influence DNA yields and ultimately identification results (Budowle, et al. 2005; Collins, et al. 2002; Leney 2006). Second, the effect of different taphonomic factors may also influence success rates.

Table 7. Chi-Square Results of Individual Elements Between Resampled and Entire Sample Data Sets

Element	χ^2, F.E.	p-value	Phi/ Cramer's	N= Resampled vs. Entire Sample	% ID'D Resampled vs. Entire Sample
Clavicle	0.175	0.676		11/19 vs. 41/78	58% vs. 53%
Femur	0.001	0.977		47/66 vs. 55/77	71% vs. 71%
Fibula	0.611	0.434		25/38 vs. 71/121	66% vs. 59%
Humerus	0.928	0.335		39/60 vs. 28/50	65% vs. 56%
Mandible	0.425	0.515		18/26 vs. 12/20	69% vs. 60%
Metacarpal	9.758	0.002	0.215	16/21 vs. 77/190	76% vs. 41%
Metatarsal	4.921	0.027	0.138	36/42 vs. 148/215	86% vs. 69%
Patella	FE	0.265		63/78 vs. 3/5	81% vs. 60%
Pelvis	1.365	0.243		14/19 vs. 25/43	74% vs. 58%
Radius	0.842	0.359		17/25 vs. 55/95	68% vs. 58%
Rib	0.913	0.339		32/45 vs. 806/1256	71% vs. 64%
Sacrum	FE	1		2/3 vs. 14/24	67% vs. 58%
Scapula	0.884	0.358		8/12 vs. 42/80	67% vs. 53%
Skull	0.046	0.831		18/37 vs. 214/457	49% vs. 47%
Tarsal	FE	0.405		2/6 vs. 17/31	33% vs. 55%
Tibia	1.266	0.261		33/43 vs. 55/82	77% vs. 67%
Ulna	9.805	0.002	0.336	13/13 vs. 40/74	100% vs. 54.1%
Vertebra	0.000	1		11/18 vs. 33/54	61% vs. 61%

Specifically, cases from the ESD are usually isolated small bone fragments devoid of soft tissue. Cases in the RD were often selected because they represented not only relatively intact elements, but also were likely to be protected within surrounding skin and soft tissue. In fact, the element chosen from a case to be resampled usually represented the best bone that could have been selected for that particular case, as opposed to a sample from the ESD where the bone must be submitted regardless of size or condition. For example, a metacarpal from the ESD would be an isolated single metacarpal bone, either intact or fragmented. However, a metacarpal from the RD would have been specifically selected because it represented the most intact and protected bone sample from the case being resampled. The metacarpal was probably dissected out from a hand that still had adherent skin and soft tissue protecting the bone from outside contaminants. This is especially true for the ulna. Unlike the metacarpal and the metatarsal which, because of their size, could possibly be submitted as "Entire Sample" and still be intact bones, the ulna, based on its size alone, by default must be fragmented if it is considered an "Entire Sample." No intact ulna could possibly fit into a 50 ml DNA sample tube unless it was a fragment. These two hypotheses together may help explain, along with disparate sample sizes, the difference between the success rates of these three elements as well as the overall differences between the two data sets' success rates.

When looking at the identification results as they are broken down by *Body Part Group,* a similar discrepancy emerges, which is again the probable result of sample size differences and differences in the identification statistics for the metatarsal, metacarpal, and ulna. A chi-square test was computed for each *Body Part Group* separately (Arm, Leg, Trunk, and Head) comparing the RD to the ESD (Table 8). Statistically significant differences for the groups Leg (χ^2 = 7.371, 1 df, p=.007; Phi=.094) and Arm (χ^2 = 17.035, 1 df, p=.000; Phi=.167) emerged. Both results were probably influenced by the radically different results for the few elements previously mentioned. For example, within the group Arm, the ulna and the metacarpal were much more successful in the RD (see Table 6), and within the Leg group, the metatarsal performed much more successfully within the RD. Both these factors were not only influenced by vastly different sample sizes, but also, again, the RD elements were chosen because they represented the "best specimen" of the case being resampled for DNA. These specimens were more likely to be covered with protective skin and soft tissue and more likely to represent intact elements, unlike a case that is submitted as an "Entire Sample," which would have lacked protection from soft tissue and may or may not be intact.

Table 8. Chi-Square Results of Body Part Groups Between Resampled and Entire Sample Data Sets

Body Part Group	χ^2, F.E.	p-value	Phi/Cramer's	N= Resampled vs. Entire Sample	% ID'D Resampled vs. Entire Sample
Leg	7.371	0.007	0.094	274 vs. 555	76% vs. 66%
Arm	17.035	0	0.167	121 vs. 490	71% vs. 50%
Trunk	0.993	0.319	0.025	116 vs. 1535	67% vs. 63%
Head	2.124	0.145	0.063	63 vs. 477	57% vs. 47%

7.3.4. Complete Elements Data Set

As previously mentioned, the CED comprises cases from the variables *Sample Size* and *Resampled* from within the WTCHRD; specifically, all cases with *Sample Size* recorded as "Entire Sample" as well as all cases that were resampled for additional DNA testing. The ESD and RD were combined to form the CED for larger, more robust sample sizes. For example, while sample sizes of nine elements were not large enough to be included in the RD analyses, combining the ESD with the RD allowed for all elements except three (the carpals, manubrium and maxilla) to be included. The CED (n=5,305) is approximately 25% of the entire WTCHRD data set (n=19,970); however, the descriptive statistics from both are remarkably similar. Thus, the CED can be used as a representative subset for the WTCHRD. For example, 56% of the cases in the CED are identified. This is nearly the same as in the WTCHRD data set where 57% of the cases are identified. There are a total of 2,749 victims reported missing, of whom

2,122 (77%) are males and 627 (23%) are females. And of the 2,749 victims, 1,598 have been identified, 1,272 (80%) are males and 326 (20%) are females. Of the 10,927 identified fragments from the WTCHRD, 84% are male and 16% are female. Similarly, 83% of the identified fragments in the CED are males and 17% are females (Table 9, Figure 2). Even the identification ratios as broken down by *Victim Location* are virtually identical (Table 10, Figure 3). The identification rate, as well as the ratios between identified males and females, (individually and number of fragments) and *Victim Location* between the WTCHRD data set and the CED are remarkably similar. Therefore, the CED closely mimics the WTCHRD data set identification statistics (only with smaller fragments); thus, this data can be used as a comparable subset for analyzing which elements are most likely to yield DNA identifications.

Table 9. Male-Female Identification Rates from All Data Sets

Fragments	Male	Female
ESD	82%	18%
RD	80%	20%
CED	83%	17%
WTCHRD	84%	16%
Missing Victims	77%	23%
ID'd Victims	80%	20%

Table 10. Victim Location Identification Rates from All Data Sets

Victims	Firefighter	Airplane	Civilian
ESD	12%	4%	84%
RD	14%	3%	83%
CED	12%	4%	84%
WTCHRD	13%	5%	82%
Missing Victims	12.5%	5%	82.5%
ID'd Victims	13%	5%	82%

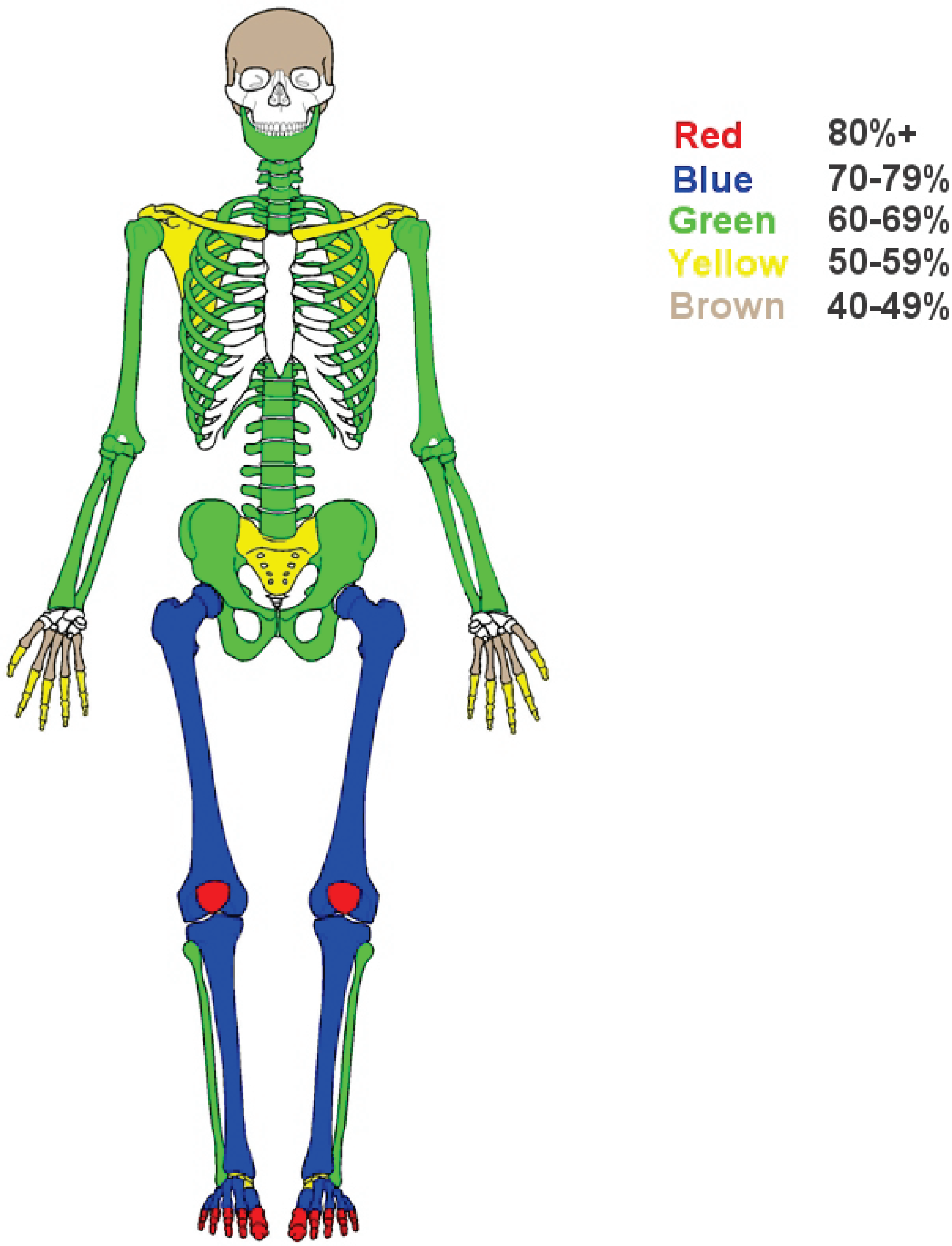
As previously mentioned, the CED has a total of 5,305 cases and is a combination of two smaller data sets, the RD and the ESD. The identification results for the total CED are presented in Table 2. Non-bone cases such as skin, soft tissue, and teeth are removed from the data set for subsequent analysis. Additionally, cases in which the exact element sampled for DNA could not be determined, such as "phalanx indeterminate" or "bone indeterminate," were also removed. Finally, in order to facilitate statistical analysis between elements, cases with sample sizes of 15 or fewer were also removed. Therefore, due to their small sample sizes, carpal (n=12), manubrium (n=7), and maxilla (n=9) are not included in the statistical analysis from the CED. However, it is worth noting that both the carpal and the maxilla performed relatively well (75% and 78%, respectively). The resulting data set comprises 3,631 cases, which will be used for subsequent analysis. Identification results for this data set are presented in Table 11 and Figure 4.

To examine individual element success rates, certain other variables must first be ruled out as influencing factors. A chi-square test was computed to evaluate the relationship between *Recovery Location* (site or landfill) and identification rate. The results indicate that despite a statistically significant relationship between *Recovery Location* and identification in the sample, the strength of this association is weak and is probably influenced by differences in sample size (χ^2 = 4.792, 1 df, p=.029; Phi=.036). Again as mentioned previously, the identification ratios between males and females as well as *Victim Location* show no significant influence on identification rates (see Tables 9 and 10). *Recovery Month* also appears to have no significant influence on DNA yield rates.

Table 11. Identification Statistics of Cases from Complete Elements Data Set Used for Subsequent Analyses

Element	Total Count	Number ID	Percent ID
Foot Phalanx	25	20	80
Patella	83	66	80
Metatarsal	257	184	72
Femur	143	102	71
Tibia	125	88	70
Mandible	46	30	65
Rib	1301	838	64
Pelvis	62	39	63
Vertebra	72	44	61
Humerus	110	67	61
Ulna	87	53	61
Fibula	159	96	60
Radius	120	72	60
Sacrum	27	16	59
Hand Phalanx	83	47	57
Scapula	92	50	54
Clavicle	97	52	54
Tarsal	37	19	51
Skull	494	232	47
Metacarpal	211	93	44
Total	3631	2208	

Figure 4. Skeletal Representation of CED Showing Elements in Ranked Order of Successful Identification



Having ruled out *Recovery Location, Sex*, *Recovery Month,* and *Victim Location* as significant influencing factors in identification success rates, the next variable to consider is the specific element sampled. For the following tests, analysis will be restricted to the modified CED described previously, using bone only where the specific element sampled is known (excluding "long bones, indeterminate," etc.). A complete table of the 3,631 cases used in the following analyses is presented in Table 11 in descending order of successful identification rates. The foot phalanx and the patella scored the highest, both at 80%. Metatarsal, femur, and tibia are all in the lower 70th percentile. Mandible, rib, pelvis, vertebra, humerus, ulna, fibula, and radius all score in the 60th percentile while sacrum, hand phalanx, scapula, clavicle, and tarsal score in the 50th percentile. Finally, skull and metacarpal score the lowest, both in the 40th percentile.

When elements are examined by *Body Part Group*, success rates break down as follows: Leg = 69%, Trunk = 63%, Arm = 54%, and Head = 49%. A chi-square test was computed to evaluate if there was a statistically significant association between *Body Part Groups* and identification rate. The results indicate that *Body Part Groups* do have a significant relationship with identification rate (χ^2 = 73.527, 3 df, p=.000). To further break these down, chi-square tests were computed to evaluate the individual *Body Part Groups* (Leg, Arm, Trunk, and Head) when compared to each other in the order that they successfully rank (Table 12). For example, the group "Leg" ranks first and is more successful than "Trunk," which ranks second. A chi-square test indicates that this difference is statistically significant (χ^2 = 10.038, 1 df, p=.002). "Trunk" ranks second and is more successful than the group "Arm"; this result is also statistically significant (χ^2 = 13.797, 1 df, p=.000). Finally, the "Arm" group performs better than the "Head" group, again, a statistically significant difference (χ^2 = 3.886, 1 df, p=.049). Clearly, the lower limb has a much higher success rate than other areas of the body, with foot phalanx, patella, metatarsal, femur, and tibia being the top five elements reported.

Table 12. Chi-Square Results between Body Part Groups from Complete Elements Data Set Analysis

Body Part Group	**χ^2, F.E.**	***p*-value**	**Phi/Cramer's**	**(*N*)**	**% Identified**
Leg vs. Trunk	10.038	0.002	0.064	829 vs. 1651	69% vs. 63%
Trunk vs. Arm	13.797	0	-0.078	1651 vs. 611	63% vs. 54%
Arm vs. Head	3.886	0.049	0.058	611 vs. 540	54% vs. 49%

7.4. Discussion

The purpose of this analysis was to examine differences in DNA identification rates between skeletal elements from the World Trade Center disaster with the intention of establishing sampling criteria for mass disaster DNA identification projects and to supplement or expand upon previous DNA sampling recommendations. To date, guidelines for DNA sampling in mass disaster management literature are almost nonexistent, and the most recent guidelines issued by the NIJ and the DNA Commission of the ISFG on DNA sampling methods from mass fatality incidents do not address which skeletal elements are most likely to result in successful DNA testing (National Institute of Justice 2005; Prinz, et al. 2007). Guidelines must account for the degradation of genetic material resulting from taphonomic factors and provide recommendations for sampling fleshed versus skeletonized remains. This highlights the need for additional data on DNA results for different skeletal elements recovered from a variety of mass fatality contexts. For example, a DNA sampling protocol for intact bodies would differ significantly from a protocol for heavily fragmented and burned remains from an airline disaster. The results of this study may be useful in establishing general guidelines for DNA sampling protocols that can be adapted to a variety of mass fatality scenarios (Mundorff, et al. 2009).

Three subsets of the WTCHRD were examined to determine which elements most successfully yielded DNA for identification. The first of the three was the RD. The RD cases represented instances when the initial DNA sample had failed and a secondary sample was removed from the case. When the second sample was removed, a Resampling form was filled out to indicate specifically what bone was resampled. For these cases, the anthropologist would attempt to remove bone samples from the most protected and intact area of the remains. For example, if the case represented a portion of a lower limb with an intact foot, the sample might be a dissected metatarsal still encased in skin and soft tissue.

Overall, weight-bearing elements performed markedly better than other areas of the body, such as the arms, and axial elements, such as the skull. However, the metatarsal and the patella were the only elements with success rates in the 80th percentile, at 86% and 80.8% respectively, both outperforming the tibia, femur, and rib (77%, 71%, and 71%, respectively). While there might not be significant inter-elemental differences between success rates, there are major management implications regarding sampling of the patella and the metatarsal instead of the femur or the tibia as in past mass fatality incidents (Boyer 2006; Butler 2005). To sample a tibia or a femur, the sampler must use a bone saw, and even cordless bone saws need to be plugged into an electrical outlet to be recharged. This limits the mortuary operation to facilities with electricity, unless they opt to pause their processing until generators arrive, which might be difficult immediately after a disaster incident. Bone saws are also incredibly labor intensive for the practitioner sampling the bone. Between sampling, either the blade must be changed, which is cost-prohibitive, or it must be properly cleaned with a10% bleach to water solution. However, cleaning is time-consuming and may introduce a potential source of contamination. Finally, removing a sample from the midshaft of a femur is intrusive and disfiguring to a body because of the amount of skin, muscle, and fat that must be cut through to reach the femur and extract a large enough sample.

From a practical management perspective, too, there are benefits to using the patella and metatarsal for identifications. Both bones can be removed easily with disposable scalpels, thus dispensing with the need for the labor-intensive bone saw, and therefore electricity, and for cleaning or changing the blades between cases, too. Disposable scalpels are much more expedient, are inexpensive, and can be easily disposed of between sampling which eliminates cross-contamination. Furthermore, removing a patella or a metatarsal is less destructive to the victim's remains, with less fat and muscle being dissected to acquire the sample; and both bones can be removed as intact elements, dramatically reducing even further the chances of contamination.

This retrospective analysis illustrates which resampled bone elements from the World Trade Center disaster, predominantly encased in soft tissue, were most successful at yielding DNA-based identifications. The management factors listed above, along with this preliminary DNA evidence that the patella and the metatarsal yield DNA in rates comparable to many other elements of the skeleton, indicate that these elements may represent optimal samples for mass fatalities involving relatively intact bodies where bone is sampled instead of muscle or blood due to taphonomic variables such as decomposition.

The second data set examined was the ESD, which represents a "worst case scenario" of small fragments of isolated bone, devoid of soft tissue, that were submitted to DNA testing in their entirety. These fragmented bones were much more degraded than elements from the RD. Again, the weight-bearing lower limb outperformed the arm, trunk, and head with the foot phalanx, femur, metatarsal, and tibia as the top four ranked bones. Unfortunately, the sample size for the patella was too small to be used in this analysis and cannot be considered during the recommendations.

When considering sampling strategy recommendations, the mitigating factors previously described should be considered. Although the femur technically scored higher than the metatarsal (71% vs. 69%), these differences are negligible and not statistically significant. However, all the factors that make the femur more difficult to sample must still be considered; therefore, due to their similar results, the metatarsal may be a preferable bone to sample from a management perspective. The foot phalanx scored the highest—the total count of the foot phalanx was 25, yielding a 79% identification rate—and must be considered as well. Although it is easier to sample than a long bone, the bone size is fairly small. Past studies have indicated that the mass of the sample can influence success rates (Leney 2006); therefore, if the foot phalanx is to be sampled, one suggestion would be to sample from the first digit in order to retrieve a larger sample. However, the metatarsal appears to be the better choice than the foot phalanx due to its size and reliability.

The third data set examined was the CED (a combination of the RD and the ESD) and provided more robust sample sizes. Again, the results show the lower limb bones yield higher DNA identification rates than the arm, trunk, or head. The foot phalanx and the patella scored identically at 80%, closely followed by the metatarsal, femur, and tibia. Using the same criteria as above, the patella and metatarsal appear to be the best elements for sampling. They can be removed as intact bones with disposable scalpels, eliminating the need for labor-intensive bone saws, electricity, and cleaning blades between samples. The bone stays whole, unlike a section of long bone, thus reducing the risk of introducing contamination. The CED results may be useful to help guide bone sampling choices when remains are fragmented and lower limb bones are not available (for example if the case is represented by a traumatically amputated arm only). Table 11 lists the bone elements in order of successful identifications.

Overall, when sampling victim remains from the World Trade Center disaster, bones of the lower limb, excluding the fibula, appear to be the best elements to sample for DNA-based identifications. This is probably because the lower limb bones (excluding the fibula) are weight-bearing with elevated levels of bone remodeling, leading to a greater density due to recently developed osteocytes. The success of the patella, which is not a weight-bearing bone, might be attributed to an increased density from the stresses of muscle attachments, similar to what Leney attributes to the success of the mandible (Leney 2006).

When remains are severely fragmented, DNA from bones that still have skin or soft tissue covering them may be slightly more protected than isolated bone fragments and may represent better samples. This is illustrated by differences in success rates of the metacarpal between the RD and the ESD (although most elements in the RD outperformed the same element in the ESD, there was a statistically significant difference between the metacarpals). The metacarpals in the RD produce significantly higher DNA identification rates than the metacarpals in the ESD (76.2% vs. 44.1%), probably because of their protective covering of skin and soft tissue in the RD. The metacarpal was likely an intact or nearly intact bone in the ESD and still resulted in the lowest yield rates of all the elements tested. One of the main differences between the two data sets comes down to skin and soft tissue protection. However, the metatarsal and patella can also be sampled as intact bones, and this might prove to reduce the amount of contamination introduced into segments of cut long bones such as the femur or tibia.

The current study has a number of limitations. First, this is a retrospective study using remains from the World Trade center disaster, which include a very unique set of circumstances and taphonomic influences. The data sets used may not be entirely representative of the total WTC victim population, and also may not reflect the full range of taphonomic conditions that affected DNA preservation. Also, teeth, which are good sources of post mortem DNA, had not been DNA tested at the time of this study and therefore were not part of the analysis. Additionally, this study could not address the influence of time-since-death because remains were recovered and DNA tested at different times. Finally, it should be noted that the identification process relied on successful DNA-typing of not only the remains but also the comparison exemplars. However, a number of victims had comparison exemplars that were insufficient or nonexistent. Thus, while some of the remains produced a DNA profile that met the minimum threshold requirement, a positive identification was not possible due to the lack of DNA exemplars. Despite these limitations, the WTCHRD provided adequate sample sizes to address variation in successful DNA-typing rates by sex, victim type, recovery location, and skeletal element.

7.5. Conclusion

The results demonstrate significant variation in DNA identification rates between skeletal elements, with higher overall successful typing rates among weight-bearing lower limb elements than among elements of the trunk, upper limb, and head (Mundorff, et al. 2009). These results will help mass fatality managers establish DNA sampling guidelines for future DVI projects. Establishing sampling guidelines that can be tailored for specific contexts will save time, money, and effort, and will ultimately aid in streamlining the identification process. From a mass fatality management perspective, the results of this study suggest that patellae, metatarsals, and foot phalanx are likely to produce successful DNA profiles at rates comparable to femora, tibiae, and ribs in many mass disaster contexts. Given the relative ease of sampling the patellae and foot elements, it may be preferable to select these elements for DNA sampling in future mass fatality incidents (Mundorff, et al. 2009).

Chapter 8.

Splitting Results

8.1. Anthropological Verification Project

Of the 19,970 cases that comprise the complete World Trade Center Human Remains Database, 16,969 (84%) went through the Anthropological Verification Project (discussed in Chapter 5). This means that these 16,969 unidentified cases were reviewed for a second time. This second review was carried out by an anthropologist who looked specifically for instances in which commingling might be present because it was missed during the initial examination. However, 3,001 cases did not have this secondary AVP examination because they had already been identified and released to the next of kin prior to its implementation in late May 2002. Of the 16,969 cases reviewed, commingling seemed to be possible in 74 cases, plus the case described as the defining case. Commingling was suspected when there were duplicate elements or fragments were not joined. These 75 cases were split; any fragments that were not attached to one another, or did not articulate together, were separated and each portion became its own case. The final results of the AVP, from an anthropological perspective, are presented below. The splits are examined to determine why cases were split, how changes in the triage protocols overtime influenced splits, and if any of the splits could have been prevented by more rigorous anthropological examination in the mortuary.

8.1.1. Splitting Procedure

When a case was split, the main portion, which was often the largest piece, usually retained the original case number. The portion of the case that retained the original case number is referred to as the primary. Segregated fragments were given new case numbers beginning with the next available case number and are referred to as cases that had been "split" from the primary. More often than not, these newly assigned cases were given numbers thousands of case numbers away from the primary number because so many other cases had been processed through the mortuary before this case was re-examined and split. The primary case file was generally amended to update the case description and to indicate that the case had been split. This notation recorded the newly assigned case numbers for each case originally associated with that primary. Often, the files for the corresponding split cases also contained a notation indicating that the case was created *as a result* of being split from a primary, and the associated primary case number was noted. The Assistant Director of Identifications responsible for postmortem records maintained a separate database of split cases, along with their associated cases. DNA testing would eventually determine if the split cases did indeed belong to the primary case from which they had been split, or whether they represented true commingling and belonged to a different individual. This chapter evaluates the AVP by examining the results of the split cases.

Cases were split for three fundamental reasons. First, duplicate elements were present, confirming commingling. Second, remains that were not or were no longer attached had been grouped together. These additional bone fragments were likely overlooked during the initial examination because they were small and deeply embedded within soft tissue, as will be shown with examples one and two. These small bone fragments were probably only revealed during the second examination because of additional decomposition over time and a more stringent examination protocol. Third, remains were grouped together because that was how the remains arrived from the site and the initial examiner thought they appeared to belong together, as will be presented in example three and was the situation with the “Defining Case” presented in Chapter 5. And finally there were mistakes, as in example four. Cases that were split because of duplicate elements were clearly commingled, but cases that were split for the second and third reasons may or may not have actually been commingled remains of different people. As will be shown, sometimes remains that were grouped together and should have been separated during triage actually belonged to the same individual.

8.1.2. Examples of Split Cases

8.1.2.1. Example 1: Artificial Fusion of Remains

A large mass of soft tissue attached to a proximal fibula was examined during the AVP and determined to be commingled. Embedded within the soft tissue was a small fragment of distal fibula, a left medial cuneiform, a metatarsal fragment, a right first toe, an unidentified bone fragment, a foot phalanx, and a small fragment of costal cartilage. These seven additional fragments were so deeply embedded within the soft tissue mass that they most likely were not even noticed during the initial examination and represent a typical example of Type 2 (disaster-induced) commingling. The large mass of soft tissue attached to the proximal fibula would retain the original case number as the primary. This case would be resampled for DNA because there is no way to determine if the original bone DNA sample was actually from the fibula, or from a commingled fragment. The additional seven fragments were all segregated, assigned their own case number, documented, and DNA-sampled. Subsequent DNA tests proved that the unidentified bone fragment belonged to the same individual as the primary (the proximal fibula with the soft tissue). The segregated distal fibula, cuneiform, toe, and phalanx were identified to a second individual. The costal cartilage was identified to a third individual, and the metatarsal fragment did not yielded enough DNA to establish an identification.

8.1.2.2. Example 2: Artificial Fusion of Remains

A fragmented right innominate with articulated proximal femur and "attached" vertebrae, encased in significant soft tissue, was examined during the AVP and determined to be commingled. Four articulated lumbar vertebra appeared to be attached to these remains by soft tissue, but closer examination revealed that the soft tissue was merely fused to the innominate, another example of Type 2 commingling. Two other small vertebra fragments were embedded within the soft tissue associated with the lumbar vertebra but not documented in the case file because they were likely not noticed during the initial examination. The right innominate, femur, and attached soft tissue became the primary case, retained the case number, and was resampled for DNA. The four articulated lumbar vertebra with attached soft tissue was split from the primary, assigned its own new case number, and sampled for DNA. Each of the two additional vertebrae fragments was also given a discrete case number and sampled for DNA. Subsequent DNA tests revealed that all the remains belonged to the same individual.

8.1.2.3. Example 3: Intentional Grouping

A partial leg, consisting of a left tibia and a left femur, represents another example of commingling discovered during the AVP examination. Due to decomposition, there was little soft tissue and skin present and the bones were not articulated. These remains were likely recovered near each other and grouped at the site into the same body bag, thus arriving at the mortuary as if they belonged together (Type 1, recovery-induced commingling). Whoever performed the original triage must have assumed that if these two bones were recovered together, they must belong together since they are anatomically close. However, they did not articulate and were not attached by soft tissue, and therefore had to be split into two separate cases. Subsequent DNA tests showed that each belonged to a different individual.

8.1.2.4. Example 4: Mistakes

The final example illustrates how a combination of factors including inexperienced practitioners, chaotic working conditions, an intense sense of urgency to get the job done, and a triage policy that was initially too lenient, led to commingling mistakes. It should be emphasized that only 75 cases of potential commingling were discovered during the AVP, but a few were obvious mistakes that could have been avoided by more diligent work.

A set of remains examined during the AVP consisted of a right hand and forearm, including an articulated distal humerus, skin, and soft tissue. Also included with these remains were another right distal humeral fragment articulated to a proximal radius and ulna encased in decomposing soft tissue. An additional mass of skin and soft tissue was also grouped with these two pieces. There is no way to understand why these two clearly overlapping elements were grouped together. Perhaps the individual examining the remains was not proficient with fragmented bones and thought one was left while the other was right and also believed that because they were recovered together they must belong together. Whatever the reason, they were split during the AVP and DNA tests confirmed they belonged to two different individuals.

Although these fragments could not possibly have belonged to the same individual because they were overlapping elements, there were instances where left and right hands were grouped together even though there was clearly nothing attaching them to each other. AVP protocol demanded that these remains be split into two cases and often DNA tests would reveal that they did belong to the same individual. This scenario was not uncommon, but because it was better to err on the side of caution—intuition about fragments belonging together was not enough—they had to be linked together by an accepted modality (DNA, anthropology, dental, fingerprint, x-ray and sometimes personal effects) to be grouped.

8.2. Results

8.2.1. Summary Statistics

Table 13 illustrates the total number of splits from each of their primaries. A total of 76 cases (primaries) were split, or 0.044% of the 16,969 cases examined during the AVP and 0.037% of the total WTCHRD. One case was dropped from the study because of conflicting paperwork, indicating inaccurate recording. Identification results of the 75 splits (statistics include the defining case as well) will be discussed in this section. A total of 293 new cases were created from the 75 split primary cases. There was a wide range in the number of fragments split from each primary (Table 14). While the majority of splits involved separating only one or two fragments from the primary case, in one instance 47 new cases were created through a split. Fifty-one percent of the split primary cases (n=38) involved the creation of a single new case, followed by 17% (n= 13) involving the creation of two new cases. Six of the split primary cases resulted in three new cases each, while another six resulted in four new cases each.

Table 13. Number of Split Cases from Each of the 75 Primaries

List 1 (1-25)		List 2 (26-50)		List 3 (51-75)	
Primary	Split Cases	Primary	Split Cases	Primary	Split Cases
1	1	26	2	51	1
2	1	27	1	52	2
3	4	28	1	53	1
4	4	29	1	54	3
5	2	30	1	55	1
6	1	31	1	56	2
7	14	32	2	57	4
8	2	33	1	58	1
9	1	34	1	59	2
10	1	35	4	60	1
11	1	36	2	61	4
12	1	37	1	62	1
13	4	38	7	63	3
14	1	39	1	64	14
15	3	40	5	65	2
16	3	41	1	66	2
17	47	42	3	67	1
18	35	43	23	68	9
19	6	44	2	69	1
20	3	45	1	70	1
21	5	46	1	71	17
22	1	47	1	72	2
23	2	48	1	73	1
24	5	49	1	74	1
25	1	50	1	75	1

Table 14. Breakdown of Primaries by How Many Cases Were Split from Each

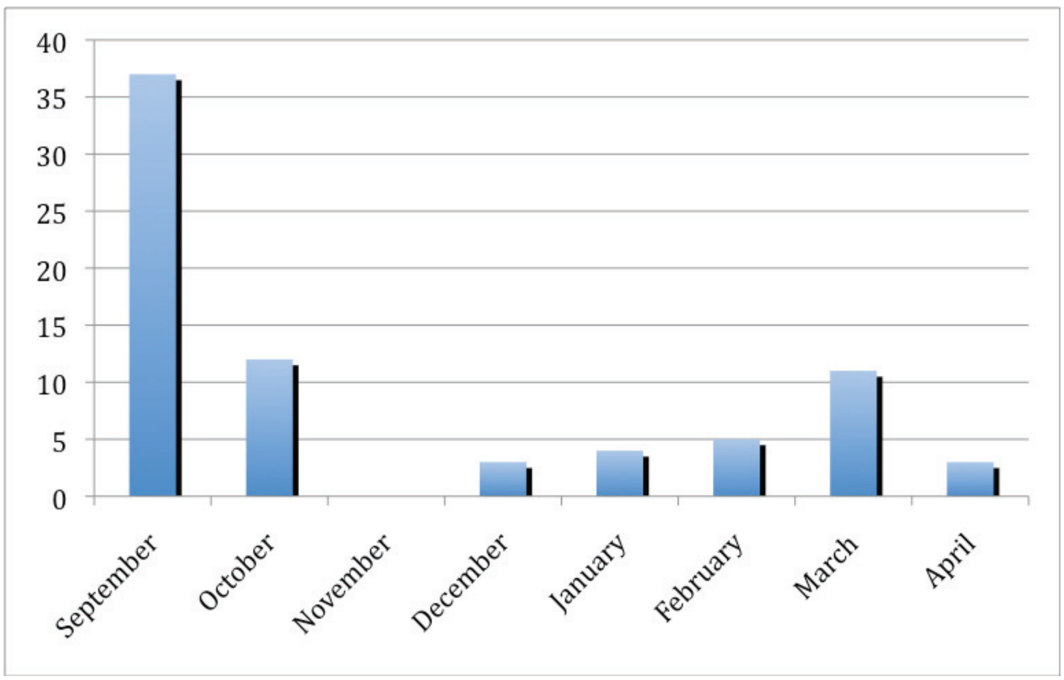
Number of Splits from the Primary	Total Number of Primaries with Corresponding Splits	Percentage of Primaries with that Many Splits
1	38	51%
2	13	17%
3	6	8%
4	6	8%
5	3	4%
6	1	1%
7	1	1%
9	1	1%
14	2	3%
17	1	1%
23	1	1%
35	1	1%
47	1	1%

Note. Over 50% had only one case split from the primary, with 47 being the most splits from a single primary.

8.2.1.1. Splits by Month: A Learning-Curve Revealed

A mentioned previously, some of the cases processed through the mortuary early in the identification project were not scrutinized during triage as carefully as cases that were processed after the initial sense of urgency had subsided. In addition, nearly complete bodies that exhibited quick means of identification such as fingerprints or dental comparisons sometimes bypassed triage all together in favor of a speedy identification. Therefore, I hypothesize that many of the cases reviewed during the AVP that needed to be split because of possible commingling might be from the early days of the identification project. In fact, 56% (n=42) of the split primaries were from cases processed through the mortuary within the first month of the disaster, with 37 of them dating from September alone. By contrast, no splits were created from cases processed in May 2002, the final month of receiving remains. This may be due to increased rigor during triage as well as the progressive decomposition the remains suffered over the eight months following the event. With time, soft tissue disappeared, freeing embedded bone fragments. Because many of the commingled remains were unrecognized fragments of bone deeply embedded into soft tissue, this became less of a problem over time. Without the soft tissue, those small fragments were simply recovered as isolated small bone fragments as opposed to becoming commingled. In fact, 65% of the splits occurred from cases processed during September and October 2001, before significant decomposition had set in and while the amount of soft tissue still adhering to most remains was significant. This also indicates that the full extent of the commingling was really not completely appreciated at the beginning of the identification project. A breakdown of the number of splits by month is presented in Figure 5. It is worth noting that there were no splits created from cases processed during November 2001, but significantly fewer total cases were processed in November than in the previous or following months. This discrepancy was due to the crash of American Airlines Flight 587 in Queens, New York on November 12, 2001. Although WTC work did not come to a complete halt on November 12, work on those remains slowed significantly while the remains from the victims of Flight 587 were processed by the NYC OCME. All the bodies from Flight 587 were autopsied and the additional fragments were processed quickly, with 100% victim identification within 28 days. Work on the WTC remains resumed normal pace mid-December.

Figure 5. This Chart Shows the Number of Splits by Month

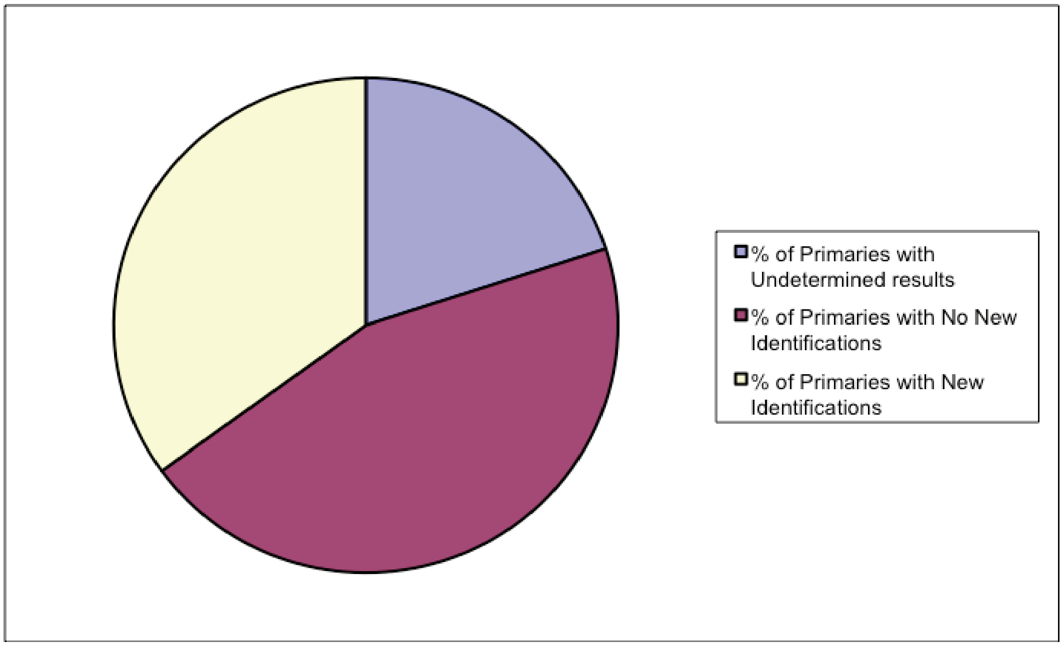


Note. Nearly half the primaries were split during September (n=37 or 49%).

8.2.1.2. Identification Results

The identification results of the splits are broken down into three different categories: splits that resulted in "New Identifications," splits with results still "Undetermined," and splits that resulted in "No New Identifications". Figure 6 shows the percent of the primaries (75 total) in each of these categories.

Figure 6. The Percentage Breakdown of Split Primaries for the Three Categories: New Identifications, No New Identifications, and Undetermined



8.2.1.3. New Identifications

Of the 75 split cases, 26 (34%) produced New Identifications from the individual with whom they were commingled. This group is defined as having at least one split case from each primary (some primaries have many splits) that was previously identified to the wrong victim. New Identifications may or may not represent a completely new victim identification because the newly identified fragment might belong to a person who has been accounted for previously. Instead, these New Identifications may represent newly identified fragments to an already identified individual. A total of 174 new cases were created from these 26 primaries, 87 of which were identified to a different individual than the corresponding identified primary. These 87 newly identified pieces represent 38 different individuals (some individuals have multiple fragments identified). Forty-two cases were identified back to the primary case they were split from, and 46 cases (including one primary) are still unknown, pending further DNA tests. These 46 still unidentified cases may provide new identifications when the results are obtained. Table 15 shows the results of the New Identifications category.

Table 15. Breakdown of Cases within the Category New Identifications

Number of primaries	26
Number of splits created	174
Number of splits newly identified fragments	87
Number of new individuals identified	38
Number of splits same as primary	42
Number of splits still unidentified	45
Number of primaries still unidentified	1

8.2.1.4. Undetermined

The Undetermined group comprises 15 primaries, or 20% of the total 75 split cases. Each primary case within the Undetermined group is associated with at least one new split case that has not yet been identified (potentially representing a new identification), while the rest of the split cases do not represent New Identifications (they are identified back to the same individual as the primary). Until all the new split cases have been identified, it will remain undetermined whether these primaries will be associated with category “New Identifications” or “No New Identifications.” In the Undetermined category, a total of 42 new cases were created from the 15 split primaries; 24 were identified as the same as the primary case from which they were split and 18 are still unknown pending further DNA studies. Three primaries are also still unknown cases and do not have any of their split cases identified yet either. Therefore, the primary as well as at least one split case from each of these three would have to be identified before they could be moved into either the “New Identifications” or “No New Identifications” category. Table 16 shows the results of the “Undetermined” category.

Table 16. Breakdown of Cases within the Category "Undetermined"

Number of primaries	26
Number of splits created	174
Number of splits same as primary	42
Number of splits still unknown	45
Number of primaries still unknown	1

8.2.1.5. No New Identifications

The final group, No New Identifications, has 34 primaries, or 46% of the total 75 primary cases. All 77 cases split from the 34 primaries have been identified and none represent new identifications. Therefore, all the new cases split out from the primaries were identified to the same individual as the primary from which they were split.

8.2.1.6. Grouped Results

Examination of the split results as a group reveals a similar pattern to that seen above. The total number of new cases created from all the splits (n=293) resulted in 87 cases, or 30% newly identified fragments, comprising 38 different individuals. Sixty-three split cases (45 from the New Identification group and 18 from the Unidentified group), or 21.5% are still unknown, and 143 or 49% have been identified to the same individual as their corresponding primary case (Table 17). Although all 63 still unidentified cases are unlikely to represent new identifications, some of them probably will, thus potentially raising the New Identification category above its current 30%.

Table 17. Grouped Results of Split Cases

Number of primaries	26
Number of splits created	174
Number of splits same as primary	42
Number of splits still unknown	45
Number of primaries still unknown	1

8.2.2. *Discussion*

The AVP was successful from both a management perspective and encouraging from a quality control perspective. To date, only 26 of the 16,969 cases examined have been shown to be commingled (with the potential of 15 more from the undetermined group). From a quality control perspective, this indicates that the initial overall triage process to sort out the commingled remains was very successful. The vast majority of the cases examined during the initial analysis were correctly triaged and the commingling was resolved then and there. Only 0.44% of the AVP'ed remains had commingling missed during the initial triage. More importantly, anthropological examination of the descriptions of all the split cases shows only five had overlapping elements, indicating clear commingling that was truly missed during triage. The rest of the split cases had remains erroneously grouped together or had instances where small shards of bone and tissue were overlooked during the initial triage. Some of these were eventually identified back to the same individual from whom they were split.

Managerially, the AVP was an important program because 26 primaries did have commingling, from which 87 new fragments were identified representing 38 additional individuals. The potential to have released commingled remains, along with the potential to have not identified these fragments, is unacceptable and therefore the operation of the AVP was successful. From a management standpoint, it may initially seem that the time and effort involved in re-examining nearly 17,000 cases, when 99.56% had no additional commingling, was wasted. However, there can be no margin for error when dealing with something as important as a human identification project. The medicolegal implications of this are obvious, but it is equally important to honor the trust of the victims' families. Misidentifications cannot be undone if the remains are cremated. Returning the wrong set of remains to a victim's family can be devastating and can disrupt the mutual trust that is both established and necessary for an endeavor such as this. Resolving only a single case of commingling would have been enough to justify the AVP. It showed that triage standards can never be too stringent. Disasters with this level of force and destruction can amount to unprecedented and even misunderstood levels of commingling, particularly Type 2 or disaster-induced commingling. The most aggressive approaches to triage of fragmented and commingled remains will probably save time and mistakes in the long term. However, an additional layer of verification, in the form of a project like the AVP, can only strengthen the quality assurance and therefore accuracy of a victim identification project.

Chapter 9.

Recommendations

This section will use the observations made in this thesis to offer several recommendations to guide those who plan and implement DVI projects. The recommendations are limited in scope, primarily address situations in which anthropological expertise can be especially useful, and fall into two broad categories. First, there are several concrete ways that an anthropologist's skills can be incorporated into the DVI process to ensure overall efficiency and accuracy. I will discuss each of these, including having an anthropologist present at the scene, having the anthropologist direct triage in the mortuary, and implementing a final anthropological review protocol before remains are released to next of kin.

Second, I will recommend ways in which the insights of an accomplished anthropologist can be incorporated into the management of the overall event. To date anthropologists have rarely occupied senior management positions in DVI efforts, but their training and expertise can make them especially valuable in certain types of disasters, especially those involving highly fragmented remains. As managers, anthropologists should be incorporated into high-level decision-making, including the development of a DNA-sampling protocol, determining what information should be collected during the mortuary examination, and working with family members and family groups.

The final recommendation is not specific to the role of anthropologists in DVI. This section will address the importance of choosing the best DVI manual as a management tool. The manuals are designed as either stand-alone guides to be used during a DVI project or as templates to be modified as an agency develops a management plan. Each manual was evaluated on its overall utility and value in helping jurisdictions design their own plans. They were also evaluated as to whether they include and successfully convey the key information necessary for managing a mass fatality as identified by a panel of experts gathered by the World Health Organization (Tun, et al. 2005).

9.1. Incorporating Anthropologists into All Aspects of the DVI Project

Forensic anthropologists should be an integral part of any DVI project, particularly incidents where human remains are scattered, fragmented, burned, or decomposed. Including anthropologists from the beginning means that they can assist with the initial assessment and evaluate the disaster for the four key themes outlined by the WHO panel (Tun, et al. 2005). Forensic anthropologists' and forensic archaeologists' participation at the disaster scene should increase accuracy in the collection and documentation of remains. The additional information collected at the scene, as well as the increased accuracy of this information, will in turn aid the identification project (Blau 2003; Stratton and Beattie 1999; Waaler 1972). In the mortuary, anthropologist-directed triage will help ensure incidences of commingling are not missed. This is particularly true for incidents with fragmented remains, which are more likely to be commingled. Properly triaging remains will also help target the fragments that are most likely to be identified and allow them to be prioritized over other remains (Kontanis and Sledzik 2008). Finally, including a final anthropological review of all identified remains prior to their release will add an additional layer of quality assurance and quality control to the project (Mundorff, et al. 2008). A final visual check of remains, against the information on who they are identified as, will further reduce instances of releasing misidentified remains (whether from contamination, transcription errors, or another reason). Each of these anthropology related tasks are described below for easy incorporation into any DVI plan.

9.1.1. Disaster Site: Include Forensic Anthropologists and Forensic Archaeologists at the Disaster Scene from the Beginning

9.1.1.1. Initial Scene Assessment

Forensic anthropologists are specialists in fragmented and otherwise compromised human remains. Most forensic anthropologists, like forensic archaeologists, also have extensive field experience in searching for, mapping, and recovering human remains from either archaeological contexts or crime scenes. For these reasons, anthropologists should be included in the assessment of any disaster scene when the four WHO themes are being evaluated. Their expertise can be useful in determining the number and condition of the remains, particularly if they are fragmented or otherwise compromised. Expertise in mapping, recovery, and excavation also allows the anthropologist to assist in determining the scope of or anticipated time needed for a full recovery of the human remains.

9.1.1.2. Mapping and Excavation

Forensic anthropologists, and in particular forensic archaeologists, are well trained in mapping sites. Having anthropologists assist with mapping disaster scenes offers an important advantage. They can accurately record the location of human remains and their association with other remains, with personal effects (for later use during identification), and with evidence. Collecting data in situ before the scene is disturbed can add significant data to the DVI project (Dirkmaat, et al. 2001). For example, in one instance involving commingled calcined bones, a pin in a tibia was used to identify one bone fragment. However, none of the thousands of other bones recovered in association with that tibia could be attributed to the same individual. Had that site been mapped and excavated with proper archaeological techniques, it is possible that other remains would have been associated with that bone. The same argument can be leveled for remains found in association with identifying personal effects. As Waaler (1972) clearly illustrated in his article, unique personal effects, found in association with human remains, can only be used to help identify victims if the information is accurately recorded at the scene. Taking the time to collect the information correctly at the outset can actually speed up identifications in the long run. Proper mapping and excavation by trained anthropologists and archaeologists should be part of the disaster scene investigation from the beginning.

9.1.1.3. Recognizing and Collecting Human Remains

Forensic anthropologists can be particularly useful at a disaster scene for recognizing and collecting human remains. Most forensic anthropologists have had extensive training in zooarchaeology and are proficient in identifying nonhuman remains that might be commingled with the human remains. Also, their deep knowledge of skeletal anatomy and experience with partially fleshed remains renders them adept at recognizing burned, decomposing, and fragmented human tissue. Other items, especially burned building material, can easily be mistaken for burned or calcined human remains (Fisher, et al. 1965; Stratton and Beattie 1999). Discriminating human from nonhuman material at the scene can reduce the complexity and cost of the DVI operation. Fewer items are collected, so fewer items are documented, fewer case numbers are assigned, fewer items are taken to the mortuary for examination, fewer DNA tests are run, and consequently less data are entered for each nonhuman remain that is not collected at the scene.

Anthropologists are also acutely aware of identification problems caused by commingled remains (Adams and Byrd 2008). Their participation in collecting the remains at the scene will help in two ways. First, anthropologists are unlikely to induce Type 1 commingling by placing more than one set of remains in a single body bag. Type 1 commingling occurs when separate remains are mistakenly grouped together in a recovery bag and is easily avoided if proper recovery techniques are followed. If remains appear to be from the same individual and are found near each other, their proximity will be noted in the map and they will be collected separately.

Second, sorting of commingled remains will not happen at the scene. If remains at the site appear to be commingled already, possibly due to the nature of the disaster (Type 2 commingling), this will be properly documented during recovery. However, sorting the commingling will be left to the anthropologists at the triage station in the mortuary—that is, under the most optimal conditions—and not in the field. Type 2 commingling is much more difficult to discern because it often involves muscle from one individual fused to the bone of another, or bone fragments deeply embedded into muscle. Even in the mortuary under optimal conditions where there is proper lighting, cleaning equipment, and time, Type 2 commingling can still be tricky, so it is important to avoid trying to deal with it at the disaster scene.

9.1.2. Mortuary: Anthropologist-Directed Triage

At the triage station in a mass fatality morgue, anthropologists can be tasked with a variety of duties. Most importantly, they remove nonhuman remains, sort out commingled remains, reassociate disparate remains, and apply a probative index to prioritize remains through the assembly line.

9.1.2.1. Removing Nonhuman Remains

Because of their in-depth knowledge of osteological detail, anthropologists are invaluable during triage in the mortuary. At triage, anthropologists initially sort out nonhuman material. Having an anthropologist remove nonhuman items (preferably at the disaster scene) during triage reduces the number of cases going through examination, the number of cases assigned official case numbers, and the number of expensive and time-consuming DNA tests.

9.1.2.2. Sorting Commingled Remains

Anthropologists' skills are utilized to separate unassociated, commingled remains, particularly if the remains are fragmented. As discussed above, it is helpful to think of commingling as falling into one of two broad categories. Type 1, or recovery-induced, commingling occurs when more than one set of remains are collected in the same body bag at the disaster scene. Having anthropologists at the disaster scene can significantly reduce this type of commingling. Type 2, or disaster-induced, commingling is much more difficult to discern and is more appropriately sorted in the mortuary by anthropologists familiar with fragmented human remains. It is extremely helpful to sort out commingling before a case number is assigned, x-rays and photographs are taken, and the case is DNA sampled. When commingling is not noted until after the examination the case must be split (as seen with the AVP). When a case is split the original documentation becomes associated with multiple cases and it becomes confusing to determine which case number and file retain what information. For example, once the case is split, what happens to the original x-ray that was taken when all the pieces were still grouped together? Which case number is that x-ray assigned to? Is it thrown away because it no longer represents a case? And if a case is split into many cases, there might be no way to determine from which piece the DNA sample was taken. What happens if that sample becomes identified? Which of the split cases does it represent, or is the identification voided? It is much simpler to have the commingling sorted from each case before the examination. This would also limit the need for projects such as the AVP that had to re-examine thousands of potentially still commingled cases.

9.1.2.3. Reassociating Disparate Remains

However, reassociating disparate pieces, by either articulation or anatomic matching, can be just as important as separating commingling before assigning a case number. Reassociation prior to examination results in fewer cases and fewer DNA tests. Also, the more pieces that can be grouped together as one case, the more remains the next of kin will receive when that case is identified. Because reassociation also increases the chances that disparate parts will be associated with a more easily identifiable piece of remains, this pre-examination consolidation may increase both the timeliness of identifications and the final proportion of remains identified. Consider, for example, two pieces, one a right hand including the distal radius and the other a large torso including the right upper extremity with proximal radius. If the hand can be matched at the radial fracture margin during triage, these two sets of remains will be grouped together even though they are not attached. If the hand can be identified by fingerprint, still a significantly quicker method of identification than waiting on DNA, the next of kin receives back both the hand and the rest of the torso.

9.1.2.4. Prioritizing Remains through Examination

Utilizing anthropologists at triage to implement a probative index will help target those remains that will be the easiest to identify (Kontanis and Sledzik 2008). This allows project managers to temporarily put aside the most difficult cases and focus their resources on the cases most likely to yield quick identifications. This can be particularly useful during a DVI project where the victim population is closed, such as an airline crash, because often the goal is 100% victim identification, not 100% fragment identification. A probative index targets more identifiable human remains during triage to be prioritized through the mortuary. Fingerprint and dental matching are quick methods of identification and so fragments with these identifiable characteristics will be processed first. Identifying fragments by these quick processes leaves fewer victim remains to wait on lengthy DNA tests for identification. The probative index can also be applied to open populations for a different reason. When remains are quickly identified through fingerprint or dental matching, a DNA sample from those identified remains can then be used as a direct reference sample for matching up other fragments by DNA. If a direct reference sample had not otherwise been available for a victim, indirect samples from family members would have been necessary. This would require processing of multiple familial samples that in turn affects the statistical threshold since an indirect match is statistically more complicated than a direct match. Therefore, implementing a probative index during triage not only allows for quicker identifications, it also allows for those identifications to then be used as exemplars for additional DNA links which will reduce additional kinship tests.

9.1.3. Identification: Final Anthropological Review

In addition to being valuable in scene assessment and investigation, and mortuary operations and management, anthropologists can play a valuable quality assurance role by finalizing identifications. Every DVI project should institute a final anthropological review project under which remains are examined before an identification is validated and released to the next of kin to ensure no misidentified remains are released. Reviewing the remains, in conjunction with the victim's biological profile and other antemortem information, has been shown to uncover potential mistakes (Budimlija, et al. 2003; Mundorff, et al. 2008). These mistakes can result from missteps at any stage of the DVI process and have included generalized DNA contamination problems, transcription errors, and mislabeling of remains. For example, following the 2004 tsunami, in Thailand a body was identified as a female victim from the UK. However, when the body was repatriated home and the casket was opened, the family found that the remains inside were male. The identification on paper was solid; the problem was that a second body bag had been mistakenly labeled with the same case number and the mislabeled bag had been sent off. Had a final anthropological review been in place, this bag would have been opened before it was returned and the mistake would have been caught before the body was repatriated. A review of all the paperwork is common practice during the DVI reconciliation stage but it does not include double-checking the physical remains. DVI personnel therefore lose their opportunity to catch any otherwise correct identifications being associated with the wrong body because of a simple labeling mistake. Implementing a final anthropology review is a cost-effective quality control and quality assurance measure that adds an additional level of confidence to all identifications. More importantly, it helps guard against losing the trust of victims' families because of a mistaken identification.

9.2. Anthropologists as Managers and Policy-Makers

Anthropologists have recently proven themselves worthy as project managers for DVIs (Sledzik, et al. 2009). Their familiarity with working on unidentified remains, working at crime scenes recovering human remains, working in mortuaries, and working alongside many other forensic subspecialists in the morgue equips them to manage most aspects of DVI projects and they should be included as part of the management team in developing DNA sampling protocols. They should also participate in decisions about what information is considered relevant to identifications and should therefore be recorded during mortuary examination. Additionally, many anthropologists have a background in the “four-field” anthropological approach, which includes an emphasis on cultural and cross-cultural perspectives and can make them valuable team members during meetings with individual family members or at family group meetings to review recovery, examination, and identification procedures. Their experience with taphonomy also makes them particularly adept at answering questions about the condition of remains.

9.2.1. Developing DNA Sampling Protocols

As this thesis has shown, anthropologists should be included with forensic biologists in developing protocols and policies for DNA sampling. Anthropologists’ understanding of bone biology, bone density, bone remodeling, and taphonomy can influence DNA sampling strategies which must be adapted to the needs of different disaster characteristics. The combination of anthropology and DNA toward victim identification has previously proven successful (Cunha, et al. 2006; Milos, et al. 2007; Parsons, et al. 2007; Yazedjian and Kesetovic 2008).

Factors such as whether the disaster involves an open versus closed population, whole bodies versus fragmented remains, or fresh versus decomposed remains should all be considered when establishing a DNA sampling strategy. For example, as this thesis has shown, the metatarsal and patella both yield DNA identifications at roughly the same rate as the femur and tibia. Therefore, if the bodies are relatively intact and bone has been chosen as the tissue to be sampled for DNA, managers should consider sampling the patella or metatarsal instead of long bones. These two bones are easier to remove (with a disposable scalpel instead of a bone saw), are cheaper to remove (in terms of equipment, electricity, and manpower), and can be removed as intact elements (thus reducing the chances of contamination). In disasters involving fragmented remains, policy-makers will need to establish protocols that determine which bones are preferred for sampling and in what order. Depending on the disaster's characteristics, Table 11 could be quite useful in guiding this prioritization. For example, the metacarpal and skull bones showed the worst results and should therefore be avoided if other elements are available to sample. However, it should be noted that these recommendations are based on a retrospective analysis from the WTC remains and further studies under more controlled conditions are needed to confirm or augment the results.

9.2.2. Deciding What Information to Collect

Ensuring that enough information is captured to secure an identification is imperative and is done in two ways. First, the proper forms, preferably paper forms that directly mirror their computer counterparts like those developed by Interpol and DMORT, must be used. When the forms and the computer program into which the information is entered match, little information is lost. However, if there is any discrepancy between the two formats, uncertainty over where to enter the data leads to significant amounts of lost information. With the World Trade Center disaster, those performing the data entry sometimes left out information from the database because the forms and computer program did not match and they were unsure where to enter it. This problem was later addressed by the File Review project, but the extra work might have been avoided had the data collection forms mirrored the computer database where the information was recorded.

The second way to ensure pertinent case information is captured is to ask for it specifically. Rather than leaving blank spots and allowing the examiner to describe remains in as much detail as they see fit, the forms should require specific details about each case and should be adaptable to the specific disaster characteristics. For example, in an incident such as a hurricane, where most of the remains are intact bodies that will be autopsied, traditional autopsy forms may be adequate. However, in a scenario involving severely fragmented remains, a traditional autopsy form is insufficient. In that case, a form that is specific to fragmented remains should be used to force the examiner to adequately document the size and other anatomical and identifiable details of each piece of remains.

Information recorded during DVI postmortem examinations differs from what is recorded during a regular autopsy and so the regular autopsy forms may not be adequate during a DVI operation. For example, if a grid system was used at the disaster scene, a recovery location should be documented on the form. Also, specific details about the DNA sample—was it muscle or bone, and if bone, specifically which bone, for example—are crucial during a DVI operation for two reasons. First, it is important to document what DNA sample was removed from the case because this often changes what the case will look like during an AVP or FAR. If a case is a small fragment of bone with attached soft tissue and the entire bone fragment is sampled for DNA the remainder of the case is now soft tissue only. Having this information properly documented in the case file will allow the anthropologist reviewing the case later to know that bone was removed for DNA testing and it is not in the description by mistake. Second, recording the specific DNA sample could eventually shed light on identification patterns as DNA test results become available. For example, if muscle is sampled for DNA, eventually muscle will no longer yield full profiles. By documenting what specifically is sampled, these patterns can be more easily discerned. Recording information about each case is important to ensure not only that the case has the best chance of being identified, but also that the DVI project is successful. The retrospective study in this thesis, examining which bones better yield DNA identifications, was possible because some cases captured that information.

Capturing the complete information on every case during the first examination avoids the need for additional review projects such as the AVP and File Review. The forms used during the WTC project did not provide adequate space for all the details of a case and did not include proper instructions for the examiners. A simple check box for name and sides of bones present, for example, could have helped with this. The lack of instruction created a wide variety in case descriptions and the less detailed descriptions later caused problems. Cases described as “torso” required re-examination during the AVP for more details. The additional detail became important in order to validate the identifications during the FAR. Because fragmentation was so severe, many individuals had multiple fragments identified and there had to be a way to confirm that there were no mistakes, such as overlapping body parts. This required much more detailed descriptions of cases than simply “torso.” Therefore, a form that is specifically designed for DVIs, and that requires consistent and specific information about every case is recommended.

9.2.3. Working with Families

As we have seen, anthropologists have unique skills that equip them to work in DVI projects in a number of specialized roles. However, there is another aspect of DVI work to which anthropologists have much to contribute. Anthropologists can be particularly helpful meeting with families, either on an individual basis or in family group meetings (Sledzik, et al. 2006). Family members often turn to the medical examiner's office to seek information about their loved one's death. They want to know about the incident, the recovery and identification process, and the condition of the remains. Families want to know specifically about the progress being made toward identifying their loved one. If this information is available, it will have been recorded during the different scientific analyses in the remains' case file. Being able to convey this information in an accessible way to family members is a valuable skill. Because anthropologists understand recovery operations, mortuary operations, taphonomic changes to human remains, and can minimally read and explain dental and body x-rays, they can share this information without being too clinical. Anthropologists have been doing this successfully in the human rights arena for years (Sledzik, et al. 2006). It is now time to include them as team members who work with families in DVI projects.

9.3. Choosing the Best DVI Manual or Guide

The 2005 panel on disaster management, organized by the World Health Organization, highlighted four key issues that mass fatality managers should assess before beginning a DVI project: "1) the existence of a manifest; 2) the condition of the remains; 3) the rate of recovery of the remains; and 4) the number of victims" (Tun, et al. 2005:455). No matter which manual is used, these considerations must be addressed early on, and preferably during an initial assessment before the DVI response begins. The Interpol, NAME, and one of the PAHO manuals successfully address these issues clearly and early (Interpol 2008; National Association of Medical Examiners 2002; Pan American Health Organization 2004).

Understanding the fundamental importance of each of these key themes will help DVI managers build a strong disaster plan. Assessing the number of victims can help determine the size and location of the mortuary, as well as the length of the recovery operation; accurately assessing both the number of victims and the length of the recovery operation will help determine monetary and personnel allocations; and whether the population is open or closed will shape the DNA sampling strategy. For example, the goal might be 100% victim identification for a closed population versus 100% remains identification for an open population. The composition of the victim population will also determine the accessibility of antemortem information, which is usually easier to compile with a closed population because a list of the names of the victims is already available. The condition of the remains can help determine DNA sampling protocols, what information will be collected during examination, and even the personnel needed. More anthropologists might be included if the remains are severely fragmented, or more fingerprint analysts might be needed for a military airplane crash where there is ready access to antemortem fingerprint records. If and how these important issues are addressed is a major consideration when assessing different DVI guides.

The Interpol DVI guide is the most comprehensive, user-friendly guide available. It not only addresses all the important WHO themes, it is also well organized and includes both AM and PM forms that mirror the corresponding computer program. If a jurisdiction were looking for a guide to help it through an incident, this would be the best choice. Its only drawback is the failure to include anthropologists. However, any jurisdiction could modify the guide to include the above recommendations of anthropological participation at the disaster scene, in the mortuary, and as part of the reconciliation team before finalizing an identification. Additionally, the Pan American Health Organization's *Management of Dead Bodies in Disaster Situations* (2004) is strongly recommended as background reading for any individual looking to develop a deep understanding of how and why victims from disasters are identified.

Chapter 10.

Conclusion

Identifying victim remains from mass fatality incidents is integral to the process of providing justice for surviving family members and communities. It is also required for legal reasons, including closing out wills, assigning insurance benefits, and prosecuting crimes (Alonso, et al. 2005; Kahana, Ravioli, et al. 1997; Ludes, et al. 1994). Accordingly, we have seen increasing efforts to identify victims, whether they are soldiers lost during wars, victims of natural disasters, war crimes, or acts of terrorism. The research in this dissertation is meant to assist future mass fatality managers, and particularly anthropologists, as they develop new disaster victim identification (DVI) plans. Most importantly, these recommendations will be useful both in the DVI pre-planning phase, and can serve as a guide during an event.

The purpose of this dissertation was to examine the major management decisions made during the World Trade Center identification project, particularly those decisions involving anthropology, to see how they affected the overall project. Specifically,

1. Did the major management decisions made during the mortuary operations of the World Trade Center identification project, particularly involving anthropology, affect the identification project? And, if so, how?
2. Did these decisions result in a more or less streamlined identification process?
3. Were the introduced programs effective, as reflected by an increase of identifications?
4. What lessons can be learned from the World Trade Center disaster victim identification project and applied to improve future victim

identification projects? What factors limit the application of these findings and restrict their generalizibility?

One additional research question regarding current disaster victim identification (DVI) manuals was also addressed:

5. Do the currently available disaster victim identification manuals adequately address the elements necessary to manage a large-scale DVI project?

10.1. Summary

The background chapter detailed the events of the World Trade Center disaster on September 11, 2001, and how those events determined the shape of the response and subsequent identification project. The participation of nonspecialists during the excavations at Ground Zero negatively affected the level of commingling, which clearly demonstrates the need to include forensic archaeologists and forensic anthropologists in future recovery operations. Disaster planners everywhere should internalize this lesson from the WTC disaster. While the circumstances at the Staten Island Landfill were likely unique to the World Trade Center event, they illustrate how anthropologists can be employed to sort out nonhuman remain to prevent those remains from becoming part of the general set of catalogued remains, saving tremendous time, effort, and expense.

The literature review discussed ideas raised by anthropologists who have worked on various aspects of mass fatality events for decades. Many of their ideas remain pertinent today. These pioneers called for anthropologists to be included in the recovery and identification of mass fatality victims. In the intervening years, anthropologists have contributed to DVI projects in many different ways, at the disaster scene, in the mortuary, on reconciliation boards, as managers and working with families (Sledzik 2009). Most of these roles are dictated by the specific characteristics of the disaster. For example, during the WTC DVI project, anthropologists did not perform examinations of remains to establish biological profiles. Because of the severe fragmentation (nearly 5,000 cases alone were smaller than 1 inch) and the open victim population, this type of analysis would have been extremely time consuming. Moreover, these presumptive identifications would have had to be confirmed by DNA or another scientific modality anyway. In other DVI projects it may be appropriate for anthropologists to perform full or partial examinations on remains to develop biological profiles. This may be particularly true if the remains are intact and the victim population is closed.

As anthropologists are incorporated into more aspects of DVI projects, their role will continue to expand and change. Since the events of September 11, 2001, anthropologists have become more involved with recovery and identification operations and are also setting policy and taking on greater leadership roles (Sledzik, et al. 2009).

The literature review also points out the absence of literature addressing overall DVI project management practices. How, when, and by whom decisions were made, as well as their repercussions, both positive and negative, are questions that need to be presented critically and evaluated in the scientific literature. Overall project assessments and lessons-learned documents, such as the one detailing the ValuJet crash (Mittleman, et al. 2000), are key to the collective learning process. This dissertation demonstrates that management decisions made during mass fatality identification projects can be critically evaluated to help improve future DVI projects. This research has examined decision making predominantly from the standpoint of one specialty, anthropology. Ideally, this dissertation would be part of an overall evaluation in which forensic biologists, medical examiners, disaster planners, family liaisons, dentists, and other specialists with significant decisional power evaluated the different management decisions made throughout the WTC DVI project. Time consuming as it is, this type of "after-action report" should be a priority and should be compiled following every major

DVI project, especially one that advances the science and practice of DVI to the degree that the WTC project did. Unfortunately, that type of report was not generated following the WTC project, nor has it been common following other major mass fatality incidents. Thankfully, the OCME has been extremely supportive of this research and there was enough data generated as a by-product of the identification process to make this research possible.

Existing DVI manuals, guides, and books were reviewed thoroughly. DVI manuals vary considerably in their content, organization, and usability. Managers planning for MFIs should carefully consider which manual they select to help in drafting their mass fatality plan. The Interpol guide, although not perfect, is the most comprehensive, despite its failure to adequately include anthropologists at the scene, in the mortuary, or during the reconciliation phase. Ideally this oversight will be addressed in future editions, but until that happens managers could apply anthropology-related insights from this thesis to augment the Interpol manual for a solid overall plan. Additionally, the Pan American Health Organization's *Management of Dead Bodies in Disaster Situations* (2004) contains comprehensive background information on all aspects of victim identification and should be required reading for any DVI manager.

The effects of several key management decisions involving anthropology on the overall WTC identification project were examined. The participation of anthropologists, as both practitioners and managers, maximized overall efficiency and increased identifications. For example, during the mortuary operations anthropologists rethought the initial triage process. In showing improved efficiency, the decision to have an anthropologist direct triage substantially reduced the overall number of cases to be examined. Approximately 2,500 nonhuman remains were discarded from January 2002 through August 2002, saving significant time and resources by avoiding thousands of unnecessary examinations, documentation, and DNA tests. Along with sorting out nonhuman remains, anthropologists also reassociated disparate remains, and separated commingled remains during triage, which increased the accuracy of the identification project. Significantly, on September 11, 2001, there was no plan to have anthropologists lead triage or serve in any other role in the DVI process. However, anthropologists proved themselves uniquely adept at this task. The unforeseen decision to have anthropologists lead triage is also a good reminder to DVI managers that being able to change procedures midstream is essential for a successful DVI project.

Toward the end of the mortuary operations, anthropologists implemented several internal review programs that increased overall project accuracy. The Anthropological Verification Project (AVP) detected cases of commingling that were missed during the initial triage. A total of 16,969 unidentified cases were re-examined for potential commingling; of these, 75 cases were split into 293 new cases. Examination of these 75 split cases confirmed identification of 87 additional fragments representing 38 new individuals from whom they were split. More than half of the split cases had been processed through the mortuary during the first month, before introduction of the more stringent triage protocols. These results further illustrate that the management decisions to have anthropologists direct triage, and to increase the triage stringency after the first weeks, likely reduced missed instances of commingling that had to be found during the AVP.

Other projects designed and implemented by anthropologists increased accuracy, streamlined the identification process, and maximized identifications. The Final Anthropological Review (FAR) confirmed identifications before they were finalized ensuring misidentifications were not released. The File Review project, directed and conducted by anthropologists, ensured that information collected during the mortuary analysis was completely and accurately entered into the WTC database. Along with forensic biologists, anthropologists initiated and participated in the Resampling program, which resulted in hundreds of additional identifications and established a dataset that was later used to examine the differences in DNA identification rates among skeletal elements (the results of which will help future DVI managers establish DNA sampling protocols to maximize DNA identifications).

Proper case documentation was also covered. This includes determining what information to document for each case and how best to document it. Using forms specifically tailored to a DVI project along with a corresponding computer program which mirrors the forms will increase the potential to capture the information needed to establish an identification and make certain that the information is correctly transposed into the database. While accurate data entry did not initially happen, it was eventually corrected during the File Review project.

The difference in DNA identification rates among skeletal elements was examined to determine which elements are best to sample following a mass fatality incident. From the WTC date set, it was found that the patellae, metatarsals, and foot phalanx produce successful DNA profiles at rates comparable to femora, tibiae, and ribs, which have been preferentially sampled in past DVI projects. In fact, the lower limb (excluding the fibula) produced better results than the upper limb, thorax, or head. Given the relative ease of sampling the patellae and foot elements, it may be preferable to select these elements for DNA sampling in future mass fatality incidents.

The final goal of this dissertation was to take lessons learned from the World Trade Center victim identification project, particularly those involving anthropology, and summarize them into simple recommendations that could be used to augment current

DVI plans. This dissertation recommends incorporating anthropologists into the management structure of DVI projects at the disaster scene, in the mortuary, and as part of quality control/quality assurance procedures before identifications are finalized. It is also recommended that anthropologists be included during the development of policies and procedures like DNA sampling protocols, deciding on what information to capture in the case file, and when working with victims' families.

10.2. Limitations

Financial considerations may be the most significant factor preventing generalizibility of these findings to future incidents. The WTC identification project was fairly unique in enjoying essentially unlimited access to funding, meaning that decision makers did not have to hesitate in deciding to DNA test every fragment found in the disaster and to keep testing as the science advanced. This also enabled hiring additional anthropologists for the AVP and the File Review project. However, other incidents may be severely constrained by budget considerations. As previously discussed by the WHO panel on mass fatality management, resources must be a consideration for any manager making significant decisions during a DVI project (Tun, et al. 2005). Under such conditions, managers will be forced to prioritize according to what are most likely to be the most cost effective practices. They will probably be unable to afford many of the redundant quality control measures discussed in this thesis. But is should be noted that this analysis has provided information that will allow managers to put into place systems to critically evaluate which fragments are more likely to yield DNA, saving significant resources. Moreover, although they may appear expensive, the type of quality control measures discussed in this thesis are probably quite economical in saving all of the expense and heartache associated with a misidentification.

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APPENDICES

Appendix A. Intake Form

Office of Chief Medical Examiner
City of New York

INTAKE FORM
Disaster 2001

*CASE #*______________________

*Name:*____ *I.D.* *Yes* *No*

*Age:*_____________________ *Race:*____________________________ *Sex:* *M* *F* *Unk*

_____ *Whole Body* _____ *Partial Body* _____ *Fragment*

DNA Sample: ___*Blood* ___ *Muscle* ____ *(Other):*_______________________

Needed:	*Done:*	*Initials:*
_____ *Photo*	______	_______
_____ *Evid. Prop.*	______	_______
_____ *X-Ray*	______	_______
_____ *Dental*	______	_______
_____ *Other* _________________	______	_______
_____ *Other* _________________	______	_______
_____ *Other* _________________	______	_______

Disposition/Storage

MLI: ____

Medical Examiner: _______________________________ *Date:* ____________________

Source. Office of Chief Medical Examiner, New York City (2001), used with permission.

Appendix B. External Form

OFFICE OF CHIEF MEDICAL EXAMINER
THE CITY OF NEW YORK

The City of New York

CHARLES S. HIRSCH, MD
CHIEF MEDICAL EXAMINER

520 FIRST AVENUE
NEW YORK, NY 10016-6402

REPORT OF EXTERNAL EXAMINATION

NAME OF DECEASED: ______________________________ M.E. #: ______ - ______ - ____________

DEVELOPMENT / NOURSIHMENT / OVERALL APPEARANCE: ______________________________

HEIGHT: _____ FT ____ IN WEIGHT: ________ LB SKIN COLOR: ________ ♂ / ♀ RACE: ________ AGE: ________

RIGOR MORTIS: ________________ LIVOR MORTIS: F/B ________________ TEMPERATURE: ________________

OTHER POST MORTEM CHANGES: ______________________________

OTHER, INCLUDING INJURIES

HAIR: TEXTURE ____________________

COLOR ____________________

LENGTH ____________________ IN

MOUSTACHE/BEARD ____________ IN

EYES: IRIDES ____________________

CONJ ____________________

ORAL CAVITY AND TEETH: ______________

TORSO: ANTERIOR ______________

POSTERIOR ______________

EXTREMITIES: UPPER ______________

LOWER ______________

GENITALIA: ____________________

SCARS:

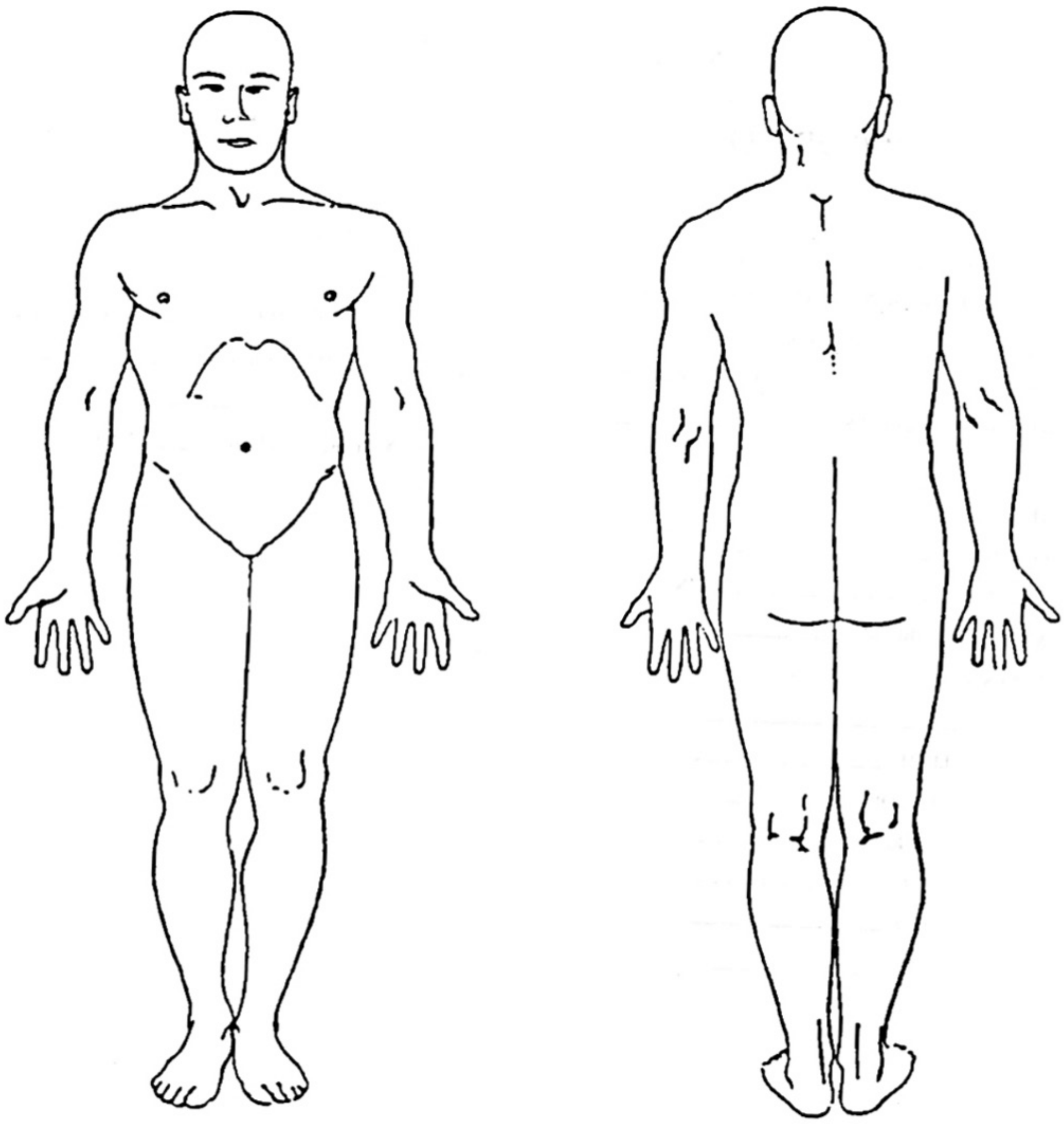
TATTOOS:

THERAPEUTIC PROCEDURES:

EXAMINED BY: ______________________________ DATE OF EXAM: ____ / ____ / ____ TIME ____ : ____ AM/PM

ME2062 (REV. 6/97)

Source. Office of Chief Medical Examiner, New York City (2001), used with permission.



Source. Office of Chief Medical Examiner, New York City (2001), used with permission.

Appendix C. Supplemental Form Used for the Anthropological Verification Project

WTC SUPPLEMENTAL
ANTHROPOLOGY EXAMINATION

DM01 - ___________________________________ Date: _____________

Forensic Anthropologist: ____________________

____
Signature

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.

Appendix D. Anthropology Worksheet Used for the Final Anthropological Review

23 March, 2009 10:08 AM

RM: N/A **Anthropology Worksheet** **Name:** [redacted] *1*

DNA Chain No: [redacted] (By DNA Chain No)

DM01	DM Description	DNA Taken	Pathologist	How ID Made	Potential Problems	Released?	Anthropology Notes	Tick if OK
[redacted]	Fragmentary right foot Approved By Anthropology 08/31/02	Muscle	Stuart Graham, M.D. 09/12/01	D N A 09/02/02		Released To Funeral Home		
[redacted]	Distal 2/3 of left femur, proximal 2/3 of left tibia, and a fragment of proximal left fibula Approved By Anthropology 08/31/02	Muscle	Douglas Freeman, M.D. 09/14/01	D N A 09/02/02		Released To Funeral Home		
[redacted]	Soft tissue Approved By Anthropology 08/31/02	Muscle	John Hayes, M.D. 09/14/01	D N A 09/02/02		Released To Funeral Home		
* [redacted]	Proximal 1/3 of right femur - 8" x 3 3/4" x 2"	Bone	Charles Catanese, M.D. 10/03/01			No		
[redacted]	FRAGMENT OF LEFT FOOT Approved By Anthropology 08/31/02	Muscle and Bone	Charles Catanese, M.D. 10/03/01	D N A 09/02/02		Released To Funeral Home		

Signed: ____________________ Date: ____________

*** NEW Link**

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.

Appendix E. Resampling Form

WTC RE-SAMPLING
SUPPLEMTENTAL

RM ___________________ DM01- _________________ Date: _____/_____/_____

Forensic Anthropologist: Amy Mundorff

_________________________________was re-sampled for DNA.

____

____

____
SIGNATURE

Source. Office of Chief Medical Examiner, New York City (2002), used with permission.