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THESIS

NAVY RECRUIT ATTRITION PREDICTION MODELING

by

Lee H. Eubanks

September 2014

Thesis Advisor: Lyn R. Whitaker
Second Reader: Samuel E. Buttrey

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NAVY RECRUIT ATTRITION PREDICTION MODELING

Lee H. Eubanks
Lieutenant Commander, United States Navy
B.S., University of Idaho, 2003

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Author: Lee H. Eubanks

Approved by: Lyn R. Whitaker
Thesis Advisor

Samuel E. Buttrey
Second Reader

Robert F. Dell
Chair, Department of Operations Research

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE	American Council on Education
AD	active duty
AFQT	Armed Forces Qualification Test
ASVAB	Armed Services Vocational Aptitude Battery
AVF	all-volunteer force
BMI	body mass index
CNRC	Commander, Navy Recruit Command
DEP	Delayed Entry Program
DMDC	Defense Manpower Data Center
DOD	Department of Defense
E-1	seaman recruit
E-2	seaman apprentice
E-3	seaman
EAOS	end of active obligated service
EBIS	Educational and Biographical Information Survey
FY	fiscal year
GED	General Education Development
HSDG	high school diploma graduate
IRB	Institutional Review Board
LRT	likelihood ratio test
MEPCOM	Military Entrance Processing Command
NCES	National Center for Education Statistics
NHES	National Household Education Survey
NRD	Naval Recruiting District
OEF	Operation Enduring Freedom
OFE	Odds for Effectiveness
OIF	Operation of Iraqi Freedom
OSD	Office of the Secretary of Defense
PSD	Personnel Support Detachment
ROC	receiver operating characteristic

ROTC	Reserve Officer Training Corps
SCREEN	Success Chances of Recruits Entering the Navy
SSN	social security number

EXECUTIVE SUMMARY

Since the creation of the all-volunteer force in 1973, the U.S. Navy has attempted to reduce the attrition of recruits who either volunteered or were drafted prior to 1973. With very little success utilizing the screening methods put in place, the U.S. Navy implemented the Navy Recruit Quality Matrix in 1984, screening potential recruits solely by a three level summary of the contributions of their Armed Forces Qualification Test (AFQT) percentile score and educational background. Though the Navy Recruit Quality Matrix has provided very little success with decreasing the attrition rate, the U.S. Navy still uses it today.

This study develops a regression model to predict a potential recruit's likelihood or probability of surviving through the first term of his or her enlistment based on information available to recruiters. This model is compared and contrasted with the predictive ability of the current Navy Recruit Quality Matrix. The results of this study give insights into first term attrition based only on what is known by the recruiter. Of particular interest are the differences between those who are homeschooled and those who are traditional high school diploma graduates. The results of this study will help determine if the Navy Recruit Quality Matrix should be modified or expanded in order to reduce the amount of first term attrition within active duty component of the U.S. Navy.

The data used for this study was collected by the Defense Manpower Data Center from fiscal year (FY) 2006–2013. The data was received in two master files, the Military Entrance Processing Command (MEPCOM) file and the Active Duty (AD) file. The MEPCOM file provided MEPCOM screening data for 247,831 U.S. Navy recruits entering active duty service during FY 2006–2012. Each recruit observation contained 87 variables, including the pseudo social security numbers (SSNs), general demographic information, the accession date, U.S. citizenship status, initial pay grade, AFQT percentile scores, required medical waivers, and required accession waivers. The AD file contained current information regarding the service members identified in the MEPCOM data set after they entered the U.S. Navy. There were 246,916 separate SSN observations with 64 variables, including the pseudo SSN, general demographic information, updated

pay grade, primary service occupation code, end of active obligated service (EAOS) date, separation date, and inter-service separation code.

The MEPCOM data was separated into two sets. The first data set consisted of 108,754 recruits who enlisted between FY 2006–2008 and had an EOAS between FY 2010–2012; the second data set consisted of 35,363 recruits who enlisted during FY 2009 with an EAOS in FY 2013. The first data set was used to build and validate logistic regression models, while the FY 2009 set was used to assess the forecasting ability of the models created. Through initial analysis of the data, it was found that 32,251, or 29.66 percent, of the recruits who were accessed within FY 2006–2008 data set were considered to be attritees. Additionally, 10,432, or 29.52 percent, of the recruits who were accessed during FY 2009 data set were considered to be attritees.

This study started with a wide range of candidate predictor variables which capture the sailors' attributes at the time of recruitment that might affect a recruit's success rate. We found evidence that among the candidate predictor variables there are recruit characteristics other than just his or her AFQT score and educational category, as captured by the Navy Recruit Quality Matrix, which indicate recruits who have a greater chance of completing their first term enlistment. These characteristics included the recruits' accession age, gender, marital status at time of recruitment, whether or not they needed at least one accession waiver, their body mass index at time of recruitment, and their pay grade at time of recruitment. Furthermore, with the likelihood ratio tests conducted to compare the final model within the study to the Navy Recruit Quality Matrix, there is evidence to conclude that the logistic regression model created from this study identifies recruits with a high probability of attrition that would normally not be identified through the Quality Matrix.

I. INTRODUCTION

A. HISTORY

After the Vietnam conflict in 1973, the United States military became an all-volunteer force (AVF), with each service maintaining its personnel strength through recruitment. However, since the introduction of the AVF, first-term attrition with recruits has continuously been a problem. At the beginning of the twenty-first century, 18 percent of Navy recruits were discharged from the service within their first six months, and more than 37 percent of them were released before the end of their first term (Larson & Kewley, 2000, p. 2). It is estimated the U.S. Navy loses millions of dollars annually each time a sailor attrites (Anderson, 2009, p. 1). Furthermore, recruit attrition severely impacts readiness, generating high turnover rates and lower than average experience levels throughout the fleet (Anderson, 2009, p. 1).

In an effort to reduce first-term attritees, Department of Defense (DOD) studies have continuously pointed to the recruitment of individuals with a traditional high school diploma.[1] Research has estimated high school diploma graduates (HSDGs) have almost an 80 percent probability of fulfilling their first-term enlistment, compared to a 60 percent probability for non-high school graduates or those with alternative high school credentials (Laurence, Ramsberger, & Arabian, 1996, p. 1). These research findings established the Three-Tier System the DOD has used for recruitment since the 1970s, separating potential recruits into three levels of educational status: non-high school graduates, high school equivalency (primarily through General Educational Development (GED) certification) graduates, and traditional high school diploma graduates. With the rise in homeschooling, and the introduction of "exit" exams traditional high school students are required to pass in order to graduate, variations of the high school diploma were created to show the completion of alternative educational programs. To account for this, the Educational and Biographical Information Survey (EBIS) was administered to

[1] Referencing Navy Recruiting Command Instruction 1130.8H, traditional high school diploma graduates are those individuals who have completed 12 years of "traditional" graded classroom instruction. The diploma must be received from the high school at which the individual completed the requirements for graduation.

some 74,000 recruits over a five-month period in 1983 (Laurence et al., 1996, p. 2). The same recruits were then tracked over the period of their first-term enlistment to observe and record the relationship between their educational background and attrition (Laurence et al., 1996, p. 2). The results from the EBIS study created the following Three-Tier System the DOD instituted in 1984 and still uses today:

Tier 1:

- Traditional High School Diploma
- Completion of one semester of college[2]

Tier 2:

- Test-based equivalency diploma (GED)
- High School certificate of attendance
- Adult education diploma[3]
- Correspondence school diploma
- Occupational program certificate
- Homeschool diploma

Tier 3:

- Non-high school graduate.

B. NAVY RECRUIT QUALITY MATRIX

Using the three-tier system as a basis, the current Navy Recruit Quality Matrix was created to aid in the selection of potential recruits. The educational tier is used in conjunction with the Armed Forces Qualification Test (AFQT) to aid in the Navy enlisted selection (see Figure 1). Those who possess a traditional high school diploma and are classified as Tier 1 are grouped in cell A, or Cu, depending on their AFQT scores, and must score a 35 or above to be considered for recruitment (Commander, Navy Recruit Command [CNRC], 2012). Recruits who are classified as Tier 2 or 3 are grouped in cell B, and must score above a 50 to be considered for recruitment (CNRC, 2012).

[2] Applies to recruits who do not have a traditional high school diploma, but has completed at least one semester of college.

[3] Adult education was later added to Tier 1 in 1993.

Current Navy Recruiting Command policy limits non-Tier 1 recruits to no more than 5 percent of the total accessions. Though some naval recruiting districts (NRDs) may restrict applicants to only Tier 1 education holders, a recent GED survey indicates the U.S. Navy does not restrict recruiting commands from recruiting only candidates from Tier 1 level of education (General Education Development Testing Service, 2009).

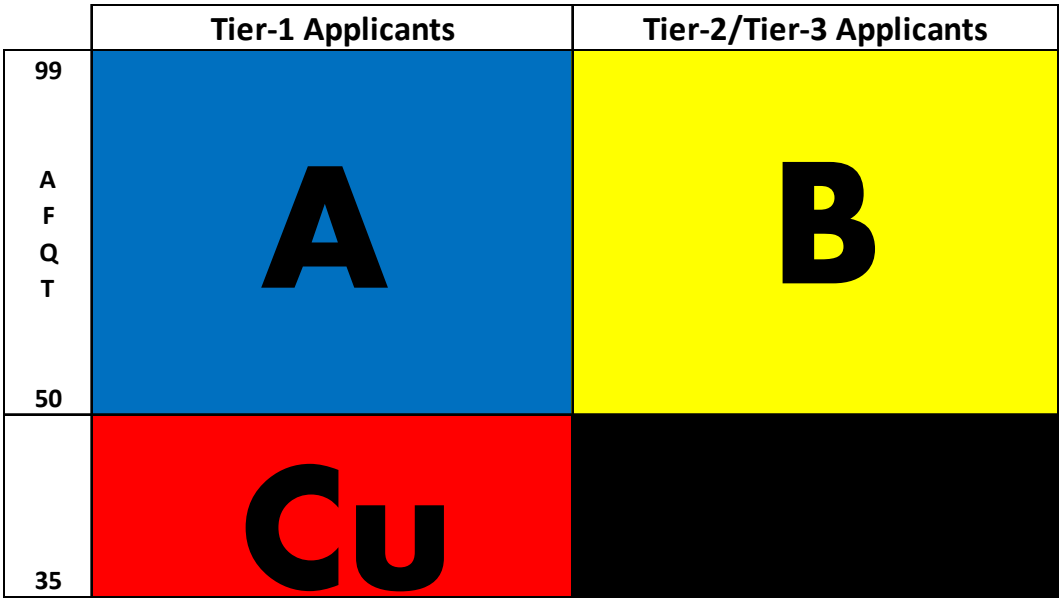

Figure 1. U.S. Navy's Recruit Quality Matrix (after CNRC, 2003).

C. PURPOSE AND BENEFITS OF THE STUDY

This study develops a logistic regression model that predicts a potential recruit's likelihood or probability of surviving through the first-term of his or her enlistment based on information available to recruiters. This model is compared and contrasted with the predictive ability of the current Navy Recruit Quality Matrix. The results of this study give insights into first-term attrition based only on what is known by the recruiter. Of particular interest are the differences between those who are homeschooled and those who are traditional high school diploma graduates (HSDGs). The results of this study will help determine if the Navy Recruit Quality Matrix should be modified or expanded.

D. ORGANIZATION OF THE THESIS

This thesis contains five chapters. Chapter I provides background and a general overview of the area of analysis. Chapter II reviews literature and studies relating to attrition and educational credentials. Chapter III discusses the variables we use in the regression model, and the descriptive results of attrition trends within these variables for all active duty Navy recruits accessed during fiscal year 2006 through fiscal year 2009. Chapter IV gives the details of building a logistic regression model to predict the probability of first-term attrition based on sailor attributes measured at the time of recruitment. This model is validated and its predictive ability compared to that of using the Navy Recruit Quality Matrix alone. Chapter V offers conclusions.

II. LITERATURE REVIEW

A. INTRODUCTION

This thesis uses logistic regression models to predict the probability of first-term attrition based on recruiting data. Since the 1950s, the U.S. Armed Forces have continued to conduct studies to identify factors associated with service members who attrite within their first enlistment, and establish screening methods to reduce the attrition. In this chapter, we examine past studies which conclude why levels of education is a worthwhile predictor of first-term attrition, illustrate the current education trends within alternate high school credentials, and examine other factors found in past studies used to predict the probability of attrition within the United States Armed Forces.

B. HISTORICAL REVIEW OF ATTRITION RESEARCH ON EDUCATION

Since the 1960s, in an effort to decrease attrition rates, the AFQT percentile score and education level of a potential recruit have been the only two variables the military services have used to determine eligibility. There are multiple reasons a service member attrites from the military, including misconduct, inaptitude, family hardship, desertion, and physical or psychological disqualification (Griffin, 1981, p. 9). However, over the years of studying military attrition, one variable continuously stands out as a strong indicator: education. After the creation of the AVF, the volunteer experiment was closely watched by Congress and DOD, scrutinizing recruitment standards and attrition levels across all military services (Eitelberg, Laurence, Perlman, & Waters, 1984, p. 5). Although lower attrition levels were anticipated with the initiation of the AVF, there was actually a 10 percent increase with first-term attrition compared to pre-AVF levels, becoming one of the most serious and costly problems within the armed forces by 1977 (Eitelberg et al., 1984, p. 9). With various DOD supported studies conducted in the 1970s consistently demonstrating that high school dropouts have much higher attrition rates than graduates of traditional high school (Buddin, 1984, pp. 16–17), the Office of the Assistant Secretary of Defense announced in 1978 that the “possession of a high school diploma was the best single measure of a person’s potential for adapting to life in the

military" (Office of the Department of Defense, 1981, p. 30). Though the spike in attrition could have been attributed to the longer enlistment terms of four years after AVF was implemented, and the implementation of discharge programs to expedite administrative discharges of marginal performers, there has not been any deviation away from recruiting based on an individual's educational diploma (Laurence, 1984, p. 9).

Mandating higher AFQT scores and limiting the recruitment of non-high school graduates has been a method of controlling attrition in the military since the 1950s. Created specifically to be a screening method, the AFQT serves a dual purpose of (1) measuring a potential recruit's mental capability of grasping military training and adjusting to military life, discarding those who do not possess such capabilities; and (2) determining the usefulness of the recruit and regulate which military occupations they are qualified for (Uhlaner & Balanovich, 1952). The introduction of the AFQT enabled all military services to become selective and recruit individuals with higher standards in order to reduce attrition; however, it did not distinguish between high school and non-high school graduates. In 1950, the U.S. Air Force was the first service to require higher minimum AFQT scores for non-graduates through a one-year trial program, but it did away with the requirement before the trial expired (Flyer, 1959). In the next few years following this program, research studies validated the assumption that recruits who failed to obtain a high school diploma had a significantly greater rate of first-term attrition and the Air Force reintroduced the education differential, requiring high school graduates to obtain a minimum of 26 on the AFQT to be eligible for recruitment, while non-high school graduates needed to score a minimum of 31 (Flyer, 1959). By 1965, all services had adopted this practice and incorporated their own minimum AFQT scores for both groups. Taking it a step further, Congress passed the fiscal year 1981 Defense Authorization Act which included a mandatory ceiling placed on the annual number of non-high school graduates recruited in the Armed Services. Though the number of non-

Tier 1 accessions is different throughout all services, the current DOD policy restricts each service branch from exceeding 10 percent.[4]

C. EDUCATIONAL TRENDS

1. Rise in Homeschooling Education

The homeschooling population in the Unites States was approximately 900 thousand during the 1999 school year (about 1.7 percent of the total K-12 population), and in recent years, the number of individuals homeschooled has grown at least 7 percent per year (see Figure 2).

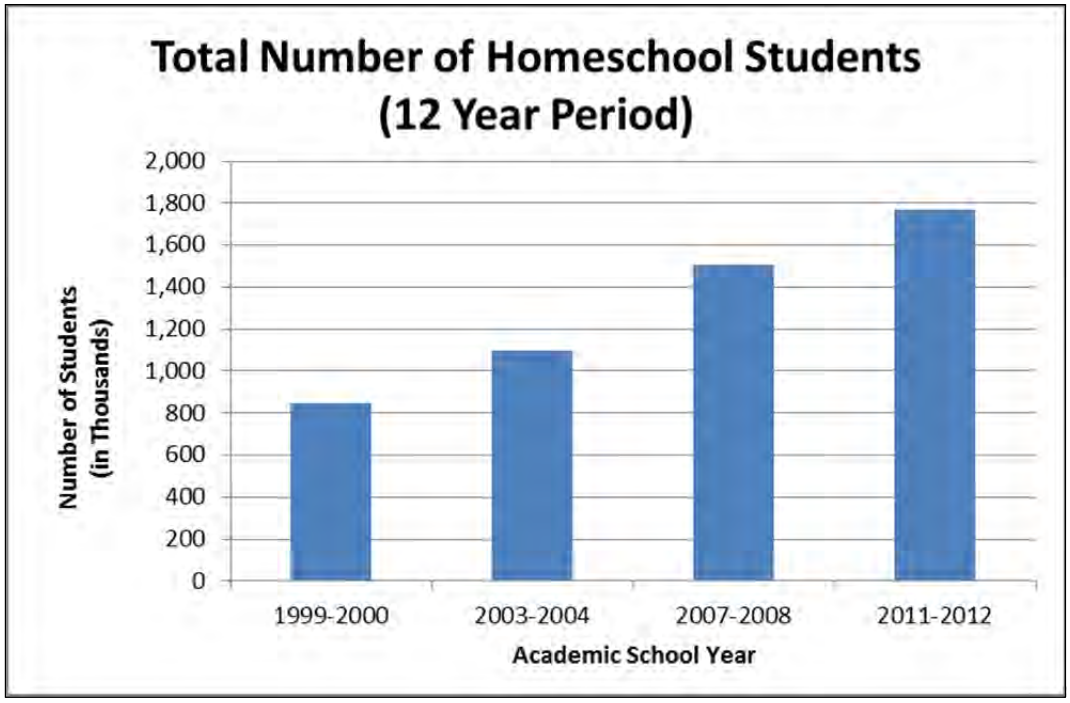

Figure 2. Number and percentage of homeschooled students ages 5 through 17 with a grade equivalent of kindergarten through 12th grade, by selected child, parent, and household characteristics (after National Center of Education Statistics [NCES], 2013).

[4] The U.S Navy, U.S. Marine Corps and U.S. Army currently restrict non-Tier 1 accessions to 5 percent each fiscal year, but, due to the current economic environment, the recruiting commands may be meeting their recruiting goals with qualified Tier 1 applicants only, decreasing the number of Tier 2/3 accessions. The U.S. Air Force allows only one percent each fiscal year.

Furthermore, the number of ninth through twelfth grade students who are homeschooled in the United States have doubled since 1999 (see Figure 3), representing approximately 3 percent of all ninth through twelfth grade students.

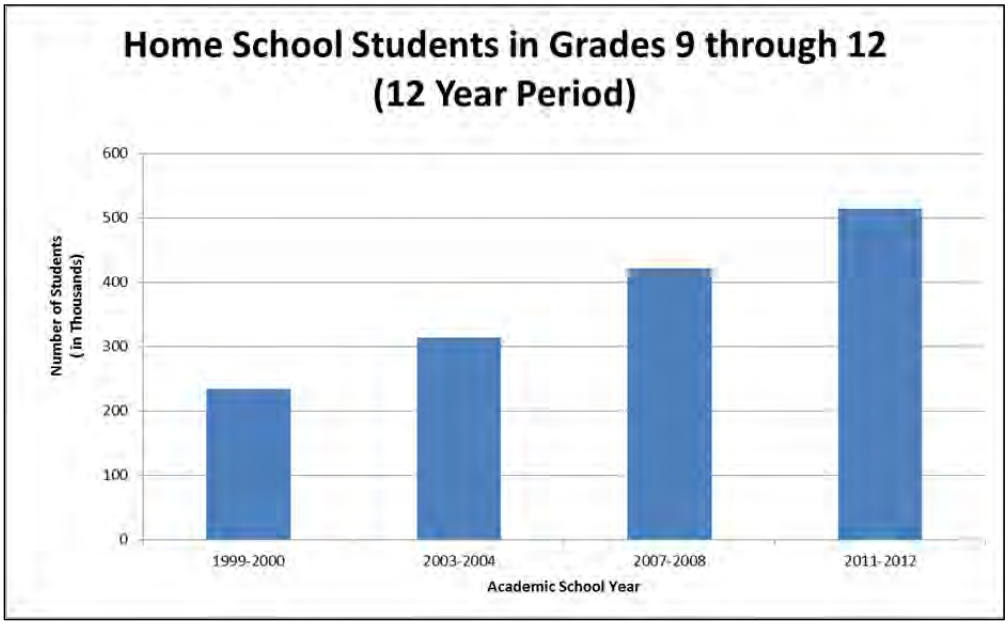

Figure 3. Number and percentage of homeschooled students ages 5 through 17 with a grade equivalent of kindergarten through 12th grade, by selected child, parent, and household characteristics (after NCES, 2013).

There are numerous reasons for the increase in the number of students homeschooled (see Table 1), but the most popular explanations parents gave as a reason they decided to take the homeschooling approach were because (1) they want to provide religious or moral education their children normally would not receive in public school systems; (2) they have a concern over the safety environment at schools; and (3) they are simply dissatisfied with the academic instruction in schools.

A recent pilot program established by the National Defense Authorization Act of FY99 found there was no statistical difference with homeschool graduates average AFQT scores than those of HSDGs or GED holders. Furthermore, the pilot program indicated homeschool graduates tend to do better than HSDGs at most Standardized Tests (Wenger & Hodari, 2004, pp. 17, 25).

Table 1. Number and percentage of homeschooled students whose parents reported particular reasons for homeschooling as being applicable to their situation and as being their most important reason for homeschooling (after NCES, 2013).

Reasons for Homeschooling				
Reasons	Applicable*		Most Important**	
	Number	Percent	Number	Percent
Concern about environment of other schools to include safety, drugs, or negative peer pressure.	935,000	85.4%	341,000	31.2%
Dissatisfaction with academic instruction at other schools	748,000	68.2%	180,000	16.5%
To provide religious or moral instruction	793,000	72.3%	327,000	29.8%
Child has a physical or mental health problem	174,000	15.9%	71,000	6.5%
Child has other special needs	316,000	28.9%	79,000	7.2%
Other reasons***	221,000	20.1%	97,000	8.8%

*Percentages do not sum to 100 because parents could choose more than one reason.

**Parents choose only the most important reason. Percentages sum to 100.

***Parents homeschool their children for many reasons that are often unique to their family situation. "Other reasons" parents gave for home schooling include: It was the child's choice; to allow parents more control over what child was learning; and flexibility.

However, though the studies illustrate similarities in AFQT scores between HSDGs and those who were homeschooled, it is important to note that the same study also concluded homeschool graduates had a much higher attrition rate than HSDGs, and only slightly lower attrition rates when compared to GED holders and high school dropouts (Wenger & Hodari, 2004, pp. 27–28).[5]

2. GED Trends in the United States

Established in 1942, the GED testing program was created after the United States Armed Forces Institute asked the American Council on Education (ACE) to develop a battery of tests to measure high school-level academic skills (Boesel, Alsalam, & Smith, 1998). During this time frame, many recruits were entering military service before obtaining a high school diploma. The concept behind these tests was to provide service members with a way to establish their education level so they could enter the regular workforce once they separated from the service. Before the GED testing program, the only alternative for returning World War II military personnel from wanting to either continue their education or join the competitive workforce was to go back to high school, which was not a realistic option for the majority of them (Boesel et al., 1998). Since then, the number of GEDs received by high school drop-outs has steadily increased over the years, with nearly 500,000 individuals receiving their GED annually today, which accounts for about 60 percent of all Tier 2 recruiting applicants.

Though the GED program was created to aid service members, studies concluded that individuals with GEDs recruited in the late 1970s had attrition rates comparable to those who had no high school diploma (see Table 2) (Laurence, 1984, p. 12). These results have been consistent over the past 30 years even though recent studies have indicated AFQT scores of GED holders are comparable to those of HSDGs who have no college experience (Wegner & Hodari, 2004, p. 12).

[5] A five year pilot program conducted from 1999 to 2004 by J. W. Wegner and A. K. (2004) concluded homeschool accessions in the U.S. Navy had a 45.3 36 month attrition rate, while public high school graduates had a 28.5 36 month attrition rate. GED: 51.1 36 month attrition rate; dropout: 48.7 36 month attrition rate.

Table 2. Attrition rates of non-prior service males with 36 month obligation. Service accessions by service, fiscal year of entry and education level (from Laurence, 1984).

Education Level/Number	Service														
	Army			Navy			Marine Corps			Air Force			Total DoD		
	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979	1977	1978	1979
Non-High School Graduate	77,175	28,246	39,356	27,073	16,854	15,410	14,655	10,171	9,538	3,718	3,924	3,878	122,621	59,195	58,182
Attition Percentage	47.9%	42.0%	43.6%	46.0%	35.7%	39.6%	41.8%	38.8%	42.9%	48.5%	46.7%	46.0%	46.7%	39.8%	42.7%
GED High School Equivalency	5,731	3,784	6,330	5,860	4,440	3,763	1,464	872	989	2,307	3,960	4,536	15,362	13,056	15,618
Attition Percentage	45.3%	43.7%	44.6%	42.1%	36.6%	38.1%	45.3%	40.7%	45.8%	46.6%	52.8%	51.3%	44.3%	43.9%	45.0%
High School Diploma Graduate and above	115,056	73,054	65,407	91,791	52,562	50,647	39,677	24,911	26,062	73,066	45,746	44,963	319,590	197,273	187,079
Attition Percentage	23.9%	21.8%	21.2%	22.0%	19.7%	21.0%	23.0%	24.2%	24.5%	23.3%	22.0%	22.8%	23.1%	21.6%	22.4%
Total	197,962	105,084	111,093	124,724	73,856	69,820	55,796	35,954	36,589	79,091	54,630	53,377	457,573	269,524	270,879
Attition Percentage	33.8%	27.9%	30.5%	28.1%	24.4%	26.0%	28.5%	28.7%	29.9%	25.2%	26.0%	26.9%	30.1%	26.7%	28.8%

D. PRE-RECRUITMENT FACTORS ASSOCIATED WITH FIRST–TERM ATTRITION

This study applies logistic regression to identify predictors, other than education and AFQT scores, which may help aid the U.S. Navy, and subsequently the rest of the U.S. armed services, in reducing attrition at the recruitment stage. Logistic regression is used for modeling outcomes from a Bernoulli trial, where the outcome has exactly two possible outcomes: "success" and "failure" (Papoulis, 2002, pp. 57–63). In this case, "success" is defined as a recruit completing his or her first-term enlistment obligation, and "failure" is defined as a recruit undergoing attrition before the first-term enlistment obligation has ended. The following five examples illustrate the use of regression analysis on military attrition and the various outcomes from their study. The first three of these examples were conducted before the Navy Recruit Quality Matrix was established in 1984.

1. Characteristics and Organizational Factors

Lau (1979) conducted a study to determine the degree to which first-term enlisted attrition was the result of individual characteristics and organizational factors. The study analyzed a sample of 4,845 males with no prior service who enlisted into the U.S. Navy in November 1976. The sample included service members who were slated to attend apprenticeship training, which prepares recruits for general detail assignments, and service members who were slated for A-school, which prepares recruits for higher-level tasks in a specific occupation or rating. Approximately one-half of the sample participated in an experimental voluntary release program while the other half served as a control group. The entire sample completed an initial survey which provided measures of demographic characteristics, pre-service attitudes, expectations, organizational climate, general living conditions, achievement needs, and perceived control over events in their lives. These recruits were surveyed again seven months later to provide measures of organizational structure and shipboard experience, expectations, organizational climate,

job characteristics, and general living conditions. Those in the experimental group were also surveyed providing measures of aspects of Navy life, expectations, organizational climate, and job characteristics.

The study indicated that 27 percent of the experimental group attrited while less than 10% of the control group attrited during the first year of the study, concluding that the voluntary separation option does influence attrition. Additionally, 38 percent of apprentice training personnel attrited, compared to 23 percent of those attending A-school, indicating that the perceptions of apprentice personnel were significantly lower than A-school participants. The largest differences between the two groups were found in training effectiveness, growth satisfaction, and experiences associated with the job assigned to the service member once he or she arrived to the fleet. This was significant since the author found that the individual's intentions of completing the first-term enlistment was the best predictor of attrition, and the elements of organizational climate and job perception pre-recruitment were substantially correlated with their intentions.

2. SCREEN as a Naval Recruiting Tool

Lockman and Lurie (1980) looked at the probability of a Navy recruit surviving the first year of service to determine if revisions needed to be applied to the Success Chances of Recruits Entering the Navy (SCREEN) table, a tool used by recruiters to screen applicants for naval enlistment between 1976 and 1984. This research observed 68,000 males and 4,500 females entering the U.S. Navy, and 15,000 males entering the U.S. Navy Reserve. All recruits enlisted into the U.S. Navy in 1977.

The results concluded that age, educational level and marital status were related to the recruit's probability of survival. As the recruits educational level increased, so did their probability of surviving the first year of enlistment. With age, it was found that recruits 17, 18, and 19 years old had higher survival rates than older recruits. Finally, with marital status, the survival rates differed among male and female service members. Male recruits who were married with dependents had a greater chance of survival than

then males who were single, while women who were married with, or without, dependents had a lower chance of surviving their first year of enlistment than female recruits who were single.

3. Evaluation of the OFE Table

Sands (1976) conducted a study to review a naval recruiting tool used from the creation of the AVF in 1973, the Odds for Effectiveness (OFE) table. Observing 364 male recruits who had no prior service, Sands' research tried to predict recruit effectiveness, which was defined as a recruit completing a four-year term of enlistment and being recommended for reenlistment. The predictors of effectiveness in this study were the individual's mental ability, number of years of school completed, and number of expulsions or suspensions from school. The study concluded that as the mental ability and level of education increased, so did the recruit's probability of being effective. As expected, those who were expelled or suspended from a traditional high school had a lower effectiveness score and were more likely to attrite.

4. Analysis of Current Educational Tier System

Andrew (2009) analyzed the effect of selected demographic characteristics on first-term enlisted attrition from the U.S. Navy. Evaluating all U.S. Navy recruits accessed from FY99 to FY03, he analyzed their likelihood of completing a first-term enlistment by the recruit's age, marital status, dependency status, gender, race, AFQT percentile scores, and their education credential.

Using probit regression models, his results indicated shortcomings in the current Educational Tier system with respect to how a recruit's education credential contributed to his or her probability to attrite. Andrew concluded his research was consistent with past studies indicating lower attrition rates with recruits who have higher AFQT scores and graduate from a traditional high school (2009). However, he found the concept of a recruit having a higher likelihood of success when they obtain education beyond high school to be erroneous after his analysis indicated a 47 percent attrition rate with recruits who had entered the U.S. Navy having "some" postsecondary education, which is considered a Tier 1 category under the current Educational Tier system. This educational

category enabled recruits, who would normally enter under the Tier 2 or Tier 3 category, to enter under the Tier 1 category simply because they completed a minimum of 15 college credits, or one semester, at an accredited postsecondary institution. Therefore, the education credential became a convenient, less-controlled avenue for non-high school graduates to qualify for enlistment with a lower AFQT percentile score, which would explain the high attrition rate.

Andrew also concluded that the demographic variable with the strongest correlation to attrition was found with recruits who were single with dependents (2009). He also found that with the group of recruits who completed the first 90 days of training, those who were more likely to attrite before completing their first-term enlistment were the recruits who were young and recruits who were married with no dependents.

5. Evaluating the Rise of Homeschooling and Distant Learning

Bukauser, Hanser, and Hardison (2014) conducted a study for the Office of the Secretary of Defense (OSD) which focused on the rise of homeschooling and distance learning education programs within the United States, and whether these education credentials should remain a suitable proxy for predicting first-term attrition. What the research group found was that overall attrition rates among recruits who were homeschooled were only slightly higher than the attrition rates among HSDGs. However, when looking at only those recruits who received an AFQT percentile score of less than 50, the attrition rate was much larger with those homeschooled when compared with recruits who were HSDGs. The research group also found that recruits who had a distance learning school diploma had a higher attrition rate than with those homeschooled, regardless of whether the recruit scored above 50 on the AFQT.

The research group recommended that OSD continue to use the current education credentials screen potential recruits, but added that those recruits who are homeschooled and receive an AFQT percentile score above 50 should be considered Tier 1 applicants. Homeschool certificate holders who score less than 50 should continue to be considered Tier 2.

E. CONCLUSION

Since the start of the AVF, attrition has had a negative impact on the armed services. Though there have been multiple recruitment screening programs applied, education and AFQT percentiles have continued to be the primary variables used to vet potential recruits. However, with alternate education certifications like homeschooling and GED on a continuous rise, the current Navy Recruit Quality Matrix and the 10- percent ceiling placed on Tier 2 applicants may be eliminating individuals who would increase the quality of manpower within the U.S. Navy. Though past studies have concluded that education has a high correlation with attrition, there has been other variables that emerge in studies which also have high correlation with attrition, such as age, job characteristics, command climate, marital status, behavior issues prior to recruitment, and the presence of "early out" programs offered to recruits to either expedite the separation of mediocre recruits or to reduce over-manning issues. In this study we applied logistic regression to evaluate the effectiveness of the Recruit Quality Matrix as a recruit screening tool.

III. DATA

A. INTRODUCTION

The data used to conduct the analysis in this study was provided by the Defense Manpower Data Center (DMDC). The data was received in two master files, the Military Entrance Processing Command (MEPCOM) file and the Active Duty (AD) file. To maintain security measures for each service member observed, the data was extracted using pseudo social security numbers (SSNs) to preserve anonymity and keep their information organized. Data was further safeguarded as specified in the approved Naval Postgraduate School Institutional Review Board (IRB) protocol. In both the MEPCOM and AD data files, there were possibilities of duplicated SSN entries for every occasion a specific variable was updated for the service member. In this case, the observation with the most up-to-date information was retained; all other duplicated SSN were excluded from the research.

The MEPCOM file provided MEPCOM screening data from all U.S. Navy recruits entering active duty service between fiscal year (FY) 2006–2012. The data was obtained through their service application, Armed Services Vocational Aptitude Battery (ASVAB) test, and medical screening. There were 247,831 separate SSN observations after excluding 186 duplicate SSN entries. The average number of U.S. Navy active duty accession for each full fiscal year is 35,404 (see Figure 4). Each recruit observation contained 87 variables, including the pseudo SSN, general demographic information, the accession date, U.S. citizenship status, initial pay grade, AFQT percentile scores, required medical waivers, and required accession waivers.

The AD file contained current information regarding the service members identified in the MEPCOM data set after they entered the U.S. Navy. This data is mostly updated through their parent command, or the Personnel Support Detachment (PSD) assisting the parent command. There were 246,916 separate SSN observations after excluding 1,503,332 duplicated SSN entries. Duplicate entries represent yearly updated snapshots of variables for the years that the sailor was on active duty. Each observation

included 64 variables, including the pseudo SSN, general demographic information, updated pay grade, primary service occupation code, end of active obligated service (EAOS) date, their separation date, and inter-service separation code.

B. MEPCOM VARIABLES

1. Accession Date

The accession date is the date the service member swears on the oath of enlistment and begins recruit training at Navy Recruit Training Command, Great Lakes, Illinois. This date establishes the service member's EAOS depending on the number of years for which he or she enlists. For most recruits, a first-term enlistment is four years.

The FYs observed in this study did illustrate a trending period where the number of recruits fell below the average (see Figure 4). From FY 2008–2011, there was a decline in the number of sailors recruited. This trend may have been due to the economic environment in the United States forcing the U.S. Navy, along with all the other services, to draw down their overall manpower strengths to manage budgetary cuts. This economic impact will be seen again as we examine other variables.

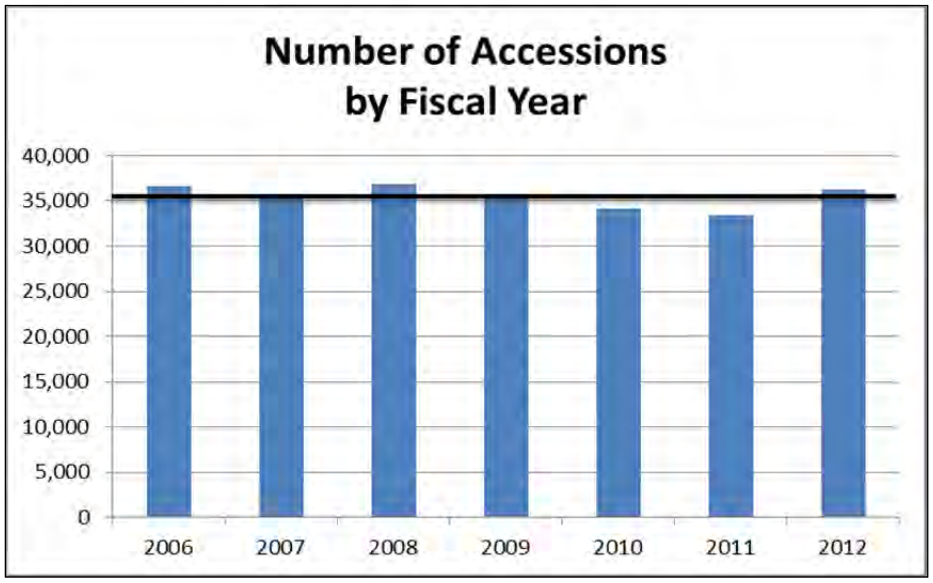

Figure 4. Number of U.S. Navy active duty recruits by fiscal year: FY 2006–2012. Average number of recruits accessed is 35,404 (after DMDC, 2014).

2. Accession Age

There are age requirements to be eligible to become a U.S. Navy active duty recruit. The minimum age is 18, but a service member can be recruited at the age of 17. Any recruit who enters service at 17 must turn 18 within sixty days from his or her accession date, and obtain parental or guardians consent if they are unmarried. The maximum age limit for an individual who has no prior service is 34, and he or she must report to recruit training prior to his or her thirty-fifth birthday (CNRC, 2012). There are some observations that had an age over the maximum limit (see Figure 5). These observations account for less than 0.01 percent of each FY population and it is assumed they had prior service; therefore, they would not be included within this study as first-term enlistee's.

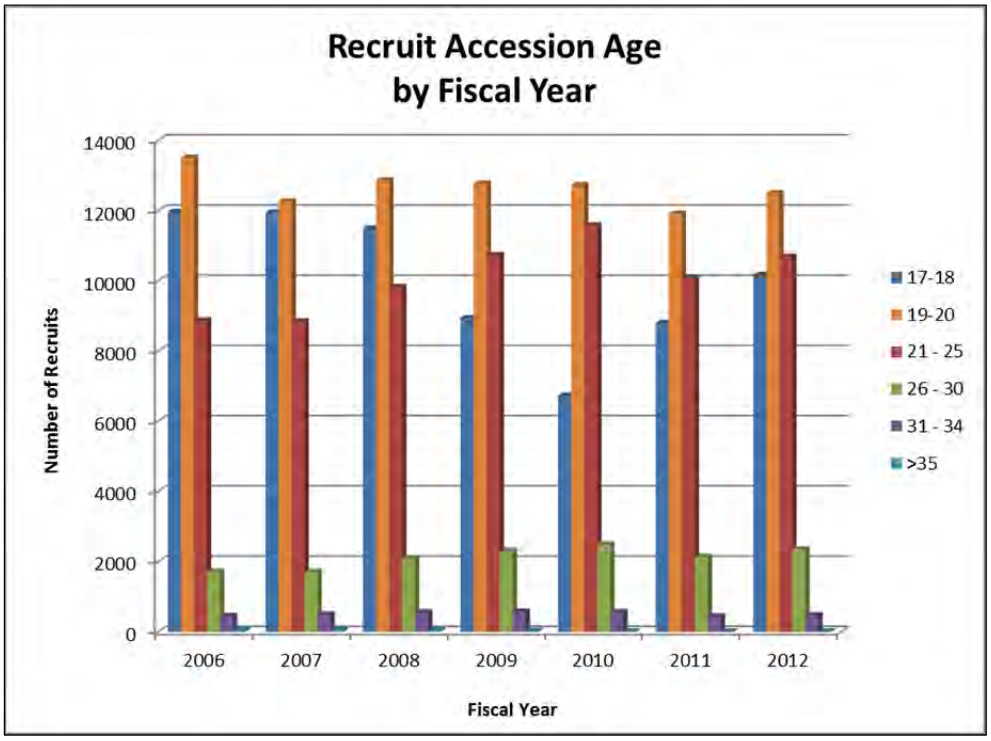

Figure 5. Distribution of U.S. Navy active duty recruits by accession age (after DMDC, 2014).

The most populous age group of recruits entering service is between the ages of 19 and 20, who represent approximately 35 percent of all recruits in each fiscal year.

Though the majority of the age groups illustrated consistency over the fiscal years, the age group with recruits between 17 and 18 showed a significant decline between FY 2008–2010.

3. Accession Education Code

One of two current variables that all military services use to predetermine a recruit's possibility of attrition, the education code indicates what Tier group a potential recruit falls into. Currently, the U.S. Navy requires at least 95 percent of all sailors recruited within a fiscal year to be Tier 1 candidates, which is reflected throughout FY 2006–2012 (see Figure 6).

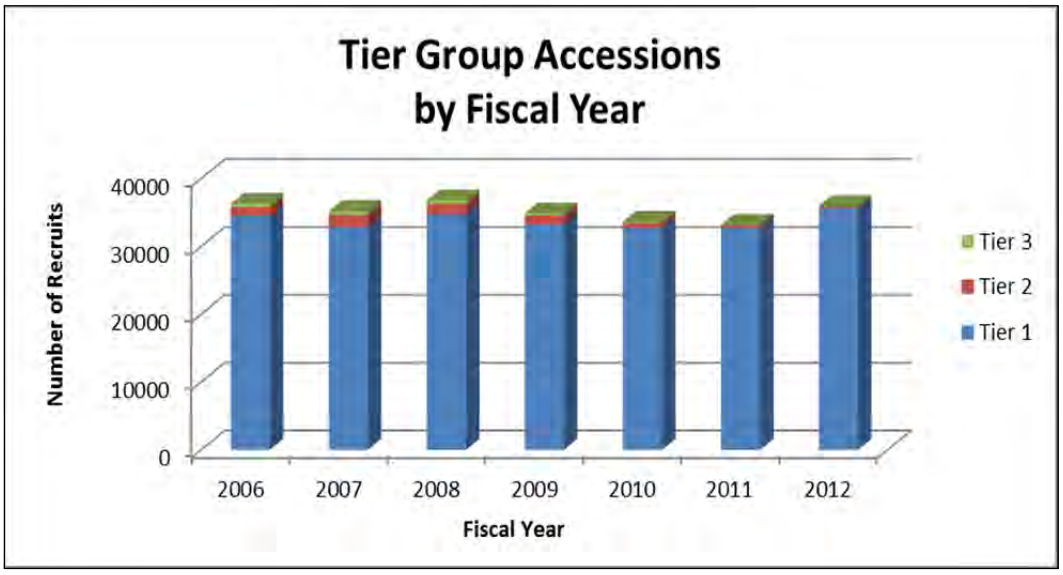

Figure 6. Accession education tier group by FY. Each bar represents the number of U.S. Navy Active Duty recruits and their Tier group (after DMDC, 2014).

a. Tier 1 Group

In accordance with U.S. Navy recruiting instructions, those who qualify to be Tier 1 applicants are (1) those who receive a diploma issued to a graduate of a public or private 12-year, "traditional," credit-based day program of classroom instruction; or (2) are non-high school diploma graduate who has completed at least one semester from an

accredited traditional or on-line post-secondary institution.[6] For all observed fiscal years, those with a traditional high school diploma represented over 90 percent of the total number of Tier 1 successions (see Figure 7).

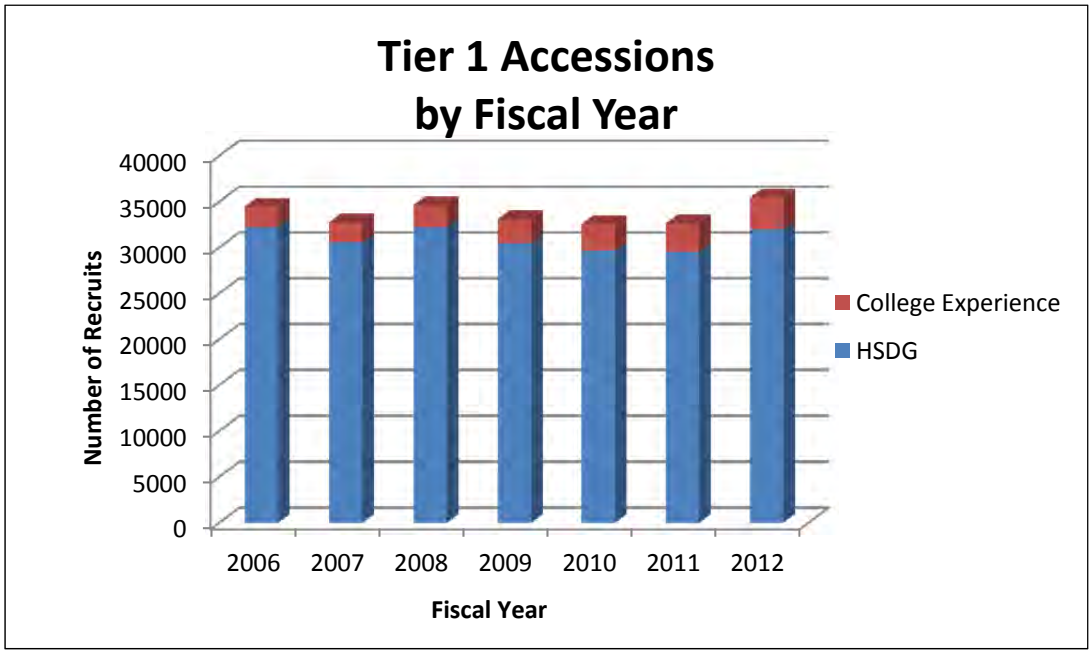

Figure 7. Tier 1 accessions for FY 2006–2012. Histogram illustrates largest portion of Tier 1 is made up of HSDGs. Both HSDG accessions and the accessions of those who have at least one semester of college are consistent throughout all the FYs (after DMDC, 2014).

b. Tier 2 Group

The educational categories that are considered Tier 2 are (1) General Educational Development (GED) or other test-based credential; (2) attendance-based high school certificate such as an alternative high school; (3) a diploma issued to a graduate of a homeschool program in accordance with state requirements; (4) a certificate received for

[6] Those who received a diploma from home school studies or from an alternative high school are also classified as Tier 1 groups per COMNAVCRUITINST 1130.8J, but they need to obtain an AFQT percentile score of 50 or above to be considered Tier 1. If they receive an AFQT percentile score less than 50 than they are not considered for recruitment. The advantage these educational categories have over the other Tier 2 education certifications is they have a 95 percent or greater probability of being recruited, while other Tier 2 categories have a 5 percent or less probability of being recruited. Because they are still required to obtain an AFQT percentile score of 50 or above to be recruited, those who received a home school or alternative high school diploma will be considered Tier 2 for this study.

completing a six-month occupational program and a minimum of 11 years of secondary education; and (5) a certificate received for completing a correspondence course.

As much as 5 percent of the total number of sailors recruited each fiscal year make up Tier 2 accessions. As discussed earlier, there appears to be a downward trend in recruitment from FY 2008–2011. This trend is also seen within the Tier 2 accessions (see Figure 8). Recruits with GEDs appear to be the majority of Tier 2 applicants for each of the fiscal years. However, starting in FY 2008, the percentage of GED certificate holders sharply decreased from 72.2 percent of all Tier 2 accession to just 30.2 percent. The percentage of all other Tier 2 categories either increased throughout the fiscal years, or remained consistent. By FY 2012, the percentage of recruits who had a GED, homeschool degree, or high school certificate of completion were approximately similar.

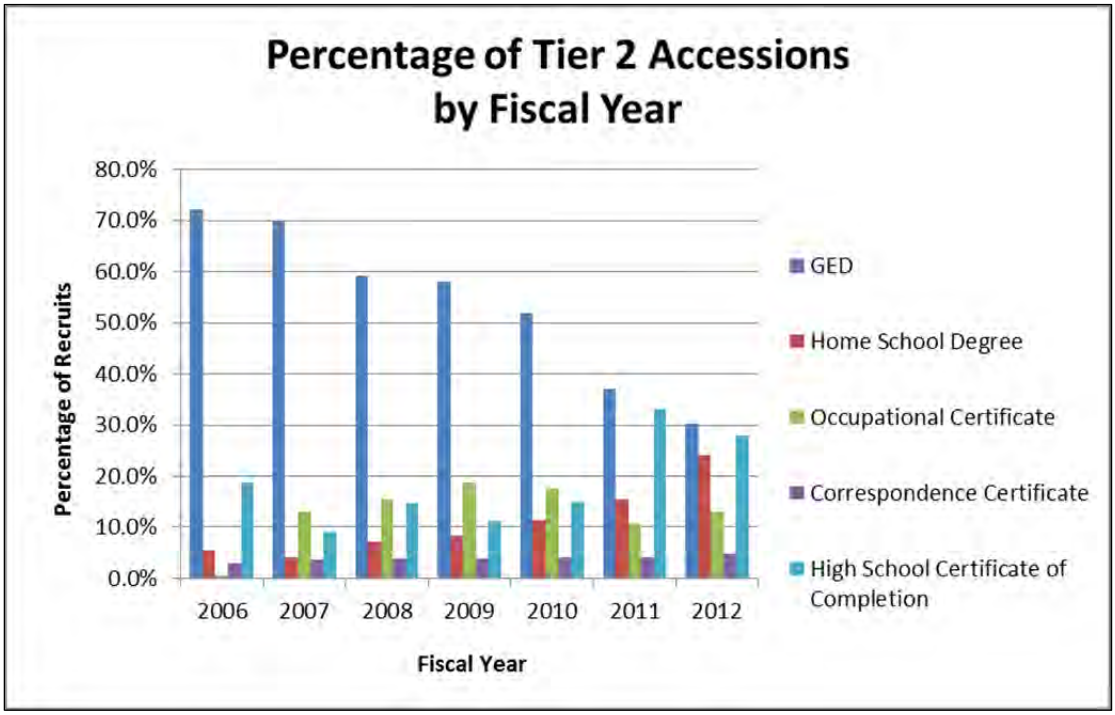

Figure 8. Tier 2 accessions for FY 2006-2012. Histogram illustrates a downward trend with Tier 2 accessions especially with GED and Occupational Certificate accessions (after DMDC, 2014).

With economic constraints forcing the U.S. Navy to reduce its manpower, coupled with the low employment rate in the United States, NRDs were able to meet their

recruiting goals with more Tier 1 applicants. This phenomenon would explain the reduction in the number of recruits with GED's and the total number of Tier 2 applicants.[7]

c. Tier 3 Group

Tier 3 applicants are individual who do not have a diploma or credential, and are not currently in a secondary education program. Currently, per U.S. Navy policy, Tier 3 applicants are not eligible for enlistment due to historically high first-term attrition rates. However, between FY 2006–2008, Tier 3 accessions accounted for nearly 1.5 percent of all sailors recruited in those FYs (see Figure 9). Though not normally eligible for recruitment, the high percentage of Tier 3 recruits could be due to the U.S. Navy's increased support in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). After FY 2008, the number of Tier 3 recruits fell sharply to 0.1 percent of the total number of accessions in FY 2012, likely due to the same economic phenomena which decreased the number of Tier 2 accessions.

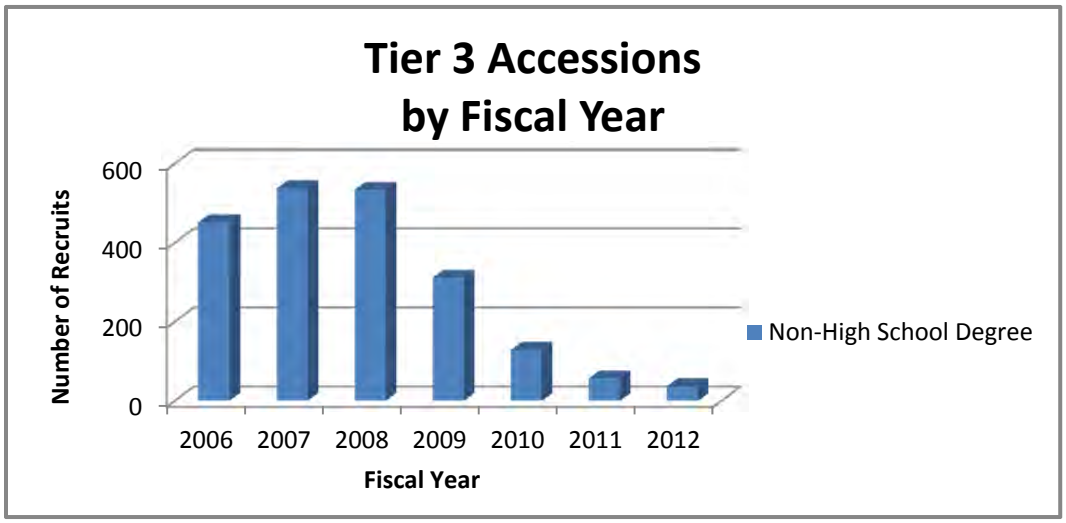

Figure 9. Tier 3 accessions from FY 2006–2012. Histogram illustrates a sharp decline of non-high school degree accessions after FY 2008 (after DMDC, 2014).

[7] Home School graduates were classified as Tier 1 per COMNAVCRUITINST 1130.8J. Therefore, they had a higher probability of being recruited over other Tier 2 education categories providing they scored an AFQT percentile score of 50 or above.

4. Accession Pay Grade

For the majority of sailors recruited, their service entry pay grade starts out at the lowest level: E-1. Approximately 65 percent of all active duty recruits accessed from FY 2006–2012 entered at this pay grade, with each FY varying between approximately 61 percent and 67 percent (see Figure 10).

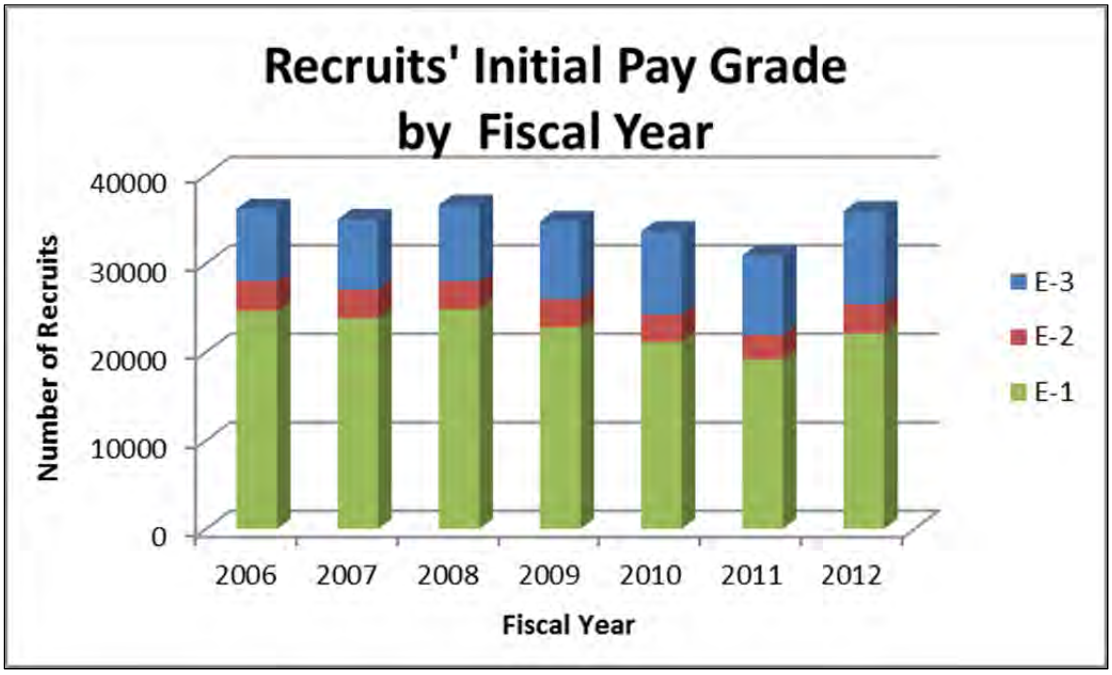

Figure 10. Initial pay grade of U.S. Navy active duty recruits from FY 2006–2012. Histogram illustrates consistency with initial pay grades of E-1 through E-3 throughout all FYs (after DMDC, 2014).

The certain situations a first-term enlistee can enter the U.S. Navy at a pay grade of either E-2 or E-3 differs depending on any one of the following situations:

(1) **College Credits**: Those who have completed 24 semester hours may be enlisted as an E-2, while those who completed 48 semester hours or more can be enlisted as an E-3.

(2) **Navy Sea Cadet Corps**: Eligible candidates must have completed the approved curriculum and reached pay-grade E-2 or E-3 in the Navy Sea Cadet Corps Program.

(3) **Junior Reserve Officer Training Corps (ROTC)**: Those who successfully completed two years of any Junior ROTC Program may be

entitled to enlist as an E-2. If they completed three years of any Junior ROTC Program then they could be eligible to enlist as an E-3.

(4) **Scouting**: Successful completion of Eagle Scout or the Girl Scout Gold Award requirements may qualify a potential recruit to enter service as an E-3.

(5) **Delayed Entry Program (DEP) Referral**: For those who enter the Navy's DEP program, they could potentially be authorized advancement up to the pay grade of E-3 if they refer a number of potential recruits who qualify for enlistment.

The number of sailors entering service as an E-2 represents about 9 percent of all observations in this study, while approximately 25 percent of the observations are represented by those entering service as an E-3.

There were observations from the MEPCOM data set which had pay grades above E-3, representing less than 1 percent of all observations. However, there are no conditions that allow any first-term recruit to enlist past the pay grade of E-3. These observations are presumed to be service members who had prior service and do not count as first-term enlistees.

5. Gender

During the observed time period, the number of males recruited represented approximately 80 percent of the total population for each FY, with females representing the other 20 percent. With a trend seen in other variables during this time period, the number of males recruited decreased from FY 2008–2011, illustrating a decline in overall recruitment (see Figure 11). However, females show a steady increase in recruitment over the FYs observed.

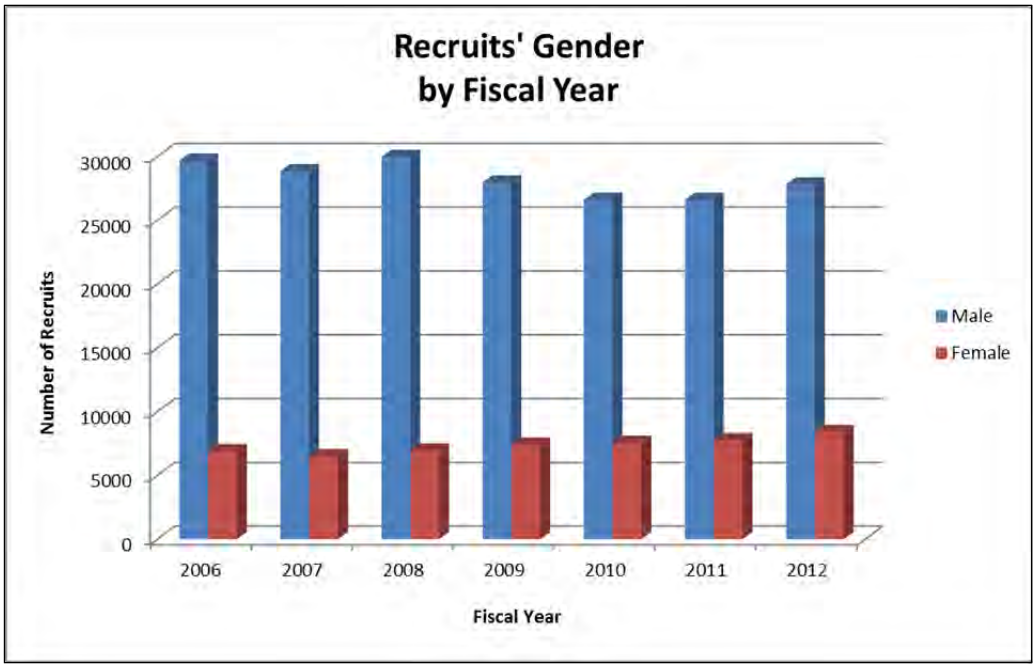

Figure 11. Recruits gender at time of accession. The number of males recruited decreased during FY 2008–2011, while the number of females recruited over the same time period steadily increased (after DMDC, 2014).

6. Marital Status

This study looks at the recruit's marital status at time of accession in three separate groups: Married, Never Married, and Other. The category "Other" consists of observations that (1) had a marriage annulled; (2) were divorced; (3) were legally separated; or (4) were widowed. The number of recruits who fall into the "Other" category is approximately 0.6 percent of all observations in the data set.

Though the number of recruits in the "Married" and "Other" categories remained consistent across all FYs observed, the number of recruits sharply declined from FY 2008–2011 (see Figure 12). These are the same FYs during which we see a decline in overall recruitment.

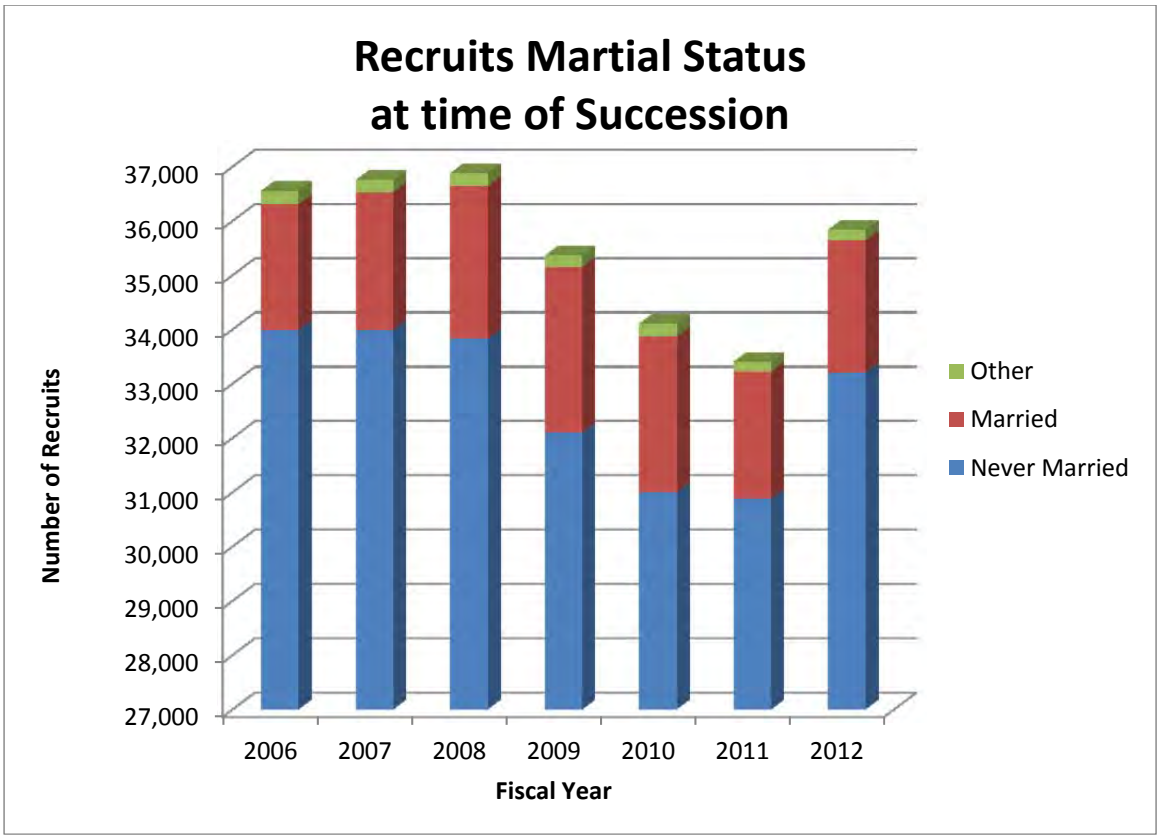

Figure 12. Number of recruits by marital status at time of succession. "Other" category consists of those who entered service married but separated, divorced, or widowed (after DMDC, 2014).

7. Number of Dependents

The number of dependents a recruit had during time of accession ranged from zero to ten children. As one would expect with the majority of recruits in this study being straight out of high school and at an age between 17 and 20, approximately 90 percent of recruits for each FY had no children as they entered the U.S. Navy (see Table 3). The percentage of recruits having more than two children is approximately 1–2 percent for each observed fiscal year.

Table 3. Number of dependents at time of succession (after DMDC, 2014).

Number of Recruits with Dependents by FY	Number of Dependents a Recruit has at time of Succession			
	Number of Dependents			
	0	1	2	>2
FY 2006	33,653	1,642	912	348
Percentage*	92.06%	4.49%	2.49%	0.95%
FY 2007	32,192	1,669	1,021	434
Percentage*	91.15%	4.73%	2.89%	1.23%
FY 2008	33,438	1,830	1,128	487
Percentage*	90.66%	4.96%	3.06%	1.32%
FY 2009	31,838	1,781	1,168	576
Percentage*	90.03%	5.04%	3.30%	1.63%
FY 2010	30,110	1,854	1,092	373
Percentage*	90.07%	5.55%	3.27%	1.12%
FY 2011	30,743	1,551	875	237
Percentage*	92.03%	4.64%	2.62%	0.71%
FY 2012	33,487	1,564	899	248
Percentage*	92.51%	4.32%	2.48%	0.69%

* Percentage of Recruits within same FY

Source: DMDC

8. AFQT Category

There have been multiple changes to the military service exam since World War II. In 1948, all the services convened to develop a uniformed aptitude test that would be used to screen potential recruits' eligibility and determine their qualification for specific jobs (Eitelberg et al., 1984, p. 14). In 1950, this joint panel introduced the AFQT as an All-Service aptitude test that focused on the applicant's verbal skills, arithmetic

reasoning, and spatial relations (Eitelberg et al, 1984, p. 15). Since 1980, the AFQT score has only focused on mathematic reasoning and verbal skills (Eitelberg et al., 1984, p. 16).

Today, the AFQT percentile score is calculated from only three of the ten subcategories within the ASVAB (see Table 4). The three subcategories include Arithmetic Reasoning (AR), Mathematics Knowledge (MK), and Verbal Expressions (VE). A standard score is then calculated as:

$$2(VE)+AR+MK$$

The components VE, AR and MK are the respective scores for the Verbal Expression, Arithmetic Reasoning, and Mathematical Knowledge portions of the equation.

Table 4. List of subcategories in ASVAB (after DMDC, 2014).

Armed Services Vocational Aptitude Battery (ASVAB) Subcategories									
Title	**Code**	**Title**	**Code**	**Title**	**Code**	**Title**	**Code**	**Title**	**Code**
General Science	GS	Word Knowledge	WK	Mathematics Knowledge	MK	Auto and Shop Information	AS	Assembing Objects	AO
Arithmatic Reasoning	AR	Paragraph Comprehension	PC	Electronics Information	EI	Mechanical Comprehension	MC	Verbal Expressions	VE

The standard score is then translated into an AFQT percentile score from an established conversion table (see Table 5). Per U.S. Navy policy, in order for a Tier 1 applicant to be eligible for recruitment he or she must be able to achieve a standard score of 187 or above to receive an AFQT percentile score of at least 35; potential recruits who are considered Tier 2 or 3 must receive at least a standard score of 204 to receive an AFQT percentile score of 50 to be eligible for recruitment.

Table 5. AFQT percentile score table (after DMDC, 2014).

Standard Score	Percentile (AFQT)	Standard Score	Percentile (AFQT)	Standard Score	Percentile (AFQT)	Standard Score	Percentile (AFQT)
80-120	1	**175**	26	**205**	51	**231**	77
121-124	2	**176-177**	27	**206**	52	**232**	78
125-127	3	**178**	28	**207-208**	53	**233**	79
128-131	4	**179-180**	29	**209**	54	**234**	80
132-134	5	**181**	30	**210**	55	**235**	81
135-137	6	**182**	31	**211**	56	**236**	82
138-139	7	**183-184**	32	**212**	57	**237**	83
140-142	8	**185**	33	**213**	58	**238-239**	84
143-144	9	**186**	34	**214**	59	**240**	85
145-146	10	**187-188**	35	**215**	61	**241**	86
147-148	11	**189**	36	**216**	62	**242**	87
149-150	12	**190**	37	**217**	63	**243**	88
151-153	13	**191**	38	**218**	64	**244**	89
154	14	**192**	39	**219**	65	**245**	90
155-156	15	**193**	40	**220**	66	**246**	91
157-158	16	**194**	41	**221**	67	**247**	92
159-160	17	**195-196**	42	**222**	68	**248**	93
161-162	18	**197**	43	**223**	69	**249**	94
163-164	19	**198**	44	**224**	70	**250**	95
165	20	**199**	45	**225**	71	**251**	96
166-167	21	**200**	46	**226**	72	**252**	97
168-169	22	**201**	47	**227**	73	**253**	98
170-171	23	**202**	48	**228**	74	**254-320**	99
172	24	**203**	49	**229**	75		
173-174	25	**204**	50	**230**	76		

Source: DMDC

In the MEPCOM data, AFQT scores are partitioned into eight AFQT categories. This study focuses primarily on the first four of these categories, which include all observations with an AFQT percentile score between 31 and 99. These categories are (1) Category 1, which includes all observations that have an AFQT percentile score above 92; (2) Category 2, which includes all observations with an AFQT percentile score between 65 and 92; (3) Category 3A, which includes all observations with an AFQT percentile score between 50 and 64; and (4) Category 3B, which includes all observations with an AFQT percentile score between 31 and 49. All other observations with an AFQT percentile score less than 31 are group together into one group called "Other." This group represented less than 0.03 percent of the total population. There were also some observations whose AFQT Category was unknown which represented less than 0.5 percent of the population.

Though the number of recruits who fell into Categories 1, 2 and 3A increased between FY 2006–2012, there was sharp decrease in recruiting those who were classified as Category 3B from FY08 to FY12 (see Figure 13). These are the same FYs during which we see a decrease in overall recruitment. Due to fiscal constraints and low unemployment rates, competitive situations may have been created where NRDs were able to meet their recruiting goals with recruits who had higher AFQT scores, producing a decline of potential recruits with AFQT percentile scores less than 50.

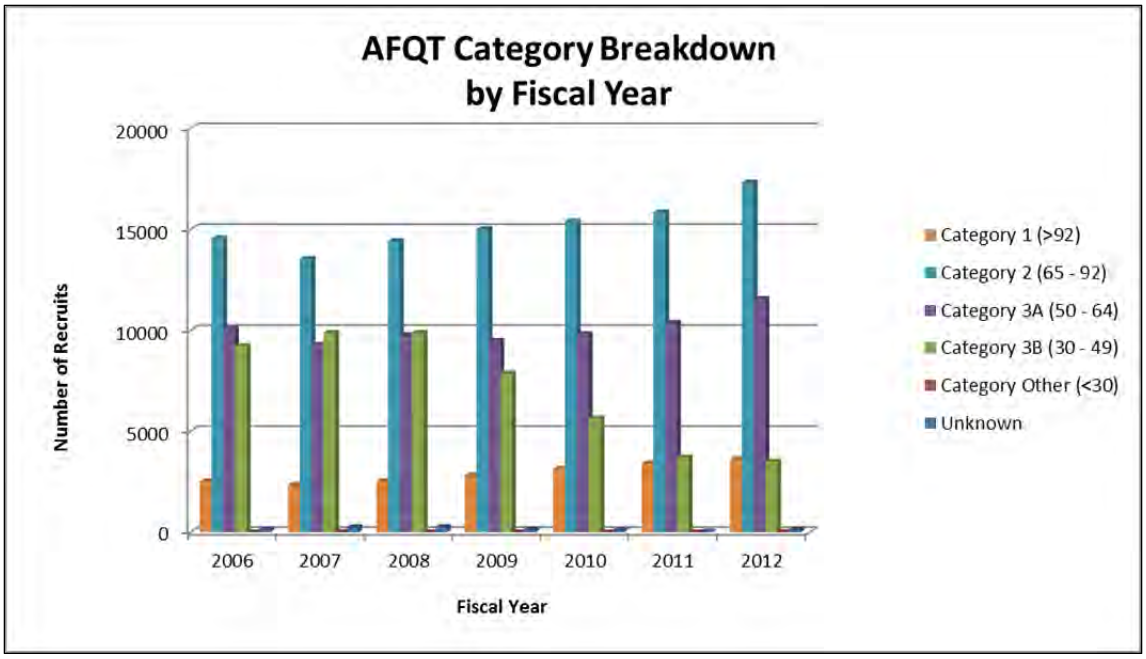

Figure 13. Number of recruits in AFQT category per FY. The number of recruits who fell in category 4A, 4B, and 4C, and those who had unknown AFQT Categories, were less than 1 percent of all recruits accessed in each FY (after DMDC, 2014).

C. FIRST–TERM ATTRITION

In this thesis, we treated all recruits as if they had a four-year commitment. In fact, less than 3 percent of all recruits observed had a first-term commitment length different than 4 years. Therefore, for this study, if a sailor was accessed into active duty on 26 October 2005, his or her EAOS is taken to be 25 October 2009. In addition, because we restrict attention to E-1, E-2, and E-3, we ignore whether a recruit has prior service or not.

The MEPCOM data was separated into two sets. The first data set consisted of 108,754 recruits who enlisted between FY 2006–2008 and had an EOAS between FY 2010–2012; the second data set consisted of 35,363 recruits who enlisted during FY 2009 with an EAOS in FY 2013. The first data set was used to build and validate logistic regression models, while the test set was used to assess the forecasting ability of the models created.

1. FY06 to FY08 Accessions

a. Overall Attrition

Using the "Separation Date" and "Separation Code" provided by the AD data set, the observations within the FY 2006–2008 set were merged with AD observations containing separation data. Out of the 108,754 observations, 69,740 active duty sailors had separated from service between the time they were recruited and date of the data. The following rules were then applied to determine which observations out of the 69,740 separations corresponded with recruits who left service before their initial EAOS, making them a first-term attritee:

(1) Recruits with a separation date before their initial EAOS were grouped together in an attrition group. This group consisted of 35,551 service members who separated before their EAOS.

(2) Recruits with a separation code indicating they were released a few months before their EAOS through an early separation program were excluded from the attrition group.

(3) Recruits with a separation code indicating they were released due to a disability were excluded from the attrition group.

(4) Recruits with a separation code indicating a death of the service member, either as a battle casualty or through non-combat situations, were excluded from the attrition group.

(5) Recruits accepted into an Officer Commissioning Program, Warrant Officer Program, or one of the military service academies, were excluded from the attrition group.

After applying these rules, 32,251, or 29.66 percent of the observations within the FY 2006–2008 data set were considered to be attritees. Tier 1 had the least number of attritions consisting of 28.87 percent of all Tier 1 accessions between FY 2006–2008 (see Figure 14). Tier 2 and 3 were almost identical with approximately a 41 percent attrition rate among all Tier 2 and 3 accessions between FY06 and FY08.

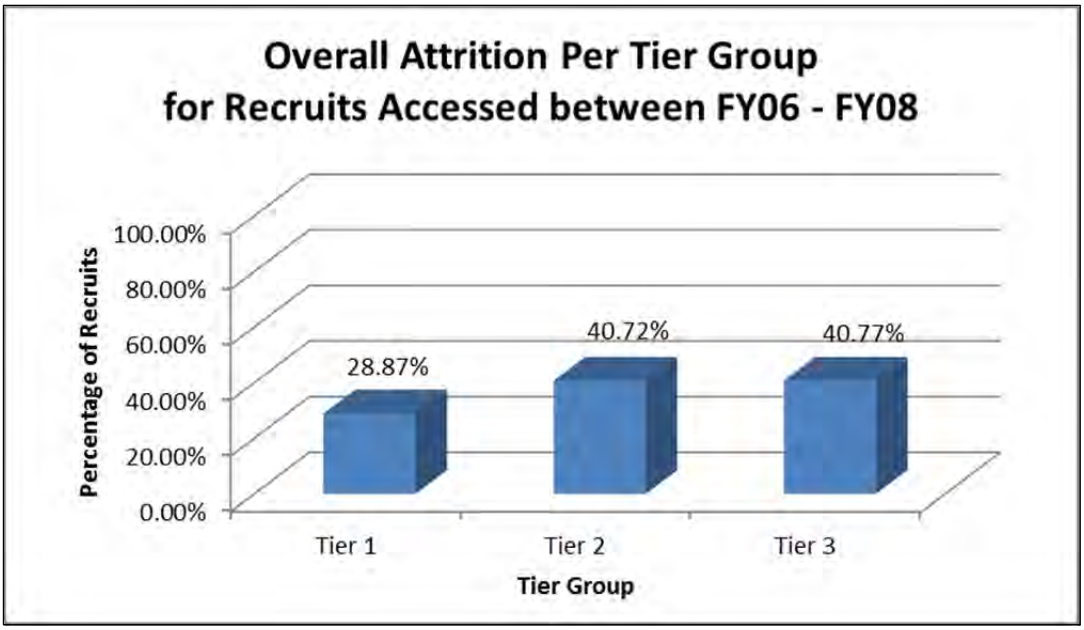

Figure 14. Attrition percentage per tier group from FY 2006–2008 data set. Tier 1 accessions have the lowest attrition rate, while Tier 2 and Tier 3 are comparable.

b. Attrition Percentage per Education Category

In order to examine attrition rates within the education categories, the training group was divided into five sections consisting of (1) traditional HSDGs; (2) GED certificate holders; (3) homeschool degree graduates; (4) alternative school graduates, including correspondence and occupational studies; and (5) college experience, for any individual who has completed at least one semester from an accredited post-secondary school. Since Tier 2 and 3 recruits must have an AFQT percentile score of at least 50 to be accessed, this section of the study only examined attritees who had a 50 or above AFQT score in each education category. The results showed those who had college experience before enlisting were least likely to attrite with an attrition rate of 23.14 percent (see Figure 15), while those with a GED certificate were most likely to attrite with an attrition rate of 42.98 percent. Those who graduated from a traditional high school did slightly better than those who were homeschooled, with HSDGs having an attrition rate of 27.60 percent and homeschool graduates having an attrition rate of 31.19

percent. Those who graduated from an Alternative School had an attrition rate of 36.94 percent, which was higher than those who were homeschooled, but lower than those with a GED certificate.

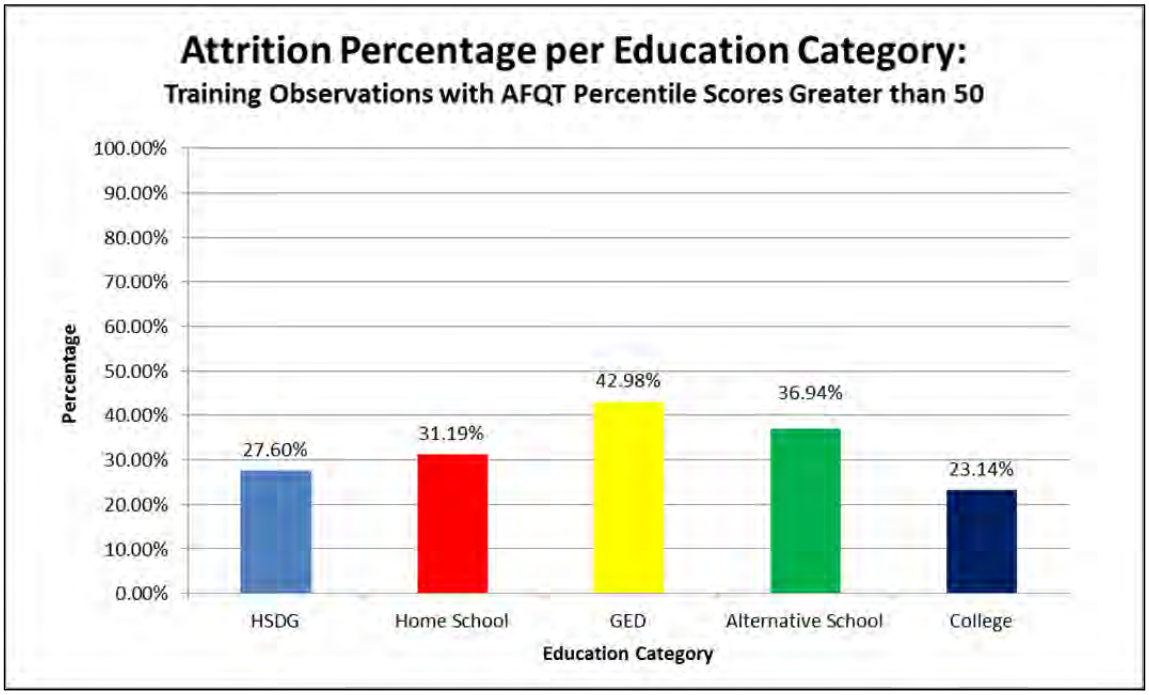

Figure 15. Attrition percentage per education category (with observation that have an AFQT percentile score above 50) based on FY 2006–2008 accessions.

c. Attrition Percentage by AFQT Category

To examine the attrition rates within the AFQT Categories, the categories were separated into five groups which are (1) Category, 1 consisting of all observations whose AFQT percentile score was greater than 92; (2) Category, 2 consisting of all observations whose AFQT percentile score was between 65 and 92; (3) Category 3A, consisting of all observations whose AFQT percentile score was between 50 and 64; (4) Category 3B, consisting of all observations whose AFQT percentile score was between 30 and 49; and (5) a group called "Other" which contained the remaining AFQT categories, consisting of all observations whose AFQT percentile score was below 30.

The training data indicated that the attrition rate increased as the AFQT percentile score a recruit had at time of accession decreased (see Figure 16). Observations within Category 1 had the lowest attrition rate at 21.64 percent, while those in Category 3B had the highest at 33.33 percent.

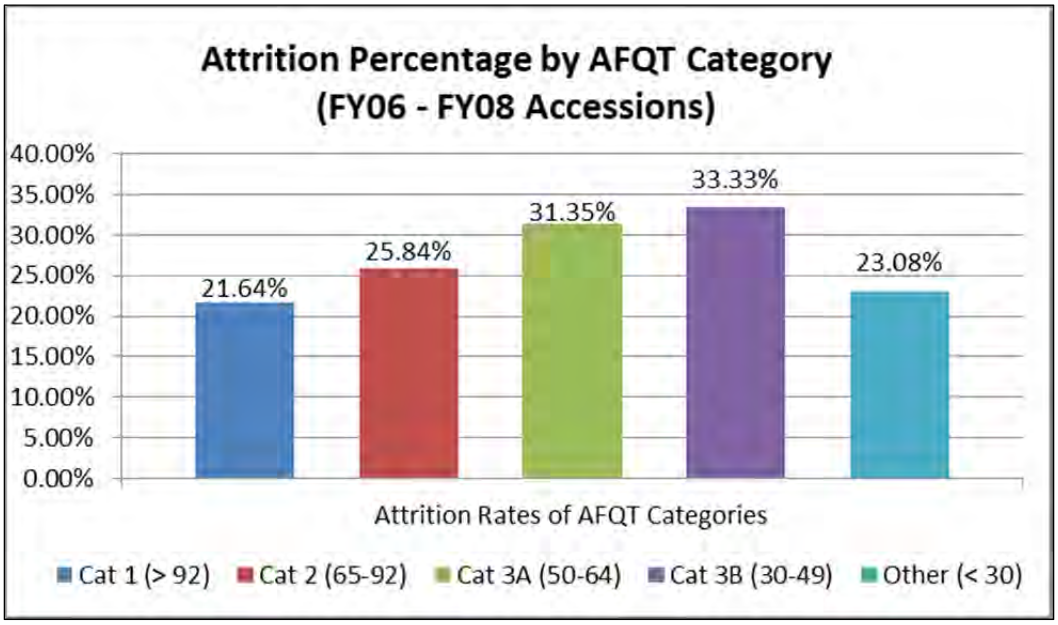

Figure 16. Attrition rate by AFQT category based on FY 2006–2008 accessions. Histogram indicates an increase in attrition as the AFQT category decreases.

The only exception within this trend was with the "Other" group whose attrition rate was slightly higher than Category 1, but less than Category 2. However, the observations within the "Other" group made up only 0.02 percent of the total observations in the training data set.

d. Attrition Percentage per Accession Age

Older recruits are less likely to attrite (see Figure 17). The age group with recruits who were 35 or older had the lowest attrition rate of 11.11 percent, while the youngest age groups of recruits with ages between 17 to 18 and 19 to 20 had the highest in the training group with approximately 31 percent. Possible reasons for this trend could be the

maturity level of older recruits, or a greater need for job employment and steady income for older recruits due to their age limiting their employment opportunities outside of the U.S. Navy.

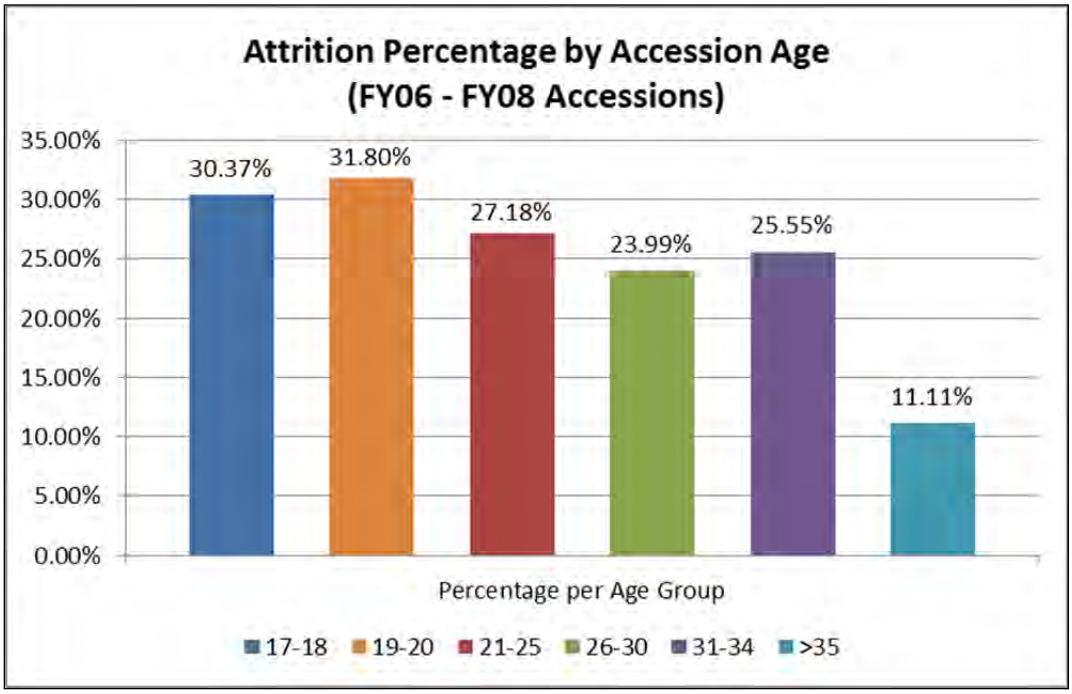

Figure 17. Attrition rates per accession age groups based on FY 2006–2008 accessions. Trend indicates lower attrition rates as the age group gets older.

e. Attrition Percentage by Gender

Within the training data, the female attrition rate was 35.28 percent and was significantly higher than the male 28.36 percent attrition rate (see Figure 18). Previous studies have found the same trend of women having a higher attrition rate, typically separating primarily due to pregnancy while men often attrite for adverse reasons. The studies further indicated if pregnancy cases were eliminated from the analysis the first-term attrition rate for men and women would be similar (Knapik, Jones, Hauret, Darakjy, and Piskato, 2004, p. 7). When the same process was applied to this study, women's attrition rate dropped from 35.28 percent to 32.91 percent but was still significantly higher than men's attrition rate.

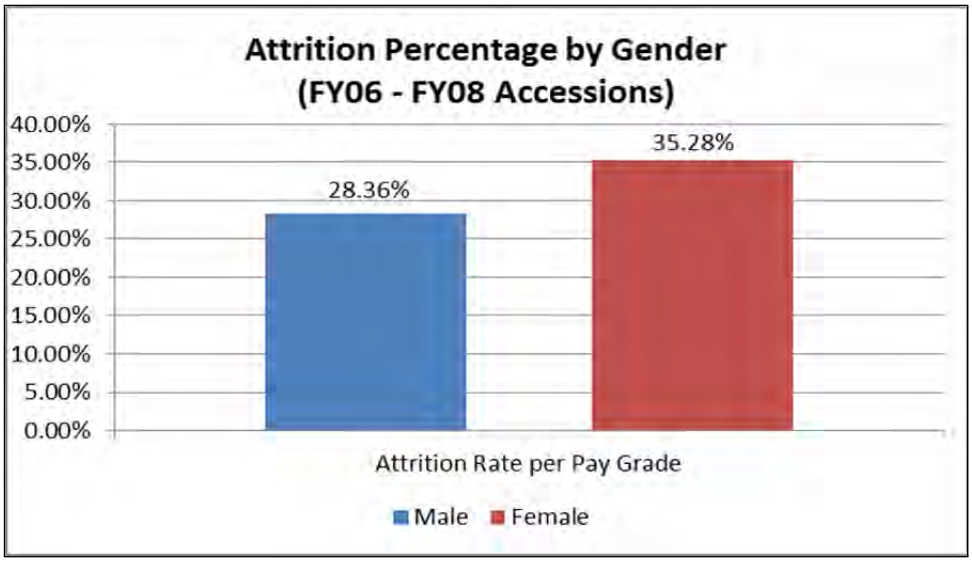

Figure 18. Attrition rates by gender based on FY 2006–2008 accessions. Histogram illustrates females having a higher attrition rate over males.

f. Attrition Percentage Per Accession Pay Grade

The accession pay grade variable in the training data illustrates a lower attrition rate as the pay grade a recruit enters active duty naval service increases (see Figure 19). Since first-time recruits can only enter service at pay grades E-1 through E-3, these were the only pay grades reviewed. Recruits having a pay grade of E-3 at time of accession had the lowest attrition rate at 22.34 percent. Those who entered at a pay grade of E-1 had the highest attrition rate at 32.68 percent.

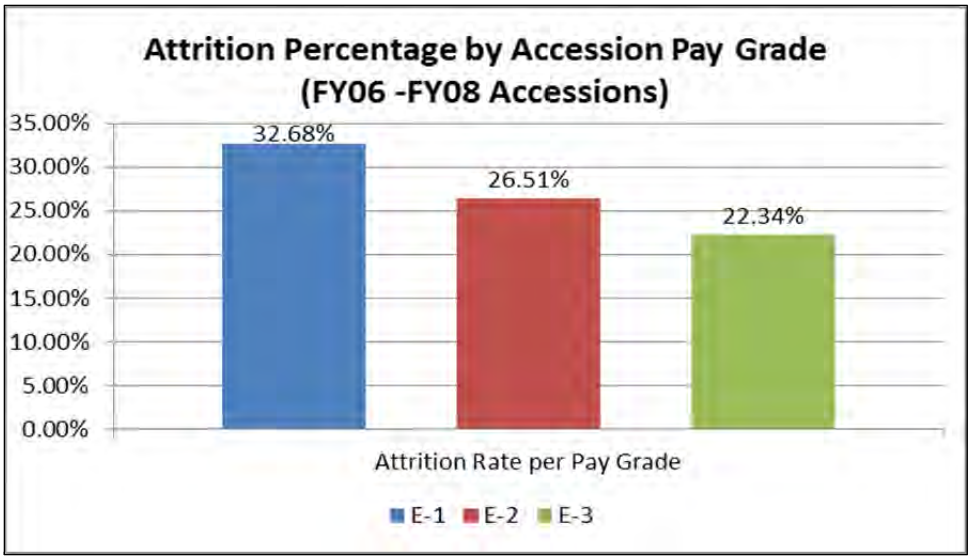

Figure 19. Attrition rates per accession pay grade based on FY 2006–2008 accessions. Figure indicates attrition rates drops as the accession pay grade increases.

g. Attrition Rates by Marital Status

Attrition rates found within the variable Marital Status were reviewed in three sections: Never Married, Married, and Other. The "Other" category consisted of observations that were recruited as divorced, legally separated, widowed or had their marriage annulled. Within the training data, those considered to be "Other" had the highest attrition rate of 36.21 percent (see Figure 20). Those who were married at time of accession had the lowest attrition rate at 25.76 percent.

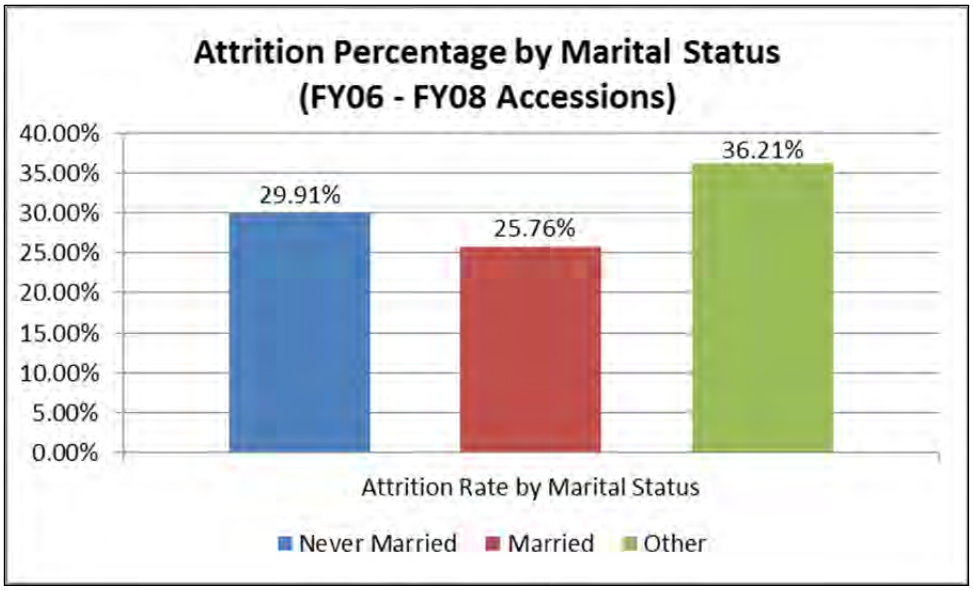

Figure 20. Attrition rates by marital status based on FY 2006–2008 accessions.

h. Attrition Rates by Number of Dependents

To assess the attrition rates of the recruits who had dependents at the time of enlistment, observations were divided into four groups which were (1) those who had no dependents; (2) those who had one dependent; (3) those who had between two dependents; and (4) those who had three or more dependents.

The group with the lowest attrition included those who had three or more dependents at the time of accession with 23.96 percent. The recruits enlisting with no dependents had the highest attrition rate at 29.87 percent (see Figure 21). The attrition rates do indicate a lower percentage as the number of dependents a recruit has increases.

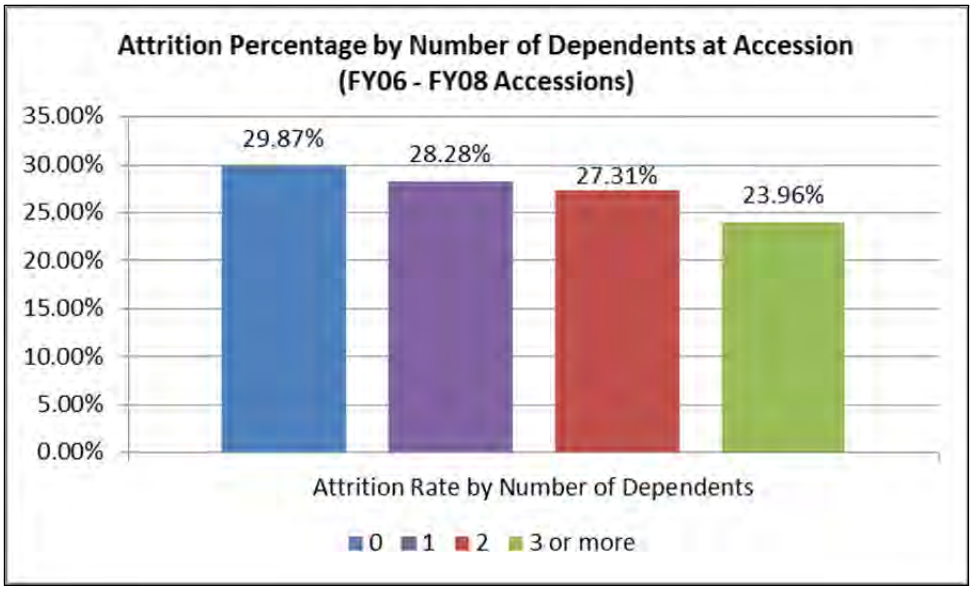

Figure 21. Attrition rate by number of dependents based on FY 2006–2008 accessions. Trend shows lower attrition rates for recruits who enlisted with dependents over those who did not.

2. FY 2009 Accessions (Test Set)

a. Overall Attrition

Out of the 35,363 initial observations, 16,273 active duty sailors had separated from service between the time they were recruited and present day. The same attrition rules that were applied to the FY 2006–2008 data were then applied to determine which recruits out of the 16,273 separations left service before their initial EAOS, making them first-term attritees.

After applying these rules, 10,432 observations within the FY 2009 data set were considered to be attritees. Tier 1 had the least amount of attritions consisting of 28.87 percent of all Tier 1 accessions during FY 2009 (see Figure 22). Tier 2 and 3 were identical with approximately a 41 percent attrition rate.

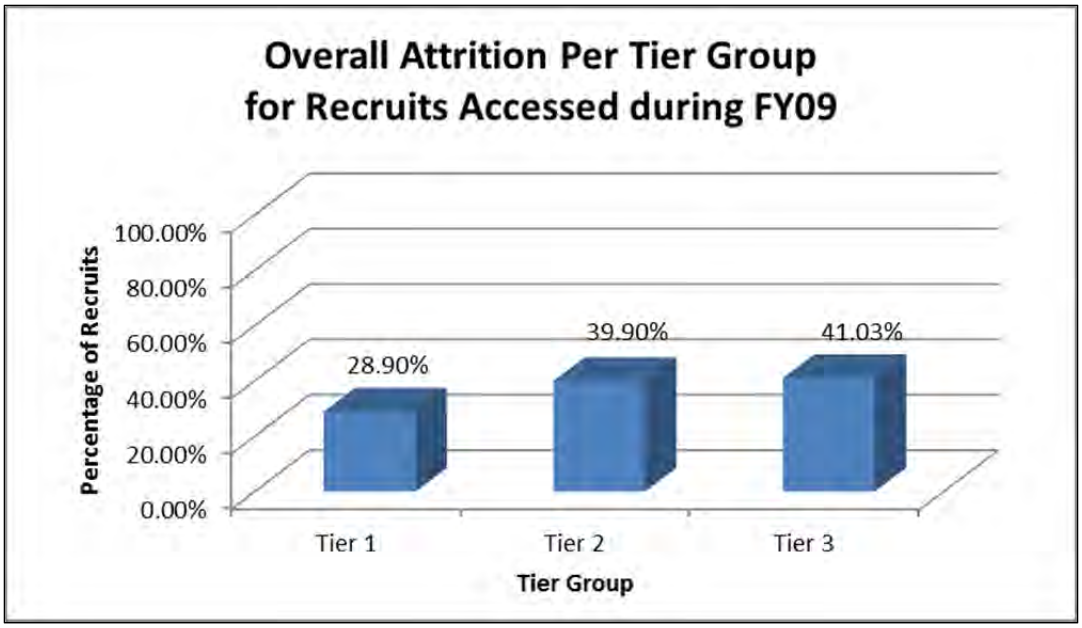

Figure 22. Attrition percentage per tier group based on FY 2009 accessions.

b. Attrition Percentage per Education Category

Like the FY 2006–2008 data set, the FY 2009 group was divided into the same 5 education categories of (1) traditional HSDGs; (2) GED certificate holders; (3) Homeschool Degree Graduates; (4) Alternative School graduates, to include Correspondence and Occupational Studies; and (5) College experience, for any individual who has completed at least one semester from an accredited post-secondary school.

The results found in the FY 2009 data set were similar to those in the FY 2006–2008 data set. Those who had college experience before enlisting were least likely to attrite with an attrition rate of 22.19 percent (see Figure 23), while those with a GED certificate were most likely to attrite with an attrition rate of 43.67 percent. Those who graduated from a traditional high school did slightly better than those who were homeschooled, with HSDGs having an attrition rate of 28.49 percent and homeschool graduates having an attrition rate of 33.33 percent. Those who graduated from an Alternative School had an attrition rate of 36.19 percent, which was higher than those who were homeschooled, but lower than those with a GED certificate.

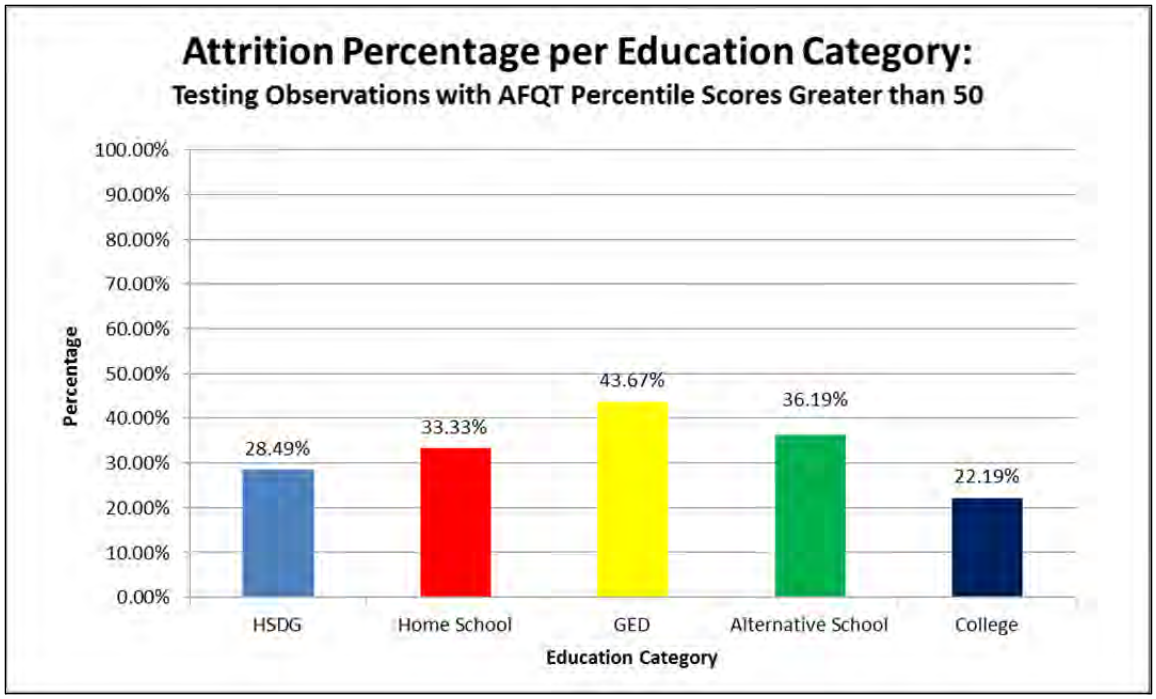

Figure 23. Attrition percentage per education category (with observations that have an AFQT percentile score above 50) based on FY 2009 accessions.

c. Attrition Percentage by AFQT Category

As with the FY 2006–2008 data set, the AFQT Categories in the FY 2009 data set were separated into five groups to examine attrition rates. These groups were (1) Category 1 consisting of all observations whose AFQT percentile score was greater than 92; (2) Category 2 consisting of all observations whose AFQT percentile score was between 65 and 92; (3) Category 3A consisting of all observations whose AFQT percentile score was between 50 and 64; (4) Category 3B consisting of all observations whose AFQT percentile score was between 30 and 49; and (5) a group called "Other" which contained the remaining AFQT categories consisting of all observations whose AFQT percentile score was below 30. Similar to the Training data, the Testing data indicated that the attrition rate increased as the AFQT percentile score a recruit had at time of accession decreased (see Figure 24). Observations within Category 1 had the lowest attrition rate at 22.56 percent, while those in Category 3B had the highest at 32.43 percent.

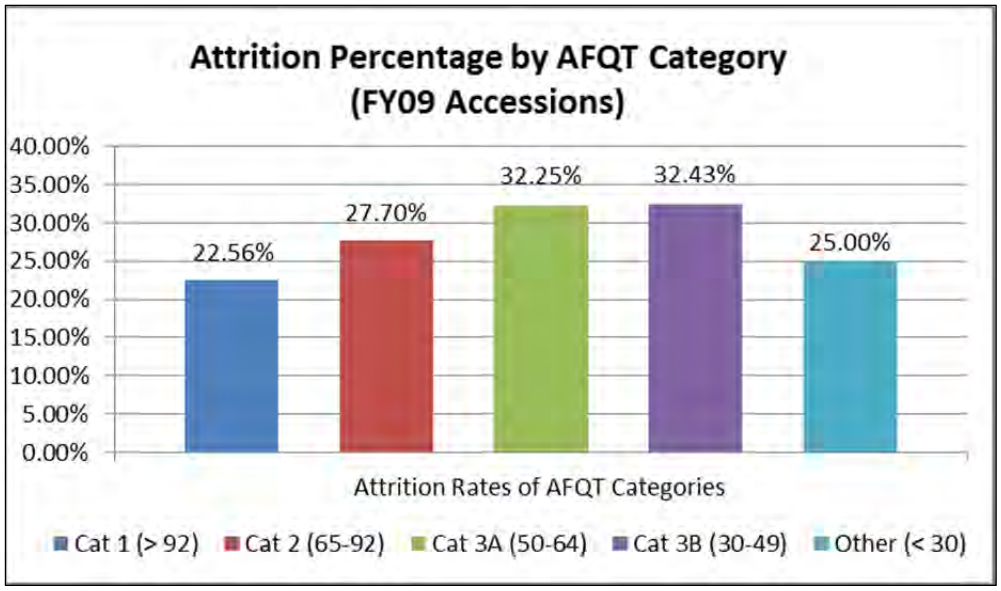

Figure 24. Attrition rate by AFQT category based on FY 2009 accessions. Histogram indicates an increase in attrition as the AFQT category decreases.

Also like the FY 2006–2008, the only exception within this trend was with the "Other" group whose attrition rate was slightly higher than Category 1, but less than Category 2. However, the observations within the "Other" group only made up 0.01 percent of the total observations in the FY 2009 data set.

d. Attrition Percentage by Age Group

The age group attrition rates within the FY 2009 data set were identical with the age group attrition rates in the FY 2006–2008 data set. The results indicated the attrition rates decrease with older recruit's (see Figure 25). The age group with recruits who were 35 or older had the lowest attrition rate of 9.09 percent, while the age groups of recruits with ages between 17 to 18 and 19 to 20 had the highest with approximately 31 percent. Again, this trend could be attributed to the maturity level of older recruits, or a greater need for job employment and steady income for older recruits due to their age limiting their employment opportunities outside of the U.S. Navy.

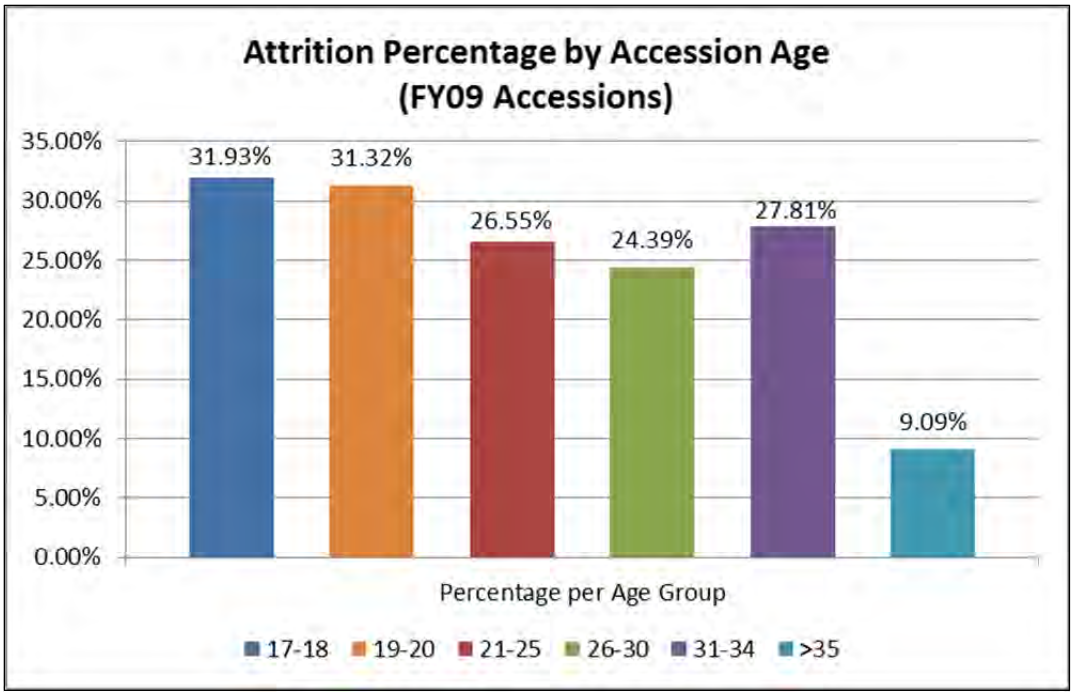

Figure 25. Attrition rate by age group based on FY 2009 accessions. Histogram indicates a downward trend with attrition as the age of the recruit increases. The only exception is those in the 31 to 34 age group which has the second highest attrition rate within the Testing data.

e. Attrition Percentage by Gender

The attrition rate by gender indicates a higher attrition percentage with women at 35.92 percent, with men's attrition rate at 27.80 percent (see Figure 26). This trend is similar to that found within the FY 2006–2008.

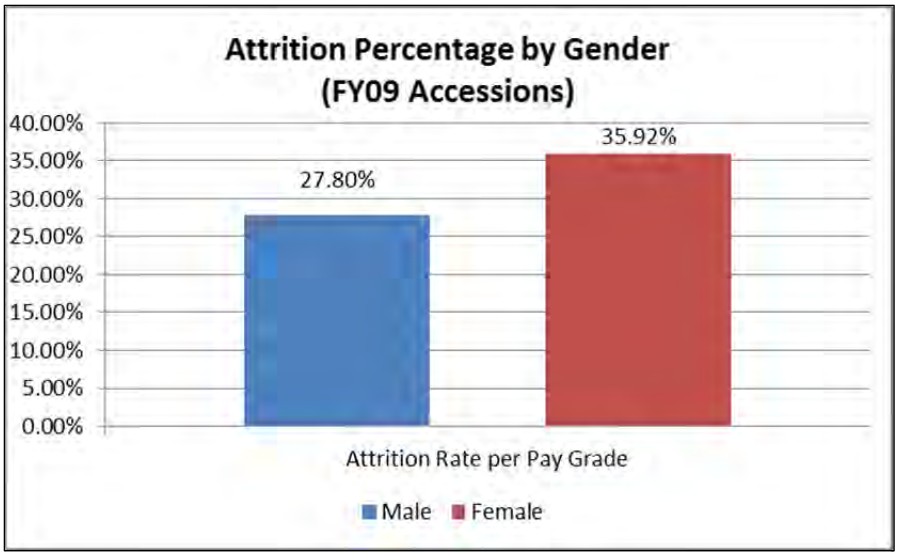

Figure 26. Attrition rate by gender based on FY 2009 accessions.

f. Attrition Percentage by Pay Grade

The accession pay grade variable in the FY 2009 illustrates a lower attrition rate as the pay grade a recruit enters active duty naval service increases (see Figure 27). Since first-time recruits can only enter service at pay grades E-1 through E-3, these were the only pay grades reviewed. The results were similar to those found within the Training set, with recruits having a pay grade of E-3 at time of accession having the lowest attrition rate at 23.01 percent. Those who entered at a pay grade of E-1 had the highest attrition rate at 32.47 percent.

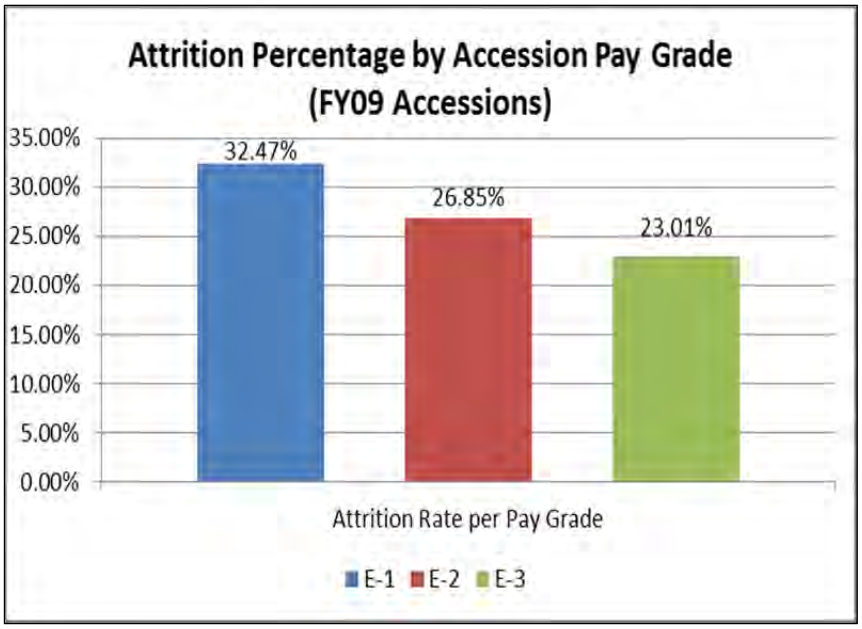

Figure 27. Attrition rate by pay grade based on FY 2009 accessions. Histogram shows downward trend in attrition as the pay grade a recruit enters service with increases.

g. Attrition Percentage by Marital Status

Attrition rates found within the variable Marital Status were reviewed in three sections: Never Married, Married, and Other. The "Other" category consisted of observations that were recruited as divorced, legally separated, had a marriage annulled, or widowed. Comparable with the FY 2006–2008 data, the marital status within the testing data found the category "Other" had the highest attrition rate at 34.95 percent (see Figure 28). Those who were married at time of accession had the lowest attrition rate at 24.61 percent.

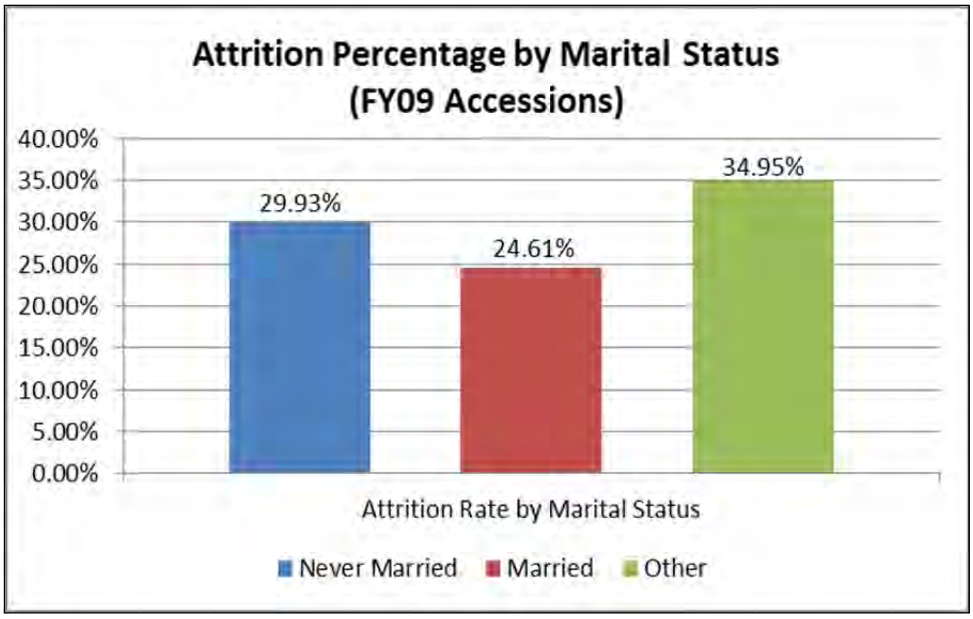

Figure 28. Attrition rate by marital status based on FY 2009 accessions.

h. Attrition Percentage by Number of Dependents

To assess the attrition rates of the recruits who had dependents at the time of enlistment, observations were divided into four groups which were (1) those who had no dependents; (2) those who had one dependent; (3) those who had two dependents; and (4) those who had three or more dependents.

The group with the lowest attrition was those who had two dependents at the time of accession at 24.57 percent (see Figure 29). The group with no dependents had the highest attrition rate at 29.8 percent.

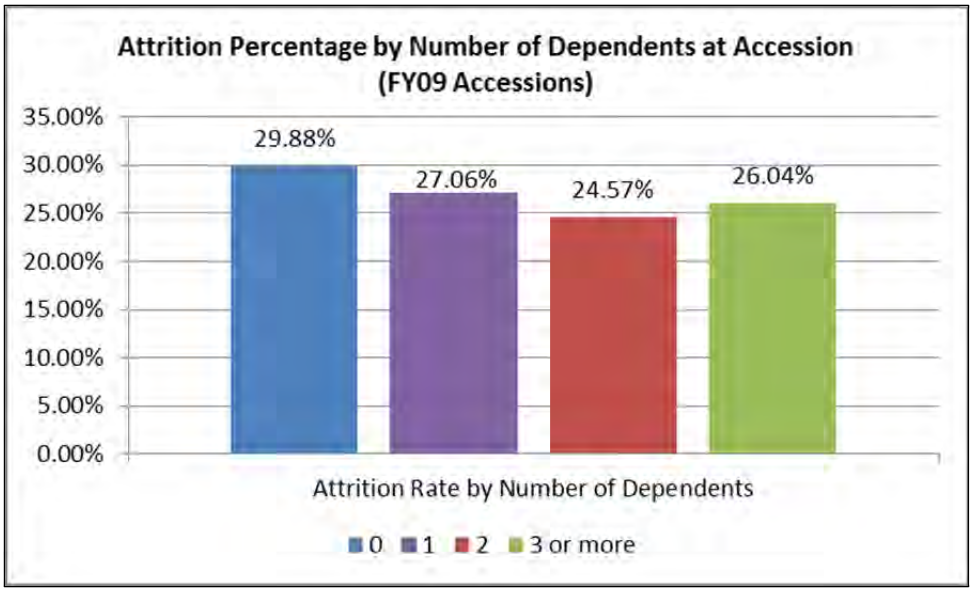

Figure 29. Attrition rate by number of dependents based on FY 2009 accessions. The group with 2 dependents had lower attrition rate.

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IV. ANALYSIS

A. INTRODUCTION

When developing regression models, the researcher must be mindful of which variable they use, and how they use them. Creating several different models that differ in methodologies and criteria for variable selection may result in models that fit equally well; however, the analyst must always be aware of the possibility of overfitting the model. An overfitting situation occurs when the analyst includes predictor variables which have very little, or no contribution to the predictive power of the model. Injecting "noise" into the model, overfitting decreases the predictive power of a model by eliminating the ability of a model to accurately identify the relationship between the legitimate predictor variables and the response variable.

This study took a number steps to ensure overfitting did not occur. First, we used a sequence of likelihood ratio tests (LRTs) to select which variables and interactions could be removed, and which could be retained. The LRT calculates a p-value that determines whether the null hypothesis model (the smaller of the two models being compared) is rejected or not. If the null hypothesis is rejected, the alternative hypothesis would then be accepted, indicating that the extra variables should be included in the model. The null probability distribution of the likelihood ratio test statistic is approximately a chi-squared distribution. Second, we reserved a randomly selected 20 percent test set from the data used to fit the model. This test set provides unbiased estimates of prediction error. If overfitting occurs than the test set error will be substantially larger than that of the training set. Further, because there are underlying changes in Navy policy, economic conditions and other events overtime, we only used FY 2006–2008 accessions for model building (with an 80:20 split for training and test sets). The FY 2009 accessions were reserved and used as a further test set to see how well these models built on prior years' data will forecast FY 2009 first-term attritions. For this study, all statistical results and graphs were created using the R program, version 2.15.2 (R Core Team, 2012).

B. FY 2006–2008 DATA

To begin this analysis, models were built using the FY 2006–2008 data set containing 108,754 recruits. To ensure data accuracy, a training and test set were created, where the training set accounted for a randomly selected 80 percent of the FY 2006–2008 data set. The test set included the remaining 20 percent.

1. Evaluation of the First Logistic Regression Model

The first model fit in this study was a baseline logistic regression model additive in all the variables discussed in Chapter III. To avoid confusion, it will be referred to as the "additive model" for the remainder of the study. All predictor variables in this model are categorical, which means each category of the variable is treated as a binary variable in of itself. These categorical binary variables take a value of 1 or 0 depending on whether the observation is represented within the category. For each categorical variable, one of the categorical binary variables (the baseline category) is left out of the model fit. Table 6 list all categorical predictor variables used in this logistic regression model, the baseline category, and the remaining categorical binary variables represented within the model.

Table 6. Predictor variables used in the first logistic regression model.

Predictor Variable	Base Line Category	Categories within Model
Age	17–18	19-20 / 21-25 / 26-30 / 31-36
Gender	Female	Male
Marital Status	Married	Never Married / Other
AFQT Category	1	2 / 3A / 3B / Other
Pay Grade	E-1	E-2 / E-3
Education Category	>H.S.	Alternate H.S. / College / GED / Homeschool / HSDG / Missing
Number of Dependents	0	1 / 2 / 3 or more

The results shown in Figure 30 illustrate the "Estimate" of the coefficients for each corresponding predictor variable, and the "Pr(>|z|)" value, or the p-value associated with each predictor variable. If a variable has a p-value of 0.05 or less, that is an indication the variable should be used within the additive model. All predictor variables have categories with p-values below 0.05 with the exception of "Number of Dependents."

```
glm(formula = Outcome ~ Age + Gender + Marital + AFQTCat + Pay +
 Ed + Dep, family = binomial, data = ltraining)

Deviance Residuals:
 Min 1Q Median 3Q Max
-1.9668 -1.3890 0.7873 0.8784 1.4169

Coefficients:
  Estimate Std. Error z value Pr(>|z|)
(Intercept) 0.35207 0.09296 3.787 0.000152 ***
Age19+ -0.05287 0.01803 -2.932 0.003371 **
Age21+ 0.03499 0.02111 1.657 0.097441 .
Age26+ 0.06953 0.04129 1.684 0.092230 .
Age31+ -0.06965 0.07107 -0.980 0.327095
GenderM 0.35630 0.01875 19.000 < 2e-16 ***
MaritalN -0.15258 0.06073 -2.513 0.011985 *
MaritalOther -0.50004 0.10277 -4.866 1.14e-06 ***
AFQTCat2 -0.15403 0.03455 -4.458 8.26e-06 ***
AFQTCat3A -0.22796 0.03601 -6.331 2.44e-10 ***
AFQTCat3B -0.35491 0.03603 -9.851 < 2e-16 ***
AFQTCatOther 0.20003 0.18391 1.088 0.276741
PayE02 0.25911 0.02712 9.555 < 2e-16 ***
PayE03 0.37708 0.02105 17.918 < 2e-16 ***
EdAlt HS 0.10107 0.08274 1.222 0.221868
EdColl 0.43782 0.06852 6.390 1.66e-10 ***
EdGED -0.13296 0.06914 -1.923 0.054477 .
EdHome 0.30753 0.15164 2.028 0.042558 *
EdHSDG 0.47827 0.05942 8.049 8.32e-16 ***
EdMissing 0.17156 0.13458 1.275 0.202397
Dep1+ -0.05516 0.05325 -1.036 0.300224
Dep2+ -0.04262 0.07217 -0.591 0.554790
Dep3+ -0.06299 0.09813 -0.642 0.520918
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

 Null deviance: 105441 on 85221 degrees of freedom
Residual deviance: 103800 on 85199 degrees of freedom
AIC: 103846

Number of Fisher Scoring iterations: 4
```

Figure 30. Summary results of the additive model.

LRTs for the categorical variable confirm the impression of Figure 30. All of the categorical variables, with the exception of "Number of Dependents," contribute to the additive model. Using the results shown in Figure 30, a recruit's probability of successfully completing his or her first-term enlistment is estimated as:

$$\hat{\pi}(X) = \frac{\exp(\hat{\eta})}{1+\exp(\hat{\eta})},$$

where the estimated linear predictor is given by:

$$\begin{aligned}\hat{\eta} = {} & 0.35207 - 0.05287x_{Age19+} + 0.03499x_{Age21+} + 0.06953x_{Age26+} - 0.06965x_{Age31+} \\ & +0.35630x_{GenderM} - 0.15258x_{MaritalN} - 0.50004x_{MaritalOther} - 0.15403x_{AFQTCat2} \\ & -0.22796x_{AFQTCat3A} - 0.35491x_{AFQTCat3B} + 0.20003x_{AFQTCatOther} + 0.25911x_{PayE02} \\ & +0.37708x_{PayE03} + 0.10107x_{EdAltHS} + 0.43782x_{EdColl} - 0.13296x_{EdGED} \\ & +0.30753x_{EdHome} + 0.47827x_{EdHSDG} + 0.17156x_{EdMissing} - 0.05516x_{Dep1+} \\ & -0.04262x_{Dep2+} - 0.06299x_{Dep3+},\end{aligned}$$

with *x*'s representing the predictor variables indicated in subscripts. Figures 31 through 36 illustrate the partial effect of each predictor variable on the estimated linear predictor, which are comparable to the attrition rates explained for each variable in Chapter III. The variable "Number of Dependents" is not shown because (with p-values > 0.5) there was no evidence that it was needed in the presence of the other predictor variables.

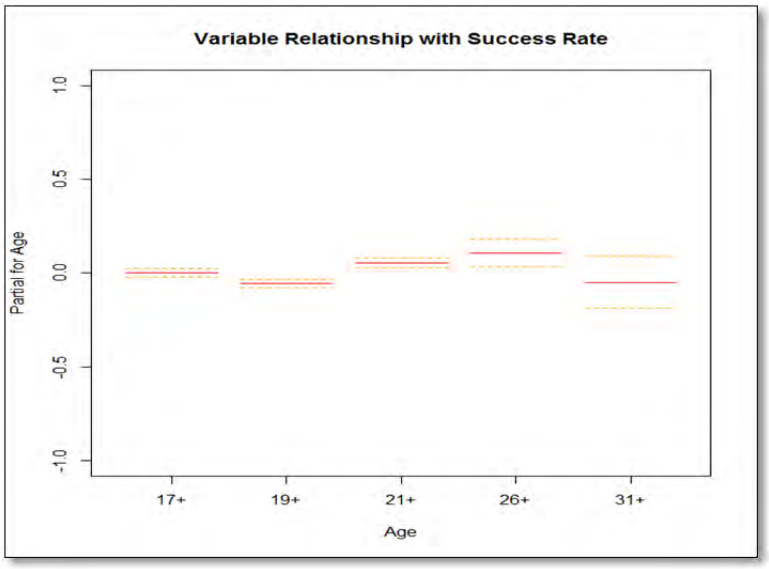

Figure 31. The partial effect of age on success rate (on the scale of log-odds of the success rate). Recruits who are age 19 to 20 have the lowest probability of success. The probability of success then increases with age. Recruits who are age 31 and up may also have a negative impact on the estimated success rate, but the large standard error makes it difficult to conclude this.

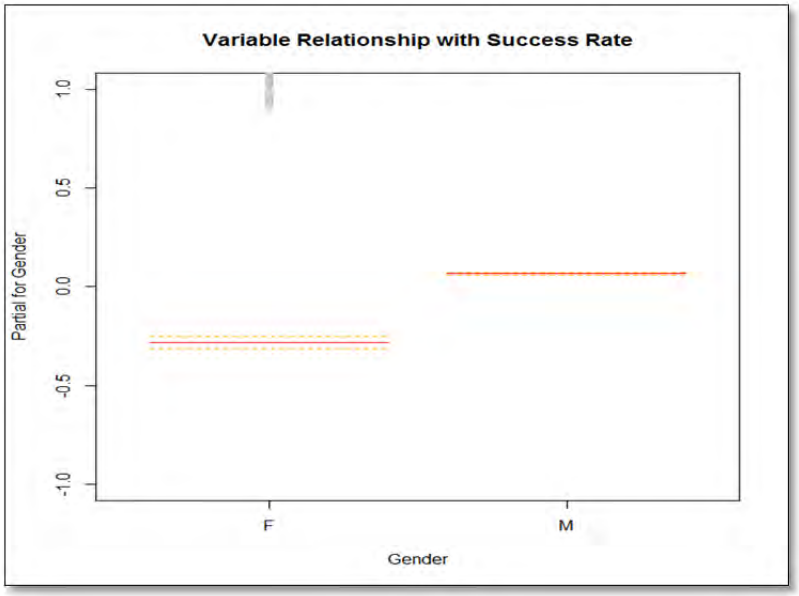

Figure 32. The partial effect of gender on success rate (on the scale of log-odds of the success rate). Females have the lowest probability of success when compared to males.

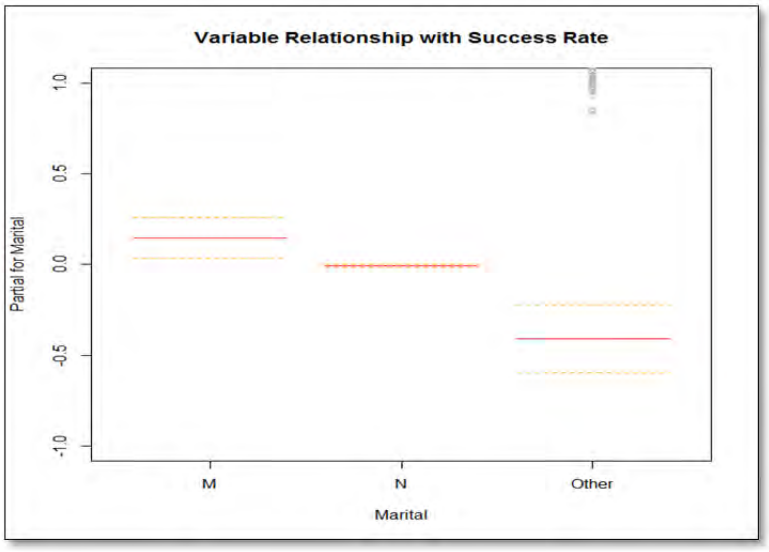

Figure 33. The partial effect of marital status on success rate (on the scale of log-odds of the success rate). Recruits who were in the "Other" category (Divorced, Widowed, Legally Separated, or had a Marriage Annulment) had a lower probability of success. Recruits who were married at the time of accession had a higher probability of success.

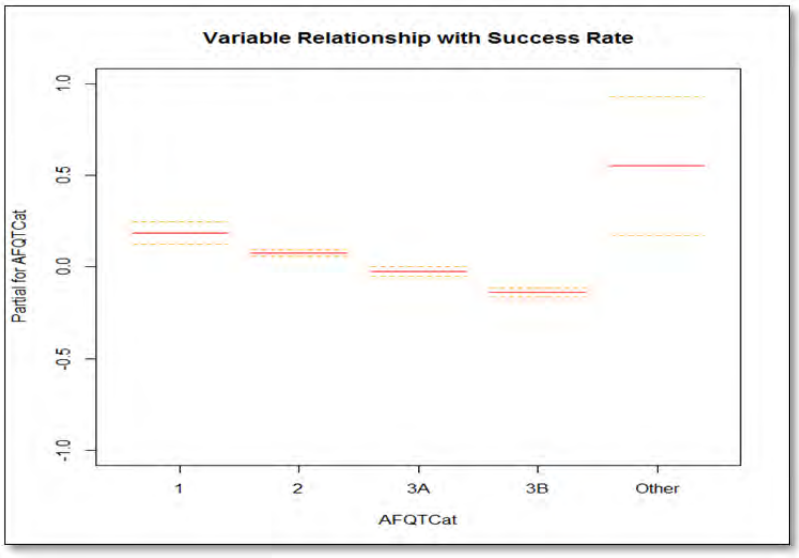

Figure 34. The partial effect of AFQT category on success rate (on the scale of log-odds of the success rate). Not accounting for recruits who fall below an AFQT percentile score of 30 (Other), recruits who fall into the AFQT category 3A had a higher probability of success. Recruits who were in the AFQT category 2 had the lowest probability of success.

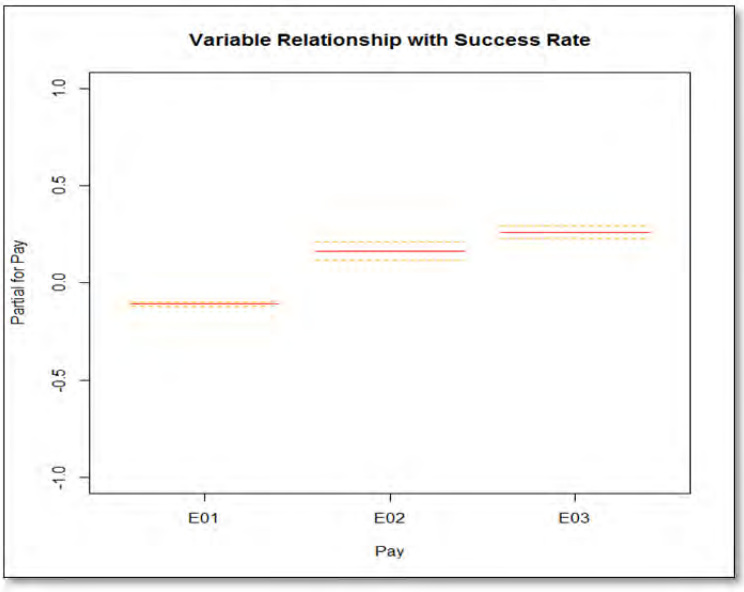

Figure 35. The partial effect of pay grade on success rate (on the scale of log-odds of the success rate). Recruits who were accessed as an E-3 had a higher probability of success over those who were accessed as E-1 or E-2. The probability of success decreases as the pay grade decreases.

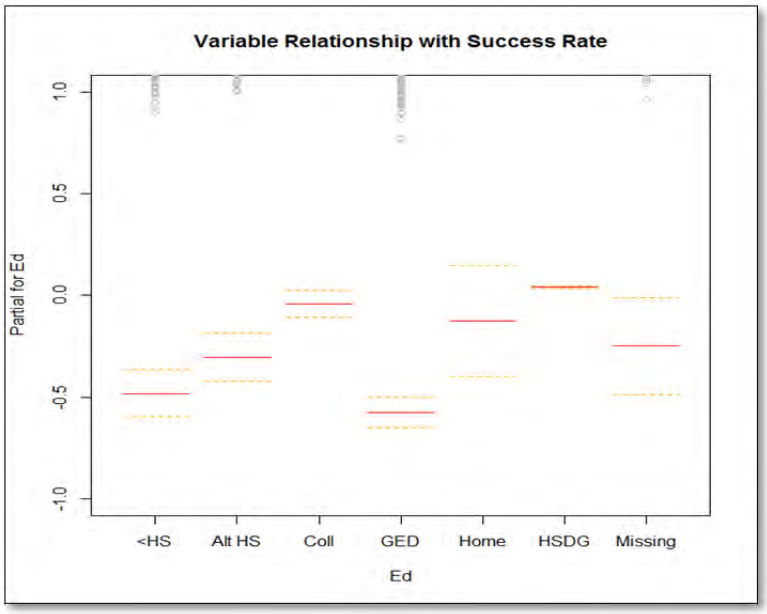

Figure 36. The partial effect of education category on success rate (on the scale of log-odds of the success rate). Recruits with a GED had the lowest probability of success, while those who were HSDGs had the highest probability of success.

2. Adding Interactions to First Logistic Regression Model

The next step in this analysis determined if there were any interactions that should be included to determine a recruit's success rate. This was simply done by building a model with each predictor variable interacting with all of the others. Only two-way interactions were considered. This created twenty-one additional variables which were added to the original model.

A LRT of the additive model against the alternative model with all two-way interactions gives a p-value well below 0.05 (see Figure 37). This gives strong evidence that at least one of the interaction terms is needed in the model.

```
Model 1: Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep
Model 2: Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep +
 Age:Gender + Age:Marital + Age:AFQTCat + Age:Pay + Age:Ed +
 Age:Dep + Gender:Marital + Gender:AFQTCat + Gender:Pay +
 Gender:Ed + Gender:Dep + Marital:AFQTCat + Marital:Pay +
 Marital:Ed + Marital:Dep + AFQTCat:Pay + AFQTCat:Ed + AFQTCat:Dep +
 Pay:Ed + Pay:Dep + Ed:Dep
 Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1 85199 103800
2 85003 103365 196 434.58 < 2.2e-16 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 37. LRT of the additive model against the model with all interactions. The p-value, indicated by "Pr(>Chi)" value, is less than 0.05. The test suggests at least one of the interaction have statistical significance in determining the recruit's probability of success.

To determine which interactions are needed in the model, we used backwards elimination until each variable had a "Pr(>Chi)," or p-value, above 0.05, where the p-value is from the LRT to see whether the corresponding variables should be in the model in the presence of the rest of the variables. The remaining interactions are reflected in Figure 38. This logistic regression model is referred to as the "final model" for the remainder of the study. We note that "Number of Dependents" is included in this final model even though it did not seem to be required in the additive model.

```
Model:
Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep +
 AFQTCat:Ed + Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep +
 Gender:Marital + AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
  Df Deviance AIC LRT Pr(>Chi)
<none>  103441 103729
AFQTCat:Ed 22 103490 103734 48.740 0.0008656 ***
Gender:AFQTCat 4 103460 103740 19.175 0.0007262 ***
Age:Pay  8 103476 103748 35.001 2.673e-05 ***
Age:Ed  23 103509 103751 67.247 3.211e-06 ***
Age:Dep 12 103477 103741 35.903 0.0003358 ***
Gender:Marital 2 103459 103743 17.681 0.0001448 ***
AFQTCat:Pay 8 103462 103734 20.753 0.0078324 **
Marital:Ed 12 103464 103728 22.231 0.0350143 *
Pay:Ed  12 103484 103748 42.831 2.412e-05 ***
Ed:Dep  18 103475 103727 33.513 0.0144559 *
```

Figure 38. Backwards elimination results. Interactions that had significant impact on a recruit successfully completing first-term enlistment.

We also tested the final model against the additive model. The LRT gives a p-value less than 0.05 and rejects the null hypothesis that the two models are equally good (see Figure 39).

```
Model 1: Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep
Model 2: Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep +
 AFQTCat:Ed + Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep +
 Gender:Marital + AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
 Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1 85977 104764
2 85856 104400 121 363.59 < 2.2e-16 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 39. LRT of the additive model against the final model. The p-value is less than 0.05. The test suggests as least one of the interactions have statistical significance in determining the recruit’s probability of success.

With large numbers of observations, it often happens that coefficients are “statistically significant,” but not practically different than zero. For example, the hypothesis tests may indicate that the extra interactions terms are needed, but adding the interactions does nothing to change the number of recruits who will be predicted to be successful or attrite. A receiver operating characteristic (ROC) curve was plotted to

further determine if the final model and the additive model differ when it comes to prediction. The ROC curve plot displays the performance of a binary model plotting the fraction of true positives out of the total actual positives (*x*-axis) vs. the fraction of false positives out of the total actual negatives (*y*-axis). Here, a "positive" means that the recruit successfully completed his or her first-term enlistment. A recruit is predicted to be positive if his predicted probability of success is greater than a threshold, and predicted negative otherwise. The accuracy of each model compared is measured by the area under the ROC curve. The plot illustrating ROC curves for both the additive model and the final model conclude the final model is a bit more accurate when predicting a recruit's success at completing his or her first-term enlistment (see Figure 40) but not by much.

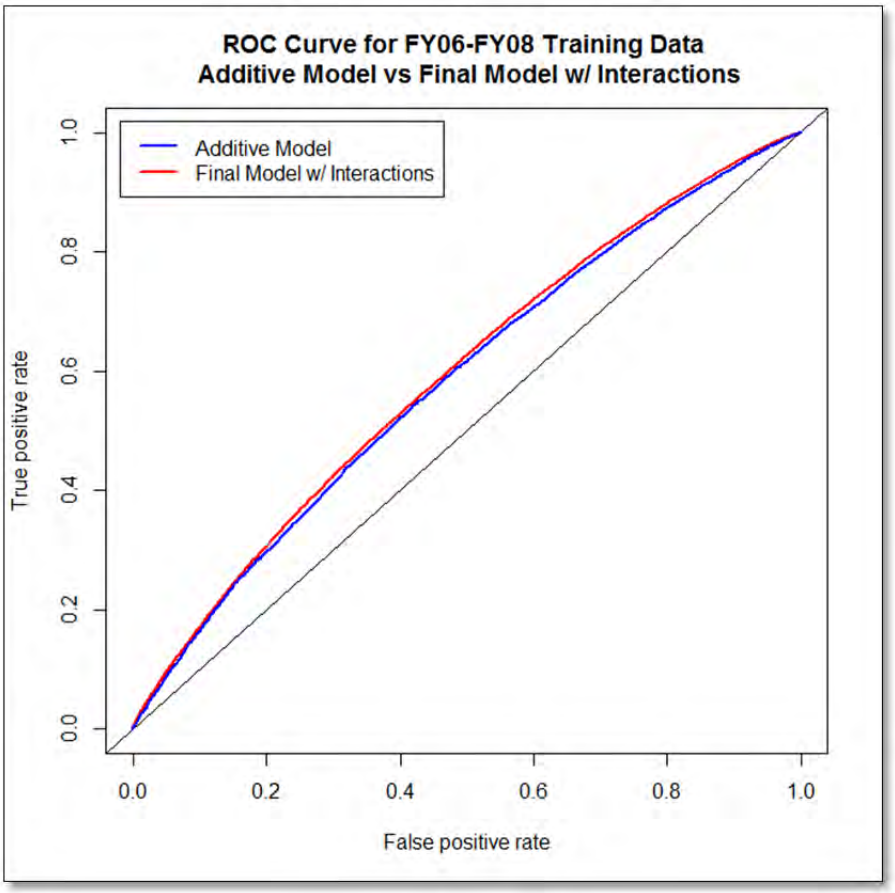

Figure 40. ROC curve plot displaying roc curves for the additive model and final model. The plot concludes the Final Model has slightly more accuracy in predicting first-term success.

3. Adding Variables Not Included in the Initial Study

There were a few key variables constructed from fields in the MEPCOM master file that were not included in the initial modeling efforts. These included:

(1) Waiver: A categorical variable indicating whether a recruit needed at least one accession waiver to be recruited. This variable included the categories of "Y" for yes, or "N" for no. Medical waivers are not accounted for in this variable

(2) Jobs: A categorical variable indicating which rating specialty the recruit entered the U.S. Navy with. This variable is categorized into either "Airman," "Fireman," "Seaman," or "Other."

(3) BMI: A categorical variable indicating the recruit's Body Mass Index at time of accession. This variable is categorized into either "0+," representing all recruits with a BMI between 0 and 24; "25+," representing all recruits with a BMI between 25 and 29; and "30+," representing all recruits with a BMI of 30 or more. The equation used to calculate the recruits BMI is:

$$\frac{703*(\text{Recruit's Accession Weight})}{(\text{Recruit's Accession Height})^2}.$$

Furthermore, the variable "AFQT Percentile Score" were only included in the final model as a categorical variable and not as a numeric variable (see Table 6).

A combination of generalized additive model fitting and LRTs were used to see if the final model could be improved by adding the variables "Waiver," "Jobs," "BMI" and "AFQT Percentile Score" to the final model without overfitting. At least one of the four variables included did have a statistical significance in predicting a recruit's success (see Figure 41).

```
Model 1: Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed +
Dep +
 AFQTCat:Ed + Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep +
 Gender:Marital + AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
Model 2: Outcome ~ I(AFQT * (AFQT > 0)) + Waiver + Jobs + BMI +
Age +
 Gender + Marital + AFQTCat + Pay + Ed + Dep + AFQTCat:Ed +
 Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep + Gender:Marital +
 AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
 Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1 85856 104400
2 85849 104291 7 109.26 < 2.2e-16 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ‘ 1
```

Figure 41. ANOVA test between the final model and the final model with added variables. Test concludes there are at least two of the four added variables with statistical significance.

Backwards elimination confirmed that all added variables have a statistical significance in the model (see Figure 42). This model is referred to as the “final model with added variables” for the remainder of the study. Figures 43 through 46 illustrate the partial effect of each of the variables on the estimated linear predictor. Of interest is that the numeric predictor AFQT percentile is important and contributes to the linear predictor statistically even in the presence of the four level categorical AFQT predictor.

```
Outcome ~ Age + Gender + Marital + AFQTCat + Pay + Ed + Dep +
 I(AFQT * (AFQT > 0)) + Waiver + BMI + Jobs + AFQTCat:Ed +
 Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep + Gender:Marital +
 AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
   Df Deviance AIC LRT Pr(>Chi)
<none>   103308 103610
I(AFQT * (AFQT > 0)) 1 103348 103648 39.607 3.106e-10 ***
Waiver  1 103331 103631 22.950 1.662e-06 ***
BMI   2 103345 103643 37.069 8.922e-09 ***
Jobs   3 103345 103641 36.193 6.818e-08 ***
AFQTCat:Ed  22 103355 103613 46.152 0.0018905 **
Gender:AFQTCat 4 103327 103621 18.721 0.0008916 ***
Age:Pay  8 103342 103628 33.620 4.759e-05 ***
Age:Ed  23 103374 103630 65.637 5.626e-06 ***
Age:Dep  12 103344 103622 35.102 0.0004511 ***
Gender:Marital 2 103328 103626 19.165 6.891e-05 ***
AFQTCat:Pay  8 103329 103615 20.305 0.0092413 **
Marital:Ed  12 103331 103609 22.364 0.0336402 *
Pay:Ed  12 103350 103628 41.353 4.277e-05 ***
Ed:Dep  18 103342 103608 33.586 0.0141603 *
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 42. Backwards elimination results. Results indicate the added variables of “Waiver,” “BMI,” “Jobs,” and “AFQT Percentile Score” have statistical significance.

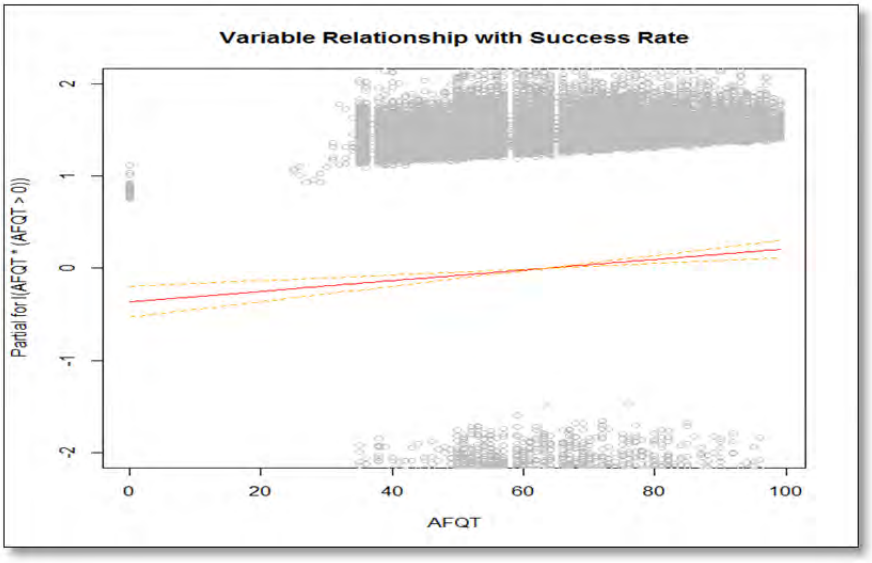

Figure 43. The partial effect of AFQT percentile on success rate (on the scale of log-odds of the success rate). The results are linear indicating a lower probability of success as the recruit’s AFQT Scores go from 0 to 99.

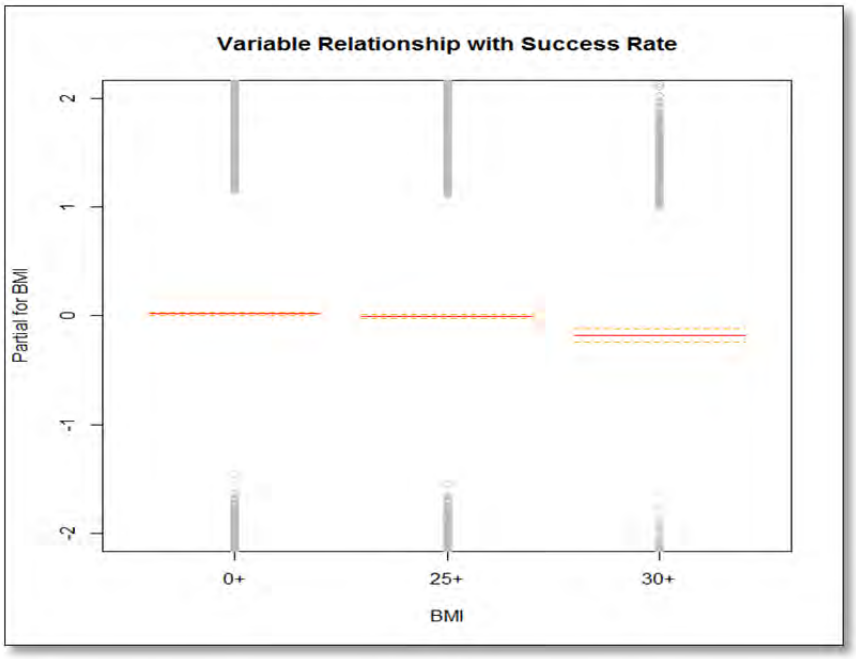

Figure 44. The partial effect of BMI on success rate (on the scale of log-odds of the success rate). The results indicate recruits who enter with a BMI at 30 or above have a lower probability of success.

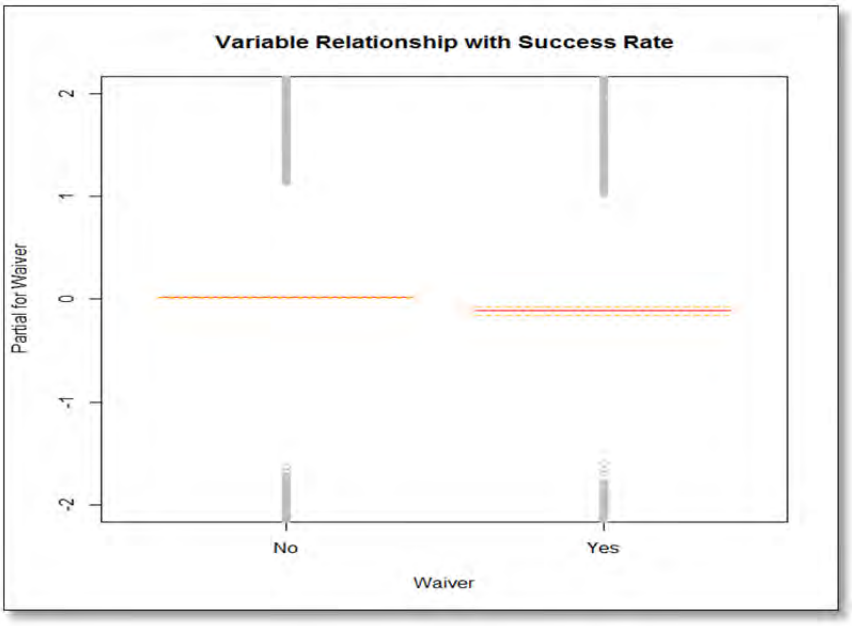

Figure 45. The partial effect of accession wavier on success rate (on the scale of log-odds of the success rate). The results indicate recruits who enter the U.S. Navy with an accession waiver have a lower probability of success than those who did not.

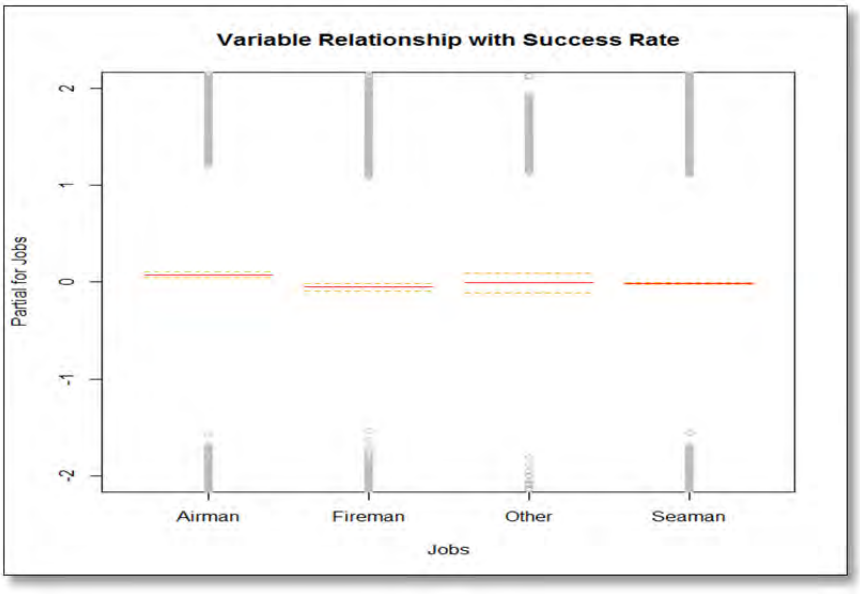

Figure 46. The partial effect of accession employment jobs on success rate (on the scale of log-odds of the success rate). The plot indicates recruits entering naval service under one of the "Fireman" rates have a slightly lower probability of success than recruits in the other rates.

4. Navy Recruit Quality Matrix Model

With a logistic regression model capable of predicting a U.S. Navy recruit's probability of success in completing his or her first-term enlistment, another model was built using the elements of the Navy Recruit Quality Matrix. A variable "Matrix" was created that consisted of four categories. Three of these categories represent the "A," "B," and "Cu" cells embodied in the Navy Recruit Quality Matrix. Category "A" included all recruits whose AFQT percentile score was 50 or above and was classified as Tier 1 applicants; category "Cu" included recruits whose AFQT percentile was below 50 and was classified as Tier 1 applicants; and category "B" included all recruits who were classified as Tier 2 or 3 applicants. The fourth category labeled "Missing" represents the recruits who did not have data supporting their AFQT score or their Tier classification. The proportion of recruits in each category is 66.5 percent, 6.6 percent, 26.5 percent, and 0.4 percent respectively for categories "A," "B," "Cu," and "Missing." The logistic regression summarized in Figure 47 yields these proportions as the estimated probability

of success. Category "A" was used as the baseline category in the model. This logistic regression model is referred to as the "matrix model" for the remainder of the study.

```
glm(formula = Outcome ~ factor(Matrix), family = binomial, data =
ltraining
Deviance Residuals:
 Min 1Q Median 3Q Max
-1.5845 -1.4651 0.8191 0.8191 1.0494

Coefficients:
   Estimate Std. Error z value Pr(>|z|)
(Intercept)  0.919878 0.009261 99.329 < 2e-16 ***
factor(Matrix)B -0.611026 0.028395 -21.519 < 2e-16 ***
factor(Matrix)Cu -0.265069 0.016758 -15.818 < 2e-16 ***
factor(Matrix)Missing -0.350110 0.118595 -2.952 0.00316 **
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 47. Summary results for the matrix model. Illustrates all categories have statistical significance in predicting a recruits probability of successfully completing their first-term enlistment.

A LRT compared the matrix model and final model with added variables. The test gives a p-value well below 0.05 (see Figure 48). Therefore the null hypothesis is rejected and we conclude that at least one of the extra variables within the final model with variables has statistical significance in determining a recruit's probability of success.

```
Model 1: Outcome ~ factor(Matrix)
Model 2: Outcome ~ I(AFQT * (AFQT > 0)) + Waiver + Jobs + BMI + Age +
 Gender + Marital + AFQTCat + Pay + Ed + Dep + AFQTCat:Ed +
 Gender:AFQTCat + Age:Pay + Age:Ed + Age:Dep + Gender:Marital +
 AFQTCat:Pay + Marital:Ed + Pay:Ed + Ed:Dep
 Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1 85996 105811
2 85849 104291 147 1519.8 < 2.2e-16 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 48. ANOVA test between the matrix model and final model with added variables. P-value concludes the Final Model has variables that have a more statistical significance in determining a recruit's probability of successfully completing a first-term enlistment.

Figure 49 illustrates the differences in the estimated probabilities of success between the final model with added variables and the matrix model. The plot indicates

the proportion of success based on the matrix model (plotted in red) is very close to the median estimated probability of success based on the final model with added variables. The variables in the more complex model yield a wider range of estimated probabilities of success. Unlike the matrix model, many of these estimated probabilities take values less than 0.5. This suggests that some individual characteristics recorded during MEPS may help suggest some recruits who are at greater risk of first-term attrition than most other recruits in the same matrix category.

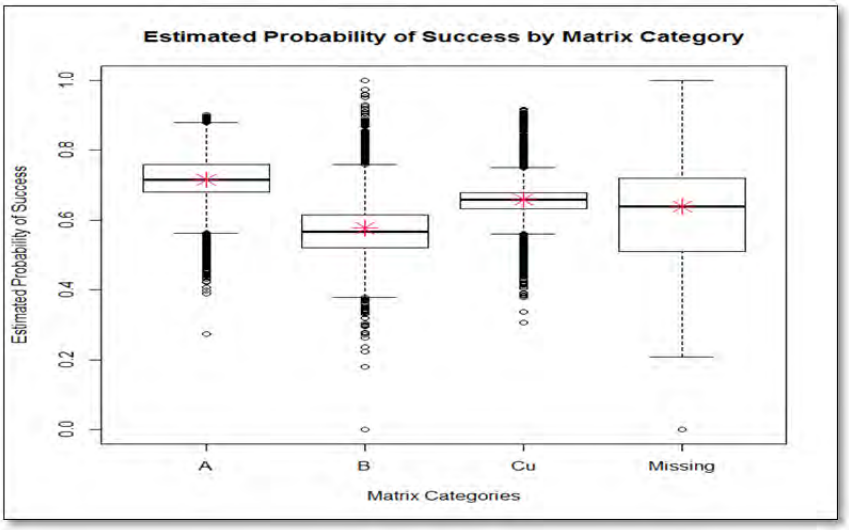

Figure 49. Comparison of success predictability between the matrix model and the final model with added variables.

5. Evaluating the Training Data against the Test Data

To evaluate the final model with added variables and the matrix model on the FY 2006–2008 test data, we first plot the ROC curve of the final model with added variables to predict success for both the FY 2006–2008 training and test sets (see Figure 50). The curves are nearly identical, indicating that there is no appreciable overfitting even with all the variables present in this model.

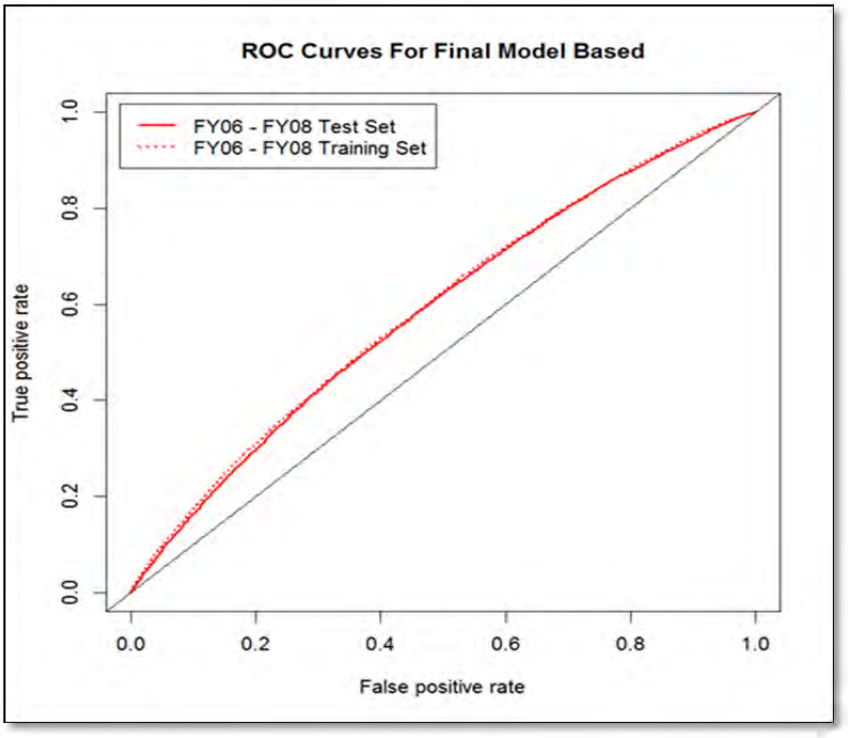

Figure 50. ROC curve indicating similarities between the FY 2006–2008 training set and test set.

Figure 51 illustrates the predictability comparisons between the final model with added variables in the FY 2006–2008 training set and the final model with added variables in the FY 2006–2008 test set. The proportion of success based on the FY 2006–2008 training set (plotted in red) are very close to the median estimated probability of success based on the FY 2006–2008 test set. The exception is with the few individuals who are missing a matrix category, representing less than 0.4 percent of the total number of recruits in the FY 2006–2008 data set.

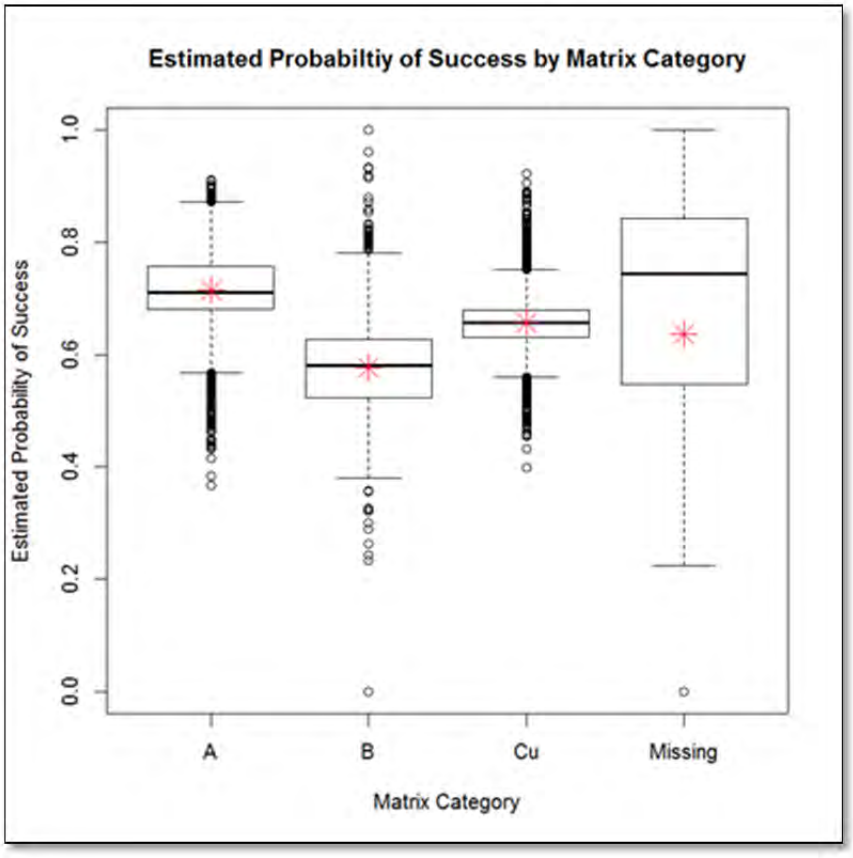

Figure 51. Comparison of success predictability between the final model with added variables from the FY 2006–2008 training and test data.

C. FISCAL YEAR 2009 DATA

The study now focuses on the FY 2009 data set which contains 35,363 recruits who were accessed in FY 2009. We note that the logistic regression model built based solely on the FY 2009 data is very similar to the models built on FY 2006–2008 data. The partial effects of the predictor variables from the final model with added variables are almost identical to those depicted in Figures 31 through 36 and Figures 43 through 46. The greatest difference in the model fits is that the FY 2009 fits did not include as many of the two-way interactions as did the FY 2006–2008 made with the additive model. However, all of the same predictor variables were present in both final models with added variables. The proportion of recruits in each category of the matrix model for both FY 2006–2008 and FY 2009 data is seen in Table 7. The proportions are very similar for both data sets.

Table 7. Comparison of the proportion of recruits in each of the matrix categories.

Proportion of U.S. Navy Recruits in Each Navy Recruit Quality Matrix Category				
FY	**"A"**	**"B"**	**"Cu"**	**"Missing"**
FY06-08	66.5%	6.6%	26.5%	0.4%
FY09	71.8%	5.7%	22.3%	0.2%

In this section we used the FY 2006–2008 model fit to forecast results for FY 2009 accessions. To do this we used the FY 2006–2008 final model with added variables to predict probabilities for the FY 2009 data set and to estimate probabilities for the FY 2006–2008 data set. The models are compared in the ROC curve in Figure 52.

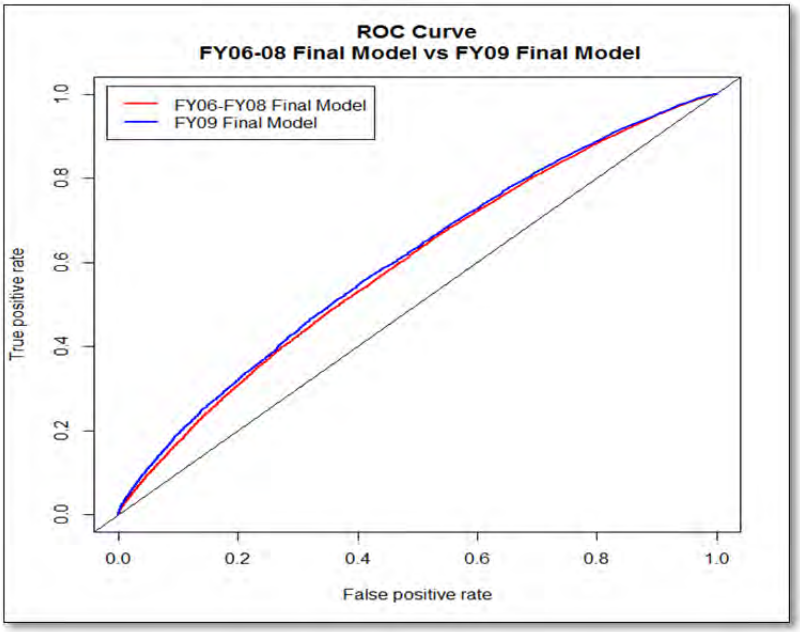

Figure 52. ROC curve indicating similarities between the FY 2006–2008 final model and the FY 2009 final model.

The results indicate that the model built on FY 2006–2008 data can be used to predict future, FY 2009, first-term success.

Furthermore, the boxplots illustrated in Figure 53 indicate similarities with FY 2006–2008 data and FY 2009 data when predicting a sailor's estimated probability of success of completing his or her first-term enlistment through each Navy Recruit Quality Matrix category. The estimated probability of successfully completing a first-term enlistment for FY 2009 accessions was then partitioned into three sections. The three sections represent the lower 10 percent of recruits found within the boxplots (all observations found below the second purple line in Figure 53), the upper 10 percent of recruits found within the boxplots (all observations found above the first purple line in the Figure 53), and the last section included the remaining recruits found between the first two sections. The percentage of those who attrite (and are successful) in the first-term by Quality Matrix category are given in Table 8.

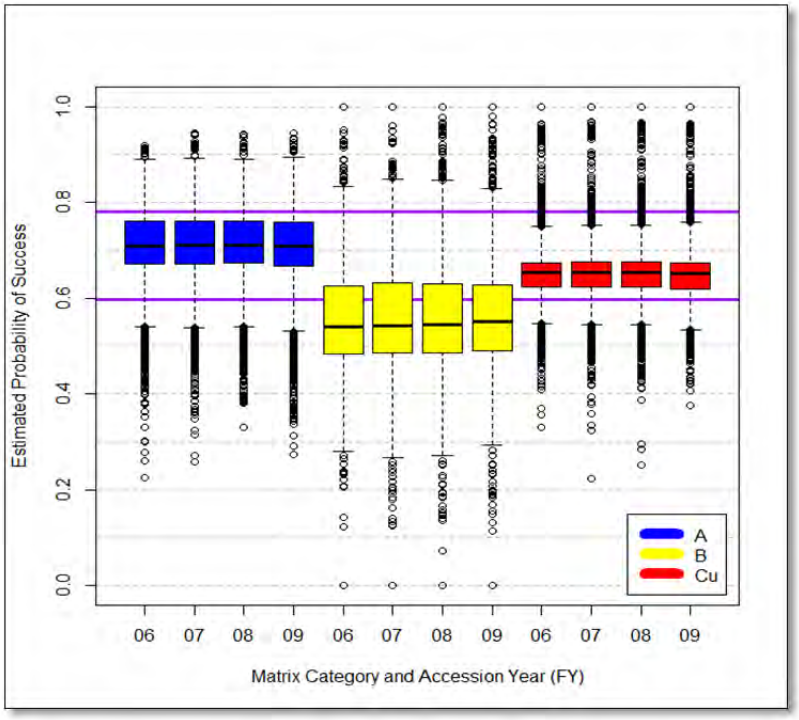

Figure 53. Boxplots illustrating final model with added variables predictabilities of determining a recruit's probability of success based on the structure of the navy recruit quality matrix.

Table 8. Probability of final model with added variables predicting a recruit's success.

Final Model Prediction Outcome of Recruits Accessed During FY06 - FY09			
Category "A"			
Outcome	**Bottem 10%**	**10% to 90%**	**Top 10%**
Attrite	37.9%	28.8%	18.3%
Success	62.1%	71.2%	81.7%
Category "B"			
Outcome	**Bottem 10%**	**10% to 90%**	**Top 10%**
Attrite	43.4%	33.1%	37.1%
Success	56.6%	66.9%	62.9%
Category "Cu"			
Outcome	**Bottem 10%**	**10% to 90%**	**Top 10%**
Attrite	39.8%	31.6%	13.2%
Success	60.2%	68.4%	86.8%

For the most part, the final model with added variables does a decent job at predicting the recruits' estimated probability of success, with the exception of the lower 10 percent of recruits who are classified as category "B." Here the probability of predicting a recruit's success is slightly better than flipping a coin.

V. CONCLUSIONS

A. REGRESSION MODEL VERSUS NAVY RECRUIT QUALITY MATRIX

The purpose of the study is to determine if there is a more accurate way to predict a U.S. Navy recruit's probability of success in completing his or her first-term enlistment. Since 1984, the Navy has recruited sailors mainly by their AFQT percentile score and their highest educational attainment. Though use of the Navy Recruit Quality Matrix is an attempt to decrease the yearly attrition rates, it has done so with very little success. This study focused on a wide range of predictor variables which capture the sailors attributes at the time of recruitment. What we found was evidence that there are recruit characteristics other than just his or her AFQT score and educational category, as used in the Navy Recruit Quality Matrix, which indicate recruits who are at risk of attriting. There is evidence to conclude that the logistic regression model built from this study identifies recruits with a high probability of attrition who would normally not be identified through the Navy Recruit Quality Matrix.

1. Educational Factors

As previous studies dealing with military attrition have concluded, this study found that a recruit's AFQT percentile score and educational background are strong indicators of determining his or her probability of success at completing a first-term enlistment. The uncategorized numeric variable of the AFQT percentile score and the six-level categorical variable of Education provide a richer predictive ability of first-term completion than does the three-level Quality Matrix. For recruits entering the U.S. Navy between FY 2006–2008, the partial effect of the AFQT percentile score on the log-odds of their success rate was nearly linear, indicating a lower probability of success for recruits with low AFQT scores; as the AFQT score increased, so did the recruits' probability of success. These were similar results when the AFQT scores were placed in a categorical variable. The results showed those recruits who were in the AFQT category 3B, with AFQT scores ranging from 30-49, had the lowest probability of successfully completing their first-term. Recruits within the AFQT category "Other," those who

scored below 30 and who had missing AFQT scores, had the highest success rate. However, due to the large standard error and the possibility the recruits who had missing AFQT scores skewed the results, their probability of success cannot be concluded.

The educational categories also showed similar results from past studies. For recruits who entered the U.S. Navy between FY 2006–2008, traditional high school diploma graduates had a higher probability of success at completing their first-term enlistment, while those with GED's had the lowest probability of success. Though those recruits who were homeschooled had a success rate comparable those who attended a traditional high school, the standard error was too large to estimate their probability of success as accurately as HSDGs.

2. Potential Characteristics to Use for Screen Recruits

With the exception of the number of dependents a recruit had at time of accession, all the predictor variables included in the logistic regression model indicated some statistical significance when determining the probability of a recruit's success. Recruits entering the U.S. Navy between FY 2006–2008 showed indications of a lower probability of success within recruits who (1) were between ages 19 and 20; (2) were either divorced, widowed, legally separated, or had had their marriage annulled; (3) were accessed with a BMI over 30; (4) were accessed with at least one waiver; and (5) entered the U.S. Navy with an enlistment rate as a "Fireman."

The study also concluded that those recruits who entered service between FY 2006–2008 at the rank of E-2 or E-3 due to certain programs had a higher probability of success than those entering at the rank of E-1. Furthermore, men had a higher probability of success over females, which is the same conclusion found in previous attrition rate studies.

B. FOLLOW-ON STUDIES

With these additional recruit characteristics identified in the study as having a statistically significant impact on a U.S. Navy recruits success rate of completing their first-term enlistment, we recommend a future review of attrition rates to determine if the

variables identified in this study continue to better screen recruits who may be at risk of attriting than the current Navy Recruit Quality Matrix. If the results are the same in future fiscal years, then the U.S. Navy should modify its recruit screening procedures to include the variables identified in this study, in particular, those variables which demonstrate a great difference in the probability of success like the recruits' AFQT percentile score, their pay grade, their gender, and their marital status. Understandably, the U.S. Navy will continue to need manpower filling "Fireman" rates, and cannot simply reject potential recruits because they are females. In these two cases, the U.S. Navy should either create or enhance current incentive programs which focus on retaining these sailors.

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