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A DYNAMIC MODEL OF NAVY ENLISTED RETENTION

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February 1984

A DYNAMIC MODEL OF NAVY ENLISTED RETENTION

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In recent years, models have been developed to assess the impact of military and civilian pay, sea duty, and other socioeconomic variables on first-term and subsequent retention. This report outlines a new, dynamic model of Navy enlisted retention behavior that spans the entire enlisted career with time-dependent pecuniary and nonpecuniary covariates. In addition to elasticity measures, a visual estimate of a career survival curve can be produced. The effects of different policies on survival (retention) can be visually analyzed. Given the results of the model's validation, highly accurate assessments of the effects of different management policies are expected.		

FOREWORD

The effort was performed under exploratory development task area ZF63-521-001-010 (Retention Planning Models) and was sponsored by the Chief of Naval Operations (OP-13). The overall objective of this task area is to develop a set of quantitative tools to enable planners to estimate retention rates for specific categories of individuals in the Navy's enlisted force. The main effort in FY83 was directed toward the development of a new dynamic model of enlisted retention, which is described in this report. The model is intended for use by military retention managers, as well as manpower and personnel researchers.

Acknowledgements are due to Dr. Philip Lurie of the Center for Naval Analyses, Alexandria, VA, for his statistical input, and to Dr. Michael Ward of the Rand Corporation, Santa Monica, CA, for providing helpful ideas and comments during the formulation of the model described herein.

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SUMMARY

Problem

In FY 1981, the Chief of Naval Operations established a goal for a 3-year sea/3-year shore rotation pattern. At that time, sea tours ranged between 3 and 5 years. For example, hospital corpsmen (HMs) served 3-year sea tours; and boiler technicians (BTs), 5-year sea tours. The move toward a more equitable sea/shore rotation was based on the premise that long sea tours have a negative effect on survival (retention) in the Navy. Since, on the average, first-termers are paid the same, regardless of their rating (i.e., job classification), there is no compensatory differential for the perceived differential in sea tours.

Determining the relationship between sea/shore rotation and retention may be more complex than a simple assessment of the effect of cumulative sea and shore months of service on retention. As indicated in the Enlisted Transfer Manual, overseas shore duty with a prescribed accompanied tour length of less than 36 months is creditable as sea duty. Thus, the key parameters of interest may be actual time at sea vs. time on shore rather than credited time at sea vs. credited time on shore. Also, different sequences of sea and shore duty within ratings may produce different retention behavior. Further, it has been suggested that it may be particularly advantageous (in terms of retention) to have first-term personnel in all ratings rotated to shore 1 year prior to the expiration of their active obligated service.

Objective

The objective of this report is to describe a new approach taken to estimate force behavior and to provide some preliminary results. The report outlines the model used to evaluate the effects of sea duty on survival (i.e., length of stay in the military), describes the data used in the investigation, and provides an analysis of the results.

Approach

The empirical research reported here was performed using the discrete version of the proportional hazards model first suggested by Cox in 1972. The model, heretofore known as the Cox regression model, is a nonparametric method for estimating a survival curve while controlling for factors that may affect survival. This method has been used primarily in the biological and biostatistical sciences. It has only recently been applied to military manpower problems and applies new model developments to these problems for the first time.

Unlike earlier Cox models, the model described here uses time-invariant covariates (e.g., race and mental category) and time-dependent covariates (e.g., dependents and consecutive quarters at sea). Although the coefficients are constant over time, the effect of a change in a variable on the conditional probability of leaving (everything else held constant) is not constant over time. Estimates of the parameters are obtained by a maximum likelihood solution.

Results

The estimates of the model's coefficients and survival rates are quite reasonable. Using data from FY78, FY79, FY80, and FY81, the estimates of survival correspond highly with actual figures. In addition, the survival figures of the new model are at least as good as, and often better than, those produced by the popular probit model. When computer time and costs are considered, the new model is clearly superior. It requires 10

hours of computer time to estimate 160 parameters for the probit model, compared with 2.5 hours to estimate 7 parameters for the new model. Additionally, the results of this model are interpretable via easily understood survival curves.

Conclusions

1. The new model is feasible for analyzing the survival probabilities of Navy enlisted personnel.
2. Higher numbers of consecutive quarters of sea duty are associated with lower survival rates for single personnel.
3. For personnel with two or more dependents, different sequences of consecutive sea months appear to produce no significant impact.

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INTRODUCTION

Problem

In FY 1981, the Chief of Naval Operations (CNO) established a goal for a 3-year sea/3-year shore rotation pattern. At that time, sea tours ranged between 3 and 5 years. Hospital corpsmen (HMs), for example, served 3-year sea tours while boiler technicians (BTs) served 5-year sea tours. The move toward a more equitable sea/shore rotation was based on the premise that long sea tours have a negative effect on survival (retention) in the Navy. Since, on the average, first-termers are paid the same, regardless of their rating (i.e., job classification), there is no compensatory differential for the perceived differential in sea tours (e.g., the BT vs. HM tour discrepancy). At the end of the 4-year first-term tour, an HM can look forward to shore duty if he/she has not already begun a shore tour, while a BT is still at sea, with generally 1 more year remaining. Responses to the Navy's Enlisted Separation Questionnaire show that sea duty has a strong effect on separation, an effect that does not diminish with subsequent reenlistment.¹

Determining the relationship between sea/shore rotation and retention may be more complex than a simple assessment of the effect of cumulative sea and shore months of service on retention. As indicated in the Enlisted Transfer Manual, overseas shore duty with a prescribed accompanied tour length of less than 36 months is creditable as sea duty. Thus, the key parameters of interest may be actual time at sea vs. time on shore rather than credited time at sea vs. credited time on shore. Also, different sequences of sea and shore duty within ratings may produce different retention behavior. For example, in the first term, 2 years of sea duty and 1 year of shore duty, followed by 1 year of sea duty and 2 years ashore, may be more advantageous for retention than are 3 consecutive years of sea duty followed by 3 consecutive years ashore. Further, it has been suggested that it may be particularly advantageous (in terms of retention) to have first-term personnel in all ratings rotated to shore 1 year prior to the expiration of their active obligated service.

Background

Because of the Navy's mission, billets are split among three rotation areas--ashore continental United States (CONUS), ashore overseas, and afloat. For the other services, personnel are rotated between CONUS and overseas billets, but all billets are ashore. Afloat billets represent approximately 60 percent of total enlisted Navy authorizations, and this percent may rise as the Navy moves toward six battle groups.

Rotation problems arise mainly from the sea-to-shore exchange of tours. As indicated previously, the minimum sea tour is currently 3 years with a maximum of 5 years. However, persons in some critical ratings, such as boiler technician (BT) and machinist's mate (MM), have experienced more than 5 consecutive years at sea. Sea duty can be characterized by (1) long workweeks, (2) constrained living conditions, (3) deployments that mean total family separation up to 8 months a year, and (4), in some instances, unappealing working conditions.

Long, contiguous tours at sea have drastic effects on retention. During their first term, with few exceptions, all enlistees serve sea tours after attending boot camp or "A" school. However, the actual length of a specific sea assignment and the sequence of sea

¹Hearold, S. L. Unpublished briefings on retention of career personnel in critical ratings. June 1983.

assignments within the first term both vary considerably. For example, general detail (GENDET) personnel are assigned to the fleet immediately following boot camp and while at sea can apply to an "A" school. If the individual is found qualified and a school seat is available, he or she may then be assigned to that school (i.e., ashore). Even those who are designated as non-GENDETs experience variation in sea tour length and sea assignment sequence. Hence, the consecutive months (weeks, quarters, etc.) of sea duty within a given period of time may be a crucial determinant of retention.

Although the relationship between pay and retention has received considerable research attention, little attention has been paid to the relationship between sea duty and retention. Further, most of the research into the sea duty issue has been relatively recent (Mauer, 1979; Smith, 1979; Waterman, Mauer, & Huntzinger, 1979; Blanco, 1980; Goldberg & Warner, 1980; Chow & Polich, 1980; Rodney, Baghelai, Samaan, Yaphe, & Malatesta, 1980). Goldberg and Warner, when controlling for other factors, including pay, concluded that the negative effects of a 10 percent increase in second-term sea duty on first-term retention rates can be neutralized by a one-multiple bonus increase. Rodney et al. found a significant, negative impact of sea/shore rotation on retention rates. Polich and Chow found that the frequency of undesirable permanent change of station (PCS) moves is negatively related to first-term reenlistment rates. Even among some officer communities, sea duty has a negative effect on retention. Nakada (1981) noted that extra sea duty for submarine officers had a significant negative impact on their first extension decision.

Research into the effects of sea duty on subsequent reenlistments has been even more sparse, because the Navy generally experienced high second-term (and later term) retention rates. However, in the late 1970s, second-term retention rates had begun to decline. Goldberg and Warner found that increased sea duty had no significant effect on second-term retention rates. Rodney et al. confirmed this finding.

Objective and Scope

The objective of this report is to provide a detailed description of a new approach taken to estimate force behavior and to provide some preliminary results. The methodology was developed by Cox (1972) and is used extensively in the biological and health sciences. The report outlines the model used to evaluate the effects of sea duty on survival, describes the data used in the investigation, and provides an analysis of the results.

APPROACH

Model Development

The empirical research reported here is performed using the discrete version of the proportional hazards model first suggested by Cox (1972). The model, heretofore known as the Cox regression model, is a nonparametric method for estimating a survival curve while controlling for factors that may affect survival. This method has been used primarily in the biological and biostatistical sciences. In one of the first nonbiological uses of the Cox model, Menken, Trussell, Stempell, and Babakol (1981) used a continuous time version of the model to analyze sociodemographic influences on divorce. The model has only recently been applied to military manpower problems and applies new model developments to these problems for the first time.

In this application, let $X_t'\beta$ denote the linear combination of covariates at time t . The conditional probability of leaving the Navy at time $t + 1$, given survival time to t , is

$$h(t) = P(t+1 | t) = h_0(t)e^{X_t'\beta}$$

where $h(t)$ is the hazard function and $h_0(t)$ is an arbitrary, unspecified, fixed base-line hazard function independent of X_t . The vector X_t contains time-invariant covariates (e.g., race and mental category) and time-dependent covariates (e.g., dependents and consecutive quarters at sea). Although the β 's are constant over time, the effect of a change in a variable on $h(t)$, the conditional probability of leaving (everything else held constant), is not constant over time. To see this, the partial derivative of $h(t)$ with respect to X_t is

$$\frac{\partial h(t)}{\partial X(t)} = h_0(t)e^{X_t'\beta} \cdot \beta$$

which is neither constant nor even linear.

Estimates of β are obtained by a maximum likelihood solution. However, instead of the usual unconditional likelihood approach, the partial likelihood method is used. This method will yield a likelihood function that is functionally independent of the unspecified base-line function, $h_0(t)$. Recall that $h_0(t)$ is not a function of the X 's. Let $R(t_j)$ be the set of individuals who are observed to leave the Navy or are censored on or after t_j ; $R(t_j)$ is called the risk set. Conditional on being in $R(t_j)$, the probability of leaving at t_j by any j^{th} individual is

$$\frac{h_0(t_j) \exp(X_j(t_j)'\beta)}{h_0(t_j) \sum_{i \in R(t_j)} \exp(X_i(t_j)'\beta)} = \frac{\exp(X_j(t_j)'\beta)}{\sum_{i \in R(t_j)} \exp(X_i(t_j)'\beta)}$$

where $X_j(t_j)$ is the t_j value of the covariate corresponding to j^{th} individual with observed time t_j . The partial likelihood function of β , then, is formed by taking the product over all leaving times, i.e.,

$$L(\beta) = \prod_{j=1}^k \left[\frac{\exp(X_j(t_j)'\beta)}{\sum_{i \in R(t_j)} \exp(X_i(t_j)'\beta)} \right]$$

Sample

The Cox regression model with time-dependent covariates requires longitudinal data for estimation. Therefore, all nonprior-service, active duty males who enlisted in the Navy during FY78 (N = 59,631) were tracked from their date of active duty until they left the Navy or until the end of the observation period. Thus, the period of observation included 20 quarters, commencing at the beginning of FY78 through the end of FY82.

Data were obtained from the survival tracking file (STF) (Gay & Borack, 1982), and the computer-assisted personnel action system (COMPAS), which was recently added to the STF and provides the capability to track enlisted personnel almost from the moment they enter the training pipeline. Table 1, which presents the disposition of these enlisted personnel, shows the number of attrites and the attrition rates for each quarter. Censored observations include those with unauthorized absences; however, the majority, those censored in quarter 16 or greater, reflect an end to the available data.

Table 1
Disposition of FY78 Cohort

Duration (Quarter)	Number of Individuals at Risk	Attrites ^a		Censored
		N	%	
1	59,631	6,186	10.4	13
2	53,432	1,202	2.2	5
3	52,225	1,296	2.5	6
4	50,923	1,239	2.4	11
5	49,673	1,078	2.2	12
6	48,583	990	2.0	17
7	47,576	950	2.0	27
8	46,599	957	2.1	39
9	45,603	878	1.9	39
10	44,686	683	1.5	52
11	43,951	703	1.6	53
12	43,195	915	2.1	65
13	42,215	759	1.8	84
14	41,372	705	1.7	105
15	40,562	841	2.1	149
16	39,572	14,740	37.2	517
17	24,315	1,046	4.3	8,955
18	14,314	332	2.3	5,017
19	8,965	151	1.7	4,448
20	4,366	28	0.6	4,338
		35,679		23,952

^a Attrites include those with Navy loss codes 801-809, 811, 813-911, 931-952, 954-961, and 980; unauthorized absences are those with loss code 050.

Variables

Table 2 presents the list of variables used in this research. The values of variables 1-4 are time-invariant, while the values of the remaining variables may vary over time. Additionally, the sea duty variable (SEA (t)) is, to an extent, cumulative. For example, if an enlisted person spends the first quarter of enlistment ashore, and then is assigned to sea duty for 3 months, to "A" school for 9 months, and to a second sea tour for 9 months, SEA (t) will have the following values for the first 8 quarters: 0, 1, 0, 0, 0, 1, 2, and 3. As discussed earlier, sea duty is viewed as exerting a negative effect on retention, probably because it can be arduous with long hours, means cramped living spaces, and can involve family separation. To capture these effects, the CDEPS variable, which is the product of SEA and DEPS for the appropriate quarter (i.e., interaction), was created.

Table 2
Variable List

Variable	Description	First Quarter Mean	First Quarter SD
1. RACE	A dichotomous variable whose value is 1 if the individual is white and 0 otherwise.	0.85	0.36
2. AGE	The individual's age at enlistment.	19.66	2.12
3. MGRP	A dichotomous variable whose value is 1 if the individual is in mental group 1, 2, or 3U, and 0 otherwise.	0.77	0.42
4. EDUC	The individual's years of completed education.	11.78	1.04
5. DEPS (t)	The individual's number of dependents in quarter (t).	3.89×10^{-2}	0.248
6. SEA (t)	The number of consecutive quarters the individual spent on sea duty as of quarter (t). Any fraction of a quarter is considered a quarter.	1.18×10^{-3}	0.034
7. CDEPS (t)	The quarterly product of SEA (t) and DEPS (t.)	0.30×10^{-4}	0.006

Model Validation

The model was validated using data from FYs 78-81. Since FY78 data was used in the model's estimation, smaller discrepancies between FY78 actual and predicted survival rates are anticipated.

Survival curve estimation is the vehicle for model validation. Remember that the Cox model produces a continuous estimate of the survival curve while probit models produce point estimates of survival. The Cox survival function can be expressed as

$$S(t) = P(T > t) = e^{-\int_0^t h(x) dx}$$

and is the probability of surviving longer than time t . ($h(x)$ is the hazard function.) With some modifications, the estimator of the survival function can be found in Lurie (1979) and Kalbfleisch and Prentice (1980).

The estimate of the Cox survival curve was compared to the survival curve estimated from the popular probit model and the survival curve derived from the actual data. Briefly, the probit survival curve was estimated from

$$1 - F(X(t)'\beta(t)) = 1 - \int_{-\infty}^{X(t)'\beta(t)} f(\epsilon) d\epsilon,$$

where $f(\epsilon)$ is the standard normal density function. The β 's in the above expression are time-indexed, indicating that up to 160 parameters ((7 covariates + constant) X 20 quarters) were estimated.

The actual survival curves were estimated using actuarial methods. From any fiscal year cohort, a set of enlisted personnel was selected who had survived up to that quarter and had the selected values of the variables. The conditional probability of continuing is the number from this set who survive the quarter divided by the number in the set at the start of the quarter. The survival rate is the product of the conditional probability of continuing in quarter t times the survival rate in $t-1$. The survival rate in quarter 1 is the continuance rate. For example, let the survival rate in quarter 2 be .985. For quarter 3, a set of enlisted personnel was selected who had more than 6 months of service, were white, were 18 years old at enlistment, were in mental groups 1, 2, or 3U, had 12 years of education, were single, and had 1 quarter of sea duty. Assume there are 300 in this set and that 200 remain at the end of the quarter. The third quarter continuance rate is, then, .667 (.667 = 200/300) and the survival rate for quarter 3 is .657 (.657 = .667 x .985).

Since the first four variables used in the estimation of this model--RACE, AGE, MGRP, and EDUC--are time-invariant, there is a large number of possible combinations of values. Including the time-varying covariates--DEPS, SEA, and CDEPS--greatly increases the possible combination of values. Therefore, the following values of the variables listed below were considered in constructing the survival curves. Except for AGE and SEA, these values were selected because they reflect the mean values of the sample.

1. RACE = 1 (white).
2. AGE = 18 (18 years old at enlistment).
3. MGRP = 1 (mental groups 1, 2, or 3U) for Figures 1, 3, 5, and 7a, and 0 (mental groups 3L, 4, or 5) for Figures 2, 4, 6, and 7b.
4. EDUC = 12 (12 years of education).
5. DEPS(t) = 0 (single individual in all 20 quarters).
6. SEA(t) = As indicated in the figure.

RESULTS

Data Analyses

Table 3 presents the mean values of nonattrites and attrites at 1, 2, 3, and 4 years. For example, the top left entry shows that 84 percent of nonattrites and 86 percent of attrites as of the end of the first year were white. t-statistic values for use in testing the appropriate hypotheses of equality are shown in parentheses.

Table 3
Means of Variables by Active Duty Status

Variable	1 Year		2 Years		3 Years		4 Years	
	Non-attrites	Attrites	Non-attrites	Attrites	Non-attrites	Attrites	Non-attrites	Attrites
RACE	.84 (-5.15)*	.86	.84 (-5.40)*	.87	.84 (-1.50)	.85	.83 (-8.36)*	.86
AGE	19.62 (-1.76)	19.70	19.63 (.81)	19.60	19.65 (7.75)*	19.35	19.83 (20.18)*	19.43
MGRP	.79 (14.34)*	.72	.78 (-6.19)*	.82	.78 (-1.33)	.79	.81 (16.74)*	.74
EDUC	11.86 (28.85)*	11.50	11.88 (14.39)*	11.58	11.91 (18.36)*	11.58	12.01 (55.01)*	11.78
DEPS	.14 (30.43)*	.04	.21 (12.63)*	.12	.32 (20.64)*	.14	.54 (35.26)*	.29
SEA	.82 (114.21)*	.14	2.90 (54.54)*	.97	5.32 (47.12)*	2.08	6.70 (-18.45)*	7.75
Sample size	49,673	9,923	45,603	3,975	42,215	3,179	24,315	17,045

Note. Number in parentheses is the t-statistic value.

*p < .05.

Table 3 reveals a number of interesting observations:

1. Attrites are more often white than nonwhite, a fact also noted by Lurie (1979). One possible explanation is the relative lack of civilian employment opportunities for nonwhites. (The period between FY78 and FY82 witnessed a dramatic increase in unemployment for nonwhites, particularly for younger blacks.)

2. Education appears to be one of the best predictors of survival in the Navy. Enlisted nonattrites generally have more years of education than do attrites. (The assertion that years of completed schooling is an indicator of one's ability to see things

through to the end is well known.) Observe that, even at the end of the fourth year, nonattrites have significantly more years of completed education than do attrites.

3. Nonattrites are also more likely to have more dependents than attrites. Warner (1981) and others have found that married people are more likely to reenlist than are single persons, probably because persons with families often place greater importance on such factors as job stability and fringe benefits (e.g., medical care) than do persons without families.

4. Nonattrites have significantly more sea duty than do attrites, except in year 4. For the first 3 years, nonattrites are likely to have more sea duty since the assignment system dictates sea duty after schooling. However, the relative difference in sea duty between nonattrites and attrites naturally declines over time and culminates in higher sea duty tours for attrites in year 4.

Model Estimates

Since these factors may be associated with one another, it is difficult to sort out independent effects without a model. Table 4, which presents the model's parameter estimates, shows that sea duty has a profound negative effect on survival. Positive coefficients indicate that increases in the variable increase risk; that is, lower survival. For single individuals, an increase in sea duty by one additional consecutive quarter increases the exit probability by more than 3 percentage points. (Note: All partial effects are evaluated at the sample means.) This significant sea duty finding may be explained by family separation effects, which may increase with family size. To address some of these family separation effects, the interaction variable, CDEPS, was incorporated. To observe the magnitude of this effect, consider the following partial derivative:

$$\frac{\partial \ln h(t)}{\partial \text{SEA}} = \beta_{\text{SEA}} - \beta_{\text{CDEPS}} \cdot \text{DEPS} = .033 - .015 \text{ DEPS}$$

Thus, if the number of dependents is below two ($2.2 = .033/.015$), increases in sea duty increase the probability of leaving the Navy. Exit probabilities decrease if there are more than two dependents. Less than four percent of the FY78 cohort had dependents upon entry. However, over the 5 years of observation, the number of married personnel and dependent children increased. The job stability and higher valuation of Navy benefits argument put forth by Warner (1981) and others explains the dampening effect of dependents on sea duty. For single individuals in this age group, family separation means separation from one's parents. A more appropriate term, then, might be homesickness.

An increase in the number of dependents by 1 decreases the probability of leaving the Navy by more than 11 percentage points. An increase in the number of dependents by 1 for sea-billeted enlisted personnel lowers the propensity of leaving further. Note:

$$\frac{\partial \ln h(t)}{\partial \text{DEPS}} = \beta_{\text{DEPS}} - \beta_{\text{CDEPS}} \cdot \text{SEA} = -.117 - .015 \text{ SEA}$$

Table 4
Determinants of Survival Probabilities

Variable	Coefficient	Std. Error
RACE	.147	.022
AGE	.029	.004
MGRP	-.263	.017
EDUC	-.257	.007
DEPS	-.117	.020
SEA	.033	.002
CDEPS	-.015	.003
Number of observations	31,336	
Log likelihood	-.18939x10 ⁶	

For these personnel, the exit probability is 13 points lower. Personnel with dependents assigned to sea do not lose their housing allowances as do single personnel. Hence, while pay is not specifically addressed in this model, the pecuniary aspects of sea duty favor those personnel with dependents and, therefore, lowers their exit probabilities.

The remaining variables corroborate the findings of earlier research. Eighty-four percent of the FY78 cohort were Caucasian and experienced higher exit probabilities. Precisely, white exit probabilities are 15 percentage points higher than nonwhites, and the effect is highly significant. Again, lower civilian opportunities for nonwhites is a possible explanation for their lower exit probabilities. An increase in the age at enlistment also increases the exit probability. This finding differs from that found by Lurie (1979).

Brighter, more educated personnel have lower propensities to attrite. Education is an excellent predictor of survivability. As noted earlier, the ability to see efforts to their completion is a common explanation. In addition, brighter, more educated personnel are placed in "better," more technologically challenging ratings. A rating-specific investigation is anticipated.

Model Validation

The Cox, probit, and actual survival curves for the various FYs are shown in Figures 1 through 7 and discussed below. Shorter periods of observation for FYs 79, 80, and 81 cohorts result in survival rates (actual and predicted) up to quarters 12, 8, and 4 respectively.

1. FY78. Figures 1 and 2 reveal a high degree of correspondence between the Cox and actual curves. Even in Figure 1a, where the largest discrepancies occur, the differences between the Cox and actual survival curves do not exceed .07. As indicated earlier in Table 1, censoring can become a problem past the 16th quarter. In deriving the actual survival curves, this problem manifests itself in small samples that fit all the

criteria (i.e., they satisfy all covariate values). In Figures 1 and 2, the actual survival curves fall off to zero rapidly at quarter 16. Finally, in Figures 1a and 2, the Cox survival curves predict actual data more accurately than do the probit curves.

2. FY79. Ignoring the censoring problem that manifests itself after quarter 12, Figures 3 and 4 again show that the Cox model has high predictive capability. A large discrepancy occurs at quarter 12 in Figure 3b, but even here the difference is not more than .06. In Figures 3b and 4b, which depict survival for those with the less arduous sea duty sequence in both mental group categories, the Cox survival curves are not superior to the probit method in estimating the actual. Smaller sample sizes used to calculate the actual survival curves in the later quarters become a problem for those with less arduous sea duty. For example, the beginning sample in quarter 11 of Figure 3a is 814 and 203 in Figure 3b. This implies that there is a higher likelihood of finding personnel at sea than ashore in quarter 11.

3. FY80. Figures 5 and 6 compare Cox, probit, and actual survival curves for FY80 cohort data. The fit between Cox and actual survival curves is very close, especially in Figures 5a and 5b, for those in the upper mental groups. Even in Figure 6a, where the largest discrepancy occurs at quarter 8, the difference is .10. For FY80 and FY81, these sampling problems became more acute, as the Navy increased the number of upper mental group accessions relative to the number accessed in the lower mental categories. Hence, the fit in Figures 6a and 6b is not as good. Moreover, a pattern exists in Figure 6 that did not exist for the lower mental groups in Figure 2, but it does exist in those groups in Figure 4.

4. FY81. The patterns established for FY80 data are evident in the FY81 survival curves shown in Figure 7; that is, the Cox model is better for predicting the upper mental categories in both fiscal years. In addition, the Cox model overpredicts survival for the lower mental categories. Smaller sample sizes due to decreased accessions of lower mental category personnel are again largely to blame.

In summary, the Cox model fits the FY78, FY79, FY80, and FY81 data very well and is potentially useful for estimating survival of Navy enlisted personnel. Technically, this means that it is reasonable to assume constant β 's over time. Remember that the Cox model is far less expensive (in terms of computer time) than the probit model (7 parameters for Cox vs. 160 for probit).

Model Predictions

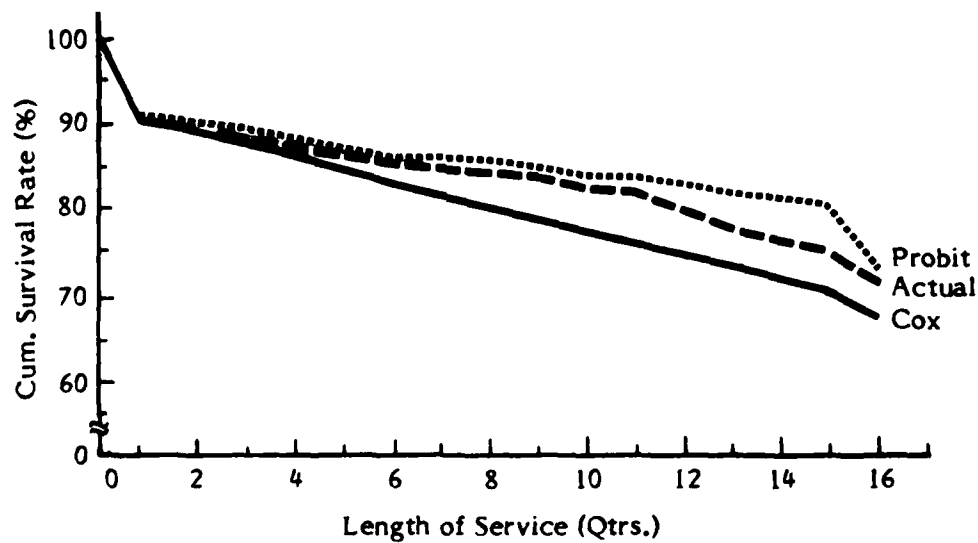
Figure 8 compares FY78 survival curves for MG1-3U and MG3L-5 personnel with a liberal sea duty sequence (characterized by 2 qtrs. ashore, followed by 4 qtrs. at sea, 4 qtrs. ashore, etc.) and an intensive sea duty sequence (characterized by 2 qtrs. ashore, consecutive followed by 14 qtrs. at sea). In both MGs, personnel are white, 18 years old at enlistment, high school graduates, and single. For MG1-3U personnel in the liberal sea duty sequence, the survival rate is 68 percent at quarter 16 (the major turning point), compared to 63 percent for those in the intensive sea duty sequence. For MG3L-5 personnel in the liberal sequence, the survival rate at quarter 16 is 61 percent, compared to 55 percent for those in the intensive sequence. In sum, the liberal sea duty sequence increased the survival probability by 10 percent at quarter 16.

The model estimates described previously and Figure 8 show that sea duty has a significant negative effect on survival in the Navy. However, this effect is dampened as

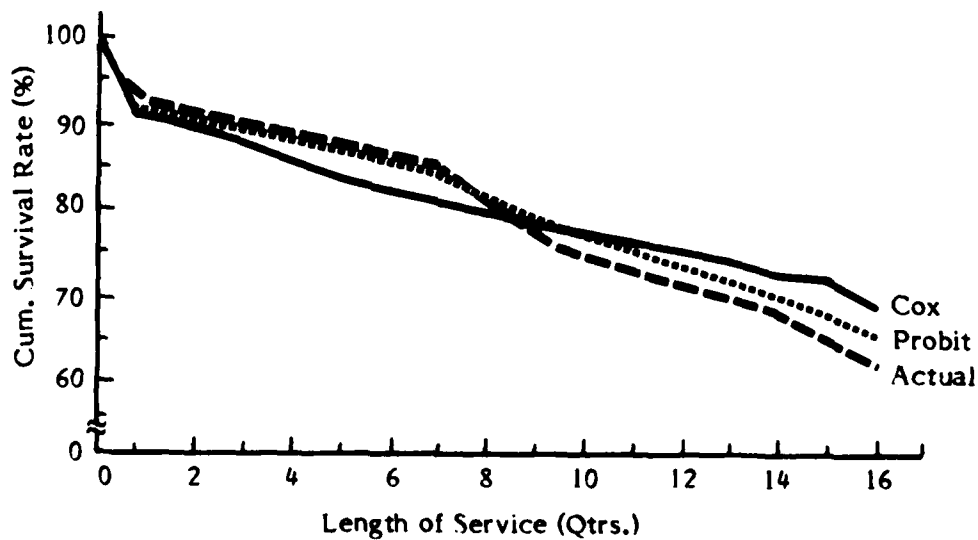
the number of dependents increases. An increase in one additional consecutive quarter of sea duty increases the exit probability by more than 3 percentage points for single personnel; however, there is no effect on those with 2 or more dependents. Figures 9 and 10 provide graphical displays of these effects.

Figure 9 compares FY78 survival curves of MG1-3U and MG3L-5 personnel with dependents (characterized by being married at the end of the 4th qtr. and having a child at the end of the 8th qtr.) with those without dependents (characterized by remaining single throughout 20 qtrs.). In both MGs, personnel are white, 18 years old at enlistment, high school graduates, and are in the intensive sea duty sequence. As shown, at quarter 16, the survival rate for MG1-3U personnel with dependents is 71 percent, compared to 63 percent for those who are single. The survival rate for MG3L-5 personnel with dependents is 64 percent, compared to 55 percent for those who are single. Thus, the survival rates for MG3L-5 personnel with dependents are nearly 10 points higher than those for single personnel at crucial quarter 16. Further, note that, while having dependents increases survival by nearly 10 points at quarter 16, having a liberal sea duty sequence increases survival by 5 to 6 points at quarter 16 over having an intensive sea duty sequence.

Finally, Figure 10 compares FY78 survival curves for MG1-3U and MG3L-5 personnel with dependents by sea duty sequence. As shown, for both groups, survival curves for intensive and liberal sea duty are identical. Again, the higher valuation of Navy benefits by those with dependents, job security, and retention of quarters pay (loss of quarters pay for single personnel at sea) are the primary reasons.

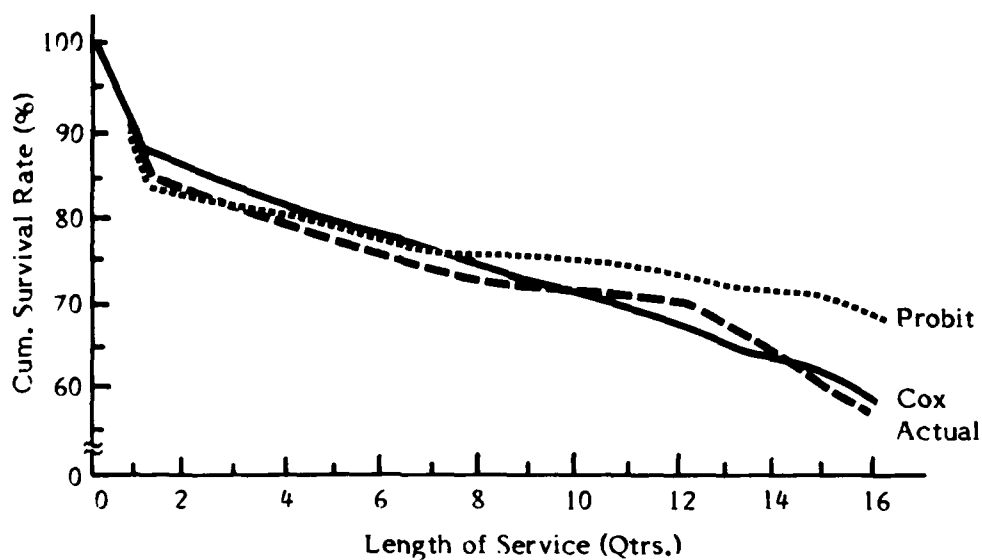


- a. Sea duty sequence over 16 qtrs.: First 2 qtrs. ashore followed by 14 qtrs. at sea.

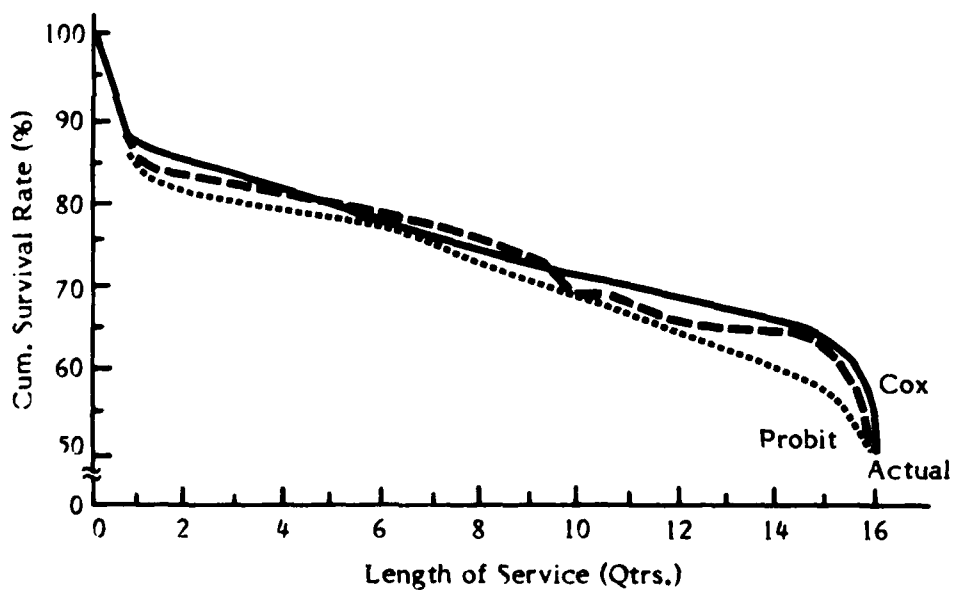


- b. Sea duty sequence over 16 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea, 4 qtrs. ashore, 4 qtrs at sea, and 2 qtrs. ashore.

Figure 1. FY78 survival curves (Values: White, 18 years, MG 1-3U, HSG, single) by sea duty sequence.

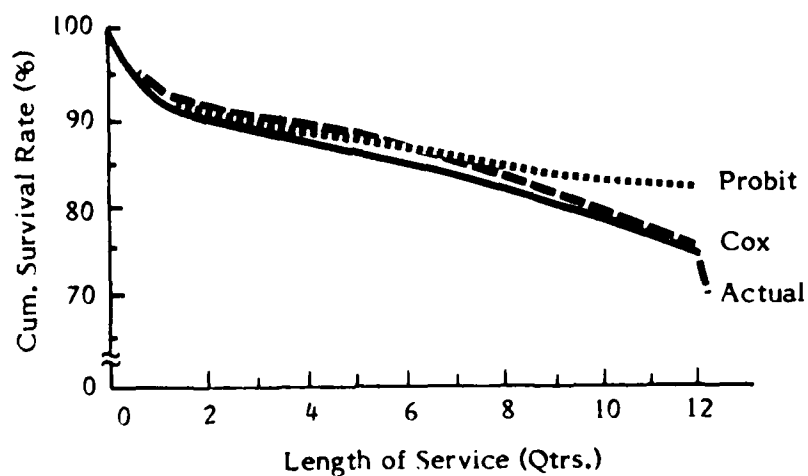


- a. Sea duty sequence over 16 qtrs: First 2 qtrs. ashore, followed by 14 qtrs. at sea.

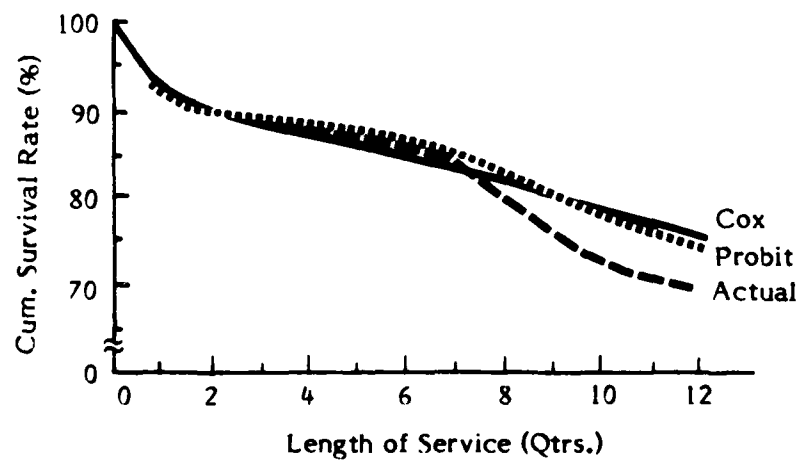


- b. Sea duty sequence over 16 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea, 4 qtrs. ashore, 4 qtrs. at sea, and 2 qtrs. ashore.

Figure 2. FY78 survival curves (Values: White, 18 years, MG 3L-5, HSG, single) by sea duty sequence.

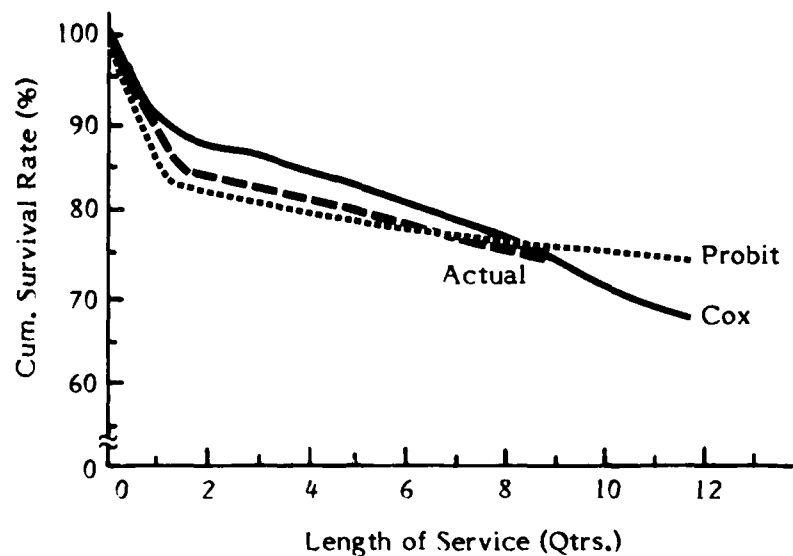


- a. Sea duty sequence over 12 qtrs.: First 2 qtrs. ashore, followed by 10 qtrs. at sea.

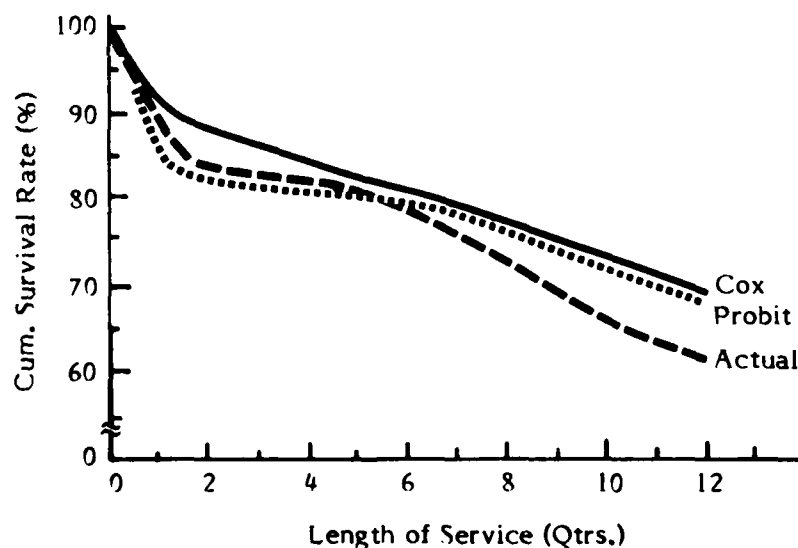


- b. Sea duty sequence over 12 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea, 4 qtrs. ashore, and 2 qtrs. at sea.

Figure 3. FY79 survival curves (Values: White, 18 years, MG 1-3U, HSG, single) by sea duty sequence.

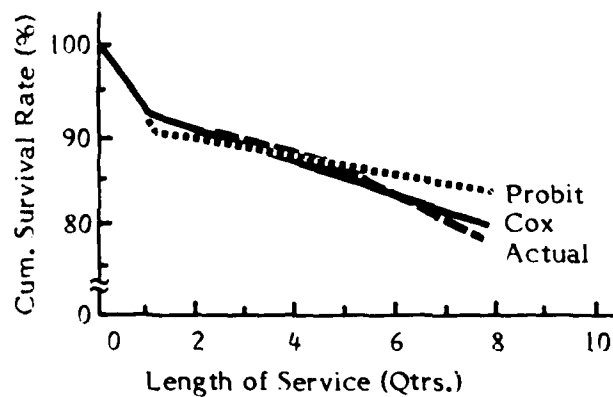


- a. Sea duty sequence over 12 qtrs.: First 2 qtrs. ashore, followed by 10 qtrs. at sea.

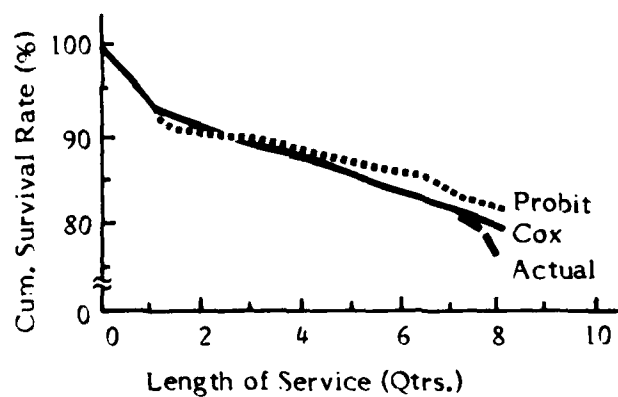


- b. Sea duty sequence over 12 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea, 4 qtrs. ashore, and 2 qtrs. at sea.

Figure 4. FY79 survival curves (Values: White, 18 years, MG 3L-5, HSG, single) by sea duty sequence.

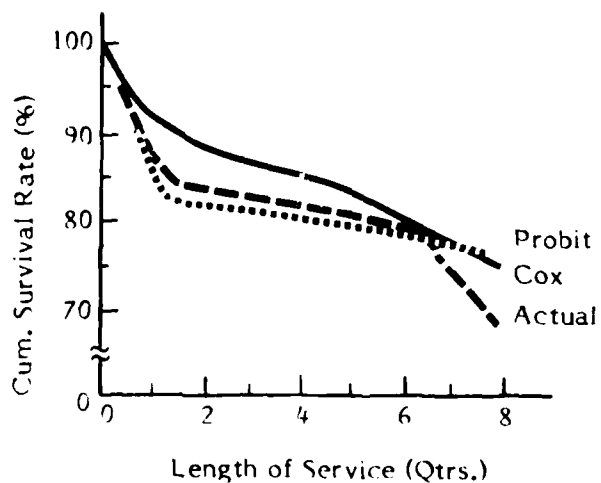


- a. Sea duty sequence over 8 qtrs.: First 2 qtrs. ashore, followed by 6 qtrs. at sea.

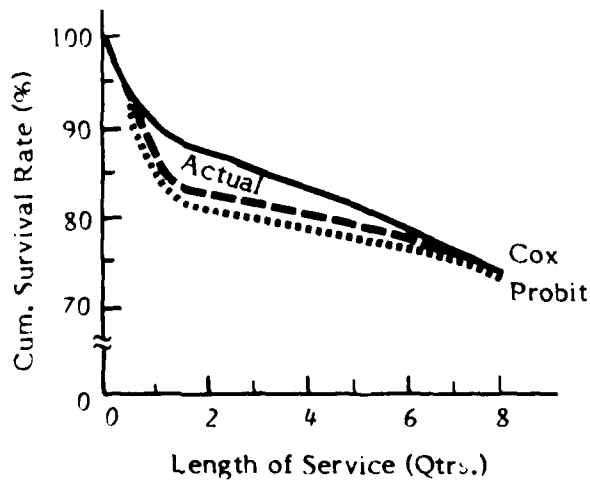


- b. Sea duty sequence over 8 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea and 2 qtrs. ashore.

Figure 5. FY80 survival curves (Values: White, 18 years, MG 1-3U, HSG, single) by sea duty sequence.

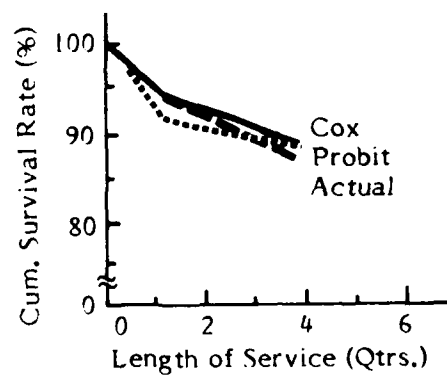


- a. Sea duty sequence over 8 qtrs.: First 2 qtrs. ashore, followed by 6 qtrs. at sea.

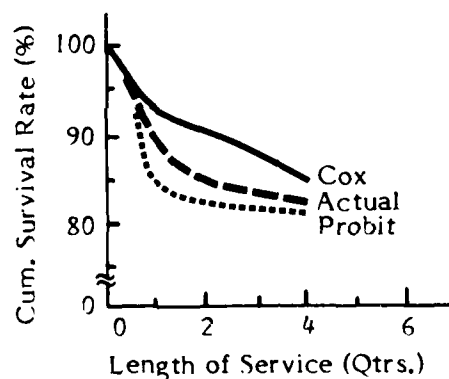


- b. Sea duty sequence over 8 qtrs.: First 2 qtrs. ashore, followed by 4 qtrs. at sea and 2 qtrs. ashore.

Figure 6. FY80 survival curves (Values: White, 18 years, MG 3L-5, HSG, single) by sea duty sequence.



a. MG1-3U.



b. MG3L-5

Figure 7. FY81 survival curves (Values: White, 18 years, HSG, single, sea duty sequence = 2 qtrs. ashore/2 at sea) by mental group.

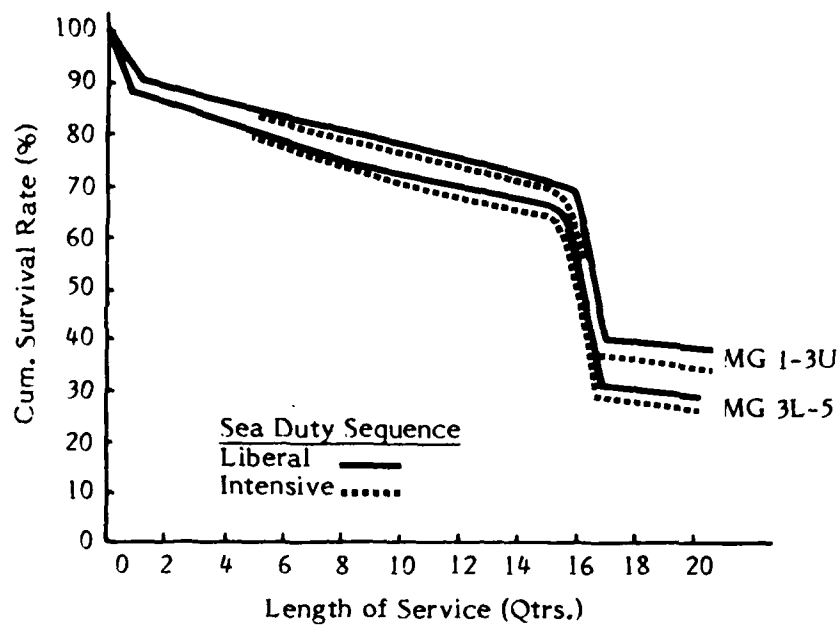


Figure 8. FY78 survival curves for mental groups (Values: White, 18 years, HSG, single) by sea duty sequence.

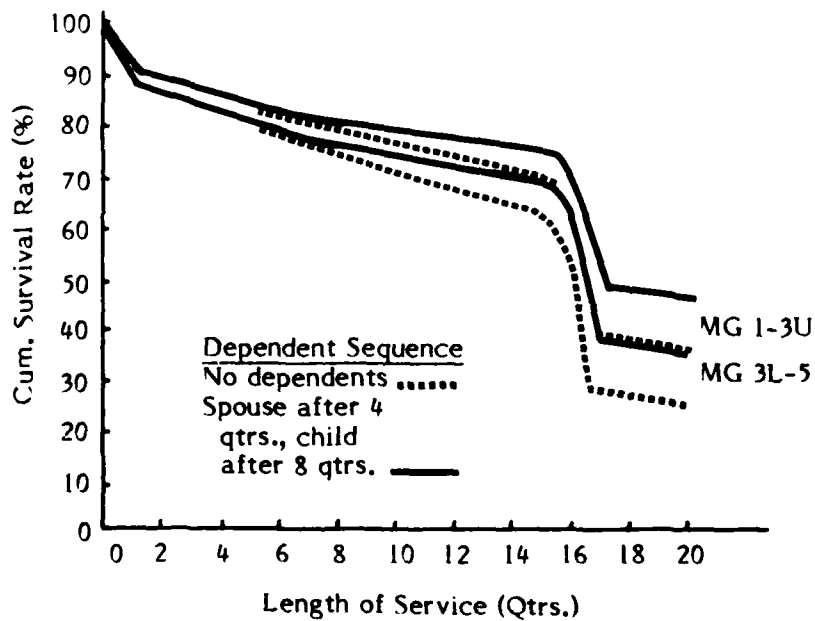


Figure 9. FY78 survival curves for mental groups (Values: White, 18 years, HSG, intensive sea duty) by dependent sequence.

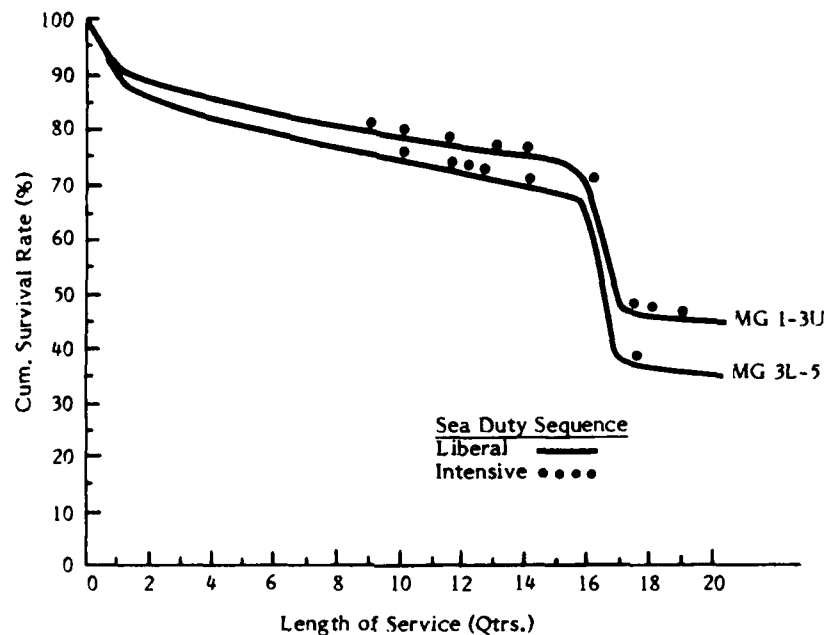


Figure 10. FY78 survival curves for mental groups (Values: White, 18 years, HSG, with dependents) by sea duty sequence.

CONCLUSIONS

The principal finding of this effort is the feasibility of using the Cox regression method in analyzing the survival probabilities of Navy enlisted personnel. The estimates of coefficients and survival rates appear to be quite reasonable. Using data from FY78, FY79, FY80, and FY81, the estimates of survival correspond highly with actual figures.

From this research, an estimate of the effect of sea duty on survival has been obtained. Higher numbers of consecutive quarters of sea duty are associated with lower survival rates for single personnel. For personnel with two or more dependents, different sequences of consecutive sea months have no significant impact. The family separation argument against sea duty may be dampened by the job security and Navy benefits enjoyed by those with two or more dependents. Although there is a desire to recoup training expenses during the first term by sending personnel for extensive sea duty, such a practice appears to lower survival for single personnel but has no effect on those with dependents. A more liberally spaced sea duty sequence for single personnel could be beneficial.

REFERENCES

- Blanco, T.A. Impact of alternative Navy-wide decrewing scenarios on fleet/SIMA skill shortages: Preliminary results. (NPRDC SR 80-27) San Diego, CA: Navy Personnel Research and Development Center, July 1980.
- Chow, W.K. & Polich, J.M. Models of the first-term reenlistment decision (R-2468-MRAL). Santa Monica, CA: The Rand Corporation, September 1980.
- Cox, D.R. Regression Models and Life Tables. Journal of the Royal Statistical Society, Series, B34, 1972, pp. 187-220.
- Gay, K. & Borack, J.I. The enlisted survival tracking file (STF): A revision. (NPRDC TN 82-27). San Diego, CA: Navy Personnel Research and Development Center, September 1982. (AD-A119 717)
- Goldberg, M.S. & Warner, J.T. Sea-shore rotation and retention (CNA 80-1294). Alexandria, VA: The Center for Naval Analyses, September 1980.
- Kalbfleisch, J.D. & Prentice, R.L. The statistical analysis of failure times data. New York: John Wiley and Sons, Inc., 1980.
- Lurie, P. M. Nonparametric methods for estimating recruit survival with cross-sectional data (CRC 402). Alexandria, VA: The Center for Naval Analyses, September 1979.
- Maurer, D. The expanded sea/shore rotation model (CRC 381). Alexandria, VA: The Center for Naval Analyses, May 1979.
- Menken, J., Trussell, J., Stempel, D., & Babakol, O. Proportional hazards life table model: An illustrative analysis of sociodemographic influences on marital dissolution in the United States, Demography, Vol. 18, No. 2, May 1981, pp. 181-200.
- Nakada, M. What matters in the first extension decision of nuclear submarine officers? (CNA 81-0130). Alexandria, VA: The Center for Naval Analyses, July 1981.
- Naval Military Personnel Command. Enlisted transfer manual (NAVPERS 15909C). Washington, DC: Author, 1982.
- Rodney, D., Baghelai, C., Samaan, J., Yaphe, M., & Malatesta, P. The impact of selective reenlistment bonuses upon first- and second-term retention. Arlington, VA: REHAB Group, 1980.
- Smith, R. J. A description of the enlisted service rotation system (N-1004 MRAL). Santa Monica, CA: The Rand Corporation, December 1979.
- Warner, J. T., Issues in Navy manpower research and policy: An economist's perspective (p. 322). Alexandria, VA: The Center for Naval Analyses, December 1981.
- Waterman, R.J., Mauer, D., & Huntzinger, R.L. The aggregate sea/shore rotation model (MOSES) (CRC 380). Alexandria, VA: The Center for Naval Analyses, March 1979.

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