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DETERMINANTS OF SLAVE AND CREW MORTALITY IN THE ATLANTIC SLAVE TRADE

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ABSTRACT

This paper measures and analyzes death rates that prevailed in the Atlantic slave trade during the late 1700s. Crew members died primarily from fevers (probably malaria) and slaves died primarily from gastrointestinal diseases. Annual death rates in this activity were 230 per thousand among the crew and 83 per thousand among slaves. The lack of immunities to the African disease environment contributed to the high death rates among the crew. The spread of dysentery among slaves during the voyage was probably exacerbated by congestion and poor nutrition. Death rates differed systematically by region of origin in Africa and season of the year. There was little interaction between the incidence of slave and crew deaths. The high death rates make the slave trade a demographic laboratory for study of health and mortality and an economic laboratory for study of markets for free labor.

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INTRODUCTION

One of the early political expressions of opposition to slavery occurred in the late 1700s when Parliament considered proposals to ameliorate conditions in the slave trade. The treatment and mortality of slaves emerged as central questions in deliberations and the debate led to collection and study of evidence on conditions in Africa, the middle passage, and the New World. Legislation in 1788 took the form of limits on the slave-carrying capacity of vessels; the requirement that slave vessels carry a surgeon who cared for slaves and who monitored conditions through a journal that noted deaths and causes of death; and a system of bonuses to ship captains and surgeons.

Controversy over the health and mortality of persons involved in the slave trade has persisted from the era of the campaign against slavery to the present. The debate continues in part because the rhetoric, the charges and counter-charges, and the tactics of the supporters and foes of the institution often obscured the underlying realities. More fundamental to modern research, however, are the facts that substantially limited information on these questions survives to the present and the levels and determinants of health and mortality are central to larger questions such as the economic costs of the slave trade to Western Europe, the profitability of slavery and the slave trade, and the impact of legislation on the slave trade.

Studies of mortality in the Atlantic slave trade have relied extensively on data from company records, newspapers, and government sources such as port records, papers required by legislation monitoring or regulating the trade, and the results of special inquiries.[1] The measure of mortality commonly constructed from these sources is the ratio of slave deaths to the number of slaves embarked, although some authors have used the ratio divided by voyage length multiplied by 1000.[2] The central questions of research have included mortality differences by region of departure from Africa, the effect of crowding on mortality, voyage length and the probability of death, the secular trend in mortality rates, and the importance of vessels that had an unusually high number of deaths.

This paper extends work in the area by analyzing 92 surgeons' logs required by Dolben's Act of 1788. The ships in the sample originated from the major supply regions in Africa and span the years 1792 to 1796. The exceptional value of the logs for measuring levels and studying determinants of mortality stems from the combination of information on dates of death, causes of death, and records for slaves as well as crew. Because dates of death and the number of persons at risk are available, true death rates can be calculated. The death rates are relevant for comparisons with the mortality experiences of other populations. The chronological record also permits study of death rates by day during loading and during the voyage as opposed to study of the journey as a whole that is common in previous work. Although the diagnostic capabilities of ship surgeons were primitive by modern standards, the symptoms of several diseases or disease categories common in the slave trade were sufficiently distinctive to be useful. This combined with the systematic enumeration of causes enables a statistical examination of causes of mortality that is more detailed then previously undertaken. The mortality records of the crew furnish a backdrop against which slave mortality can be compared and contrasted.

The analysis begins with death rates by cause of death. The results of this inquiry suggest a plan of action for study of major causes of death during loading and during the voyage. The next portion compares the findings of this paper with previous work, and the last section considers the generality of the results. The analysis generally accepts the data at face value;

the hazards of doing this and features of the data are discussed in the appendix.

DEATH RATES BY CAUSE OF DEATH

Construction

The surgeon maintained a chronological journal of loadings and unloadings, usually in categories of men, women, boys, and girls, although sometimes only males and females or men and women were enumerated. Slaves were frequently held on board until departure for the West Indies. Slaves unloaded include those sold to other vessels and pawns (captives held as security before transactions were completed) and sick slaves returned to shore.[3] Slave sales or transfers to other ships were extensive on a few vessels. A computer program written for these data tabulates the number at risk each day from first loading to the final destination in the West Indies.

Muster rolls establish the crew size at the time of departure from England for 45 out of 92 vessels in the sample. Crew size for the remaining vessels was estimated from a regression of crew size on tons.[4] The available muster rolls show that relatively few crew members left the ship or were taken on board before the ship reached the West Indies. As an approximation it was assumed that crew size changed only through deaths. Thus the estimated number of crew at risk may be inaccurate for particular vessels.

Death rates were calculated from the chronological record of deaths and data on the average number of person-years at risk during a particular time period.[5] The tables express results in annual rates per 1000 to facilitate comparisons with other populations.

Medical Knowledge

The information available on casues of death must be approached cautiously given the rudimentary medical knowledge of the late 1700s.[6] The difficulties stem from the lack of a germ theory of disease to guide inquiry and from the poor state of medical instruments and procedures necessary for precise diagnosis. In making a diagnosis that would guide treatment the surgeons drew upon visible symptoms of the patient. Unfortunately not all important symptoms of a particular disease were visible, the symptoms may have changed over time as the disease ran its course, and some diseases with distinctly different causes have symptoms in common. The problems of identification were compounded if the patient had more than one disease.

Medical diagnosis of cause or causes of death is important for investigation of socioeconomic and epidemiological factors in mortality. Knowledge of the disease or diseases involved conveys information about the net influence of the prevalence of pathogens, mechanisms of transmission, and the susceptibility of individuals in the population. Unfortunately the surgeons recorded few visible detals and their observations were often grouped under broad headings such as "fevers," "dysentery," and "diarrhea." The fevers no doubt included malaria and probably yellow fever and the gastrointestinal diseases no doubt included shigellosis (bacillary dysentery)and possibly amoebic dysentery.[7] However, fever sometimes accompanies gastrointestinal diseases and vomiting and diarrhea may accompany malaria and yellow fever.[8] Thus it is not safe to conclude that "fevers" were confined entirely to diseases spread by mosquitoes or that gastrointestinal diseases such as "diarrhea" were confined entirely to diseases spread by ingestion of contaminated matter.

Patterns

Tables 1-4 show the death rates calculated for slaves and crew during loading and the voyage. Comparisons involving the overall rates given in the last row of the third column of each table demonstrate that loading and the voyage were extraordinarily hazardous to life. The rates are exceptional when placed in the proper perspective of the probable age range of the slaves and crew. Death rates are ordinarily highest during infancy, then decline during childhood and reach a minimum just before or during adolescence. The rates usually rise gradually for many years beyond the minimum and then accelerate upwards in the 60s and beyond. Under ordinary circumstances most deaths were confined to the very young and the old. Typical eighteenth-century Western European populations in the age range 10-34, for example, probably had average annual death rates not exceeding roughly 1 percent.[9] Furthermore, the upper limit of recorded experience for this age group when not living under severe circumstances such as war or famine is less than 2 percent.[10] The slaves and crew faced death rates several times higher than their contemporaries engaged in ordinary activities. The slave trade therefore provides a laboratory for study of health and mortality under extreme circumstances.

The slave trade was relatively hazardous for the crew, particularly during loading. Compared to slaves the death rates of the crew were more than 5 times higher during loading and nearly twice as high during the voyage. The absolute levels of crew death rates were on the low to middle range of magnitudes reported by others for European populations residing in western Africa during the eighteenth and nineteenth centuries.[11] The surgeons logs support the view that western Africa was the "white man's grave." The extraordinary death rates for the crew raise interesting questions about the operation of markets for free labor that engaged in the slave trade. Comparisons of the slave trade with other types of voyages would add a dimension of perspective to the slave trade and may provide insights into causes of mortality.

The chances of death changed considerably during the course of loading and the voyage. Among slaves the safest period occurred about 3 to 6 months before departure; the death rate at this time was 22.8 per thousand, or in the neighborhood of twice the rate expected for settled populations not facing severe circumstances. From this low the rate nearly tripled to 64.5 per thousand during the four weeks before departure, continued to rise during the early part of the voyage, and reached a peak of 145.9 per thousand during days 29-42 of the voyage. Slave death rates followed an inverted-U shape during the voyage and differed by a factor of roughly 2 to 1. Compared to slaves, crew death rates were less volatile during loading and reached a plateau of nearly 350 per thousand in weeks 5-12. Over three-quarters of all crew deaths during the voyage occurred within the first four weeks.

During the operations of loading and the voyage over 60 percent of the crew deaths were from fevers and over 40 percent of the slave deaths were from gastrointestinal diseases. The share of crew deaths from fevers was slightly higher during loading (68%) compared to the voyage (54%). Among slaves the shares of deaths from gastrointestinal diseases were approximately constant during loading (38%) and the voyage (41%). Gastrointestinal diseases claimed 16 percent of crew deaths and fevers amounted to 8 percent of slave losses.

The minor causes of slave deaths included respiratory diseases (5%), suicide (3%), scurvy (2%), insurrection (2%), and accidents. Among crew deaths 8 percent involved accidents (primarily drowning), 2 percent scurvy, 1 percent respiratory, and 1 percent insurrection. The "other" category includes well-defined but relatively infrequent ailments such as yaws and dropsy, several poorly-described diseases (e.g. "sudden death," "sulks," "fits," "delirium," and "relaxed"), and many illegible entries. Most of the slave deaths from respiratory diseases (89%) and scurvy (88%) occurred on the voyage, particularly near the middle and the end of the trip, which is consistent with claims and evidence that the voyage was debilitating. The low death rates from scurvy suggest that measures sometimes taken as early as the late eighteenth century to include vitamin C in the diet through foods such as lime juice may have been used.[12] Information on exact dates of death available in the logs indicates that slave suicides were concentrated during or shortly after slaves were first loaded and at the time the ship left Africa.

It is important to note that smallpox and measles were virtually absent as causes of death in these data. Inoculation against smallpox was practiced in England as early as the mid 1700s, and the availability of the technology suggests that it may have been used on slaves.[13] It is also possible that native Africans practiced inoculation.[14] Because the logs pertain to only to a few years (1792-1796), it is also possible that epidemic conditions for this disease were temporarily favorable.

Implications

Because the underlying causes and methods of transmission of many diseases are quite different, the investigation of determinants of mortality will be undertaken by disease category. The data in Tables 1-4 make it clear that fevers and gastrointestinal diseases should be the focus of attention. Other causes of death are relevant to the entire picture, but their frequency of occurrence--even for the most important minor causes such as accidents among the crew and respiratory diseases among slaves--is so low that systematic study is not feasible with these data.

The configurations of death rates by day of loading, day before departure, and day of voyage suggest that determinants of mortality substantially involved a time-dependent process. The importance of time is easily seen for gastrointestinal diseases involving slaves; death rates more than doubled from the beginning to the end of loading and continued to climb, reaching a peak during the third to the fifth week of the voyage. The pattern of death rates resembles the beginning, height, and end of an epidemic.

The concepts of agent, host, environment, and incubation period as employed by epidemiologists are useful for understanding mortality from dysentery.[15] The spread of an infectious disease depends upon the probability of contact between an infectious agent and individuals, and the susceptibility of individuals. The amount of infectious material in the environment is a function of the number of infected individuals or hosts of the agent, the duration and extent to which infectious material is expelled by hosts, the rate of survival of the agent in the environment, the route of entry into the host, and the existence of alternative reservoirs or hosts of the agent. The availability of hosts varies with the mobility and interpersonal contact within the population group, and the immunity or other means of resistence to the agent by individuals. The incubation period is the interval of time between contact with an infectious agent and the onset of illness. Each disease has a characteristic incubation period, which may vary among individuals. The discussion so far has assumed a situation with case-to-case transmission of disease, but the concepts can easily be extended to include the spread of infection from a central source such as contaminated food or liquid.

The epidemiology of malaria and yellow fever involve intermediate hosts. The parasites responsible for these infections spend part of their life cycle inhabiting mosquitoes and so the path of transmission is from man (or other host) in his infectious stage, to mosquito, and subsequently from mosquito to man. These diseases therefore involve populations of mosquitoes and humans (or other hosts), each with its own set of susceptible and infective hosts.

African natives were ordinarily infected with malaria as children, and those who survived had a limited immunity to further symptoms, but could act as hosts.[16] Thus malaria was hyperendemic in coastal areas of western Africa, and the spread of the disease among European newcomers resembled a stochastic version of contamination from a central source. Unlike malaria, yellow fever kills the victim within 5 to 7 days or follows by rapid recovery and life-long immunity that prevents the individual from acting again as a host. The yellow fever parasite occasionally died out in parts of Africa, particularly in isolated areas, but the chances of an epidemic increased as the nonimmune population grew and as contacts with the outside carried the disease. Europeans may have contributed to periodic yellow fever epidemics as nonimmune hosts.

The spread of infectious disease is a complex process that can be summarized using mathematical models.[17] In a simple deterministic model of an epidemic, for example, disease spreads by contact between infectives and susceptibles, there is no removal from circulation by death, recovery, or isolation, and infections remain contagious throughout the epidemic. The epidemic curve shows the rate at which new cases accrue over time under the conditions or parameters specified by the model. The time pattern of deaths is derivable from the epidemic curve by incorporating magnitudes for the share of those infected who fail to survive and the delay from the onset of symptoms to death. More complex models can involve infection and removal, intermediate hosts, geographical spread, stochastic phenomena, latent and infectious periods, and lost immunity. The *a priori* formulation of a model appropriate for slaves or crew would be difficult in part because many conditions relevant to the model are unknown. Indeed, the relevant conditions are an important object of investigation. Nevertheless, an epidemic model is a useful framework for thought. Some of the parameters in such a model were given and others were under the control or influence of slave traders, ship captains, and surgeons. The extent and nature of control are topics for the next section of the paper.

ANALYSIS OF MAJOR CAUSES OF DEATH

Approach

Given the importance of time in an epidemic process it is fortunate that surgeons recorded information on a daily basis. The unit of observation selected for a regression analysis of determinants of mortality is daily information for a particular ship. We chose a logit model in which the dependent variable takes on the value of 1 if there were one or more deaths from a particular cause.[18] Separate regressions are required for slaves and crew on the grounds that these groups arrived with substantially different immunities and lived under considerably different conditions. Because there was contact with shore and provisions were available from shore during loading but not during the voyage, it is appropriate to analyze mortality during loading separate from mortality during the voyage.

Loading

The variables available for study of mortality during loading include region of origin in Africa, slaves per ton on the ship, season of the year, and time. These variables are motivated below. Experiments with other variables are discussed at the end of this section.

Region. Differences in death rates by location could have been caused by variations in the rate of exposure to pathogens, the number and virulence of pathogens, and the immunities and other means of resistence by individuals to disease. With regard to risks of exposure, the nature of activities required by the crew while slaving may have differed by region. For example, the distance that the ship anchored from shore, whether the ship anchored along the coast or in a river or delta, the amount of time spent by the crew on ship versus the interior, and sources of food and water may have been important determinants of mortality. Among slaves the risks of exposure may have been influenced by the duration of time from inland capture to loading, the locations of forts or prisons relative to sources of disease, the extent of crowding while being held on shore, and sources of food and water. It is virtually impossible to acquire reliable information about the number and virulence of pathogens that existed in the late eighteenth century. However, it should be recognized that differences could have existed as a function of climate, topography, migration, and the extent of adaptation of pathogens to hosts. The immunities of individuals were influenced by the degree of adaptation to a disease environment. Thus the extent to which slaves exported from a particular port were acquired in regions remote or otherwise differing in disease environment of the port of exit may have influenced mortality. Excluding the few who had been to Africa or the West Indies previously, the crew generally had little or no resistence to malaria or yellow fever. The general health and diet of slaves and crew were important particularly for resistence to gastrointestinal diseases; nutrition apparently has little impact on the course of malaria or yellow fever.[19] Therefore the health of slaves at the time of initial capture, exertions of the journey to the coast, and diet while being held on the coast or on board ship may have influenced deaths from dysentery. In conclusion, it should be recognized that the large number of possible regional determinants of mortality and the lack of information about most of them will make it difficult to identify specific sources of locational differences in mortality that may be found. It should be noted that the influence of a particular region on mortality could have changed overtime, but that lack of data restricts study of this issue.

Slaves per Ton. Gastrointestinal diseases such as shigellosis are often highly contagious.[20] Transmission is common through the fecal-oral route, usually by way of contaminated hands or food. Shigellosis does not confer long-term immunity because reinfections are frequent, and the multiplicity of strains precludes resistence to all varieties. Assuming that all instances of gastrointestinal diseases were not acquired by contamination from a central source such as food or water, the spread of these diseases would have varied with density. Thus slaves per ton may have influenced slave death rates. To the extent that the crew avoided slaves and slave living areas or had resistence, death rates of the crew would have been unrelated to slaves per ton.

Season. The number of sites available for mosquito larvae, and therefore the mosquito population, may have increased during the rainy season.[21] In addition, mosquitoes have may been more active and survived for longer periods in humid as opposed to dry weather. Thus the chances of infection from malaria may have increased during the rainy season. Some observers have noted an increase in the incidence of "fevers" during the rainy season.[22] Rain and high humidity may also have prolonged the survival and increased the probability of transmission of bacteria responsible for gastrointestinal diseases.

Time. The spread of infectious disease inevitably involves time. Factors that may influence the profile of mortality over time include patterns of activity that affect the chances of exposure to pathogens, the mechanism of transmission, the incubation period of the disease, and the interval from the onset of illness to death. Diseases have characteristic incubation periods and intervals from the first symptoms to death. Given information about causes of death, the time profile of mortality may be informative about the mechanism of transmission and the patterns of activity that led to disease.

The results involving slaves and crew are given in Tables 5 and 6. Since the chances of deaths should have been a function of the number of persons at risk, the regressions include the number of slaves (or crew) as independent variables. The values of -2 log λ, where λ is the likelihood ratio, show that each regression is highly significant. Significance tests for groups of coefficients are given in the notes to the tables.

Among slaves the deaths from fevers and gastrointestinal diseases by region of origin were systematically higher in the Bight of Biafra. Compared to other regions, the probability of deaths among slaves boarded in the Bight of Biafra was 31 precent higher for gastrointestinal diseases and 58 percent higher for fevers.[23] The Bight of Biafra was also deadly for the crew, especially for gastrointestinal diseases. However, the chances of crew deaths from fevers were systematically highest on the Windward Coast and systematically lowest on the Gold Coast. The highest chances of crew deaths from gastrointestinal diseases occurred in Senegambia.

Crowding, or slaves per ton, was included in the regressions involving fevers on the grounds that some gastrointestinal diseases may have been misdiagnosed as fevers. Because the relationship between crowding and mortality may have been nonlinear, the regressions include a polynomial in slaves per ton. The tests reported in the notes to Table 6 show that crowding had no systematic influence on crew deaths. The explanation for the lack of association is unclear, but if the diet and health of the crew was relatively good, it would have imposed a gastric acid barrier to the spread of gastrointestinal infections. It is also possible that the crew avoided contact and therefore contamination from slaves, or that the crew was largely immune (i.e. the crew was the source of slave gastrointestinal infections) to the diseases involved. The tests reported in the notes to Table 5 establish that slave deaths were systematically linked to crowding. Figure 1 shows that the chances of gastrointestinal infection implied by the regression increased roughly ten fold as the ships approached carrying capacity. This pattern is consistent with higher probabilities of transmitting infection through contact as density increased. If some gastrointestinal diseases were misdiagnosed as fevers, it is not surprising that the chances of deaths from "fevers" would have been related to slaves per ton. Figure 1 shows, however, that the chances of deaths from fevers eventually declined as slaves per ton rose. The reason for this pattern is unknown, but it is possible that some of the fevers were caused by mosquitoes and that for reasons of safety and control of the cargo, the ships anchored further from shore at high densities.

The chances of crew deaths from gastrointestinal diseases were not systematically related to time as measured by a polynomial in day of loading. The day of loading coefficients involving fevers were significantly different from 0 at .10; deaths were systematically lower early in the loading process, possibly because of the delay between infection and mortality for diseases such as malaria.

Slave deaths from gastrointestinal diseases were systematically higher during the rainy season (June, July, and August north of the equator and December, January, and February south of the equator).[24] Rain apparently had no influence on the chances of crew deaths from gastrointestinal causes or on deaths from fevers. Infective mosquitoes may have been sufficiently prevalent year-round that the chances of infection varied little by season of the year.

It is also possible that infective mosquitoes were more prevalent during the rainy season and that patterns of activity, such as expeditions to the interior, were curtailed in ways that offset the greater risk of infection.

Experiments with other variables include a proxy for the price of slaves, a measure of association between slave and crew deaths, measures of duration that slaves had been on board, the age and sex ratios of slaves, recent loading of slaves, year of activity, and month of the year. Since bonuses and other income received by the captain, the surgeon, and the crew varied with the value of the cargo, there were incentives to improve care as a function of slave prices. Unfortunately, reliable annual data on slave prices are lacking or have not yet been assembled for the late eighteenth century. Experiments using the price of sugar as a proxy for the price of slaves failed to uncover any systematic relationship with slave mortality. The incentives at low prices may have been sufficient to elicit all the care that they were willing to exert, or were able to exert given the primitive state of health care knowledge. The reasons in theory why the price of slaves and the price of sugar may not have been highly correlated also suggest that sugar prices may have been a poor proxy for slave prices; for example, fluctuations in weather could have changed the supply and therefore the price of sugar in ways that had little influence on slave prices.

In an effort to investigate the possible transmission of gastrointestinal diseases from slaves to the crew and vice versa, dummy variables representing death of slaves (or crew) from gastrointestinal causes within the previous week were included as explanatory variables in the regressions for gastrointestinal diseases. The results showed that there was no systematic interaction between slave and crew mortality.

Because individual slaves were not tagged by date of entry or exit from the ship, it is impossible to measure accurately the length of time that the typical slave had been on board. Since life on the ship was probably debilitating, duration aboard may have influenced the incidence and course of disease. Experiments with measures of average duration constructed on various assumptions about flows (such as first on, first off and last on, first off) were unsatisfactory; the procedures sometimes produced impossible results (negative numbers of slaves at risk on some days, for example) and in those cases in which the measures could not be rejected out of hand, there was no systematic association with mortality.

Differential patterns of exposure, immunity, and resistence to disease may have affected death rates by age and sex. Children, for example, may have acquired fewer immunities than adults. Patterns in African societies of demand for labor and access to food by age and sex and differential treatment after enslavement could have led to differential mortality for males and females. In the subset of observations providing the relevant information, the shares of the cargo enumerated as females and children were included as explanatory variables. Age and sex composition had no statistically significant influence on fevers, but the chances of deaths from gastromtestinal causes were systematically higher among females and children.

The chances that someone harbored or transmitted a disease may have increased with the number of slaves or crew aboard and with the recent addition of slaves to the ship. Experiments with these variables failed to uncover any systematic influences. Quadratic terms in the number of slaves and number of crew, and the number of slaves loaded within the previous week were statistically insignificant when included in the regressions for fevers and for gastrointestinal diseases.

Although the data employed in the paper pertain to only 5 years (1792-1796), it is possible that captains and surgeons adjusted to the incentives of Dolben's Act in ways that reduced mortality. A linear term in year of the activity was included in the regressions, and the coefficient was negative and statistically significant (t=-3.47) for gastrointestinal diseases but statistically insignificant for fevers. During the voyage the coefficient of the year was statistically insignificant in both regressions. It is possible that health was improved by methods that applied while loading but not during the voyage.

The regression models incorporate seasonal phenomena by including a dummy variable for the rainy season, but in reality seasonal phenomena influencing health and mortality were more complex than this simple dichotomy. Patterns of rainfall, food supply, insect vectors, and human activities varied throughout the year and by region in ways that make it difficult to predict the net influence of all relevant factors.[25] Empirical investigation of these phenomena among slaves is restricted by the small number of deaths that occurred during loading. Among the crew there is sufficient information to include dummies in month of loading as regressors in the equation for fevers on ships that loaded north of the equator. In these data crew deaths were systematically lower during the dry season months of March (t=-2.33) and April (t=-2.58). Captains were probably aware of seasonal patterns because days spent loading peaked in March (10.7 percent of all days spent loading) and were lowest during the summer months of the rainy season.

The Voyage

Although the variables available for study of mortality during the voyage are similar to those employed for loading, the interpretations may differ.

Region of origin, for example, ecompasses only those aspects such as general health or patterns of activity immediately before departure that continued to have an influence during the voyage. Thus contrasts between regional effects during loading and the voyage may suggest interpretations of the regional variables.

Table 7 shows that the chances of slave deaths from fevers were relatively high among ships departing from Sierra Leone, the Bight of Benin, and Congo-Angola. Senegambia, Sierra Leone, Congo-Angola, and especially the Bight of Biafra were major sources of slave deaths from gastrointestinal diseases. The small sample size limited regional comparisons involving the crew to the Bight of Biafra versus other regions. Companions of Tables 5-8 show that the Bight of Biafra was deadly for slaves and crew. The negative coefficient for crew size in gastrointestinal diseases is unexpected. Errors in crew size estimates may have contributed to this result, although it does not register in this way in other regressions. Perhaps there was specialization within the crew in the case of large ships in ways that concentrated contamination from gastrointestinal diseases.[26]

Crowding as measured by slaves per ton had no systematic influence on the chances of deaths for slaves or crew during the voyage. The equations shown in Tables 7 and 8 include only a linear term in slaves per ton on the grounds that the range of the variable was small across ships during the voyage; however, a third degree polynomial in slaves per ton is also statistically insignificant. The lack of association contrasts with the systematic association found for slaves during loading. Figure 1 shows that the chances of slave deaths tended to level-off at high densities; thus if the lack of association at high densities during loading applied to the voyage then the finding may be an artifact of the limited range of observation during the voyage.

Table 8 shows that crew mortality rates from fevers and gastrointestinal diseases were negatively related to length of loading, but the coefficients are marginally significant. If there was a systematic association involving length of loading and these causes of death, then the interpretation may be that the level of exposure to disease increased during loading such that those who survived were more immune to attacks and death during the voyage.

Day of the voyage systematically influenced slave deaths from fevers and gastrointestinial diseases and crew mortality from fevers.[27] The relationships estimated from the regressions are given in Figure 2. In each case the estimated probabilities of deaths follow an inverted-U pattern as a function of time. Among slaves the peak occurred about 25 days into the voyage for fevers and 31 days into the voyage for gastrointestinal diseases. Crew deaths from fevers peaked about 12 days into the voyage. The prevalent and most deadly form of malaria in Africa was P. falciparum.[28] This form usually has an incubation period of 10 to 14 days, but may be longer, and may kill up to 25 percent of nonimmune adults within 2 weeks of a primary attack.[29] The days immediately before a ship's departure usually involved considerable loading of slaves and interaction with shore. The interaction probably increased the crew's exposure to infective mosquitoes; this combined with the range of incubation periods and the delay from first symptoms to death is consistent with the time profile of crew mortality from fevers. Yellow fever runs its course within 5 to 7 days, and so it is unlikely that infections received on shore contributed to the peak observed during the voyage. However, the putrid fevers diagnosed by surgeons are consistent with yellow fever, and it is possible that infected mosquitoes taken aboard incubated the virus in ways that led to deaths from the disease more than one week into the voyage.

Compared to the distribution for the crew, slave deaths from fevers peaked about 2 weeks later and were more concentrated in the upper tail. The distribution resembles that for gastrointestinal diseases. Most slaves had probably been infected with malaria prior to capture, while traveling to the coast, or while being held on the coast. It is doubtful that slaves with fever symptoms were loaded. Furthermore, relapses do not occur in P. falciparum.[30] These considerations combined with the possibilities for misdiagnosis and the sensitivity of deaths from "fevers" to density during crowding suggest that a large share of the slave deaths attributed to "fevers" during the voyage may have been of gastrointestinal origin.

The time pattern of deaths from gastrointestinal diseases shown in Figure 2 is consistent with diffusion by personal contact and with contamination from a central source. In the case of personal contact the time pattern of deaths on individual ships would have resembled an inverted-U, and in the latter case the incidence of the first death across ships would have followed the inverted-U pattern, but deaths on a particular ship should have been bunched together, differing only by individual differences in the incubation period. While it is impossible to measure the relative importance of these processes from the available data, information in Tables 9 and 10 suggests that spread by personal contact was a general tendency. Table 9 shows that the average interval from the beginnng of the voyage to the first death was 17.1 days, which is significantly less than the interval of roughly 30 days predicted by the central source hypothesis. The incubation period for shigellosis ranges from 1 to 6 days and averages 5 days.[31] The fact that the average intervals between deaths 1 and 2 and between 2 and 3 exceeded the average incubation period casts further doubt on the central source explanation. In addition, the size and decline of the intervals is consistent with a diffusion by contact process. Table 10 shows that one-half of the ships with 2 or more deaths from gastrointestinal diseases had average intervals between deaths that exceeded the upper range of the incubation period of 6 days. Because 10 out of 26 ships had average intervals under 5 days, however, one cannot rule out instances of contamination from a central source. Indeed, instances of more complex processes such as spread by contact combined with contamination from a central source are well within the scope of the data.

Experiments conducted with other variables include the ratio of actual to expected voyage length, dummy variables representing interaction of slave and crew deaths from gastrointestinal causes within the previous week, measures of average duration that slaves had been on board, age and sex ratios, and quadratic terms in crew size and number of slaves. The latter four experiments were also conducted for loading and the results were similar with the exceptions that death of a slave from a gastrointestinal disease had a marginally significant (t=1.85) positive influence on the chances of crew deaths and that the shares of females and children had positive but not statistically significant influences on gastrointestinal diseases. Possible interpretations of the interaction between slaves and crew are that crew health, and therefore resistence, deteriorated from loading to the voyage, and that the amount of contamination from slaves was greater during the voyage because slaves ill with dysentery could not be sent on shore. Females and children vulnerable to disease while loading may have acquired immunities and possibly more food by the time of the voyage. With regard to expectations, predicted length was calculated from a regression of observed length on ship size in tons, region of origin in Africa, and destination in the West Indies (Jamaica versus the outer islands).[32] The argument for including the ratio of actual to expleted length is that provisions would have been depleted and death rates should have risen on unusually long voyages. The ratio of actual to expected length, interacted with day of the voyage or entered alone, had no systematic influence on crew or slave deaths from fevers or gastrointestinal diseases. This result is not surprising in view of the findings, shown in Figure 2, that deaths from the diseases in question were concentrated in the middle of the voyage.

COMPARISONS WITH OTHER RESEARCH

Important topics of earlier research on the Atlantic slave trade include variations in mortality by place of origin in Africa, crowding, voyage length, age and sex ratios, epidemics, and the relationship between slave and crew mortality. The following section compares the finding of this research with previous work in each of these areas.

Location in Africa

At the outset it should be recognized that mortality comparisons across regions are hazardous because factors other than region may have been involved. This qualification aside, others have found high rates of mortality in routes from East-South Africa (Mozambique) and Biafra.[33] Comparisons with Mozambique are not possible because the data of this study do not include voyages from that area. There are many possible explanations for high death rates from Biafra, including adverse health at enslavement, poor conditions on the journey to the coast and while being held for shipment, the exposure of slaves from remote areas to a new disease environment, and a harsh disease environment. While high death rates for slave and crew in Biafra (shown in

Tables 5-8) could have been the result of the coincidence of different factors, the poor experience of slaves and crew is consistent with a harsh disease environment.

Crowding

Although contemporary critics of the slave trade widely regarded crowding or "tight packing" of slaves as unhealthy, early regulations limited crowding, and connections between density and mortality are inherently plausible within a framework of the spread of infectious disease, recent quantitative studies fail to establish a connection between slaves per ton and mortality.[34] This paper demonstrates that variations in crowding were crucial to variations in death rates during loading. The contrasting results are reconcilable by Figure 1, which shows that the chances of deaths changed little with increasing density above 1.5 slaves per ton. Admittedly Figure 1 does not extend to densities in the area of 2 to 3 slaves per ton that prevailed outside the era of regulation, but findings by others that overall mortality varied little across voyages within the higher ranges are consistent with the hypothesis that the relationship changed little across high densities. It appears that Dolben's Act may have had little effect on mortality because the limits on crowding were not sufficiently restrictive.

Voyage Length

It has been widely, though not universally, noted that the share of the cargo dying increased with time at sea.[35] Whether there should have been a positive relationship has not been debated. Instead controversy centers on the profile of mortality within the voyage, and specifically on the relative importance of high mortality rates at the beginning as opposed to the end of the journey. It has been argued that the former would have been associated with poor conditions in Africa and the latter with poor conditions on the voyage, especially near the end of unusually long voyages. Neither of these patterns is supported by this study, at least not for the major causes of death studied in detail. This research suggests that high density possibly aggrevated by poor health before loading and poor nutrition during the voyage led to high death rates from gastrointestinal diseases near the middle of the voyage.

These results suggest directions for further research. Data on voyage length and share of slaves who died may be inadequate for measuring the importance of provisioning because the diseases involved are crucial to the argument; specifically, if there was screening before loading one would expect deaths from epidemic diseases having relatively long incubation periods (such as smallpox and measles, in which it is about two weeks) to accumulate near the end of the voyage. Furthermore, deaths resulting from reduced provisions need not have been concentrated at the end of the voyage. Delays in voyages crossing the equator occurred frequently in the doldrums off the coast of Africa. Ship captains probably adjusted provisions as a function of where the ship was in relation to where it was expected to be.[36] Thus, rations could have been cut early in the voyage and restored near the end of an unusually long journey. Even with "normal" provisions the journey was probably debilitating, and thus the rise in death rates from respiratory diseases and scurvy reported in Table 3 is consistent with the argument that conditions on the ship were important to health.[37] Third, high death rates early in the voyage may be consistent with poor conditions in Africa, but low death rates early in the voyage do not necessarily imply that conditions in Africa were "good";

captains and surgeons may have avoided areas with epidemics and may have been successful in screening slaves in poor health. Finally, greater attention shoud be given to the interaction of conditions in Africa with those on the ship. One of the contributions of the study of heights has been to alert researchers to the nature and extent of interaction among nutrition, disease, and growth.[38] Thus, for example, the effects of famines in Africa on mortality during the voyage may have been a function of crowding, provisioning, and voyage length.

Age and Sex

Studies examining differential mortality by age have usually found that rates were higher for children.[39] No systematic pattern has emerged involving males versus females. Findings in this study that chances of deaths from gastrointestinal diseases during loading were higher for children and females are generally consistent with previous work.

Epidemics

Although the role of epidemics are difficult to appraise from aggregate measures such as the share of slaves embarked who died, it is clear from qualitative evidence for the entire slave trade that the spread of infectious diseases such as dysentery, smallpox, and measles were important in overall mortality. As many as 20 to 30 percent or more of the ships in some trades, especially those of the seventeenth and early eighteenth centuries, had deaths as a share of slaves embarked in excess of 15 percent.[40] In these data the average share of slaves who died was 2.4 percent, the share exceeded 4 percent for only 10 out of 92 vessels (the distribution is given in Table 11 of the appendix) and the highest share in the sample was 13.8 percent. The favorable record stems in part from the lack of deaths from smallpox and measles. It also appears that the spread of dysentery may have been contained in these data relative to vessels that had high mortality rates; only 60 percent of the ships in the sample reported one or more and only 33 percent reported two or more deaths from gastrointestinal diseases.

Slaves and Crew

The issues of slave and crew mortality involve comparative levels and the extent of interrelation. The few data available on these questions indicate that crew mortality exceed that for slaves and that the two were positively, though, weakly, correlated.[41] The fact that slaves and crew tended to die from different causes would lead one to expect at most a weak positive correlation between overall slave and crew death rates. This study suggests that passage of gastrointestinal diseases from slaves to crews during the voyage was a source of that correlation. Though minor in these data, respiratory diseases and scurvy may have been important causes of death common to slaves and crew in earlier eras of the trade.

Although the literature on the slave trade seldom includes estimates of crew mortality, West Africa acquired a reputation among Europeans as the "white man's grave." Crew death rates probably remained high until progress was made against malaria and yellow fever beginning in the mid-nineteenth century. Thus the finding in this paper that the annual death rate during loading and the voyage combined was 229.5 per thousand for the crew is not surprising in light of other studies. The comparable figure among slaves of 82.8 per thousand is surprising for the extent to which it was below that for the crew. The next section discusses the low death rate for slaves.

CONCLUDING REMARKS

Using data giving date and cause of death this study has found that fevers and gastrointestinal diseases were the major cause of death for slaves and crew in the English slave trade to the West Indies during the late 1700s. The crew died primarily from fevers (mostly malaria) contracted in Africa, and gastrointestinal diseases such as dysentery that spread during the voyage were the major cause of slave deaths. The chances of slave and crew deaths varied systematically by region of origin in Africa, season of the year, and day of the voyage; for slaves alone by density on board ship, age, and sex; and for the crew alone by recent occurrence of slave deaths from gastrointestinal diseases during the voyage.

The incidence of mortality as measured by the number of deaths as a share of slaves embarked was low in these data compared to the slave trade in other times, which raises the question of the generality of these results. In light of this study, why might death rates have been higher elsewhere? There are several possible explanations. First, diseases such as smallpox and measles that were prevalent in other times were virtually absent from these data. Inoculation may have been effective in reducing the incidence of smallpox on the ships of the surgeons' logs. Second, knowledge and experience involving health and mortality in the slave trade had accumulated by the late 1700s. Practices at this time were not guided by a germ theory of disease, but presumably trial, error, and observation had eliminated some practices that contributed to deaths. One would expect that the rise in slave prices that occurred from the late 1600s provided an incentive for innovation in health care.[42] Third, Dolben's Act may have lowered mortality. To the extent that limits on capacity allowed room for more provisions, health may have improved.[43] The fact that deaths from respiratiory diseases and scurvy were low in these data is consistent with this explanation. In addition, the incentives of the act may have encouraged surgeons to screen carefully slaves in poor health. Fourth, conditions on slave ships were unhealthy, and the less time spent in this environment, the lower the share of slaves who died. Loading times and voyage length declined from the seventeenth through the end of the eighteenth century.[44] Finally, nutritional and demographic conditions in Africa could have changed in ways that led to slaves who were in better health before loading. Additional studies of slave mortality that make use of data on date and cause of death and conditions in Africa may shed light on these issues.

Studies of modern labor markets show that workers receive higher wages for jobs that, other things being equal, are unpleasant or dangerous.[45] The acquisition of crew members for slave ships constitutes an economic laboratory for study of employment under very hazardous conditions. Interesting questions about this labor market include the size of compensating wage differentials, whether higher wages were received for destinations to the higher mortality regions of Africa, the extent to which prospective crew members were informed about the risks, and the nature of compensation. With regard to the last point one might expect that crew members who were knowledgeable about the risks would have insisted on some compensation in the form of a signing bonus that was spendable before the hazardous journey began.

Comparative studies of mortality rates on ocean voyages would help to place the slave trade in perspective and to elucidate causes of mortality on slave and non-slave voyages.[46] Data on non-slave voyages to the U.S. are available, for example, from passenger lists and from forms required by the Passenger Act of 1819. The agenda for research on these questions should include the relationship of health before departure to health and mortality during the voyage, the influence of provisioning on mortality, crowding and mortality, seasonal patters of mortality, age and sex distributions and mortality, the course of death rates during the voyage, and the time trend in mortality.

Appendix: Discussion of the Data

Origins

"An act to regulate, for a limited time, the shipping and carrying of slaves in British vessels from the coast of Africa," also known as Dolben's Act, emerged from the parliamentary debates over the slave trade in 1788.[47] The act limited vessels to five slaves for every three tons of burden up to 201 tons, and one slave per ton for every ton above 201.[48] Ship captains exceeding this limit were subject to a fine of £ 30 per slave above the limit. Surgeons on board slave ships were required to maintain a journal encompassing slave loading, slave and crew deaths, and causes of death. The law specified that the collector at the port of destination was to administer on oath to the surgeon attesting the truth of the journal. Captains received £ 100 and surgeons received £ 50 if deaths as a fraction of the largest number of slaves on board did not exceed 2 percent. The awards were £ 50 and £ 25, respectively, if the rate did not exceed 3 percent.

Characteristics

An extensive search of the House of Lords Record Office and the Public Record Office produced 92 surgeons logs that are substantially complete.[49] The typical journal begins with a brief description of the vessel (name, names of master and surgeon, home port and tonnage) followed by sections on loading and unloading by day in categories of men, women, boys, and girls; chronological lists of slave and crew deaths; and the oath signed by the surgeon.

The dates of departure from Africa of the ships in the sample span the period from 1792 to 1796. Roughly one-third of the departures occurred in 1793 and only 9 voyages took place in 1794. The typical vessel loaded for 119 days, (s.d. = 92 days) but the range of experience encompassed 1 to 529 days.

Approximately 28,770 slaves departed from Africa, of whom 63.7 percent were males and 9.6 percent were children. The average ship carried 313 slaves and had a capacity of 222 tons. All the major regions of supply along the west coast of Africa are represented in the sample; 3 originated from Senegambia, 11 from Sierra Leone, 2 from the Windward Coast, 13 from the Gold Coast, 7 from the Bight of Benin, 8 from the Bight of Biafra, 18 from Congo-Angola, and the area of origin for 30 vessels is unknown. The typical voyage took 56 days (s.d. = 15.3 days) and the range was from 23 to 105 days. All the slaves were destined for the British West Indies and three-quarters of the ships went to Jamaica.

Biases

The logs of 16 vessels specify the day of arrival at the port of destination. Arrival times for 71 vessel were inferred from the day the surgeon's oath was signed. Arrival information is incomplete or lacking for 5 logs. Presumably the surgeon ceased to record deaths when the vessel reached port.[50] If the oath was administered after the day the vessel reached port, then death rates calculated for the end of the voyage would be biased downwards because the number of days at risk for recording deaths would be overstated.

Fortunately 12 vessels reported the actual day of arrival and have the oath. In this sample the average lag between the day of the oath and the reported day of arrival is 2.1 days, and the range is from 0 to 5 days. The distortion to calculated death rates is relatively minor if the experience of these vessels applied to those for which we lack information.

Throughout the period of the slave trade entrepreneurs commonly rewarded masters, surgeons, and certain members of the crew for efforts to maintain the health of the cargo. Bonuses took the form of shares of the sales receipts, head money, and privilege slaves.[51] The extent to which Dolben's Act may have contributed to total incentives is not clear; entrepreneurs could have allowed legislated incentives to substitute for their own.

Table 11 shows the frequency distribution of recorded deaths as a share of slaves exported from Africa. The clusters of observations at or below 2 percent and 3 percent combined with the cut-off point for bonuses under Dolben's Act raise the suspicion that some deaths may not have been recorded.

The observation that death rates in the Atlantic slave trade were relatively low during the 1790s appears to support the underreporting thesis.[52] In defense of the data, however, it should be recognized that good reasons exist for the low death rate (see the concluding section of the paper). While substantial underreporting cannot be entirely ruled out, the favorable situation with respect to epidemic diseases of smallpox and measles, for example, makes the calculated death rates plausible.

Even if there was substantial underreporting, the implications for our understanding of determinants of mortality heavily depends upon selectivity of underreporting. If deaths were not reported at random, for example, then many conclusions about regional influences, seasonal patterns, and the course of events during the voyage remain largely intact.

A selective form of underreporting perhaps worth discussion involves the end of the voyage. The decline in calculated death rates after the middle of the voyage combined with the chronological organization of the journals suggests that a simple strategy for collecting bonuses under Dolben's Act for ships that were near the margin for collection was to neglect to report deaths near the end of the voyage. Since all slaves loaded had to be accounted for, this required falsification of loading records. While this form of under-reporting may have existed, it is relevant to note that the time profile of deaths (available for gastrointestinal diseases only) on vessels that exceeded the 3 percent minimum reached a peak on day 35 of the voyage and then declined at a rate similar to that for the entire sample shown in Figure 2.

Sample Means

Table 12 lists the sample means of variables employed in the regressions. These data depict the nature of the sample and are required for calculating probabilities along the lines of those discussed in the text.

FOOTNOTES

1. Mortality in the Atlantic slave trade is the central concern of the following studies: Philip D. Curtin, "Epidemiology and the Slave Trade," Political Science Quarterly, 83 (1968), 190-216; Herbert S. Klein and Stanley L. Engerman, "Shipping Ptterns and Mortality in the African Slave Trade to Rio de Janeiro, 1825-1830," Cahiers d'etudes Africaines, 15 (1975), 381-398; "Slave Mortality on British Ships, 1791-1797," in Roger T. Anstey and P.E.H. Hair, eds., Liverpool, the African Slave Trade and Abolition (Liverpool, 1976), pp. 113-125; "A Note on Mortality in the French Slave Trade in the Eighteenth Century," in Henry A. Gemery and Jan S. Hogendorn, eds., The Uncommon Market: Essays in the Economic History of the Atlantic Slave Trade (New York, 1979), pp. 261-272; Herbert S. Klein, The Middle Passage (Princeton, 1978); Johannes Postma, "Mortality in the Dutch Slave Trade, 1675-1795," in Henry A. Gemery and Jan S. Hogendorn, The Uncommon Market: Essays in the Economic History of the Atlantic Slave Trade (New York, 1979), pp. 239-272; Robert Stein, "Mortality in the Eighteenth-Century French Slave Trade," Journal of African History 21 (1980), 35-41; Joseph C. Miller, "Mortality in the Atlantic Slave Trade: Statistical Evidence on Causality," Journal of Interdisciplinary History 11 (1981), 385-423; Raymond L. Cohn and Richard A. Jensen, "The Determinants of Slave Mortality Rates on the Middle Passage," Explorations in Economic History 19 (1982), 269-282; "Mortality in the Atlantic Slave Trade," Journal of Interdisciplinary History 13 (1982), 317-329; and David Eltis, "Mortality and Voyage Length in the Middle Passage: New Evidence from the Nineteenth Century," Journal of Economic History, 44 (1984), 301-308. See also Philip D. Curtin, The Atlantic Slave Trade: A Census (Madison, 1969); Richard Nelson Bean, The

British Trans-Atlantic Slave Trade, 1650-1775 (New York, 1975); Michael Craton, Sinews of Empire: A Short History of British Slavery (New York, 1974); Roger Anstey, The Atlantic Slave Trade and British Abolition, 1760-1810 (London, 1975); Tommy Todd Hamm, The American Slave Trade with Africa, 1620-1807 (Ph.D. dissertation, Indiana University, 1975); James A. Rawley, The Transatlantic Slave Trade: A History (New York, 1981).

2. Miller, "Mortality in the Atlantic Slave Trade," and Eltis, "Mortality and Voyage Length" employ the second measure.

3. A total of 7 slaves in the sample were returned to shore as sick. These unloadings were arbitrarily counted as deaths.

4. The estimated relationship is

$$\underset{(5.43)}{\text{Crew} = 11.64} + \underset{(8.46)}{0.07956}\ \text{Tons},\ N = 45,\ R^2 = .62$$

T-values are given in parenthesis. Simple non-linear functional forms fit little or no better than the simple linear form.

5. The terms "death rate" and "mortality rate" are sometimes used loosely and interchangeably. According to usage by demographers death rates are based on the average number of person-years at risk during a time period and mortality rates are based on the number at risk at the beginning of a time period. If there is little change in the number of persons at risk during the interval, the difference between the measures is small. Given the loading and unloading of slaves it is approiate to use death rates as opposed to mortality rates in this paper. For a discussion of terminology see Henry S. Shryock and Jacob S. Siegel, The Methods and Materials of Demography (Washington, 1975), vol. 2, chap. 14.

6. For discussion of medical knowledge in the eighteenth century see Christopher Lloyd and Jack L. S. Coulter, Medicine and the Navy, 1200-1900,

vol. III, 1714-1815 (Edinburgh, 1961), and H. Harold Scott, A History of Tropical Medicine, 2 vols. (London, 1939).

7. The potential for contaminated water suggests that typhoid may have contributed to deaths from fevers. Typhus is an unlikely cause of fevers because it is usually associated with blankets and clothing characteristic of colder climates.

8. Symptons of tropical diseases are discussed in G. Thomas Strickland, Hunter's Tropical Medicine (Philadelphia, 1984) and Oscar Felsenfeld, The Epidemiology of Tropical Diseases (Springfield, Ill., 1966). R. Hoeppli, Parasitic Diseases in Africa and the Western Hemisphere: Early Documentation and Transmission by the Slave Trade (Basel, 1969), p. 62 notes that as late as the early nineteenth century dysentery was thought to be but one of the symptoms of malaria.

9. Data in B.R. Mitchell, European Historical Statistics, 1750-1970 (New York, 1975), Table B6 show that crude death rates in European populations of the late 1700s and early 1800s commonly fell in the interval of 20 to 30 per thousand. The model West level 7 life tables of Ansley J. Coale and Paul Demeny, Regional Model Life Tables and Stable Populations (Princeton, 1966) has crude death rates in the neighborhood of 30 to 35 per thousand (given reasonable assumptions of the range of European birth rates), and is a conservative (high mortality) benchmark for these populations. The average of the age-specific mortality rates for males in the level 7 table for age groups 10-15 to 30-34 is 10.4 per thousand.

Soldiers not engaged in combat are a reference group against which the experiences of slaves and crew can be compared. The annual death rate among Dragoon guards serving in the United Kingdom from 1830 to 1836 was

14 per thousand from disease and 1.3 per thousand from suicide, murder, and accidents (see Parliamentary Papers, Statistical Report on the Sickness, Mortality, and Invaliding Among the Troops in the United Kingdom (London, 1839), p. 4).

10. The model West level 1 life table has crude death rates in the neighborhood of 47 to 51 per thousand (given reasonable assumptions about the range of European birth rates). In this table the average of the age-specific mortality rates for males in the age groups 10-14 to 30-34 is 18 per thousand.

11. Philip D. Curtin, "The White Man's Grave; Image and Reality," Journal of British Studies 1 (1961), 94-110; The Image of Africa: British Ideas and Action 1780-1850 (Madison, 1964); K.E. Davies, "The Living and the Dead: White Mortality in West Africa, 1684-1742," in Stanley L. Engeman and Eugene D. Genovese, Race and Slavery in the Western Hemisphere: Quantitative Studies (Princeton, 1975), 83-98; H.M. Feinberg, "New Data on European Mortality in West Africa: The Dutch on the Gold Coast, 1719-1760," Journal of African History 15 (1974), 357-371.

12. See Lloyd and Coulter, Medicine and the Navy, pp. 293-328 for a discussion of the conquest of scurvy.

13. Ibid, pp. 348-352. Klein, The Middle Passage, p. 229, notes that inoculation pervaded the slave trade by the second half of the eighteenth century.

14. Marc H. Dawson, "Smallpox in Kenya, 1880-1920," Social Science and Medicine 13B (1979), 245-250; Eugenia W. Herbert, "Smallpox Inoculation in Africa," Journal of African History 4 (1975), 539-559.

15. Abraham M. Lilienfeld, Foundations of Epidemiology (New York, 1976), Chap. 3 and Brian MacMahen and Thomas F. Pugh, Epidemiology: Principles and Methods (Boston, 1970), Chaps. 1-4.

16. Curtin, "White Man's Grave," pp. 95-97.

17. Classic works in the area include Norman T. J. Bailey, The Mathematical Theory of Epidemics (New York, 1957) and Hugo Muench, Catalytic Models in Epidemiology (Cambridge, Mass., 1959).

18. The share of deaths occurring on days in which there were two or more deaths was so low that it justifies the use of a logit model as an approximation for calcuating probabilities of death. Only 3.3 percent of crew deaths from fevers, for example, occurred on days in which there were two or more deaths. Among the eight data sets used, the largest share of deaths occuring on days in which there were two or more deaths (12.7 percent) involved slaves dying from gastrointestinal diseases during the voyage.

19. Strickland, Hunter's Tropical Medicine; Paul F. Russell, Luther S. West, Reginald D. Manwell, and George MacDonald, Practical Malairology (London, 1963).

20. Strickland, Hunter's Tropical Medicine, pp. 279-282; Felsenfeld, Epidemiology, pp. 130-134.

21. Leonard Jan Bruce-Chwatt, Essential Malariology (London, 1980) pp. 117-120; Russel et al., Practical Malariology, p. 237 and pp. 239-240.

22. Joseph C. Miller, "The Significance of Drought, Disease, and Famine in the Agriculturally Marginal Zones of West-Central Africa," Journal of African History 23(1982), p. 23.

23. The probabilities were calculated from the regression coefficients and the logistic function by evaluating other independent variables at their sample mean. Similar calculations giving relative risks of deaths for other variables can be done using the sample means given in the appendix.

24. Seasonal patterns of rainfall are from Roland Oliver and Michael Crowder, The Cambridge Encyclopedia of Africa (Cambridge, 1981), p. 43.

25. Kenneth F. Kiple and Virginia Himmelsteib King, Another Dimension to the Black Diaspora: Diet, Disease, and Racism (Cambridge, 1981); W.B. Morgan and J.C. Pugh, West Africa (London, 1969); Jean Delmont, "Paludisme et variations climatiques saisonnieres on savane soudanienne d' Afrique de l'Ouest," Cahiers d'Etudes Africaines 22 (1982), 117-133.

26. There is evidence that captains assigned some of the ship's crew the only task of cleaning the ship. See George Francis Dow, Slave Ships and Slaving (Salem, Mass., 1927), pp. 82-83.

27. The last 13 days of observations for voyages going to Jamaica are not included in the regressions on the grounds that provisions acquired from a landfall on one of the outer islands may have lessened the comparability with non-Jamaica-bound voyages. Thus all voyages "ended" when a landfall was made.

28. Curtin, "White Man's Grave," p. 95.

29. Strickland, Hunter's Tropical Medicine, p. 534.

30. Ibid., p. 523.

31. Ibid., p. 280. The long incubation period for amoebic dysentery (20 to 90 days) suggests that spread of this disease was not primarily responsible for the inverted-U pattern. However, poorly-nourished slaves who

contracted the disease on shore could have died from it during the voyage.

32. The regression is

$$\text{Length (in Days)} = \underset{(10.2)}{41.11} \; \underset{(-1.42)}{-0.0227}\ \text{Tons}$$

$$+ \underset{(3.42)}{20.98}\ \text{Gold Coast} + \underset{(2.02)}{23.70}\ \text{Benin} + \underset{(5.04)}{17.64}\ \text{Biafra}$$

$$+ \underset{(2.85)}{11.01}\ \text{Congo-Angola} + \underset{(5.02)}{12.95}\ \text{Jamaica},\ N = 176,\ R^2 = .25.$$

The omitted variables are Senegambia, Sierra Leone, and Windward Coast. This group of variables was omitted because there was no statiscally significant difference in voyage length from these areas. The data source is the Return to an Order of the Right Honorable the House of Lords dated the 10th of July 1799, directing that the clerk of the Parliments do cause to be extracted from the several log books and Journals of Ships employed in the Slave Trade in each year 1791 to 1797 ..., dated 28 July 1800. Only those observations from this source having all relevant information on tons, origin, destination, and dates were used.

33. For discussions of regional patterns see Eltis, "Mortality and Voyage Length"; Postma, "Mortality in the Dutch Slave Trade"; Klein, *Middle Passage*; Klein and Engerman, "Slave Mortality on British Ships"; Klein and Engerman, "Shipping Patterns and Mortality"; and Curtin, *Atlantic Slave Trade*, chap. 10.

34. Sanderson, "The Liverpool Delegates and Sir William Dolben's Bill," *Transactions of the Historic Society of Lancashire and Cheshire* 124 (1972), 57-84 discusses the views of contemporaries. Recent quantitative studies on this question include Eltis, "Mortality and Voyage Length"; Postma, "Mortality in the Dutch Slave Trade"; Klein, *The Middle Passage*; and Klein and Engerman "Slave Mortality on British Ships"; and "A Note on Mortality in the French Slave Trade."

35. Investigations of mortality rates and voyage length include Eltis, "Mortality and Voyage Length"; Cohn and Jensen, "The Determinants of Slave Mortality Rates"; Miller, "Mortality in the Atlantic Slave Trade"; Postma, "Mortality in the Dutch Slave Trade"; Klein, The Middle Passage; Klein and Engerman, "Slave Mortality on British Ships;" "A Note on French Mortality in the French Slave Trade;" "Shipping Patterns and Mortality;" and Curtin, Atlantic Slave Trade.

36. Dow, Slave Ships, pp. 144-145 discusses problems of adjusting provisions during the course of the voyage. The questions facing the captain can be formulated as an optimal control problem. See Morton I. Kamien and Nancy L. Schwartz, Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management.

37. By way of perspective on the data in Table 3, relatively few voyages in these data were unusually long by standards of the entire slave trade (only 8 percent exceeded 75 days, for example), and limits on slave capacity under Dolben's Act may have enabled ships to carry additional provisions.

38. See, for example, Richard H. Steckel, "Slave Height Profiles from Coastwise Manifests," Explorations in Economic History 16 (1979), 363-380 and Robert W. Fogel et al., "Secular Changes in American and British Stature and Nutrition," Journal of Interdisciplinary History 14 (1983), 445-481.

39. Postma, "Mortality in the Dutch Slave Trade"; Klein, The Middle Passage; and Klein and Engerman, "Slave Mortality on British Ships."

40. Eltis, "Mortality and Voyage Length"; Postma, "Mortality in the Dutch Trade"; Klein and Engerman, "A Note on Mortality in the French Slave Trade;" "Shipping Patterns and Mortality;" Klein, The Middle Passage.

41. Klein and Engerman, "A Note on Mortality in the French Slave Trade;" Curtin, Atlantic Slave Trade, pp. 282-284.

42. Data on slave prices are available in Bean, The British Trans-Atlantic Slave Trade, p. 76; William Dickson, Mitigation of Slavery (London, 1814), pp. 259-260.

43. Dow, Slave Ships, p. 86 discusses the lack of space for food on slave ships.

44. The point on voyage length has been made by Raymond L. Cohn, "The Trend in Deaths of Slaves in the Middle Passage," mimeo (Illinois State University, 1984). Information on time spent in loading in an earlier era of the trade is available in Postma, "Mortality in the Dutch Slave Trade."

45. Robert S. Smith, "Compensating Wage Differentials and Public Policy: A Review," Industrial and Labor Relations Review 32 (April 1979), 339-352.

46. Some work has been done in this area. See, for example, James C. Riley, "Mortality on Long-Distance Voyages in the Eighteenth Century," Journal of Economic History 41 (September 1981), 651-656; Raymond L. Cohn, "Mortality on Immigrant Voyages to New York, 1836-1853," Journal of Economic History 44 (June 1984), 289-300; Farley Grubb," Mobility and Mortality on the North Atlantic Passage: Evidence from Eighteenth-Century German Migration," mimeo (University of Delaware, 1984).

47. The text of the act is given in Elizabeth Donnan, Documents Illustrative of the History of the Slave Trade to America (Washington, 1931), vol. 2, pp. 582-589. F.E. Sanderson, "The Liverpool Delegates," discusses the debate.

48. If more thn 40 percent of the slaves were children (defined as no more than 4 feet 4 inches) then every five children over the 40 percent counted as four slaves.

49. Judy Collingwood conducted the search. Logs that failed to give dates of slave deaths were ignored. Information sometimes missing from the papers available to me includes dates of loading (2 logs), crew deaths (27 logs), destination (1 log), causes of crew deaths (5 logs out of the 65 containing crew deaths), and causes of slave deaths (9 logs).

50. There is one known exception. The surgeon on a ship for which the day of arrival is known continued to record deaths for nearly two weeks after arrival.

51. Incentives are discussed in Anstey, The Atlantic Slave Trade, p. 34.

52. Information on the time trend of mortality is available from Klein, The Middle Passage; Eltis, "Mortality and Voyage Length"; Curtin, Atlantic Slave Trade; chap. 10; Cohn, "The Trend."

Table 1

Annual Death Rates per Thousand of Slaves During Loading by Cause of Death[a]

Days before Departure	Person-Years at Risk[b]	Total	Fevers[c]	Gastro-intestinal[d]	Respiratory[e]	Scurvy	Accident[f]	Suicide[g]	Insurrection	Other	Not Given
1-28	1565.65	64.5	10.9	24.3	1.9	0.0	0.6	0.6	1.9	10.2	14.1
29-56	869.66	35.6	11.5	14.9	0.0	0.0	1.1	2.3	0.0	1.1	4.6
57-84	537.08	31.7	5.6	14.9	1.9	1.9	0.0	3.7	1.9	1.9	0.0
85-196	701.23	22.8	1.4	8.6	0.0	1.4	4.3	0.0	0.0	1.4	5.7
197+	192.39	52.0	5.2	10.4	0.0	0.0	0.0	26.0	0.0	5.2	5.2
Total	3866.01	45.3	8.3	17.3	1.0	0.5	1.3	2.6	1.0	5.2	8.0

Source: Surgeons' Logs.

a. Listed under the first cause of death given if there was more than one cause.

b. Calculatd as person-days at risk divided by 365.

c. Includes fever (66%), malignant fever (9%), pleuratic fever (6%), bilious fever (3%), nervous fever (3%), putrid fever (3%), yellow fever (3%), inflamatory fever (3%), and remittent fever (3%).

d. Includes flux (51%), dysentery (37%), diarrhea (9%), worms (1%), and mortification in the bowels (1%).

e. Includes inflamation of lungs (50%), consumption (25%), and decline (25%).

f. Includes drowned (100%).

g. Includes jumped overboard (80%), and chooked himself (20%).

Table 2

Annual Death Rates per Thousand of Crew During Loading by Cause of Death[a]

Days of Loading	Person-Years at Risk[b]	Total	Fevers[c]	Gastro-intestinal[d]	Respiratory[e]	Scurvy	Accident[f]	Suicide	Insurrection	Other	Not Given
1-28	148.12	168.8	144.8	6.8	0.0	0.0	13.5	0.0	0.0	6.8	0.0
29-56	131.36	342.6	228.4	30.5	0.0	7.6	45.7	0.0	0.0	7.6	22.8
57-84	115.42	346.6	225.3	78.0	17.3	0.0	34.7	0.0	0.0	0.0	0.0
85-196	256.09	187.4	140.6	23.4	0.0	0.0	15.6	0.0	0.0	7.8	3.9
197+	101.54	187.1	78.8	39.4	0.0	0.0	9.8	0.0	0.0	0.0	59.1
Total	752.53	237.9	160.8	39.1	2.7	1.3	22.6	0.0	0.0	5.3	13.3

Source: Surgeons' Logs.

a. Listed under the first cause of death given if there was more than one cause.

b. Calculatd as person-days at risk divided by 365.

c. Includes fever (60%), putrid fever (26%), bilious fever (5%), remittent fever (4%), malignant fever (2%), nervous fever (2%), yellow fever (1%), and hectic fever (1%).

d. Includes flux (58%), dysentery (33%), diarrhea (4%), and inflammation of liver (4%).

e. Includes consumption (100%)

f. Includes drowned (94%), and a fall (6%).

Table 3

Annual Death Rates per Thousand of Slaves During the Voyage by Cause of Death[a]

Days of Voyage	Person-Years at Risk[b]	Total	Fevers[c]	Gastro-intestinal[d]	Respiratory[e]	Scurvy	Accident[f]	Suicide	Insurrection	Other	Not Given
1-14	1098.70	98.7	17.3	32.8	3.6	0.0	0.0	5.5	6.4	20.0	12.7
15-28	1092.11	138.3	25.6	68.7	4.6	1.8	2.7	0.9	0.0	17.4	16.5
29-42	1014.72	145.9	17.7	61.1	10.8	7.9	2.0	2.0	0.0	23.7	20.7
43-56	711.57	98.4	14.1	40.8	7.0	4.2	0.0	1.4	0.0	25.3	5.6
57+	500.12	68.0	12.0	20.0	14.0	2.0	0.0	0.0	0.0	14.0	6.0
Total	4417.22	115.7	18.3	48.0	7.2	3.2	1.1	2.3	1.6	20.4	13.6

Source: Surgeons' Logs.

a. Listed under the first cause of death given if there was more than one cause.

b. Calculated as person-days at risk divided by 365.

c. Includes fever (59%), nervous fever (14%), bilious fever (9%), yellow fever (4%), pleuratic fever (4%), putrid fever (2%), malignant fever (2%), hectic fever (2%), remittent fever (1%), acute fever (1%), and enlarged spleen (1%).

d. Includes flux (53%), dysentery (27%), worms (11%), diarrhea (8%), and dry belly ache (0.5%).

e. Includes consumption (41%), peripneumony (16%), inflammation of lungs (16%), pleurisy (16%), decayed lungs (6%), weakness (3%), and decline (3%).

f. Includes drowned (100%).

g. Includes jumped overboard (90%), and choked himself (10%).

Table 4

Annual Death Rates per Thousand of the Crew During the Voyage by Cause of Death[a]

Days of Voy-age	Person-Years at Risk[b]	Total	Fevers[c]	Gastro-intest-inal[d]	Respir-atory[e]	Scurvy	Acci-dent[f]	Suicide	Insur-rection	Other	Not Given
1-14	69.46	287.9	158.4	57.6	0.0	14.4	28.8	0.0	0.0	0.0	28.8
15-28	68.50	365.0	175.2	87.6	14.6	0.0	14.6	0.0	29.2	29.2	14.6
29-42	62.82	127.3	15.9	63.7	0.0	31.8	15.9	0.0	0.0	0.0	0.0
43-56	45.04	111.0	22.2	22.2	0.0	0.0	00	0.0	0.0	22.2	44.4
57+	38.63	25.9	25.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	284.45	207.4	91.4	52.7	3.5	10.5	14.1	0.0	7.0	10.5	17.6

Source: Surgeons' Logs.

a. Listed under the first cause of death given if there was more than one cause.

b. Calculated as person-days at risk divided by 365.

c. Includes fever (69%), bilious fever (8%), putrid fever (8%), malignant fever (8%), nervous fever (4%), and remittent fever (4%).

d. Includes flux (53%), dysentery (33%), diarrhea (7%), and diseased liver (7%).

e. Includes consumption (100%).

f. Includes drowned (100%).

Table 5

Regressions of Slave Death per Day While Loading
from Fevers and Gastrointestinal Diseases
on Number of Slaves,
Region of Loading in Africa, Slaves per Ton, and the Rainy Season

	Fevers		Gastrointestinal	
Variables	Coeff.	t-value	Coeff.	t-value
Number of slaves	0.002475	1.06	0.001802	1.05
Senegambia			0.03392	0.03
Sierra Leone	0.1901	0.32	-1.288	-1.73
Gold Coast	-0.8971	-1.18	-0.2184	-0.52
Bight of Benin	0.5738	1.07	-0.01123	-0.02
Bight of Biafra	1.571	2.81	0.8900	1.87
Congo-Angola	-1.937	-1.76	-0.2633	-0.67
Slaves per Ton	5.610	1.02	1.858	0.69
(Slaves per Ton)^2	-1.858	-0.27	0.1508	0.04
(Slaves per Ton)^3	-0.4410	-0.17	-0.2657	-0.20
Rainy Season	0.2654	0.34	1.045	2.94
Constant	-8.768	-6.30	-6.747	-10.84
N = 9,804	-2 log λ = 47.647		-2 log λ = 67.402	

Source: Surgeons' logs. Dependent variable = 1 if there was at least one death from a particular cause in a day on a given ship, 0 otherwise. Significance tests for groups of coefficients: (a) Fevers, -2 log λ = 16.44, d.f. = 5, significant at less than .005 (region); -2 log λ = 8.74, d.f. = 3, significant at .05 (slaves per ton); (b) Gastrointestinal, -2 log λ = 8.90, d.f. = 6, significant at .20 (region); -2 log λ = 60.96, d.f. = 3, significant at less than .005 (slaves per ton). The omitted variables are Windward Coast, and Unknown.

There were no deaths from fevers in Senegambia and the Windward Coast, and no deaths from gastrointestinal diseases on the Windward Coast.

Table 6

Regressions of Crew Death per Day While Loading
from Fevers and Gastrointestinal Diseases
on Crew Size,
Region of Loading in Africa, Slaves per Ton, and the Rainy Season

	Fevers		Gastrointestinal	
Variables	Coeff.	t-value	Coeff.	t-value
Crew size	0.02237	1.38	0.09979	2.17
Senegambia			4.980	4.67
Sierra Leone	-0.09644	-0.32	0.9252	1.02
Windward Coast	1.873	4.80		
Gold Coast	-0.9095	-2.39	1.817	3.05
Bight of Benin	-0.8399	-1.57		
Bight of Biafra	1.097	3.29	3.181	3.82
Congo-Angola	0.1559	0.55		
Slaves per Ton	0.9898	0.66	2.001	0.43
(Slaves per Ton)^2	-1.063	-0.48	-0.4498	-0.07
(Slaves per Ton)^3	0.4660	0.51	-0.5323	-0.19
Day of Loading	0.003671	0.51	0.03177	1.54
(Day of Loading)^2	-0.3541×10^{-4}	-0.75	-.0001544	-1.42
(Day of Loading)^3	0.3924×10^{-7}	0.49	0.1965×10^{-6}	1.26
Rainy Season	0.04709	0.16	0.2754	0.44
Constant	-5.046	-8.80	-12.21	-6.56
N = 7,790	$-2 \log \lambda = 58.557$		$-2 \log \lambda = 40.959$	

Source: Surgeons' logs. Dependent variable = 1 if there was at least one death from a particular cause in a day on a given ship, 0 otherwise. Significance tests for groups of coefficients: (a) Fevers, $-2 \log \lambda = 42.30$, d.f. =

d.f. = 6 significant at less than .005 (region); $-2 \log \lambda = 3.28$, d.f. = 3, significant at .40 (slaves per ton); $-2 \log \lambda = 6.24$, d.f. = 3, significant .10 (day of loading); (b) Gastrointestinal, $-2 \log \lambda = 31.42$, d.f. = 4, significant at less than .005 (region); $-2 \log \lambda = 1.62$, d.f. = 3, significant at .70 (slaves per ton); $-2 \log \lambda = 2.48$, d.f. = 3, significant at .50 (day of loading). The omitted variable is region of loading Unknown. There were no deaths from fevers in Senegambia and no deaths from gastrointestinal diseases in the Windward Coast, the Bight of Benin, and Congo-Angola.

Table 8

Regressions of Crew Death per Day During the Voyage from Fevers and Gastrointestinal Diseases on Crew Size, Region of Loading in Africa, Slaves per Ton, Length of Loading, and Day of the Voyage

	Fevers		Gastrointestinal	
Variables	Coeff.	t-value	Coeff.	t-value
Crew Size	0.04128	0.92	-0.1373	-2.46
Bight of Biafra	1.492	3.00	1.586	2.60
Slaves per Ton	0.9057	0.80	-2.015	-1.46
Length of Loading	-0.007240	-1.79	-0.009305	-1.57
Day of Voyage	0.1116	0.98	-0.1091	-0.44
(Day of Voyage)^2	-0.005679	-1.19	0.0100	0.75
(Day of Voyage)^3	0.3812×10^{-4}	0.70	-0.0002102	-1.02
Constant	-6.640	-2.68	1.478	0.47
N = 2,596	-2 log λ = 29.405		-2 log λ = 24.210	

Source: Surgeons' logs. Dependent variable = 1 if there was at least one death from a particular cause in a day on a given ship, 0 otherwise. Significance tests for groups of coefficients: (a) Fevers, -2 log λ=15.90, d.f.=3, significant at less than .005 (day of voyage); (b) Gastrointestinal, -2 log λ=6.74, d.f.=3, significant at .10 (day of voyage). The omitted variables are Senegambia, Sierra Leone, Windward Coast, Gold Coast, Bight of Benim, Congo-Angola, and Unknown.

Table 9

Average Intervals in Days Between Successive Deaths of Slaves from Gastrointestinal Diseases During the Voyage

	Day of Voyage of First Death	Deaths 1 & 2	Deaths 2 & 3	Deaths 3 & 4	Deaths 4 & 5	Deaths 5 & 6	Deaths 6 & 7 or more
Mean	17.1	6.9	8.3	4.9	3.9	2.9	2.9
s.d.	9.9	6.3	8.6	4.7	5.2	2.0	3.6
N	26	26	20	15	11	10	41

Source: Surgeons' logs.

Table 10

Frequency Distribution of the Average Interval Between Successive Slave Deaths from Gastrointestinal Diseases During the Voyage

	1-2 Days	3-4 Days	5-6 Days	7-8 Days	9-10 Days	11 or more Days	Total
Frequency	2	8	3	5	2	6	26
Percent	7.7	30.8	11.5	19.2	7.7	23.1	100.0

Source: Surgeons' logs.

Table 11

Frequency Distribution of Slave Deaths as a Percent of Slaves Exported from Africa

Interval[a]	Frequency
0.0	4
0.2	0
0.4	1
0.6	5
0.8	7
1.0	8
1.2	6
1.4	1
1.6	6
1.8	12
2.0	4
2.2	2
2.4	4
2.6	5
2.8	7
3.0	8
3.2	1
3.4	1
3.6	0
3.8	0
4.0	0
over 4.0	10

Source: Surgeons' logs.

a. 0.0 denotes no deaths, 0.2 denotes greater than 0.0 and less than or equal to 0.2, etc.

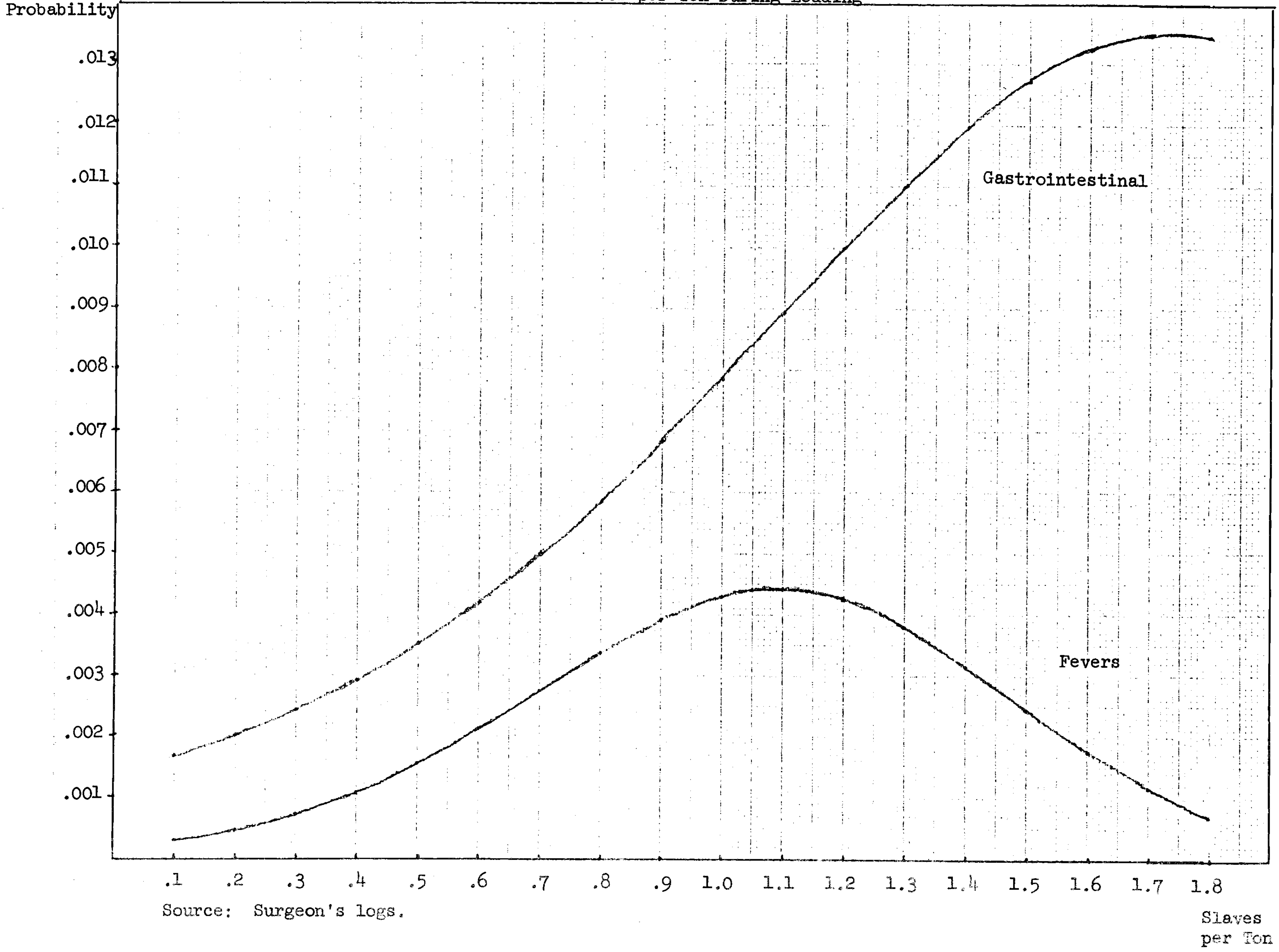
Table 12

Sample Means of Regression Variables

Variables	Slaves, Loading	Crew, Loading	Slaves, Voyage	Crew, Voyage
Number of Slaves	131.8		301.8	
Crew Size		27.45		24.73
Senegambia	.0136	.0171	.0167	.0231
Sierra Leone	.1258	.1815	.1068	.1421
Windward Coast	.0351	.0196	.0184	.0092
Gold Coast	.1633	.1983	.1432	.2022
Bight of Benim	.0900	.0760	.0943	.0851
Bight of Biafra	.0337	.0363	.0787	.1090
Congo-Angola	.1715	.1716	.2161	.2092
Unknown	.3672	.2995	.3259	.2200
Slaves per Ton	.5680	.5636	1.421	1.442
$(\text{Slaves per Ton})^2$	.5306	.5254		
$(\text{Slaves per Ton})^3$	.5924	.5920		
Day		100.1	26.39	26.17
Day^2		18081	1001	996.2
Day^3		$.46635 \times 10^7$	46192	46469
Rainy Season	.1352	.1616		

FIGURE I

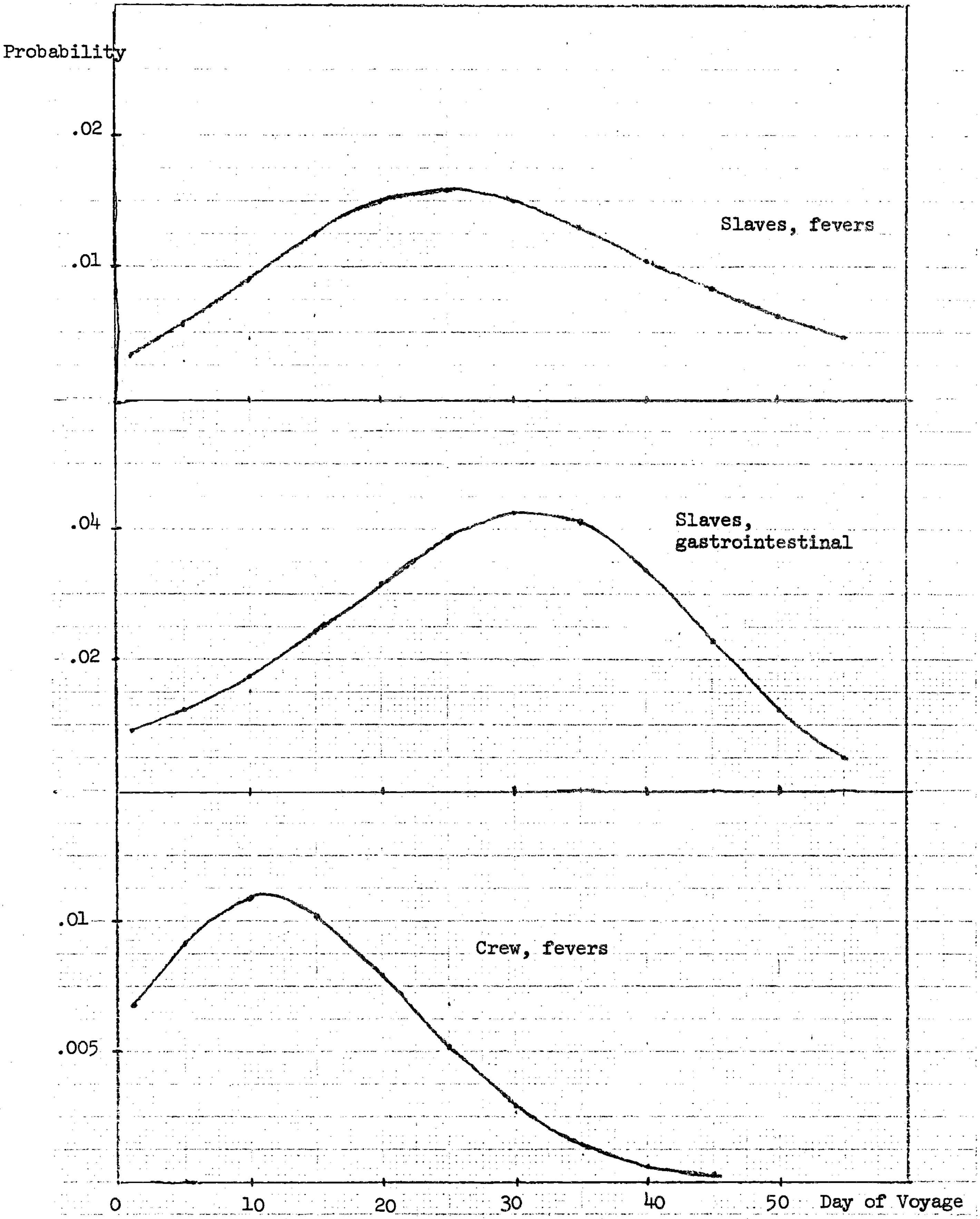
Probability of a Slave Death per Day from Fevers and Gastrointestinal Diseases as a Function of Slaves per Ton During Loading



Source: Surgeon's logs.

FIGURE 2

Probability of a Death by Day of the Voyage for Slaves or Crew by Cause of Death



Source: Surgeons' logs.