BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 11

STUDIES ON SHIP CASUALTIES IN THE BALTIC SEA 1979 — 1981

Helsinki University of Technology
Ship Hydrodynamics Laboratory
Otaniemi, Finland

P. Tuovinen, V. Kostilainen and A. Hämäläinen

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
— HELSINKI COMMISSION —

BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 11

STUDIES ON SHIP CASUALTIES IN THE BALTIC SEA 1979 — 1981

Helsinki University of Technology
Ship Hydrodynamics Laboratory
Otaniemi, Finland

P. Tuovinen, V. Kostilainen
and A. Hämäläinen

1984

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
— HELSINKI COMMISSION —

ISSN 0357-2994

ISSN 0357-2994

Helsinki 1984. Government Printing Centre

CONTENTS

Abstract

Data relating to a total of 471 ship casualties in the Baltic Sea in the years 1979-1981 have been compiled, statistically analysed and the results are presented. The discussion comprises local and seasonal distributions, along with distribution of the casualties by other time-dependent variables. Also the flags, types, ages, lengths and speeds of the ships in casualties are covered in the analysis. Simple mathematical models to describe some of the phenomena are considered.

A novel method to evaluate the causes of casualties is developed and the results of its application are presented. The economic aspects of the consequences of the casualties are discussed.

A glance at general marine traffic engineering is included in the paper.

1. INTRODUCTION

A systematic collection of information on the maritime casualties in the Baltic Sea began in the Ship Hydrodynamics Laboratory of the Helsinki University of Technology at the beginning of the year 1979. The purpose of the data collection is the development of a reliable and uniform data base which increases the knowledge of the accident phenomena. This report is a statistical analysis of the collected data base including the years 1979-1981. Additional information on the economic aspects of the casualties has been compiled and the possibility to construct an economical model for the assessment of the cost of the casualties is discussed.

Efforts to put marine safety on a scientific basis have created a new discipline called marine traffic engineering. To set the present study into the right frame of reference a short account of general marine traffic engineering is presented.

2. MARINE TRAFFIC ENGINEERING

2.1 Definition and Scope

The interdisciplinary science which investigates the problems of marine traffic is usually called marine traffic engineering. It can be considered as a specialized branch of the general operational research. It has been defined [1] as "the study of marine traffic and the application of the results of such studies to improvements in navigation facilities and traffic regulations".

A very wide range of studies has been published to date, especially in the publications of the Navigation Institutes. These studies have investigated, broadly speaking, the following aspects of the maritime traffic phenomena: traffic features, casualties and economics. All these aspects are more or less interrelated but the classification made serves as an outline.

2.2 Traffic Features

The basic traffic features of a given sea area are the number of ships and their tracks, sizes, speeds, types, cargo and nationalities. There have been many traffic observation projects to obtain the distributions of these fundamental variables. The first systematic traffic survey was done in 1963 in Japan [1] where the marine traffic had become heavily congested. Nowadays over 30 surveys a year are done in Japan alone [2]. In Europe particularly the Dover Strait has been under continuous surveillance. In the Baltic Sea the Polish traffic measurements in the southern Baltic, started in 1979, are worth mentioning [3].

There are currently two supplementary methods of observation of the traffic in use [2][4]: visual and radar method. In the radar method the positions of all ships in the area are plotted or photographed e.g. every five minutes from a marine radar display equipped with a reflection plotter. The vessels must also be identified, usually visually. Used alone visual observation has the advantage of simplicity and is particularly useful for the measurement of traffic passing along a relatively narrow waterway. The time span of a survey may be from a few days to a whole year. The methods of processing and representing the survey data are still developing, and much work is going on at present [4], especially in the UK, the Netherlands and Japan, and there will hopefully be more advances in the future.

Mathematical modelling and simulation of the traffic phenomena have become possible when the traffic observations have supplied the necessary underlying data. Statistical, analytical and simulation models of e.g. traffic flow and traffic capacity [2][4] have been built. The reported practical applications have been few, but theoretical modelling is a promising area where efforts are increasingly being concentrated.

Marine traffic engineering has had its widest practical applications in the development of marine traffic services [5]. Marine traffic service means the creation of traffic separation schemes and information systems in ports and congested waterways. There are currently over a hundred separation schemes worldwide.

2.3 Casualties

Maritime casualties can be divided into two distinct groups according to their primary causes: traffic accidents and technical accidents. Collisions, groundings and rammings are traffic accidents; explosions and fires, founderings, capsizings, floodings, weather and ice damage are technical accidents. The justification of the grouping is evident: the remedies against traffic accidents can be found in the development of the traffic situations and environment but the technical accidents call for technical developments of the ships. Marine traffic engineering has mainly concentrated on the accidents of the traffic type.

The complex nature of marine accidents and the difficulties in conducting direct experiments have been the reasons why the collection and analysis of various accident data files or bases have been the predominant method of safety study. Governmental agencies of most seafaring countries compile national or regional statistics. The best known independent collection of worldwide casualty statistics is the data bank of Lloyd's Register of Shipping.

One of the difficulties of the statistics method has been the lack of a uniform international code of investigation and recording [6], which reflects the cooperation lacking in the field. Another problem is the quality of the information collected. The experience gained [7][8][9] in statistical analyses shows that only information of a general nature can be obtained and detailed conclusions are generally not possible. The usefulness of the statistics lies in their diagnostic ability: they show what and where the main problems are. The importance especially of human factors as contributory causes in marine traffic accidents has emerged from the statistical analyses.

The introduction of ship simulators has opened a promising new field of human factors study which can be of help in casualty studies. Apart from pure training, simulators can be used to investigate a variety of topics [10][11]: bridge layout, ergonomics of equipment, human response to various navigational situations and so on.

2.4 Economic Aspects

Proper assessment of the costs and benefits of each proposed new traffic or safety measure is beneficial to society as a whole. In practice costs and especially benefits are difficult to estimate. An estimate of total losses resulting from marine accidents should take into account both direct and indirect costs. The costs of repair, lost cargo and laydays are examples of direct costs which are in theory possible to estimate. Indirect costs, e.g. the price of human life lost or damaged environment are difficult to express in monetary terms. On the benefits side, a US Coast Guard study [12] came to the conclusion that, except in rare cases, no quantitative assessment is possible of the extent to which any specific safety action is effective in reducing the risks of marine accidents.

Due to the difficulties mentioned, reported economic studies on marine traffic and safety have been scarce, though there have been many papers [13][14][15] pointing out the present unsatisfactory situation: the great public and private investments in marine safety have to be made without a proper knowledge of their effect.

2.5 The Way Ahead

Marine traffic engineering as a science is now at the age of twenty, which is a short time indeed for a science. Spectacular and costly tanker accidents like that of Torrey Canyon have had one positive side-effect: marine traffic engineering study has been intensified. The most promising areas of future study seem to be mathematical modelling and the use of simulation techniques. The neglected economic aspects will probably get more attention in the future. As one omen, a couple of new reports [16][17] which give some practical results have been published recently.

3. BALTIC CASUALTY DATA BASE DEVELOPMENT

3.1 Background

The systematic collection of maritime casualty statistics was started in the Ship Hydronomics Laboratory of the Helsinki University of Technology at the beginning of 1979. The special features of the Baltic Sea and the general benefits of regional casualty statistics were the main motivations for the selection of the casualties in the Baltic as the object of the study.

The Baltic Sea has many special features as a sea route. The fairways are shallow and winding near the coasts and in the archipelagoes. There are areas of heavy traffic congestion like the Kiel Fjord or the Danish Sounds, where there is also heavy crossing traffic. In the winter large parts are covered by ice which hampers traffic.

Worldwide casualty statistics have certain disadvantages: if a safety analysis is based on worldwide statistics, this casualty data should include a great variety of different local conditions. Compilation and management of such a large data base would be impossible under present conditions and maintaining uniformity in data collection methods is difficult.

The drawbacks of worldwide statistics can be avoided by concentrating on the casualties of a limited geographical area. The environmental conditions are uniform and the special features of the marine traffic are better known. The casualties are comparatively few in number which makes it possible to collect more detailed information on each case with limited resources. However, if the area selected is too limited, the smallness of numbers can create a statistical problem. The sample size becomes too small. The Baltic Sea forms a natural well-defined homogenous area with "enough" accidents for a sufficient sample to be drawn without spreading the time span over so many years that the essential features might have changed, thus distorting the picture.

3.2 Scope of the Data Base

The planning of this data collection is based on the experience gained from earlier statistical studies [7][18][19] performed in the Ship Hydrodynamics Laboratory. The study programme is documented in [20][21]. The principal aims are: the collection of a reliable and uniform data base of ship casualties in the Baltic Sea; the collection of data concerning damage to the environment caused by ship accidents; increasing knowledge of marine accident phenomena in the Baltic Sea through statistical analyses.

The following definitions and restrictions are applied:

- The Baltic Sea in the Danish Sounds lies to the south of a line from Höganäs to Grenå.
- Only casualties to merchant ships of 100 gross tons and above are included, because information on them can be found in the Register of Ships of Lloyd's Register.

  Only ships in commission, not e.g. on dock or before delivery, are included.

3.3 Data Sources

The first information on an accident is usually obtained from Lloyd's List. In this newspaper there is a special section in which marine casualties all over the world are briefly reported. The name of the ship together with the date, place and nature of the casualty are usually given. In some cases the initial information on an accident is derived from local Finnish newspapers or foreign maritime journals, e.g. the Swedish Shipping Gazette. First the questionnaires, which will be discussed later, are sent to the master and if no answer is received a new letter is addressed to the shipowner.

The methods used have some obvious deficiencies. Not every casualty is reported in Lloyd's List or other publications. In particular the casualties of the Union of Soviet Socialist Republics or the German Democratic Republic ships in their own territorial waters are seldom reported. Secondly the total percentage of questionnaires returned is not very high. In the years 1979 to 1981, 125 out of 273 or 46 percent were returned. The answers obtained will certainly be to some degree biased, because the shipmasters will find some questions embarrassing.

An important data source is the casualty files of the maritime authorities. In order to complete the data base with this additional information the maritime authorities in the countries around the Baltic have been contacted. In Table 1 the authorities contacted are summarized.

TABLE 1. Authorities contacted

Denmark	Ministry of Industry, Marine Division Ministry of the Environment
Finland	The National Board of Navigation
GDR	Board of Navigation and Maritime Affairs
FRG	Federal Ministry of Transport, Maritime Section Deutsches Hydrographisches Institut
Poland	Maritime Appeal Court in Gdynia
Sweden	The National Administration of Shipping and Navigation; Generaltullstyrelsens Kustbevakningssektion
USSR	Ministry for Land Reclamation and Water Management, Maritime Section

The Finnish and Swedish authorities have been very cooperative and their data have been obtained and added to the data base.

Due to the lack of resources of the Danish Ministry of Industry detailed information obtained has been scarce.

It was promised that data collected in the GDR would be made available but up till now no data have been obtained, except in two cases of oil spills.

Detailed systematic data on ship casualties are not collected in the Federal Republic of Germany. Poland has notified that they will not make their data available. No response has been obtained to inquiries sent to the USSR.

The failure to get all the information from the authorities naturally has an adverse effect on the reiiability of the data base. For instance, such a basic variable as the real number of major accidents in the Baltic remains unknown.

The data collected by means of sending questionnaires to masters can be called primary data because they are collected at source. The data obtained through authorities are called secondary data. The secondary data may be both biased and inappropriate. The bias results from the fact that a report is already a more or less subjective interpretation of an occasion. The objectives of the authorities in recording may differ from those of casualty research, and some factors relevant to casualty research are not recorded.

The sources used have been selected of necessity: no other sources have been available. The ideal primary source [22] would be from a full scale investigation of each case. Unfortunately, even if the investigation was "without prejudice" and resources were available to undertake the exercise, the key interviewees may have been lost, or the way in which they perceived the casualty may be incorrect.

3.4 Data Collection

There are, broadly speaking, two ways to decide which data to collect and store on a casualty file. First, hypotheses which need to be tested are suggested and then data to test them are collected. Secondly, all the available data on marine casualties can be collected and the hypotheses are suggested and tested later. The appropriate approach lies somewhere between these approaches [22].

Experience gained from the earlier studies [7][18][19] suggested which information would be both relevant and possible to obtain. The three questionnaires given in the Appendix were designed for a systematic measurement of the relevant variables. The questionnaire on page A **4** of the Appendix named "Report of maritime oil or chemical spilllage" was adopted in 1980 and it is meant for the collection of information from authorities.

The earlier studies indicated clearly that the information obtained with the conventional questionnaires can not provide guidance on detailed safety analysis. Much more is required if casualty statistics are to play an efficient and active role in promoting safety. Special difficulties arise in making the casual relationships clear. Symbolic modelling by means of functional block diagram and fault trees has proved to be an effective aid in safety analysis [23]. They can be used effectively to indicate the relationships between physical factors or between all of these. They can be used to determine the effects that can be generated by a change in any of the factors or in the interrelationships. In addition, these models permit easy understanding and recognition of the factors leading to the individual casualty.

Data relating to the 707 ship casualties in the Baltic in 1971-1975 [7] were gone over and all factors relevant to the casualties were collected and classified. After discussions with captains of varying backgrounds and with a psychologist some factors were added. Finally a collection of blocks representing factors relevant to casualties in the Baltic Sea Area was obtained.

The block scheme is presented on page A 3 in the Appendix. The purpose is to trace the sequence of events relevant to the casualty by connecting the appropriate blocks with lines. In the block scheme of the Appendix there are two examples of casualties presented.

The questionnaire on pages A 1– A 2 of the Appendix, "Ship Casualty Card", is a conventional one. It is meant for the collection of general and background data on a casualty. The Ship Casualty Card, the block scheme and a scheme with examples facilitating the understanding of the purpose of the logic diagram are sent to a master of a ship involved in a casualty. There are questionnaires in two languages available, in German and in English.

If no answer is received from the master or owner, the questionnaire and the block scheme are filled by our researcher on the basis of the available information. The same applies to cases where an authority is the initial primary source.

3.5 Evaluation of Causal Factors and Their 'Relationship

It is often assumed that an accident is caused by one definite factor and if this factor could have been eliminated the undesired event would not have occurred. Although this position might be defensible in some rare cases, it oversimplifies the problem. In general a casualty is the result of several causes, or more correctly an unwanted chain of events.

Using the block scheme described above the systematic tracing of the relevant sequence of events is possible. This combination of elements is then used for classification of individual factors in each casualty. In this classification it is essential to evaluate each factor from the point of view of its effect upon the casualty.

Each factor is classified in one of the following four categories:

1. Essential Factors
   Absence of an essential factor or its replacement with right-functioning factor would have prevented the casualty with a probability P = .9-1.0.

2. Part Factors
   Absence of a part factor or its replacement with right-functioning factor would not alone have prevented the casualty. Prevention of the casualty would require the eliminating of the effect of at least two part factors.

3. Conducing Factors
   A conducing factor has an effect on the occurrence of the casualty, eliminating a conducing factor alone or together with other factors would not, however, have prevented the casualty.

4. Indefinite Factors
   The causal relationship of an indefinite factor to the occurrence of a casualty is indefinite or insignificant.

The classification stated above does not concern the elements Deck Officer, Pilot, Helmsman and Look-out Man, which are to be regarded as "addresses" of human factors. Also the group of elements under the heading of Nature of Casualty will not be classified because they are consequences of a certain combination of factors.

The effect of each factor upon the casualty is measured by its weight coefficient. The values of weight coefficients are determined after the classification of the factors according to the following principles:

1. Maximum values of weight coefficients are taken from Table 2.

TABLE 2.

Category of the Factor	Maximum Weight Coefficient
Essential Factor	1
Part Factor	.5
Conducing Factor	.2
Indefinite Factor	0

2. The sum of weight coefficients of the part and conducing factors for each casualty may not be greater than 1. With this limitation the relative overestimation of the part and conducing factors is prevented.

3. If the sequence of events contains one or more essential factors belonging to the group "Actions" and the sum of weight coefficients of the part and/or conducing factors of the previous branches of the sequence is equal to 1, then the weight'coefficient of these essential factors is taken to be 0.

   This corresponds to the situation where environmental conditions and the condition of the navigator altogether exceed the human capability to take the right action.

4. If the sequence of events of a casualty is not considered to be satisfactorily cleared up, then the

sum of weight coefficient of all factors should be less than 1. Otherwise the sum = 1.

Thus the casualties which have not been cleared up can not distort the analysis, and no cleared up case is overestimated.

Let the weight coefficient of a factor i in a casualty j be w_{ij}, and the number of factors included in the analysis n, and the number of the casualties in the data base m. Then the "effect level" e_i of a factor i is defined by the equation:

$$e_i = \frac{\sum_{j=1}^{m} w_{ij}}{\sum_{n=1}^{m} \sum_{i=1}^{n} w_{ij}} .$$

The effect level can be interpreted as a probability:

$$e_i = 0 \text{ if } w_{ij} = 0 \text{ for all } j,$$

$$\sum_{1}^{n} e_i = 1.$$

If an accident is selected at random, the probability that factor i has been the cause of the accident is e_i. The effect level is a useful measure in ranking different factors according to their overall effect on casualties.

3.6 Coding and Processing

The vast amount of information collected can be managed, described and analysed most conveniently on a computer. The casualty information has been coded and a permanent file on DEC-20 computer has been created. The analyses have been made using the statistical package SPSS [24][25] which has been found to be very suitable for this purpose. The structure of the permanent file created makes it easy to update old and add new cases.

4. ANALYSIS OF THE DATA BASE

4.1 Basic Sample Characteristics

The population of this statistical study consists of all the merchant accidents which have taken place in the Baltic Sea to ships of 100 gross tons or above in the years 1979-1981. For the reasons mentioned in section 3.3 it has not been possible to collect relevant information on the entire population, but the collected data base is a sample or a part of the population.

In order to be able to use the sample in making inferences about the population, the sample must be representative. A representative sample includes, in approximately the same proportion as in the population from which it is taken, any classificatory factor that might influence the phenomena to be studied. This feature is guaranteed only in a probability [26] or random sample. Every element in the population must have some chance of selection. Apparently this condition is not fulfilled here. Casualties to the USSR, Polish and the GDR ships in their own territorial waters have a much smaller chance of selection than their evident proportion suggests: casualties on the Swedish and Finnish coasts have an over-representation because of the ample additional data obtained from the maritime administrations of both countries. The effect of this bias on each factor or variable considered is in practice impossible to quantify but it has to be considered when drawing conclusions on the basis of the sample.

The sample consists of 471 casualties and the number of ships involved is 529. Table 3 shows the ways the data were obtained by flag. A total of 273 ships were contacted by letter and 125 answers were received. 237 ships not mentioned in Lloyd's List were obtained through authorities. Here it is clearly seen how the additional information from authorities effects the flag distribution by enlarging the Swedish and Finnish representation. In 19 cases the address of the shipowner was not found and reports in Lloyd's List were the only source.

TABLE 3 Number of questionnaires sent and returned by flag

Flag	Total number of questionnaires sent	Number of questionnaires returned	Additional ships from authorities
FRG	38	19	23
Greek	35	8	2
Swedish	31	16	86
Finnish	25	18	81
USSR	19		5
Polish	17	11	4
Dutch	16	8	3
British	13	9	
Norwegian	11	8	8
Panamanian	11	2	3
Danish	10	5	10
Singaporean	8	5	1
GDR	6	2	4
Liberian	4	A	1
Cuban	3		–
Icelandic	3	2	–
Brazilian	2	2	1
Cypriot	2	–	–
Indian	2	–	–
Spanish	2	–	1
Turkish	2	2	–
Bangladesh	1	1	–
Belgian	1		–
Czechoslovak	1	–	–
French	1	–	–
Hungarian	1	–	–
Israeli	1	–	1
Italian	1	–	–
Malaysian	1	1	–
Moroccon	1	1	–
Netherlands Antilles	1	–	–
Nigerian	1	–	–
Portuguese	1	1	–
Sudanese	1	–	–
Chinese	–	–	1
Japanese	–	–	1
Madagascar	–	–	1
	273	125 (46%)	237

During the coding the principal source of the available information on each ship was determined. This rather subjective assessment gives credit to the source where the amount of information on causal factors was thought to be most informative. Table 4 indicates the result:

TABLE 4. Principal source of information

year	own answer	authority	newspaper	other ship
1979	56	132	61	5
1980	41	73	48	2
1981	26	60	21	1
total	123	265	130	11

The source "other ship" refers to collisions where only own answer of the case has been available or the other answer has been defective. The quality of information is poorest in cases where Lloyd's List has been the principal source of information, because the causes of casualties are seldom discussed in that newspaper.

The annual numbers of ships in accidents together with the distribution of the primary source of information is depicted in Fig.1. The primary source means the source from which the first information of the casualty is obtained. The ratio between the number of ships from newspapers and the additional ships from authorities seems to have remained the same over the three years. This means that there seems to have been no changes in the sampling method which could cause bias to the sample. The decreasing trend in the number of accidents which emerges from Fig.1. can evidently not be explained by a change in the sampling method.

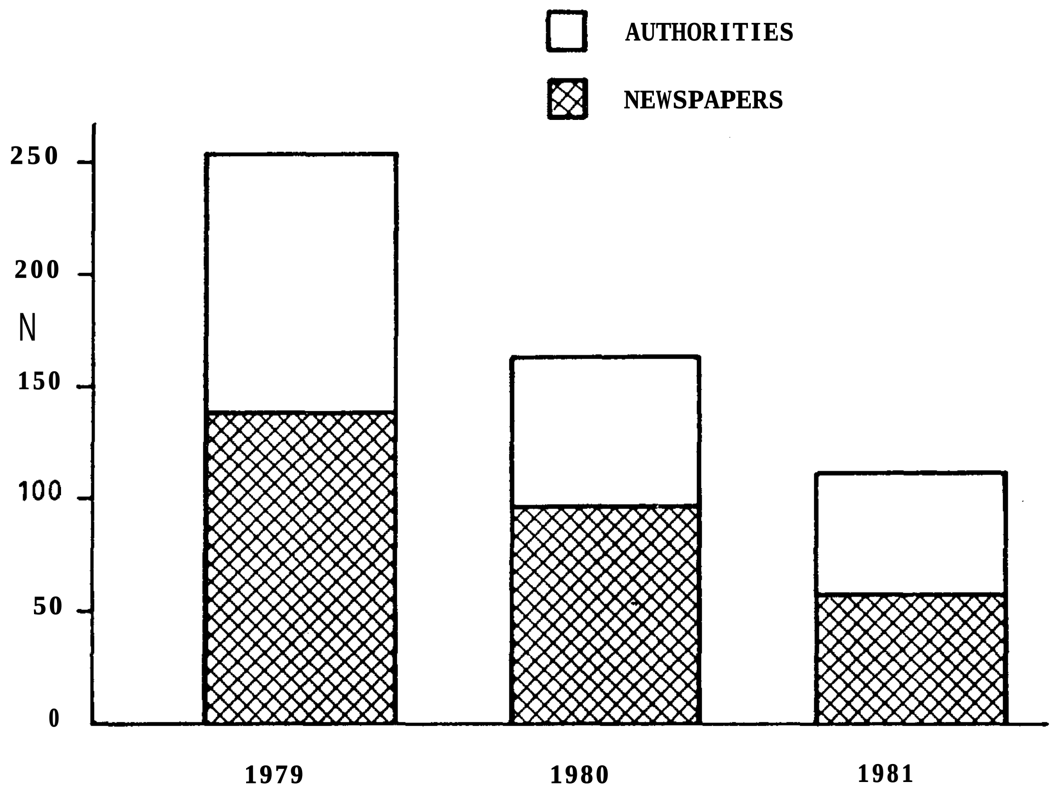


Fig .1. Number of ships by a primary source of information

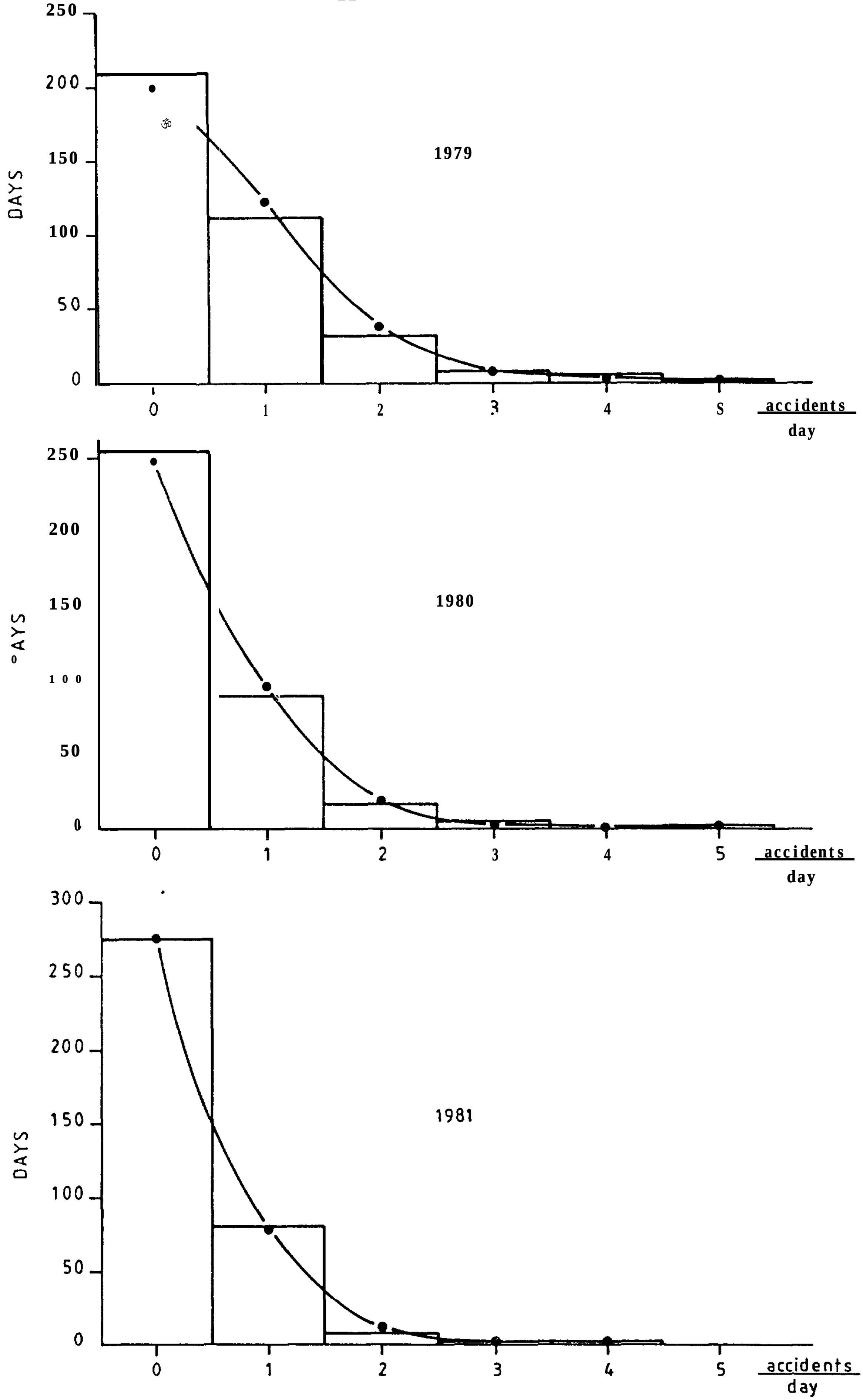


Fig.2. Number of days by the number of accidents per day

4.2 Poisson Distribution

The use of the observed past frequency of marine accidents in prediction of the future frequency necessitates the establishment of a statistical model which fits the past data. By assuming that the model will continue to apply in the future the appropriate prediction can be made with some degree of confidence. For marine accidents, which are isolated events occurring in a continuum of time, it might reasonably be expected that the model most likely to describe their frequency of occurrence would be the Poisson distribution or a distribution derived from it [27].

If events occur independently of one another at a constant average rate, the number of events per unit of measurement will follow the Poisson distribution [28]. In the context of marine accidents the condition which demands that the average rate of accidents be constant is clearly not satisfied: changes in weather, fluctuations in traffic etc. change the average rate. However, if the Poisson distribution fits the observed data sufficiently well, the condition is apparently not excessively violated and the distribution is an adequate one as a model of the phenomenon.

To test if the Poisson distribution can be used as a model to describe the frequency of accidents in the Baltic, the number of days on which 0, 1, 2... accidents had occurred were calculated for each year. That each year should be taken separately follows from the fact seen in Fig. 1: the number of accidents per year differs greatly, which means that the average rate has not been constant from year to year.

The Poisson distribution is fitted to the observed data in the following way: if the average number of accidents per day is m, then the probability of having k accidents in a day is given [28] by the formula:

$$P(N=k) = \frac{m^k e^{-m}}{k!}$$

The expected number of days in a year having k accidents is 365 x P(N=k) or 366 x P(N=k) in a leap year. As an example the distribution is fitted to the data of the year 1981 in Table 5. In 1981 there were 103 accidents with known data and thus

$$m = \frac{103}{365} = 0.282.$$

TABLE 5. Accidents per day in 1981

k, number of accidents per day	0	1	2	3	4	5
observed days	275	80	8	1	1	0
P(N=k)	0.754	0.212	0.030	0.0028	0.0002	0
expected days, 365xP(N=k)	275	78	11	1	0	0

The observed numbers of days for each year are given as histograms in Fig.2. where the expected values of the Poisson distribution are also drawn as dots in a continuous line.

The fit was tested by means of a χ^2 test. In essence this test [29] gives the probability of a possibility that the differences between the observed and expected values have arisen by chance though the underlying distributions are the same. If this possibility is 5 percent or less, the discrepancy between the theoretical and observed distribution is considered to be significant and the theoretical model must be rejected. Now the probabilities were for the years 1979, 1980 and 1981 0.15, 0.75 and 0.90, respectively. The fit seems to be good enough and the Poisson distribution is an adequate model to be used in investigating accident frequencies.

As an application of the Poisson model the total numbers of accidents in the three years are compared on the basis of the average number of accidents per year. The annual accident numbers are shown in Fig.3. on a quarterly basis. The line of all accidents indicates a decreasing trend. The number of accidents in the year 1979 was 223, 1980 144 and 1981 104; thus the average rate is 157 accidents per year.

Is it possible to suppose that the differences in the number of accidents per year have arisen by pure chance though the average rate or a probability of an accident has remained the same over the three years? The answer is obtained as in the fit test above by calculating the probabilities of getting the observed numbers of accidents when the average rate or the expected number is 157. If the probabilities are 0.05 or less, it must be concluded that the average rate has decreased significantly in the three years.

The Poisson model is adopted. The probabilities of getting the observed numbers are calculated from the Poisson distribution with the average rate m = 157; N denotes the number of accidents per year:

1979: $P(N \geqq 223) = 1 - P(N \leqq 222) = 1 - \sum_{k=0}^{222} \frac{m^k}{k!} e^{-m} = 0.5 \cdot 10^{-6}$.

1980: $P(N \leqq 144) = 0.16$.

1981: $P(N \leqq 104) = 0.037$.

The calculated probabilities indicate that the differences in the number of accidents are statistically very highly significant. There is ample evidence to reject the hypothesis that the differences from the three year average have arisen by pure chance. The differences from the two-year averages can be tested in the same way. The average of the years 1979-1980 is m_1 = 183.5 and for 1980-1981 m_2 = 124 accidents per year:

$m = m_1$ 1979: $P(N \geqq 223) = 0.002$.
1980: $P(N \leqq 144) = 0.001$.

$m = m_2$ 1980: $P(N \geqq 144) = 0.04$.
1981: $P(N \leqq 104) = 0.04$.

Also the differences from the two-year averages are significant. On the basis of these statistical tests it must be concluded that the decreasing trend observed in accident numbers is real.

4.3 Types of Casualties and Their Local and Seasonal Distributions

The percentages of the different types of casualties are shown in Fig.4. Collisions are ship-to-ship collisions where both ships are under way. Rammings are ship-to-object collisions: a moored ship is also defined as an object.

Fig.5. shows how casualties are distributed according to the type of the sailing area where the casualty took place. The distribution of casualty types in each sailing area are shown in Fig.6. The absolute numbers of casualty types are crosstabulated by sailing area in Table 6. The ranking of sailing areas according to their proportions of casualties is the same as [7] in the years 1971-1975. Sounds, passages and port areas are places where most casualties occur.

TABLE 6. Numbers of accidents by sailing area

	OIL DISCHARGE	FIRE	GROUNDING	COLLISION	RAMMING	FOUNDERING.LIST	WEATHER DAMAGE	ICE DAMAGE		Row Total
OPEN SEA	0:		3	4	16	4	11	2	3	43 9.4
OPEN COAST		0:	3	32	16	2	7	0f	3	63 13.8
SOUND. PASSAGE	0;	1;	107	27	7	2	0	3		147 32.2
APPROACH TO PORT		0:	50:	0		3	60	0	1	60 13.1
PORT AREA	1		1:20	17;	100		3	1	1	144 31.5
Column Total	0.:	1.1	46.6	213 17.3	79 26.0	119	23 5.0	0.:	11 2.4	457 100.0

The basic marine traffic features mentioned in section 2.2 are not measured in the Baltic. The only available sources of traffic data are the national maritime statistics which have been found to be very unsuitable for the purpose of detailed traffic analysis, both in the course of this study and elsewhere [30]. The Danish and Swedish statistics are not detailed enough and give the numbers of port calls on a yearly basis; the USSR and Polish statistics have not been available.

The traffic data which have been collected from [31][32] [33] are presented in Fig.7. The figures are based on the number of arrivals to ports or in the case of the Kiel Canal on the number of passings on a monthly basis. Fig.7 gives no information on the total number of ships at risk per month, but it clearly indicates the seasonal variations in the traffic. In the northern part of the Baltic the seasonal variation is marked. In the spring of 1979 the ice conditions were exceptionally difficult even in the southern part of the Baltic Sea. Specially adverse ice and weather conditions in February 1979 explain the heavy

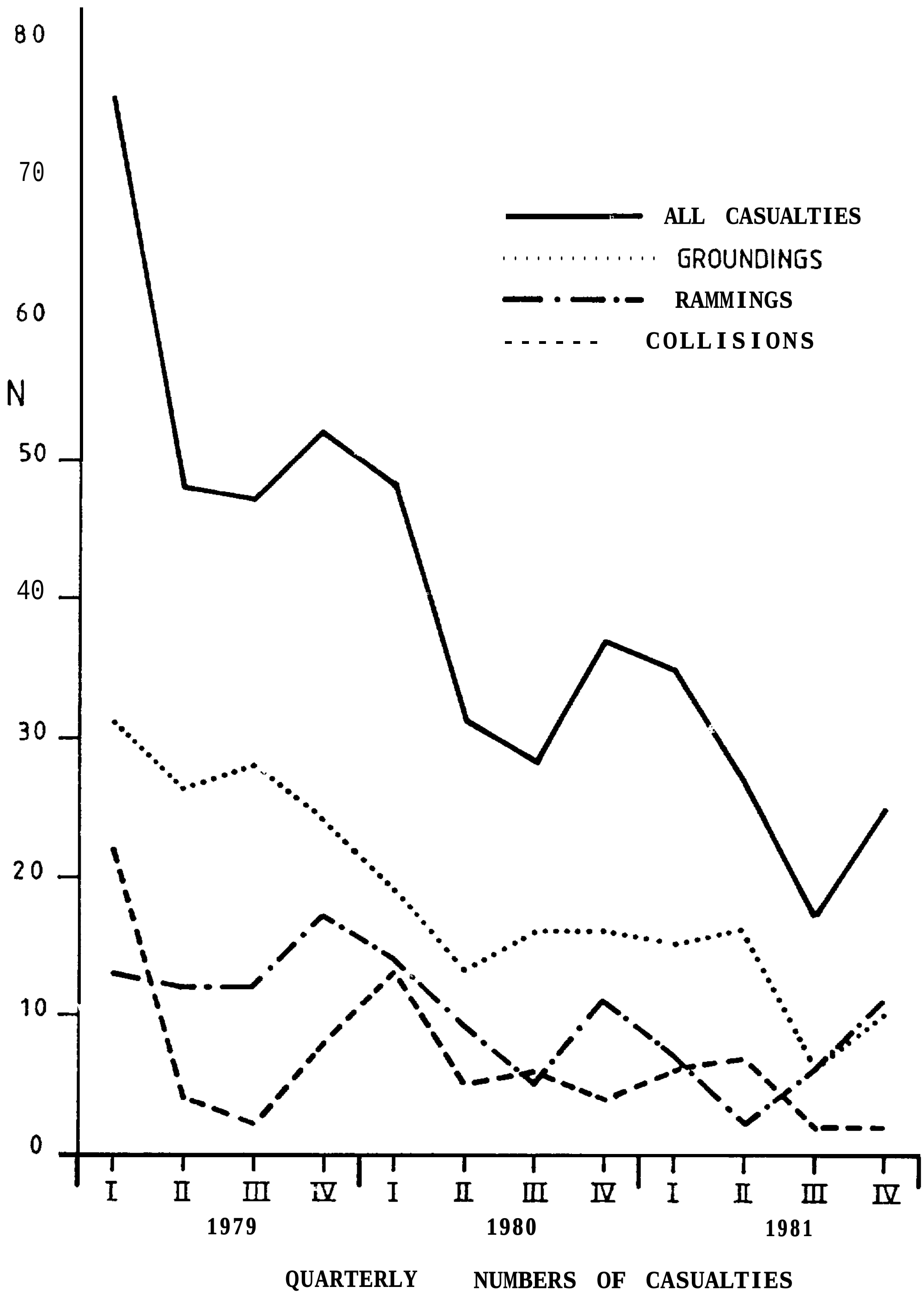


Fig.3. Quarterly numbers of casualties

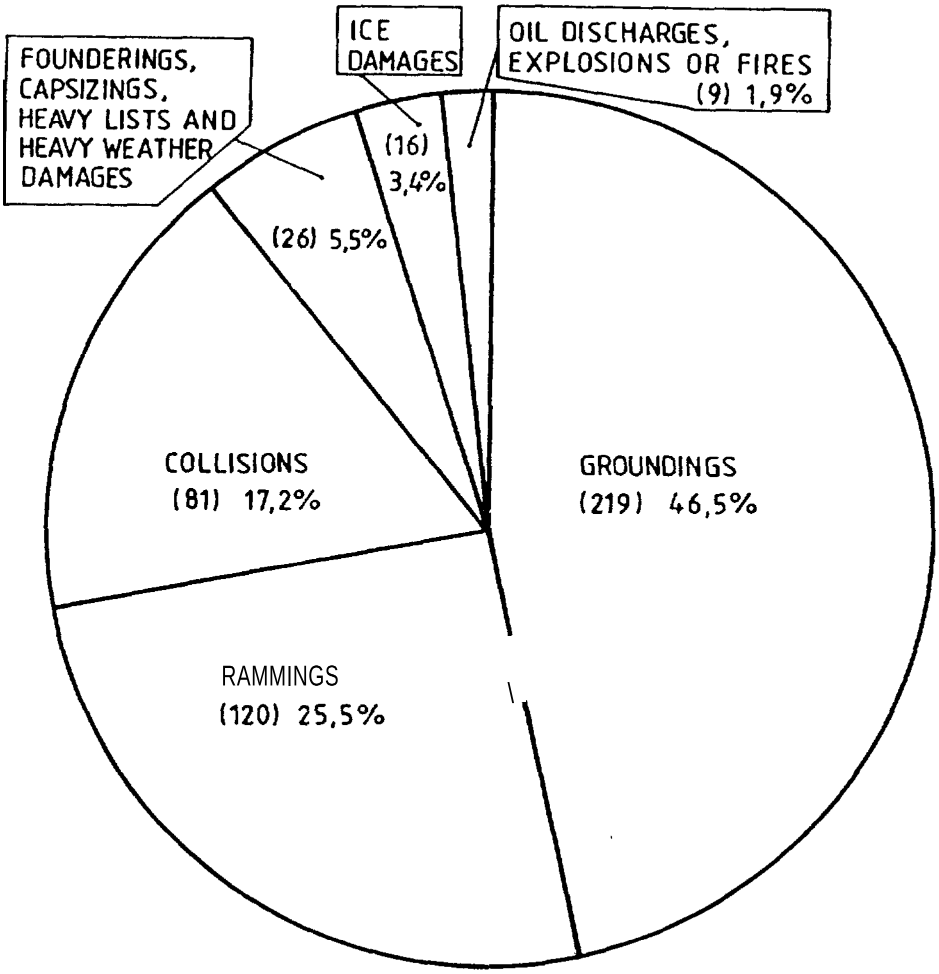


Fig.4. Numbers and percentages of the 471 casualties by their type

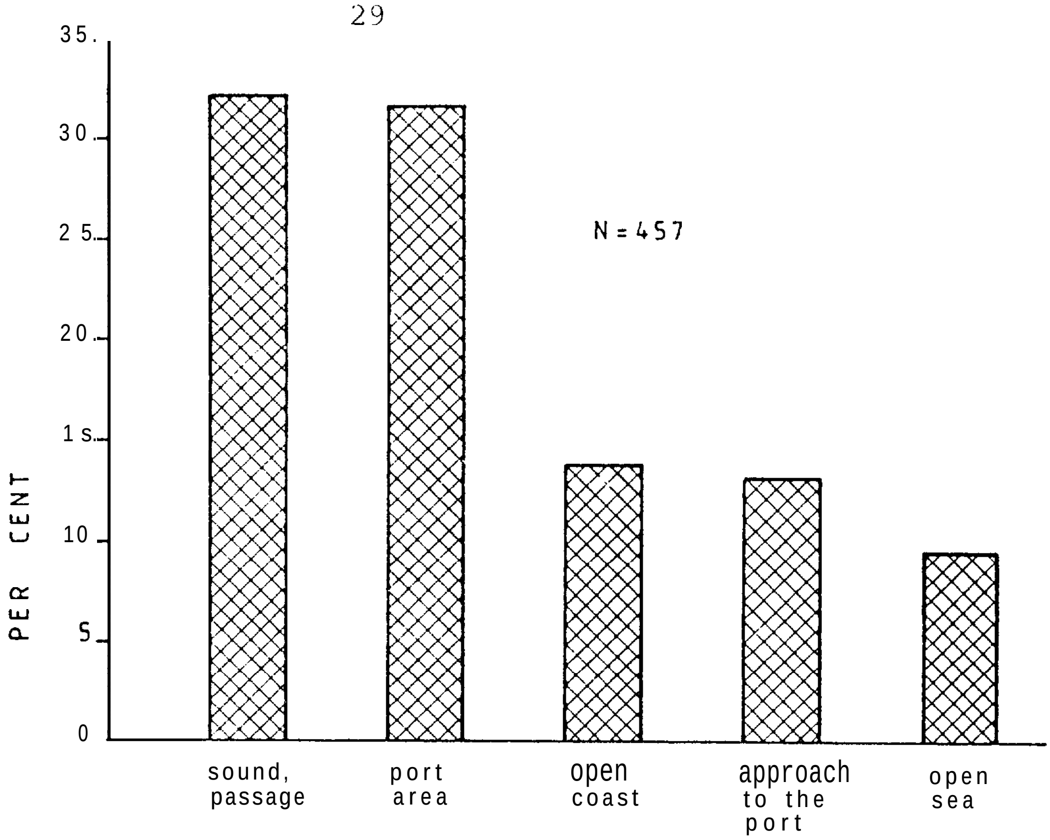


Fig.5. Distribution of casualties by different types of sailing area

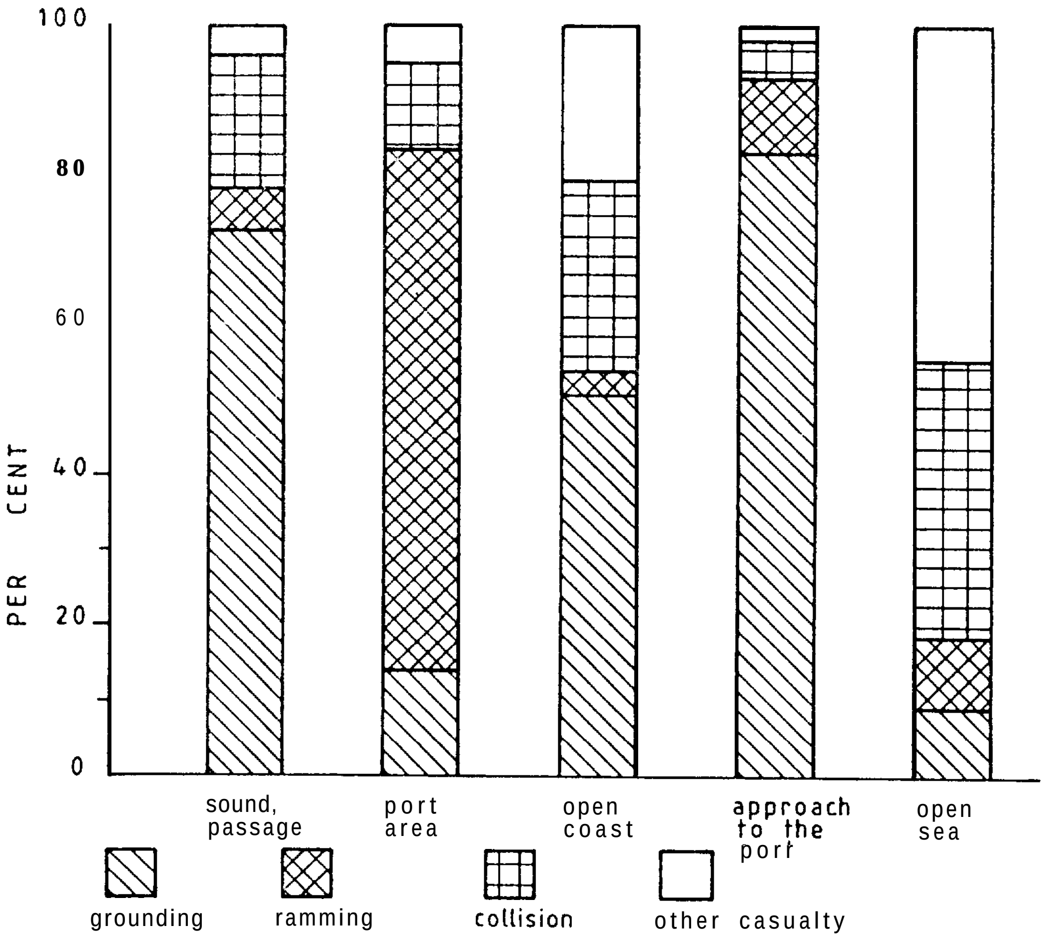


Fig.6. Distribution of casualty types by sailing area

reduction of traffic in the Kiel Canal and the ports of the Federal Republic of Germany. The Kiel Canal traffic is usually almost free from seasonal variations. The effects of the abnormal ice conditions can also be seen in the more than usual reduction in the arrivals to Finnish ports in February 1979. The same kind of unusual drop in arrivals to Finnish ports in the spring of 1980 was caused by a long strike in the Finnish merchant fleet.

The number of casualties was exceptionally high in the first quarter of 1979, as can be seen from Fig.3. The adverse ice and weather conditions mentioned are an evident explanation for the increase.

Fig.8 shows the relative number of accidents in nine different districts of the Baltic and the division into districts which has been applied is presented in Fig.9. The lack of detailed traffic data makes it impossible to assess if there are more casualties in some districts than their traffic would suggest. As mentioned, the geographical non-representativeness of the sample futher distorts the picture.

The distribution of casualty types in the nine districts is given in Fig.10 and the absolute numbers of different casualty types are crosstabulated by district in Table 7. The proportions of different casualty types in each district seem to be about the same except in Kiel Fjord, the Gulf of Finland and the Gulf of Bothnia. The high proportion of rammings in Kiel Fjord is caused by the fact that contact with a lock gate is quite a common casualty at the Holtenau Locks which are situated at the eastern end of the Kiel Canal. The relatively high number of collisions in the Gulf of Bothnia and Finland can be explained by ice conditions: a common type of collision takes place in an ice convoy when a ship gets stuck and another ship coming behind cannot stop in time to avoid a collision. In the Gulf of Bothnia 11 of 22 collisions happened in ice convoy, in the Gulf of Finland 5 of 11.

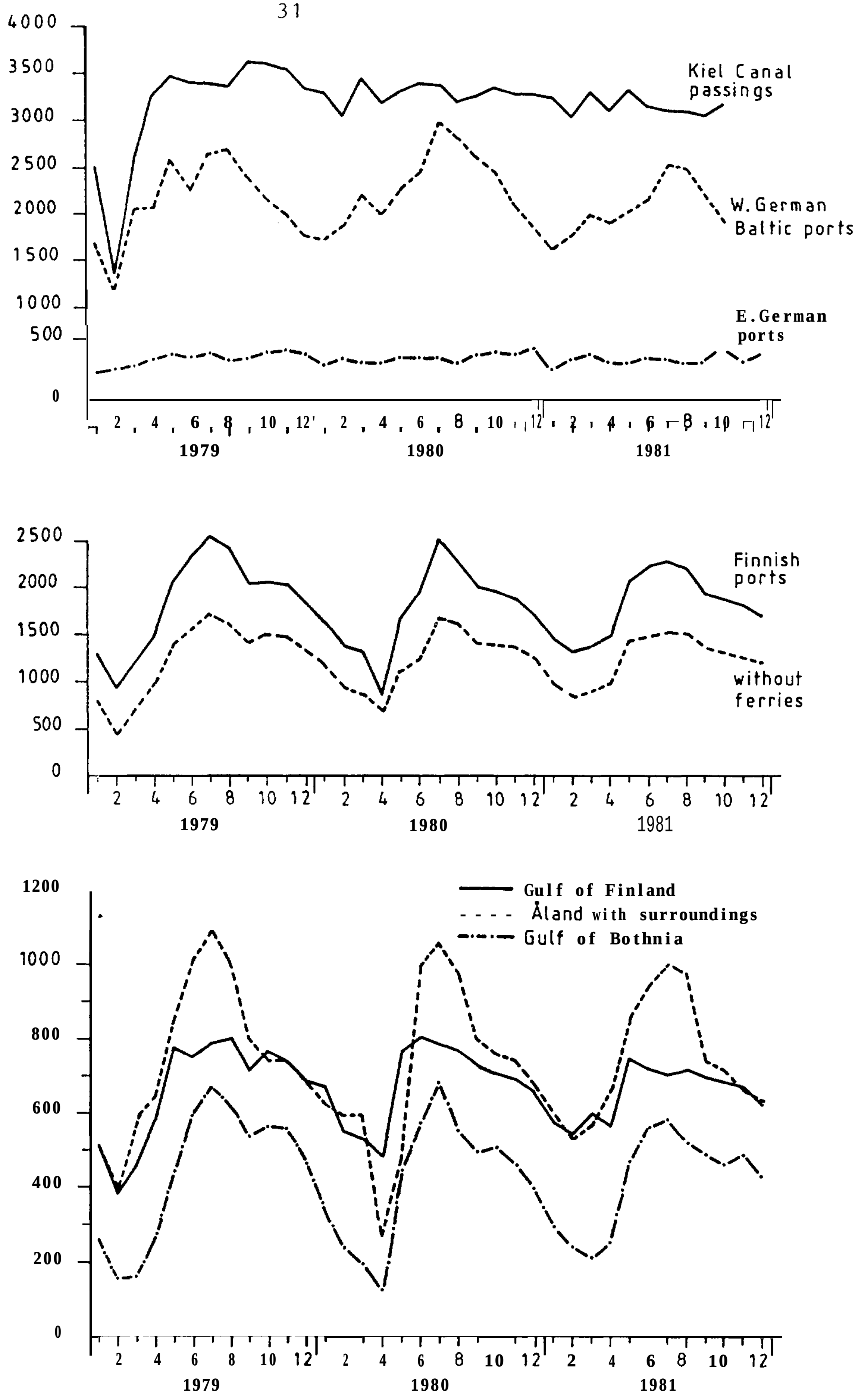


Fig.7. Highest: 'Number of Kiel Canal passings, arrivals in the German Democratic Republic and the Federal Republic of Germany ports excluding passenger ships.
Middle: Arrivals in Finnish ports, all ships and without passenger ferries.
Lowest: Arrivals in Finnish ports divided into three areas, all ships.

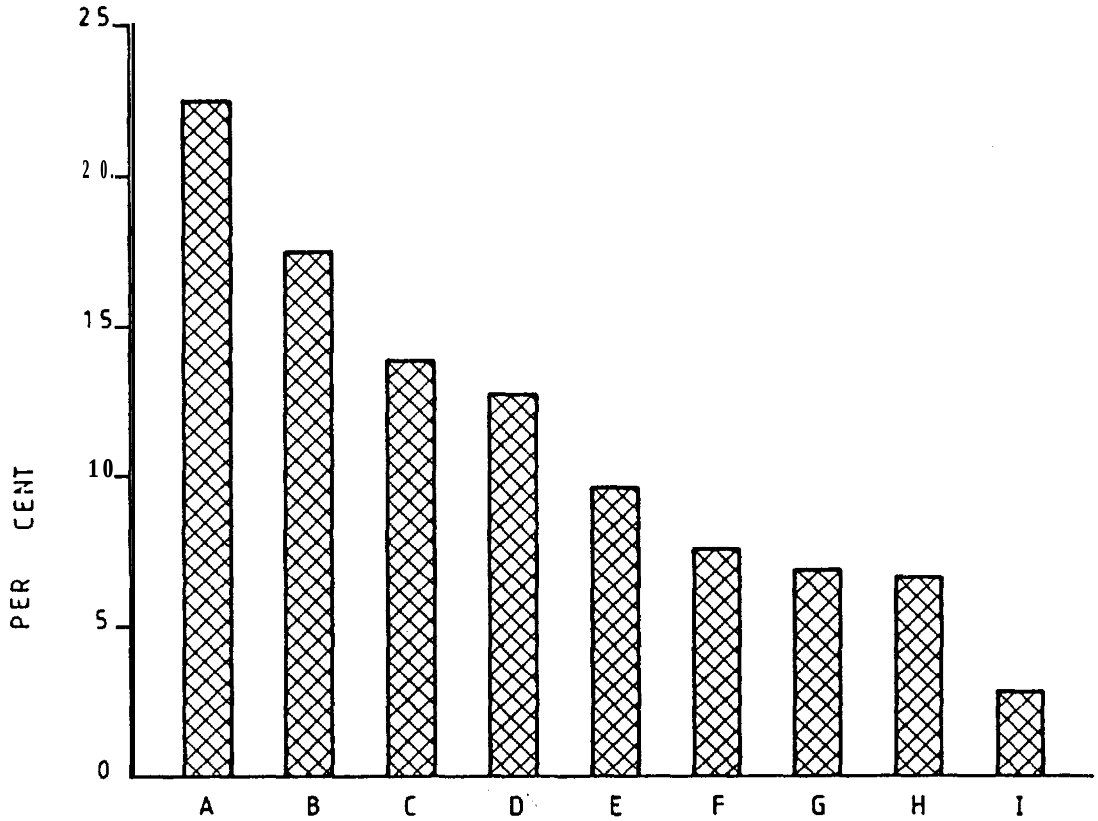


Fig.8. Local distribution of casualties.
For codes see Fig.9.

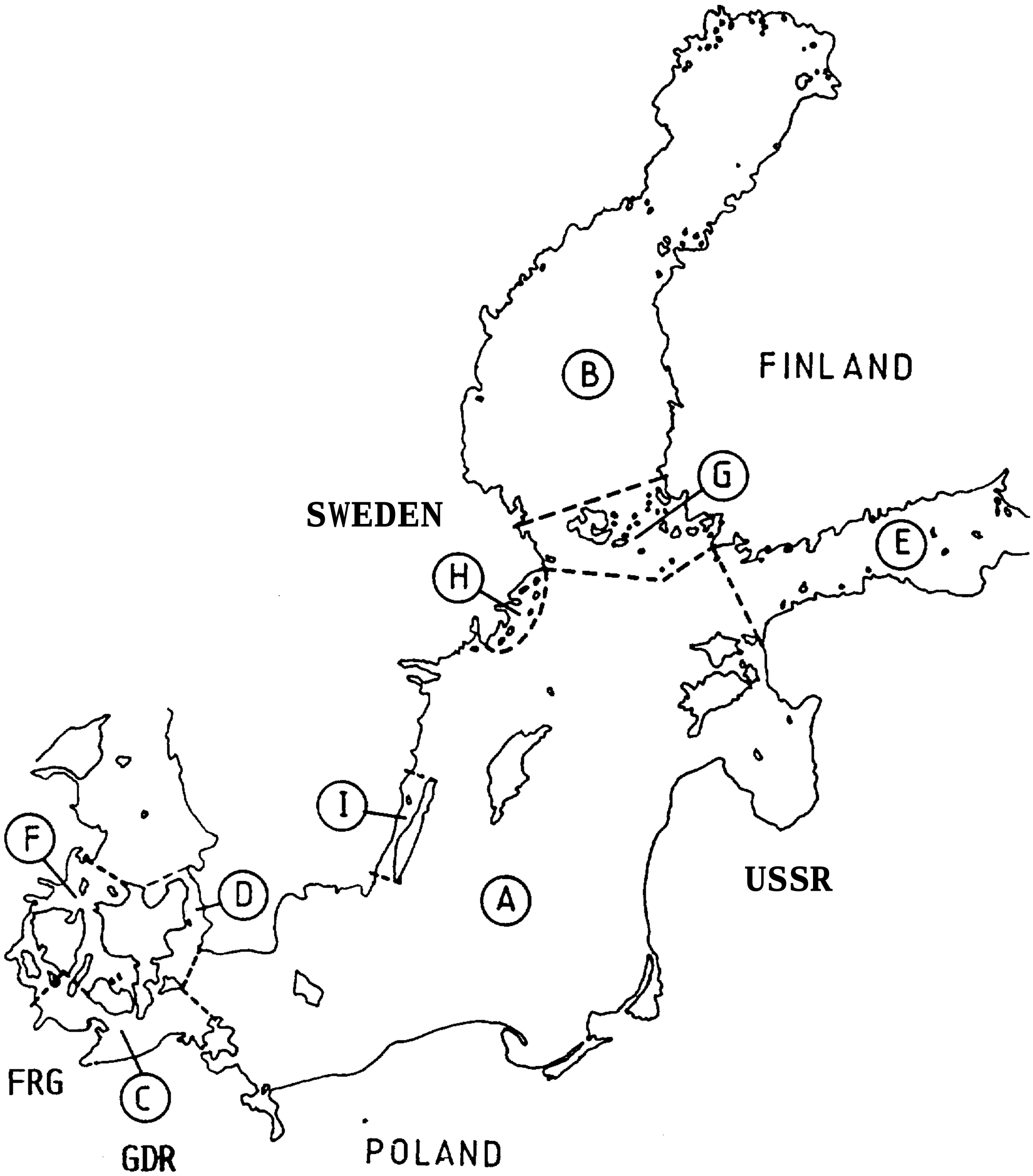


Fig.9. The Baltic Sea divided into 9 districts

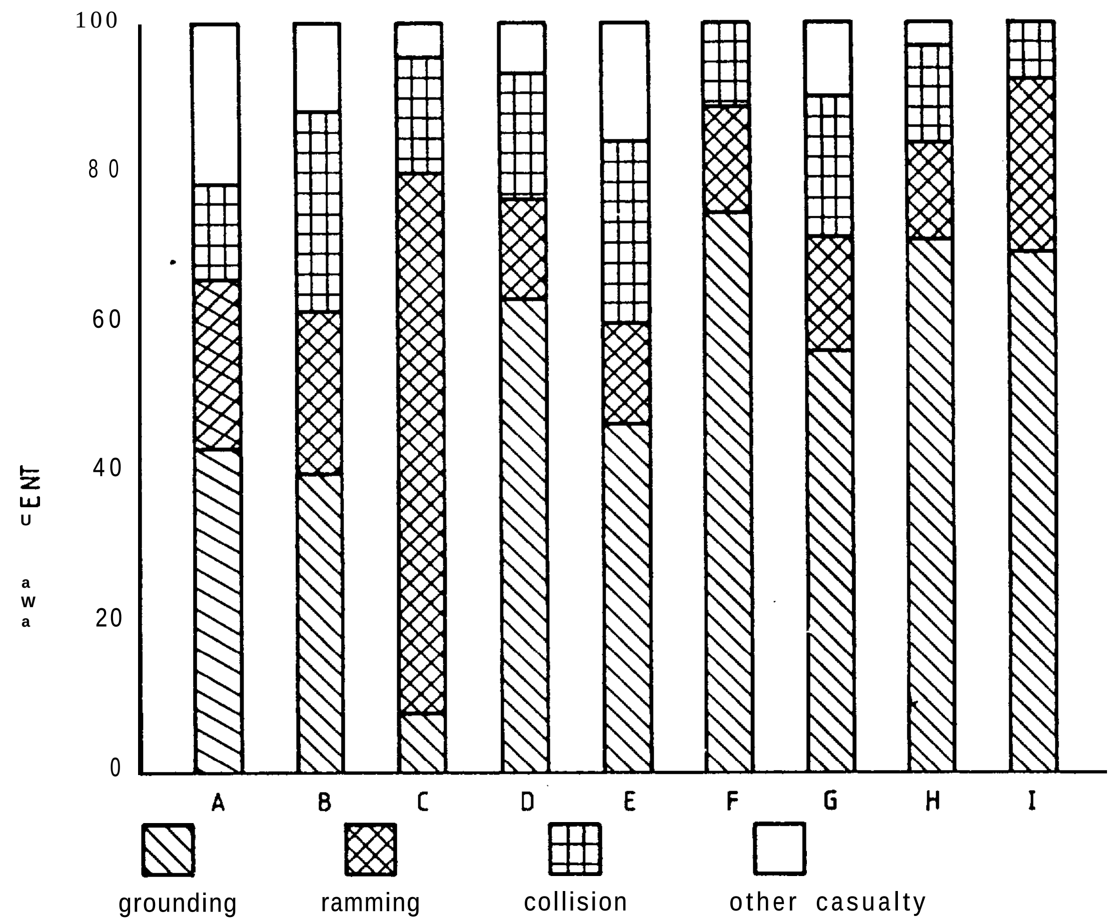


Fig.10. Distribution of casualty types in different parts of the Baltic. For codes see Fig.9.

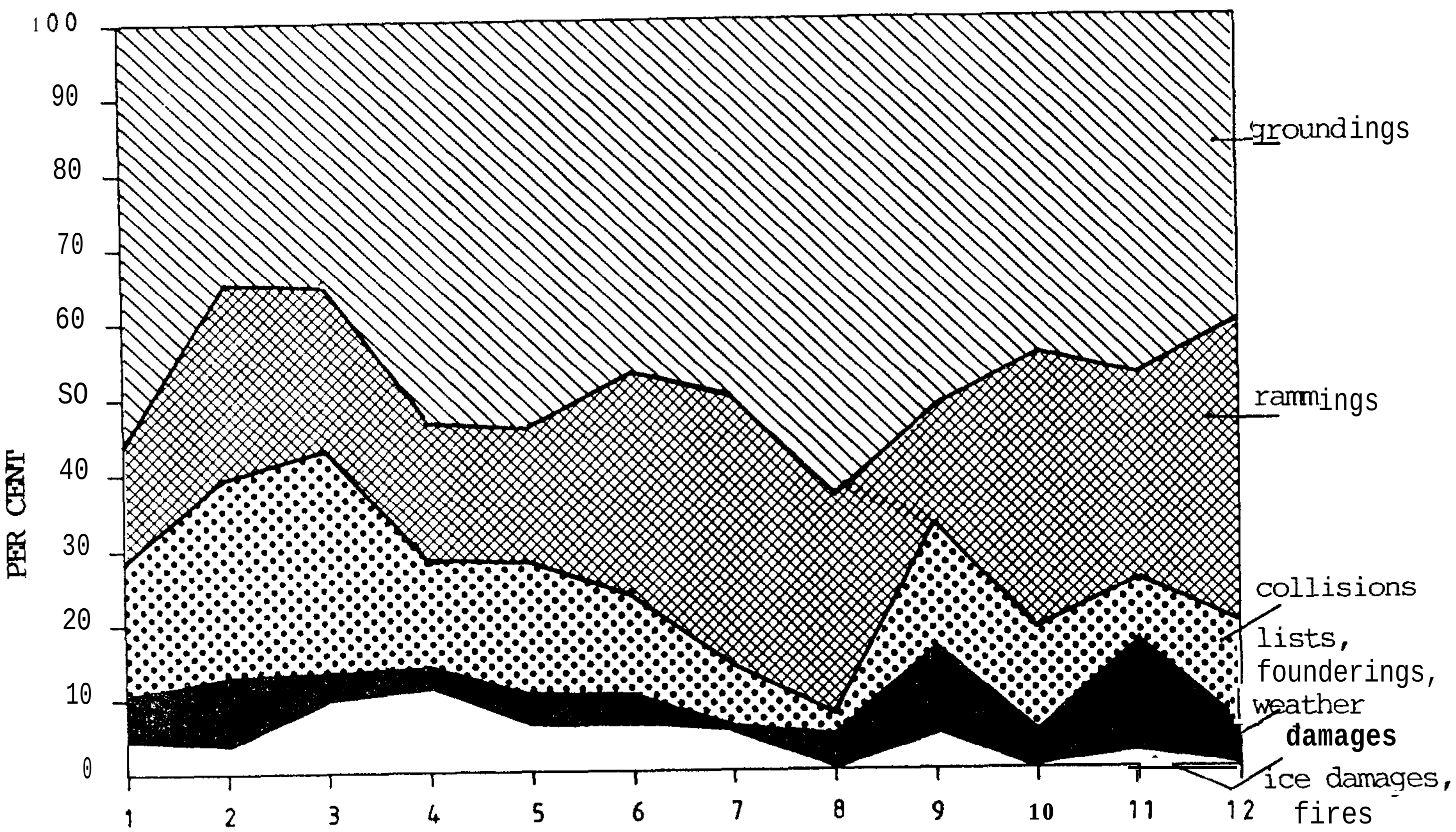


Fig.11. Seasonal relation between different types of casualties

TABLE 7. Number of casualties in different parts of the Baltic

	OIL DIS-CHARGE	FIRE	GROUN-DING	COL-LISION	RAMMING	FOUNDER-ING,LIST	WEATHER DAMAGE	ICE DAMAGE	Row Total
SOUND	0	2	38	10	8	2	0	0	60 12.7
GREAT BELT	0	0	27	4	5	0	0	0	36 7.6
FEHMARN & KIEL	1	1	5	10	47	1	0	0	65 13.8
KALMAR SOUND	0	0	9	1	3	0	0	0	13 2.8
OTHER PARTS	0	4	46	13	24	15	2	2	106 22.5
STOCKHOLM'S APPR	0	0	22	4	4	1	0	0	31 6.6
ALAND WITH SURR	0	0	18	6	5	2	0	1	32 6.8
GULF OF BOTHNIA	0	1	33	22	18	0	1	8	83 17.6
GULF OF FINLAND	0	0	21	11	6	2	0	5	45 9.6
Column Total	0.:	8 1.7	219 46.5	81 17.2	120 25.5	23 4.9	3 0.6	16 3.4	471 100.0

The seasonal relationship between different types of casualties is illustrated in Fig.11 and the absolute numbers of groundings, rammings and collisions are shown in Fig.3 on a quarterly basis. The self-evident facts that ice damages take place in the winter and founderings, heavy lists, capsizings and weather damages happen in the stormy autumn period emerge from Fig.11. From Fig.3 it is seen that the casualty figures within a year have maxima at the beginning and at the end of the year and a minimum in the summer. Thus it is evident. that the environmental conditions are very important contributory causes of casualties.

4.4 Time of the Day and Day of the Week

The distributions of casualties by watches are shown in Fig.12. The hypothesis that the occurrence of a casualty is the same in every watch was tested statistically using the χ^2 test explained in section **4.2.** Table **8** summarizes the calculated probabilities that the observed numbers of of the sample have been taken from a uniform distribution. In groundings and collisions the probabilities indicate that the hypothesis can be accepted. In ramming the probability is less than **0.05** and the hypothesis is rejected.

TABLE **8.** χ^2 test probabilities

groundings	collisions	rammings	all cas.
0.60	**0.50**	**0.03**	**0.70**

The observed variations from the uniform distribution in groundings and collisions are thus not found to be statistically significant. This merely means that the possible trends are not very strong. These distributions resemble those found earlier [7] in the Baltic or worldwide [34]. No evidence can, however, be found from Fig.1 **2** that there would be a correlation between the number of groundings or collisions at a certain time and e.g. the diurnal change of the physiological or psychological capabilities of the navigator.

No exact information on the daily distribution of arrivals in and departures from ports were available, but the peak period of rammings is evidently coincident with the traffic peak at ports, which is the sailing area where most rammings take place, as seen in Fig. **6.**

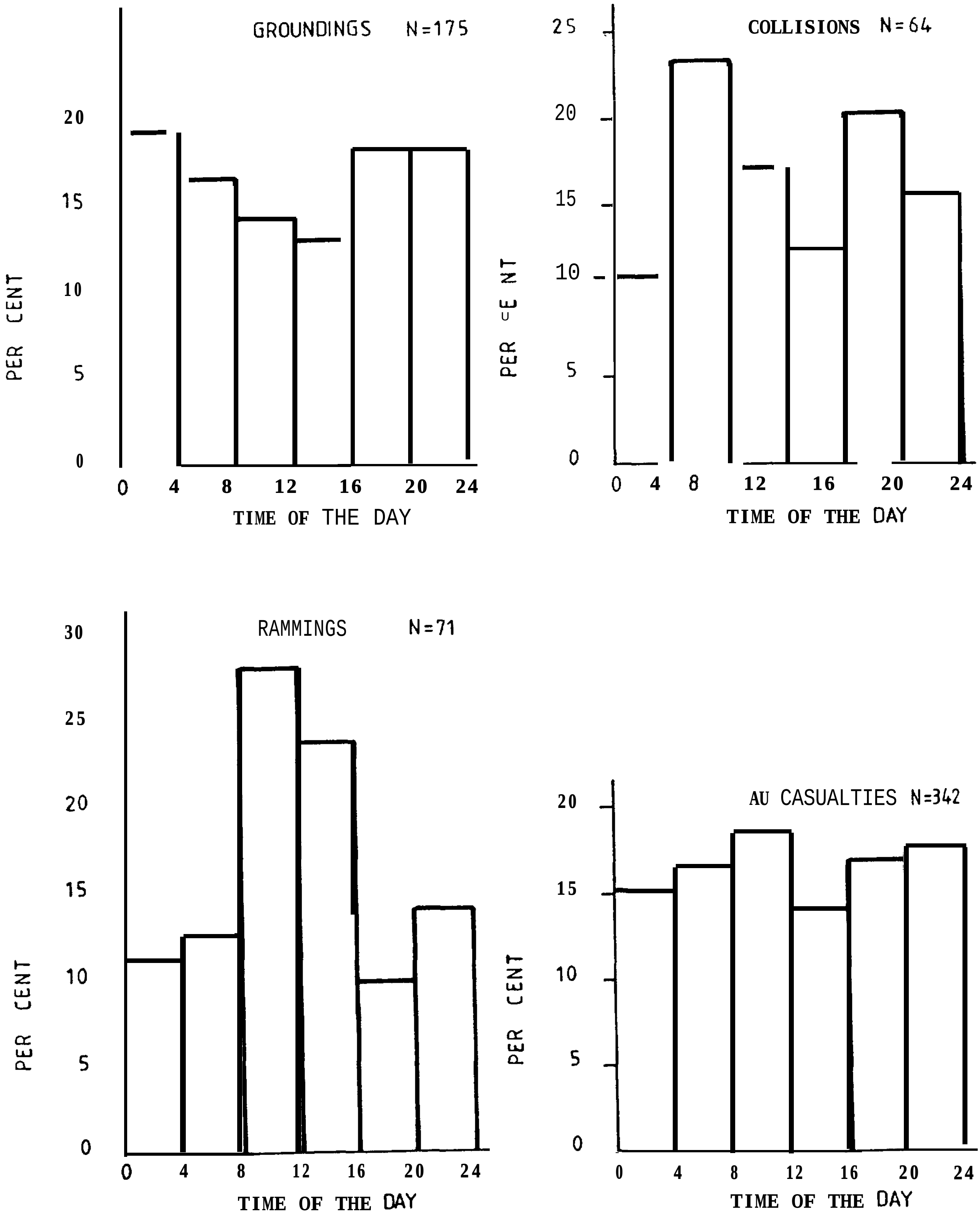


Fig.12. Distribution of casualties by watches

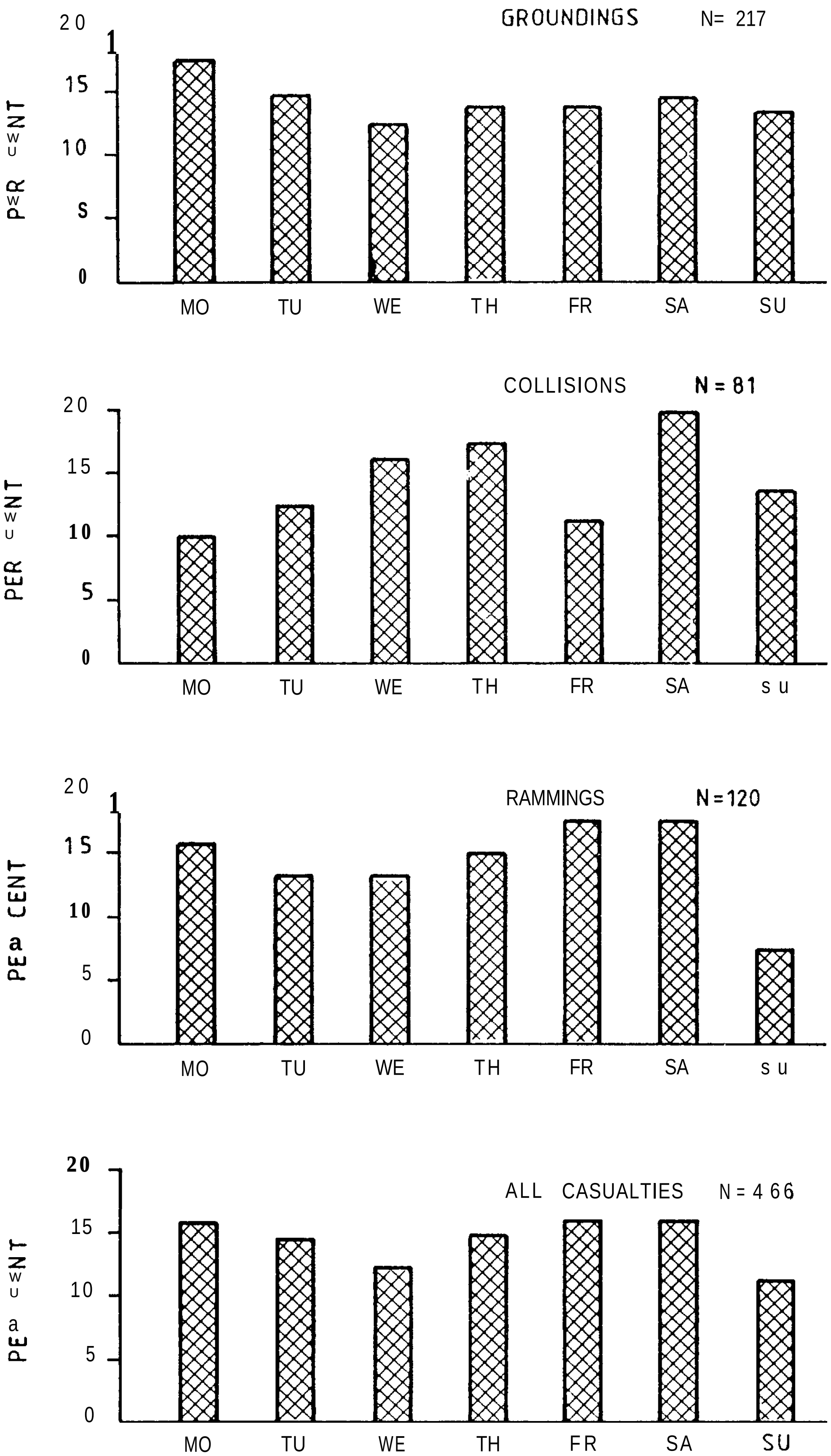


Fig.13. Distribution of casualties by days of the week

The distributions of casualties by days of the week are presented in Fig.1 **3.** As above, a hypothesis of a uniform distribution is made and tested with χ^2 test. The results of the testing are given in Table **9.** The test indicates that the fit of the uniform distribution to the observed values is good and it is reasonable to say that no day is more accident-prone than others, with the possible exception of rammings. Though the low number of rammings on Sundays has not been found to be statistically significant, it is evident that the scarcity in casualty numbers reflects a real situation: arrivals in and departures from ports are generally at a minimum on Sundays.

TABLE 9. χ^2 test probabilities

groundings	collisions	rammings	all cas.
0.85	0.65	0.40	0.80

4.5 **Flags**

The flags or the official countries of registry of the ships in the sample are shown in Table 10.

Do ships of various flags have a different probability of getting involved in casualties in the Baltic? The numbers of casualties of various flags can be compared only on the basis of a variable which takes into account the amount of exposure. The only available exposure variable has been the number of the Kiel Canal passings and the arrivals in Finnish ports in the years 1979-1980.

TABLE 10. Flags of ships in casualties

Flag	Number of ships in accidents	Percentages of all ships in accidents
Swedish	112	21.2
Finnish	107	20.2
FRG	65	12.3
Greek	47	8.9
USSR	25	4.7
Danish	21	4.0
Polish	21	4.0
Norwegian	19	3.6
Dutch	19	3.6
Panamanian	17	3.2
British	13	2.5
GDR	10	1.9
Singaporean	8	1.5
Liberian	6	1.1
Icelandic	3	0.6
Cypriot	3	0.6
Brazilian	3	0.6
Spanish	3	0.6
Cuban	3	0.6
Italian	2	0.4
Belgian	2	0.4
Indian	2	0.4
Turkish	2	0.4
Netherlands Antilles	2	0.4
Israeli	2	0.4
Other flags	12	2.4

In Table 11a the number of arrivals [31] by flag in Finnish ports in the years 1979-1980 are presented. Fifteen flags with the highest quota of the traffic are included. The numbers of casualties sustained by ships of these fleets in the two years are also shown. The casualties included have taken place in the Gulf of Finland, the Gulf of Bothnia or in the surroundings of Åland. These districts are seen in Fig.9 as E, B and G, respectively.

Table 11b is a similar presentation based on the Kiel Canal passings [33] by flag. The casualties included have taken place in the Fehmarn Belt and Kiel Fjord or in district C of Fig.9.

TABLE 11a Arrivals in Finnish ports and casualties in Gulf of Finland, Gulf of Bothnia and Åland with surroundings in 1979-1980

Flags	Traffic No	Rank	Casualties Rank	No	Cas./traffic 10^3
Finnish	6090	1	1	55	
FRG	5073	2	2.5	19	3.7
USSR	4071	3	5	6	1.5
Swedish	1352	4	2.5	19	
Dutch	997	5	4	10	10.0
Norwegian	583	6	6	5	8.6
British	502	7	8	3	6.0
Polish	461	8	10.5	1	2.2
Danish	371	9	13.5	0	0
GDR	364	10	13.5	0	0
Greek	198	11	8	3	15.0
Icelandic	114	12	13.5	0	0
French	105	13	13.5	0	0
Panamanian	91	14	8	3	33.0
Singaporean	77	15	10.5	1	13.0

TABLE llb Kiel Canal passings and casualties in Fehmarn Belt and Kieler Bucht in 1979-1980

Flags	Traffic No	Rank	Casualties Rank	No	Cas./traffic 10^3
FRG	35748	1	2	7	0.20
Polish	5371	2	4.5	4	0.75
USSR	5331	3	4.5	4	0.75
GDR	4408	4	4.5	4	0.91
Dutch	4069	5	12	1	0.25
Swedish	3798	6	10	2	0.57
Danish	3325	7	10	2	0.60
Finnish	3099	8	10	2	0.65
Greek	1867	9	1	12	6.43
Panamanian	1367	10	14	1	0.73
British	1044	11	4.5	4	3.83
Norwegian	1003	12	14	1	1.00
Cypriot	814	13	14	1	1.23
Singaporean	594	14	7.5	3	5.05
Liberian	542	15	7.5	3	5.56

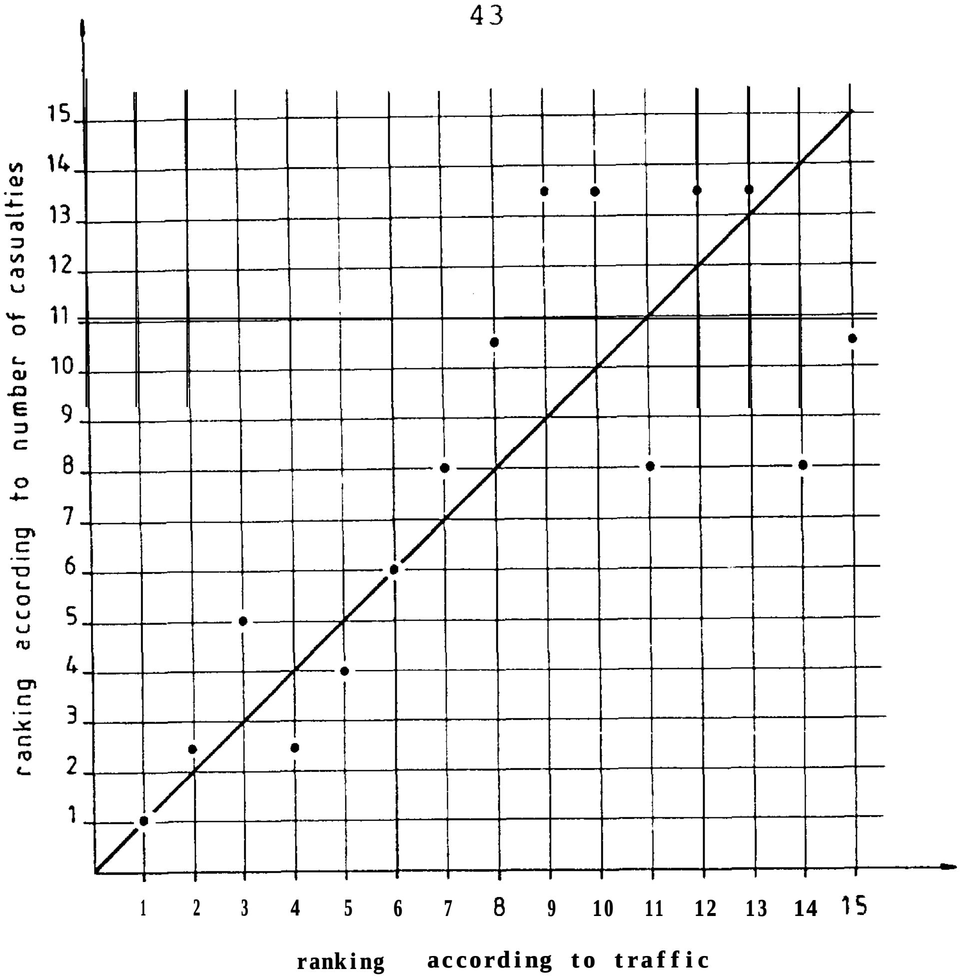


Fig.14. Ranking of casualties vs traffic by flag in the northern part of the Baltic

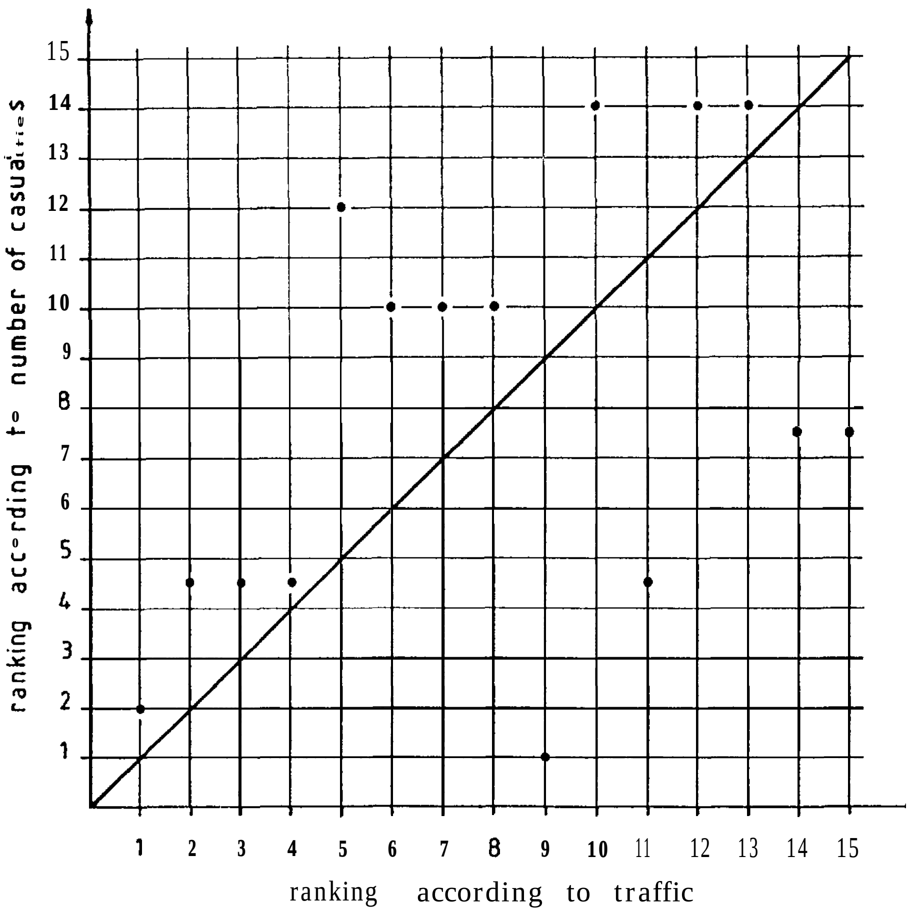


Fig.15. Ranking of casualties vs traffic by flag in the southern Baltic

The traffic figures are by no means absolute ones. But it is reasonable to suppose that they represent the relative proportions which the fleets of different flags have of the traffic in the named districts of the Baltic. Therefore, the correlations between the traffic and casualty figures of various flags are measured by calculating two correlation coefficients based on ranks. For this purpose both the traffic and casualty numbers of Tables 11a and 11b are ranked: in the case of traffic, rank 1 is given to the flag having the greatest traffic, rank 2 to the next highest, etc; the casualty numbers are ranked in the same way. If the number of casualties is the same, the rank assigned is the average of the ranks which would have been assigned if the numbers had differed slightly. The ranks are given in both Tables.

The ranks of traffic and casualties are depicted in Figs. 14 and 15. If there was a perfect rank agreement between the amount of traffic and the number of casualties of each flag, the points should lie on the diagonal straight line, but now the points are somewhat scattered. To test statistically whether the sample data give real indication of association in the ranking, two rank correlation coefficients, Spearman's ρ and Kendall's τ were calculated [35]. Roughly speaking, a value of a coefficient near 1 indicates association, a value near 0 lack of association. A reasoning similar to that with the χ^2 test is employed. If the probability to obtain the calculated value of the coefficient is 0.05 or under, it must be concluded that there is a real association between the variables. The values of the coefficients together with the probabilities of obtaining them when there is no association are given in Table 12.

TABLE 12. Rank correlation coefficients

Districts	ρ	P	τ	P
E, B, G	0.831	0	0.629	0
C	0.463	0.05	0.371	0.03

The values of correlation coefficients differ from zero significantly and there is association between the amount of traffic and the number of casualties. But the correlation is far from perfect which is manifested in the scatter of Figs.14 and 15. There are many possible reasons for that: some flags may be more prone to casualties than others; the amount of traffic as measured here may not be an appropriate variable to measure the amount of exposure; a possible mixture of both mentioned reasons. Many statistical casualty studies [8][36] have found some marked variations in the casualty rates of different flags and, therefore, it is reasonable to interpret the scatter as an expression of this.

Each arrival in a port or each passing through the Kiel Canal can be interpreted as a trial which leads to two posible outcomes: a casualty or a non-casualty. If p, the probability of a casualty is assumed to be constant in n arrivals, the number of casualties in n arrivals follows the binomial distribution. If p is small and n is large, the Poisson distribution with the parameter $m=np$ can be used as an approximation of the binomial distribution [28].

The Poisson distribution will be used to determine which flags have statistically higher or lower casualty rates than all flags on the average. First it is assumed that p is the same constant for all flags, the two areas have naturally a different p and they are considered separately. The probability of getting the observed number of casualties in the known number of arrivals or passings is calculated from the Poisson distribution for each flag separately. As usual, the probability of 0.05 or less indicates a statistically significant discrepancy from the assumption.

From Table 11a the number of arrivals is 13007 and the number of casualties is 51. The Finnish and Swedish ships have been excluded from these figures because of the mentioned sampling error. Thus the average probability of a casualty per arrival is $p = 3.9 \cdot 10^{-3}$. To illustrate the use of the test it is applied to the Polish ships. Number of arrivals is n = 461 and the Poisson parameter m = np = 1.8, the observed number of casualties is one:

$$P(N \leq 1) = \sum_{k=0}^{1} \frac{m^k e^{-m}}{k!} = 0.46$$

The probability value is very common and the casualty rate of Polish ships in the northern part of the Baltic can be considered to be normal or near the average of all flags.

The areas of Tables IIa and IIb were tested separately. All flags from Table IIb were included. The calculated probabilities and their significances are presented in Table 13. If the probability indicates a statistically significant difference from the average casualty rate, the direction is also given: "+" means higher "-" means lower than average value.

TABLE 13. Poisson probabilities and their significances

Flag	Gulf of Finland, Gulf of Bothnia Åland		Kiel Fjord, Fehmarn Belt	
	P	Significance	P	Significance
British	0.310	no	0.007	yes, +
Cypriot			0.435	no
Danish	0.235	no	0.584	no
Dutch	0.007	yes, +	0.220	no
GDR	0.242	no	0.377	no
Finnish			0.628	no
French	0.670	no		
Greek	0.044	yes, +	0	yes, +
Icelandic	0.638	no		
Liberian			0.007	yes, +
Norwegian	0.083	no	0.505	no
Panamanian	0.006	yes, +	0.749	no
Polish	0.463	no	0.524	no
Singaporean	0.259	no	0.009	yes, +
Swedish			0.584	no
USSR	0.004	yes, -	0.518	no
FRG	0.490	no	0	yes, -

The period investigated here is only two years long, and the traffic and casualty numbers are few. This means that especially in the case of flags whose casualty numbers are based on a small traffic may reflect a random effect which would be smoothed off if the time span were longer. Therefore, the results are more reliable in the case of flags which have larger traffic numbers.

Table 13 indicates that most flags show a casualty rate which does not differ significantly from the average. Greek ships seem to have a higher than average rate. Liberian, Panamian and Singaporean ships also have higher than average rates in either area concerned but their small traffic may affect the reliability of this conclusion. Quite surprisingly, Dutch ships in the northern Baltic and British ships in the southern Baltic have a higher than average rate. Lower than average rate of the USSR ships is evidently caused merely by the sample error.

4.6 Ship Type, Age, Length and Speed

Table 14. shows the division of ship types by different casualty types. Dry cargo ships include ordinary general cargo, RoRo and container ships and bulk carriers; car ferries and passenger ships are ferries; special vessels include fishing vessels, tugs, etc.

TABLE 14. Ship types by nature of casualty

	OIL DIS-CHARGE	FIRE	COL-LISION	GROUN-DING	RAMMING	FOUNDER-ING, LIST	WEATHER DAMAGE	ICE DAMAGE	Row Total
DRY CARGO SHIP	0	5	137	89	94	16	2	14	357 67.6
TANKER	0	1	37	18	11	2	0	0	69 13.1
FERRY	1	1	18	10	11	2	1	1	45 8.5
ICEBREAKER	0	1	5	9	1	0	0	0	16 3.0
SPECIAL VESSEL	0:	0	23;	2	12	3	0	1	41 7.8
Column Total	0.:	8 1.5	220 41.7	22.s 138 26.1	119	42:	3 0.6	16 3.0	528 100.0

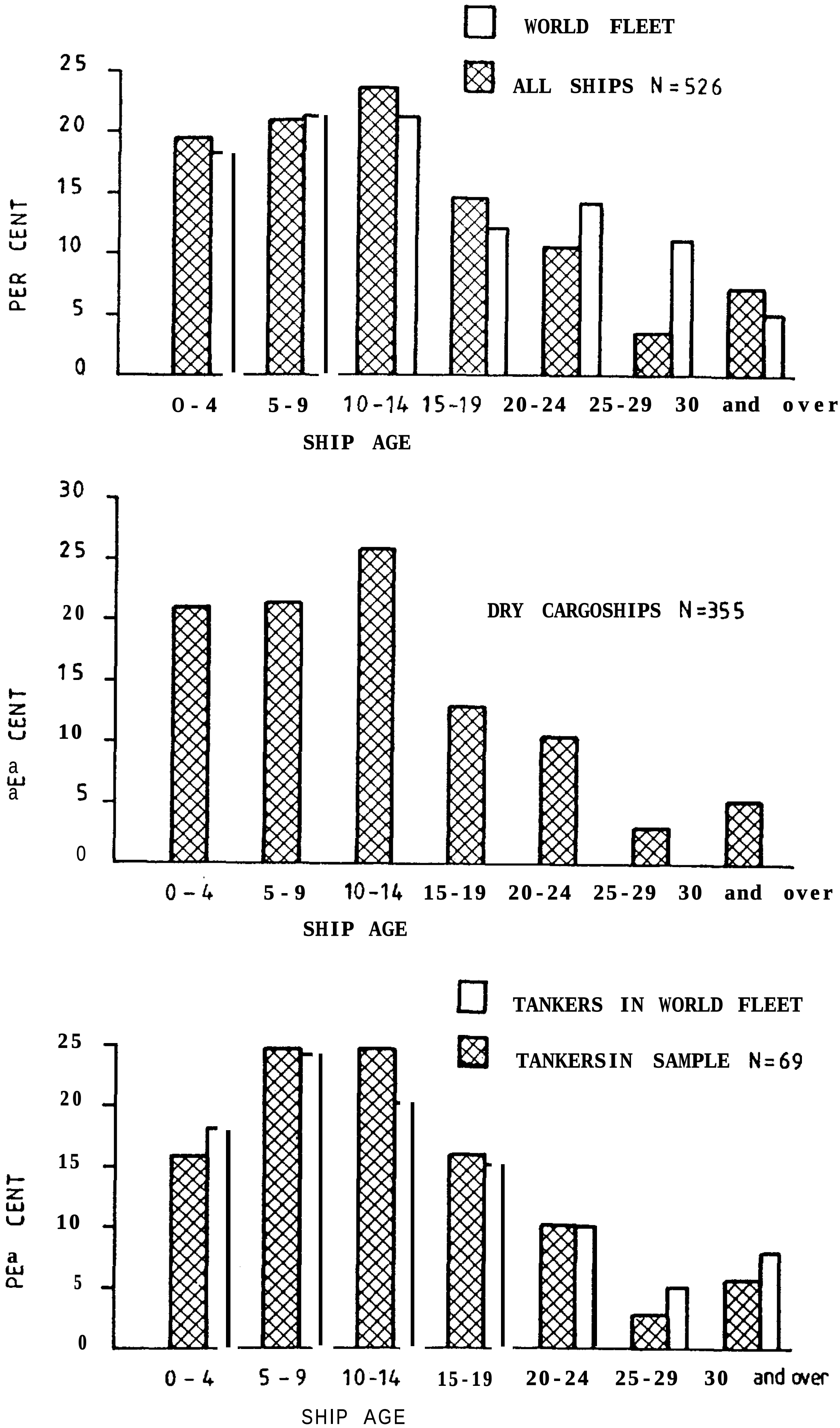


Fig.16. Age distributions of all ships, dry cargo ships and tankers

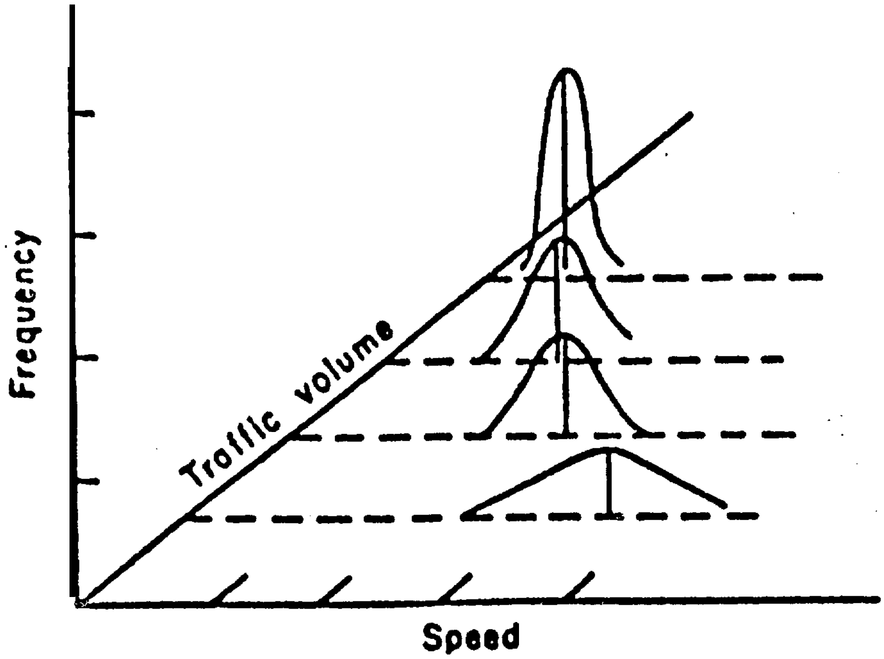


Fig.17 Relationship between traffic volume and speed [4]

Lack of knowledge about the type distribution of the total traffic makes it impossible to assess if some type categories have more or less casualties than their quota of the traffic would imply. The percentage of different ship types are about the same as in the years 1971-1975 [7].

Age distributions of all ships, dry cargo ships and tankers in the sample are depicted in Fig.16, where also the corresponding distributions of all ships and tankers of the total world fleet in the year 1980 are given. The similarity between the sample and the world fleet distributions is evident from the histograms. The median age of all ships in the sample is 12.0 years and 12.6 years in the world fleet, for tankers the median age is 11.9 and 12.0 years, respectively. It is reasonable to assume that the age distribution of ships navigating in the Baltic does not differ substantially from that of the world fleet. If this assumption is correct, it follows that no age class seems to have markedly more casualties than expected.

The age distributions of Finnish or Swedish ships operating in the Baltic is not known but here again the distributions of the fleets offer a reasonable approximation. The ages are published [31][38] in such a form that the median is the only suitable parameter to describe the average age. Table 15. presents the sample and fleet (1980) particulars of the age distributions of Finnish and Swedish dry cargo ships, age in years. The standard median test [29] was employed to get information on whether it is likely that the

TABLE 15. Dry cargo ship age medians

	Fleet		Sample	
	median	ships	median	ships
Finnish	14.38	212	14.33	64
Swedish	10.28	271	11.96	47

sample median is equal to the fleet median. The test gave the probability 1.0 for the Finnish data and the probability 0.45 for the Swedish data that the respective age medians are equal. This confirms the conclusion that on the average the ages of ships involved in casualties do not differ from the ages of the whole population.

The parameters of age distributions of ships in the three most common types of casualties are shown in Table 16, age in years.

TABLE 16. Ship age parameters by casualty type

	ships	mean age	standard dev.
groundings	220	15.62	14.16
collisions	136	13.13	12.08
rammings	119	11.96	10.75

Do the differences in the mean ages indicate that the age distributions in different types of casualties are not the same? To test the differences statistically two standard tests, z – test [39] and Mann-Whitney U test [27], were employed. The tests give the probabilities of the occurrence of the observed differences between the samples under the hypothesis that the underlying distributions are the same. Z – test is a parametric test which gives the probability that the means are equal; Mann-Whitney U test is a non-parametric test which assesses the probability that both the forms and the locations of the distributions are the same. Table 17 summarizes the calculated probabilities between the various casualty types.

As usual, the differences are taken to be statistically significant if the probabilities are 0.05 or less. Both tests indicate that the average age of ships in groundings is significantly higher than in rammings and almost significantly higher than in collisions. The ship age distributions in collisions and rammings do not differ essentially.

TABLE 17. Probabilities from z and U tests

between	z	U
groundings and collisions	0.078	0.149
groundings and rammings	0.008	0.020
collisions and rammings	0.415	0.303

The parameters in length distributions of the three most common ship types of the sample in groundings, collisions and rammings are presented in Table 18. Z, U and median tests were used to find out if the differences in the mean or median length imply statistically significant differences in the underlying distributions. The calculated test probabilities are summarized in Table 19. Z – test is applicable only to cases where the number of ships in both samples is over 30. It emerges from Tables 18 and 19 that the average length of general dry cargo ship is significantly higher in rammings than in collisions and likewise significantly higher in collisions than in groundings. The observed differences in the case of tanker and bulk carrier lengths are not significant. This reflects a common feature in connection with small samples: even large differences may turn out to be non-significant.

It can be summarized that on the average the ships in groundings seem to be older and smaller than those involved in collisions and rammings.

TABLE 18. Ship length parameters by casualty type

	ships	mean length	standard dev.	median length
general cargo ship				
groundings	100	70.86	28.08	64.38
collisions	67	85.12	30.76	77.73
rammings	64	103.58	24.55	102.22
bulk carriers				
groundings	29	149.92	41.87	151.82
collisions	14	142.34	33.47	140.00
rammings	22	144.08	43.03	153.33
tankers				
groundings	37	113.98	57.13	98.89
collisions	18	117.75	40.38	113.33
rammings	11	135.26	37.89	143.33

TABLE 19. Z, U and median test probabilities

between	Z	U	median
general cargo ships			
groundings and collisions	0.002	0	0
groundings and rammings	0	0	0
collisions and rammings	0.002	0.004	0.045
bulk carriers			
groundings and collisions	-	0.294	0.128
groundings and rammings	-	0.669	0.872
collisions and rammings	-	0.650	0.305
tankers			
groundings and collisions	-	0.584	0.252
groundings and ramnings	-	0.244	0.125
collisions and rammings	-	0.431	0.264

No direct measurements of ship speed distributions in the Baltic are available. It is, however, reasonable to assume that the speed of ships, when navigating freely, is approximately normally distributed. Japanese marine traffic measurements confirm this assumption. In Fig.17 [4] the relationship between traffic volume and speed is qualitatively depicted. The variable traffic volume can be changed to poor visibility, because both greater traffic volume and poorer visibility decrease the mean and the variance of the speed distribution but the distribution remains normal.

The distributions of speeds at the time of groundings, collisions and rammings are shown in Fig.18. It is evident that these distributions are not normal but the speeds have clustered towards the lower speeds. The forms of the distributions conform with the results of the years 1971-1975 [7]. The particulars of the distribution are tabulated in Table 20, in knots.

TABLE 20. Speed distributions

	mean	standard dev.	median	number of ships
groundings	6.47	4.51	5.78	94
collisions	4.50	4.43	2.80	75
rammings	1.98	1.80	1.46	41

The forms of the speed distributions in collisions and rammings suggest that some theoretical distribution could be fitted to the observations. The form of the distributions and the fact that the mean and the standard deviation are approximately equal in both cases hint that the exponential distribution [40] might be an appropriate choice. The probability density function for v = speed is

$$f(v) = ce^{-cv}, \ v \geq 0.$$

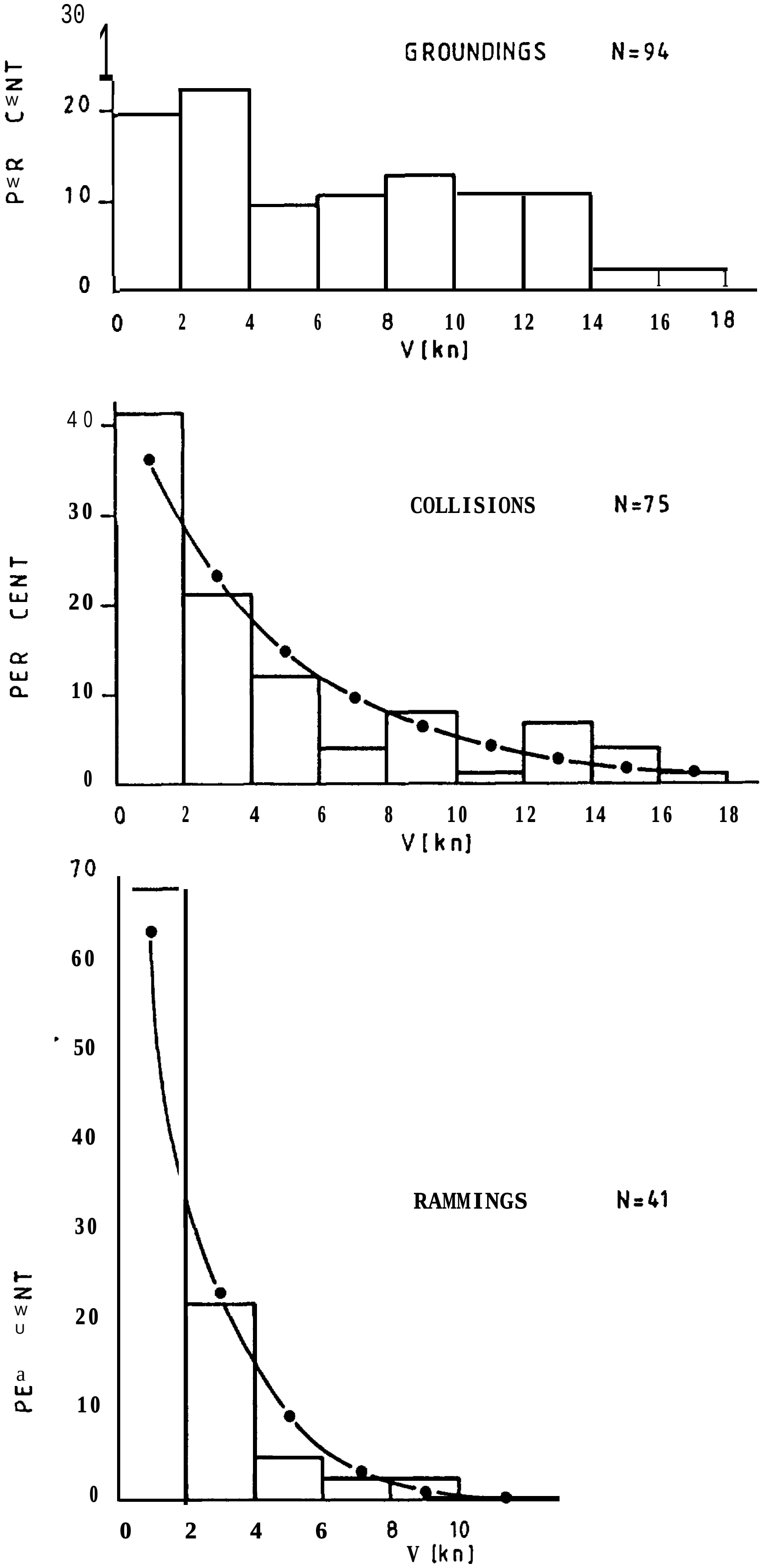


Fig.18. Speed distributions of ships in groundings, collisions and rammings

The mean m and the 'standard deviation s are equal and are related to the distribution parameter in the following way: $m = s = 1/c$. The cumulative probability function or the probability that speed $v \geq a$ is

$$F(v) = P(v \leq a) = 1 - e^{-ca}.$$

The exponential distributions which have the same means as the corresponding sample means in collisions and rammings have been plotted on the observed histograms in Fig.18. The agreement with the observed distribution seems to be good and it has been tested using the usual χ^2 method described in section 4.2. The test gives the probabilities 0.40 for collisions and 0.80 for rammings which implies that the discrepancies between the theoretical and observed distributions are far from significant. The exponential distribution is an adequate mathematical model to describe the speed distribution of ships in collisions and rammings. In groundings no theoretical model has been found.

The sample model found can be used e.g. in estimating the probable speeds in rammings and collisions. These are of interest in structural design of ships [41] or in construction of piers. For instance, what is the speed v_o in rammings which is exceeded only with the probability 0.01? In rammings c = 1.98 (Table 20.):

$$P(v>v_o) = 1 - P(v \leq v_o) = e^{-cv_o} = 0.01.$$

$$\Rightarrow v_o = 9.1 \text{ knots} = 4.7 \text{ m/s}.$$

4.7 Causes of Casualties

The potential number of causal factors and their combinations associated with marine casualties is high. As an example of this the causal factors given in the block scheme of the Appendix are considered. There are 60 factors listed in the scheme, but the total number of factors which were needed to describe the causes of the casualties in the sample is 68. In principle, if only one factor is taken as a cause of a casualty, there are 68 possible factors which can appear as a cause. If two factors are needed, there are N = 68'67 = 4558 possible different casualties when the order of the blocks is of importance. If no attention is paid to the order, the number of different possibilities is $M = \frac{1}{2} \cdot 68 \cdot 67 = 2278$. In general k factors of 68 can be combined in N or M ways which are calculated [28] by the formulas:

$$N = \frac{68!}{(68-k)!}, \qquad M = \frac{68!}{k!(68-k)!} .$$

For instance: k = 3, N = 300694 and M = 50116; k = 4, N = 19545240 and M = 814385 and so on. This exemplifies how great the number of different casualties can be when there are many contributory factors which have to be taken into account as causes of casualties.

In other words, each casualty consists of an individual collection of causes. In order to be able to assess on the basis of the sample which causal factors appear to be more common and important, the evaluation procedure described in section 3.5 was devised and applied.

In the block scheme the factors have been divided into three distinct groups: Environmental conditions; Technical deficiencies and their reasons; Human factors with a subgroup actions. The average effect of a causal factor of each group can be examined by calculating separately the mean value of the weight coefficients given to the factors of each group. The mean values of weight coefficients are shown in Table 21 which is based on all casualties in the sample. On the basis of Tables 2 and 21 it is clear that a technical deficiency, when it is present and has been identified as one of the causes of a casualty, has on the average a more marked effect on the occurrence of the casualty than the factors of the other groups. This merely reflects the fact that often a single technical fault, e.g. an electrical black-out, at a critical moment can lead to a casualty, but many simultaneous environmental and human factors are usually present in casualties without a technical fault.

TABLE 21. Mean weight coefficients by factor groups

	Number of factors weighted	Mean weight
Environmental conditions	640	0.317
Technical deficiencies	96	0.519
Human factors and actions	302	0.382

By employing the effect level explained in section 3.5 the relative importance of the three factor groups can be examined. Table 22 shows the effect levels or probabilities of the three groups in different types of casualties. The most unorthodox result is the low proportion of human factors in collisions, only 17 percent, though the usual figure most often quoted [34] is about 80 percent. One evident reason for the low ratio is the weighting principle number 3 of section 3.5. The definition of the environmental conditions and the exceptional environment of the Baltic are other reasons for the high ratio of environmental conditions. Table 23 presents the most important single factors with their probabilities in groundings, collisions and rammings. In collisions all five factors belong to the group environmental conditions, and especially the factor heavy ice conditions is a typical Baltic feature.

Table 24 gives the probabilities of the three groups in different parts of the Baltic in groundings, rammings and collisions. The low number of casualties may have a random

TABLE 22

The relative importance of the three factor qroups in different types of casualties

	Accidental discharge of oil N=1	Explosion or fire N=8	Grounding N=219	Collision N=81
Environmentai conditions	0	0	0.44	0.77
Technical deficiencies and their reasons	0	0.80	0.11	0.07
Human factors and actions	1.00	0.2	0.45	0.16

	Hamming N=120	Foundering, capsizing, heavy list N=23	Heavy weather damage N=3	Ice damage N=16
Environmental conditions	0.49	0.41	0.80	0.91
Technical deficiencies and their reasons	0.22	0.48	0.20	0
Human factors and actions	0.29	0.11	0 •	0.09

TABLE 23

The most important factors and their probabilities in the three most common types of casualties

Grounding N=219		Collision N=81		Ramming N=120	
Improper manoeuvre	0.11	Heavy ice conditions	0.28	Storm	0.15
Miscalculation of the position	0.10	Fog	0.12	Heavy ice conditions	0.09
Misobservation	0.09	Other ship manoeuvring against rules	0.12	Improper manoeuvre	0.09
Storm	0.06	Other ship, no reactions to the critical situation	0.06	Main engine failure	0.08
Narrow channel, passage	0.06	Narrow channel, passage	0.04	Improper assistance of tugs	0.05
Poor marking of fairway	0.05				

effect on the results of the individual districts, but generally no striking differences can be seen between the different parts of the Baltic. From Tables 22 and 24 it can be concluded that in a grounding or collision the cause is a technical failure with an approximate probability 0.10. In a ramming this probability is about twice as high. Thus it can be said that a technical failure is not a very common cause of a grounding, ramming or collision.

The most important single causal factors and their probabilities in the different parts of the Baltic in groundings, rammings and collisions are shown in Tables 25, 26 and 27, respectively. From them and Table 23 the following conclusions can be drawn:

In groundings the most probable causes both in the northern and southern Baltic seem to be of navigational or human kind: improper manoeuvre, miscalculation of the position and misobservation show high probabilities. Of environmental conditions, narrow channel, passage and poor marking of the fairway are important causes in groundings.

In rammings heavy ice conditions and storm are the most probable causes, especially in the northern Baltic. Technical failures seem to be often present in the rammings taking place in the southern Baltic.

- As already mentioned in section 4.3, heavy ice conditions in the northern Baltic are very important causes in collisions, and together with fog or poor visibility they constitute the most probable causes of a collision. The high probabilities of factors indicating the fault of other vessels stem from the bias in the sample: in his answer a shipmaster of a vessel in collision often blamed the other vessel, and answers were seldom obtained from both ships.

TABLE 24

The relative importance of the three factor groups in different parts of the Baltic Sea in groundings, rammings and collisions

Groundings	1 N=38	2 N=27	3 N=5	4 N=9	5 N=46	6 N=22	7 N=18	8 N=33	9 N=21
Environmental conditions	0.54	0.39	0.32	0.44	0.37	0.43	0.48	0.44	0.49
Technical deficiencies and their reasons	0.14	0.12	0.14	0.05	0.16	0.13	0.10	0.10	0.01
Human factors and actions	0.32	0.49	0.54	0.51	0.47	0.44	0.42	0.46	0.50

Rammings	1 N=8	2 N=5	3 N=47	4 N=3	5 N=24	6 N=4	7 N=5	8 N=18	9 N=6
Environmental conditions	0.24	0.65	0.31	0.67	0.43	0.45	0.40	0.64	0.96
Technical deficiencies and their reasons	0.19	0.22	0.43	0.33	0.19	0.03	0.17	0.17	0
Human factors and actions	0.57	0.13	0.26	0	0.38	0.52	0.43	0.19	0.04

Collisions	1 N=10	2 N=4	3 N=10	4 N=1	5 N=13	6 N=4	7 N=6	8 N=22	9 N=11
Environmental conditions	0.59	0.91	0.89	0.75	0.66	0.68	0.66	0.89	0.83
Technical deficiencies and their reasons	0.18	0	0	0	0.07	0	0.02	0.02	0.13
Human factors and actions	0.23	0.09	0.11	0.25	0.27	0.32	0.32	0.09	0.04

Legend:
1 The Sound
2 Great Belt
3 Fehmarn Belt and Kiel Fjord
4 Kalmar Sound
5 Other parts of the Baltic
6 Stockholm approach
7 Åland with surroundings
8 The Gulf of Bothnia
9 The Gulf of Finland

TABLE 25

The most important factors and their probabilities in groundings in different parts of the Baltic Sea

The Sound N=38	
Miscalculation of the position	0.12
Narrow channel, passage	0.08
Heavy ice conditions	0.08
Misobservation	0.07
Storm	0.07

Great Belt N=27	
Miscalculation of the position	0.20
Misobservation	0.10
Improper manoeuvre	0.10
Poor marking of fairway	0.06
Narrow channel, passage	0.05

Fehmarn Belt and Kiel Fjord N=5	
Miscalculation of the position	0.32
Improper manoeuvre	0.14

Kalmar Sound N=9	
Tiredness	0.18
Miscalculation of the position	0.15

Other parts of the Baltic N=46	
Misobservation	0.14
Miscalculation of the position	0.10
Improper manoeuvre	0.10
Electr. black out	0.08
Negligence of critical situation	0.08
Storm	0.07

Stockholm approach N=22	
Improper manoeuvre	0.19
Narrow channel, passage	0.09
Storm	0.08
Fog	0.07
Autopilot failure	0.06

Aland with surroundings' N=18	
Improper manoeuvre	0.14
Tiredness	0.11
Darkness	0.08
Storm	0.08
Poor marking of fairway	0.07
Misobservation	0.06

The Gulf of Bothnia N=33	
Poor marking of fairway	0.13
Misobservation	0.13
Miscalculation of the position	0.12
Improper manoeuvre	0.12
Narrow channel, passage	0.05
Darkness	0.04

The Gulf of Finland N=21	
Improper manoeuvre	0.19
Negligence of critical situation	0.09
Narrow channel, passage	0.08
Darkness	0.07
Poor marking of fairway	0.07
Improper decision	0.07

TABLE 26

The most important factors and their probabilities in rammings in different parts of the Baltic Sea

The Sound N=8	
Misunderstanding of instruction or command	0.19
KaMeWa failure	0.19
Storm	0.17
Improper manoeuvre	0.15

Great Belt N=5	
High speed	0.35
Storm	0.30
Main engine failure	0.22

Fehmarn Belt and Kiel Fjord N=47	
Main engine failure	0.26
Improper assistance of tugs	0.11
Steering engine failure	0.07
Display failure	0.01
Negligence of critical situation	0.07

Kalmar Sound N=3	
Heavy ice conditions	0.33
Electr. black out	0.33
Storm	0.13

Other parts of the N=24	
Improper manoeuvre	0.16
Improper assistance of tugs	0.11
Storm	0.08
Main engine failure	0.06
KaMeWa failure	0.06
Lack of training with the ship in quest.	0.06

Stockholm approach N=4	
Misunderstanding of instruction or command	0.43
Fog	0.20
Current	0.13
Storm	0.13

Aland with surroundings N=5	
Improper manoeuvre	0.23
Fog	0.17
Storm	0.13
Heavy ice conditions	0.10

The Gulf of Bothnia N=33	
Storm	0.22
Heavy ice conditions	0.22
KaMeWa failure	0.10
Improper decision	0.09
Improper manoeuvre	0.07

The Gulf of Finland N=21	
Storm	0.46
Heavy ice conditions	0.14
Darkness	0.11
Other ship on collision course	0.10

TABLE 27

The most important factors and their probabilities in collisions in different parts of the Baltic Sea

The Sound N=10	
Other ship manoeuvring against rules	0.16
Fog	0.15
Heavy ice conditions	0.13
Improper decision	0.10
Breaking of mooring wire	0.08

Great Belt N=4	
Other ship manoeuvring against rules	0.27
Fog	0.22
Darkness	0.09
Heavy ice conditions	0.09
Narrow channel, passage	0.09

Fehmarn Belt and Kiel Fiord N=10	
Other ship manoeuvring against rules	0.18
Other ship, no reaction to the critical situation	0.17
Darkness	0.08
Heavy surrounding traffic	0.08

Kalmar Sound N=1	
Fog	0.50

Other parts of the Baltic N=13	
Other ship manoeuvring against rules	0.19
Fog	0.11
Misobservation	0.10
Other ship, no reaction to the critical situation	0.08
Other ship passing or overtaking of a too close distance	0.06
No reaction to the critical situation	0.06

Stockholm approach N=4	
Fog	0.23
Other ship manoeuvring against rules	0.18
Misunderstanding of instruction or command	0.15
Heavy ice conditions	0.13
Misobservation	0.08

Aland with surroundings N=4	
Heavy ice conditions	0.45
Other ship passing or overtaking at a too close distance	0.16
Other ship manoeuvring against rules	0.16
Improper manoeuvre	0.12
Negligence of critical situation	0.10

The Gulf of Bothnia N=22	
Heavy ice conditions	0.50
Fog	0.11
Other ship, no reactions to the critical situation	0.06
Narrow channel, passage	0.06
Other ship on collision course	0.06

The Gulf of Finland N=11	
Heavy ice conditions	0.48
Other ship, no reactions to the critical situation	0.11
Steering engine failure	0.10
Other ship manoeuvring against rules	0.08
Fog	0.05

The effect of a pilot on the causal configuration in groundings is examined in Table 28 where the probabilities of the three factor groups and the most prominent single factors in groundings are presented with a pilot and without a pilot on the bridge at the time of the casualty. In groundings with a pilot the emphasis is more on the environmental conditions than in cases without a pilot. This is, of course, not surprising because the pilots are working on routes which are difficult to navigate.

TABLE 28. Probabilities of causal factors in groundings with a pilot and without a pilot

	Pilot N = 61		No pilot N = 124	
Environmental conditions	0.54		0.38	
Technical deficiencies and their reasons	0.12		0.09	
Human factors and actions	0.34		0.53	
	Improper manoeuvre	0.15	Miscalculation of the position	0.13
	Poor marking of fairway	0.09	Misobservation	0.12
	Narrow channel, passage	0.09	Improper manoeuvre	0.10
	Fog	0.06	storm	0.06
	Misobservation	0.05	Tiredness	0.06
	Miscalculation of the position	0.05	Narrow channel, passage	0.05
	Darkness	0.05	Negligence of critical situation	0.05

Table 28 is interesting as an indication of the ability of the evaluation method used. Evidently the method gives results which are qualitatively in the right direction. The main problems associated with the determination of the causal factors were found to be the following:

- Information obtained on the causes of casualties was often defective both in the answers of the ship-owners and in the secondary data obtained through the authorities. This is a typical situation in statistical casualty studies.

- The classification and weighting of the factors which are more or less surely known to have affected the casualty is very sensitive to subjective interpretations of the evaluator.

4.8 Consequences of Casualties

The most important known consequences of the casualties in the sample are summarized in Table 29. The evident common measure of the seriousness of a casualty is the monetary value of the consequences. Unfortunately, the original casualty data collected do not contain information on this aspect, but the possibilities to assess the costs will be discussed in chapter 5.

TABLE 29. Consequences of the casualties

consequence	number
lives lost	35
injuries	51
total losses	15
cargo damages	28
hull damages	328
engine damages	17
propeller damages	40
rudder damages	20
oil outflows	13
damages to objects	88

Table 30 shows the division of the losses of lives by casualty type, and also the mean or expected number of lives lost in each casualty type is given. The number of cases which lead to loss of life is small, but evidently a foundering or capsizing and a fire or explosion are potentially the most serious casualty types which threaten the lives of seamen. This inference is amplified by the

TABLE 30. Loss of life by casualty type

	lives lost	number of cases	number of casualties	expected number per casualty
founderings, capsizings	25	5	22	1.13
fires, explosions	3	2	8	0.375
collisions	7	3	134	0.052

figures in Table 31 which presents the injuries by casualty types. Also in injuries the actual number of cases which lead to an injury is small, and fires and founderings have the highest expected value of injuries per casualty. Information on the loss of life and injuries was derived from 526 and 521 ships, respectively, or from almost every ship in the sample.

TABLE 31. Number of injuries by casualty type

	number of injuries	number of cases	number of casualties	expected number per casualty
fires, explosions	22	2	8	2.75
founderings, capsizings	7	2	22	0.318
collisions	21	5	131	0.160
rammings	1	1	117	0.008

Information on total losses was derived from 523 ships. The 15 total losses were distributed by casualty types in the following ways: 1 through a fire; 3 through groundings; 2 through collisions; 1 through a ramming and 8 through founderings or capsizings.

Cargo, hull and engine damages were ranked in three different categories: slight, moderate and severe damages. This classification is susceptible to subjective interpretations, but it gives some measure to estimate the severity of the damages. Tables 32 and 33 show the distribution of cargo and engine damages in different casualty types, and also the mean number of cargo and engine damages of any severity per casualty are calculated. Information on cargo damages was derived from 430 ships, on engine damages from 426 ships. Cargo and engine damages seem to be rare in groundings, collisions and rammings, which are the most common casualty types.

TABLE 32. Number of cargo damages by casualty type

	slight	moder-ate	severe	sum	casu-alties	meannumber per casualty
fires, explosions	-	1	-	1	4	0.25
groundings	2	5	2	9	180	0.05
collisions	4	1	1	6	109	0.06
rammings	3	-	-	3	107	0.03
founderings, capsizings, heavy lists	3	3	2	8	11	0.73
heavy weather damages		1	-	1	3	0.33

The ranking distributions of hull damages in groundings, collisions and rammings are depicted in Fig.19, where also a similar ranking distribution of the damages to objects in rammings is given. A hull damage of some degree is very probable in all the three casualty types: the mean number per casualty is 0.77 in a grounding, 0.82 in a collision and 0.64 in a ramming. But as can be seen in Fig.19, the damage is most likely slight or moderate. Damages to objects in rammings seem to be quite common but it was found difficult to estimate their severity.

TABLE 33. Number of engine damages by casualty type

	slight	moderate	severe	sum	casualties	mean number per casualty
fires, explosions	1	1	1	3	5	0.60
groundings	7	1	4	12	181	0.06
collisions	1	-		1	106	0.01
rammings	1	-	-	1	104	0.01

Information on the 40 propeller damages was derived from 425 ships. The calculated mean number of propeller damage per casualty is 0.15 in groundings; 0.03 in collisions and rammings; 0.5 in ice damages. Propeller damage seems to be a common ice damage, more common than a hull damage: the mean number of hull damages in ice damages is 0.33. However, the small number of ice damages in the sample lowers the reliability of this conclusion.

Rudder damage was reported in 20 of 422 ships. The mean number of rudder damage per casualty is 0.08 in groundings; 0.01 in collisions and rammings; 0.31 in ice damages.

Information on the 13 outflows was derived from a sample of 481 ships. Obviously many more than 13 oil spills have taken place in connection with ship casualties in the Baltic in the years 1979-1981, but because of the publicity given to oil accidents the sizes and effects of the unknown cases are probably small.

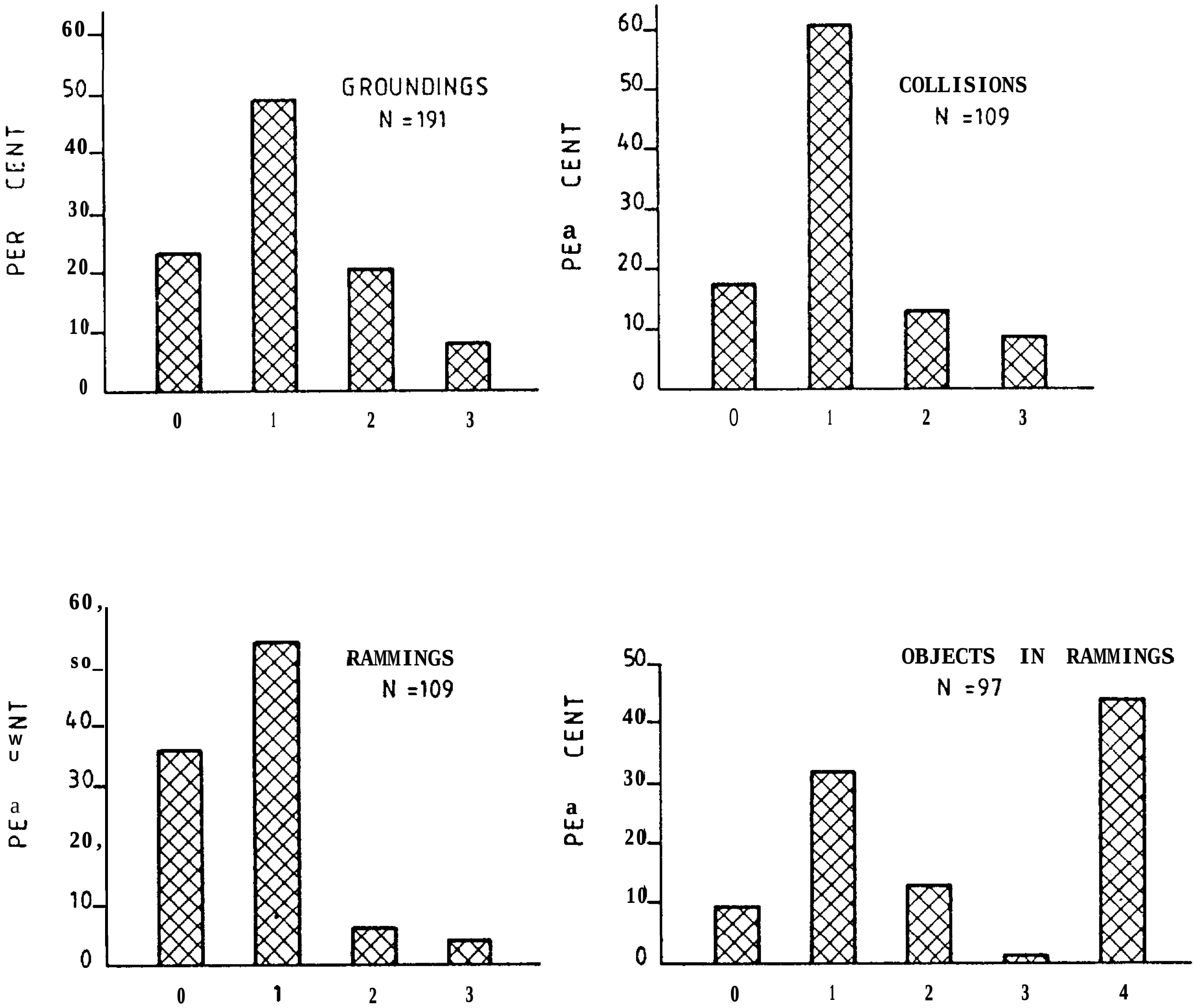


Fig.19. Hull damages in groundings, collisions and rammings and damages to objects in rammings.

Legend: 0 = no damages
1 = slight
2 = moderate
3 = severe
4 = damages with unknown severity

Ten of the oil outflows were consequences of groundings; one took place in a collision and one in connection with ice damage; one casualty was an accidental discharge of oil. The total amount spilled in the reported oil leakages was 22065 tons, but the reported amounts are evidently only very rough estimates. About 21000 tons of the total amount was spilled in two spectacular tanker groundings, and thus the remaining cases were of an essentially smaller order of magnitude. This fact is evident from the difference between the mean and the median value of the oil spilled: the mean is 1700 tons per spill, but the median is only 100 tons, which clearly reflects a lack of symmetry in the size distribution [35].

The small number of oil spills makes an attempt to draw any statistical conclusion superfluous. Even if the sample was essentially larger, an estimation of the probable amount and frequency of future oil spills would be a very difficult statistical problem because of the following general features of oil spills [42] which were also identified in the present sample: the size range of an individual spill is extremely large; the great majority of oil spills are at the lower end of this range; most of the oil spilled is spilled in a few very large spills. Evidently, a single-number estimate of the amount of oil spilled based on the actual data would be meaningless. According to [43], the most promising methods of evaluating accident and spill probabilities combine the statistical analysis of historical casualty data with analytical models expressing the kinematics of accident scenarios, but these models are still under development and lie outside the present study.

5. COST OF MARINE CASUALTIES

5.1 Introduction

The economic aspects of marine casualties will be briefly discussed in this chapter. The objective is to identify the most relevant cost variables and to estimate their values where possible. Knowledge of costs is an important factor to consider when developing safety regulations and systems, or when characterizing the severity of vessel casualties.

The collection of cost data was not a part of the original data base project. The shipowners' cost data are mostly trade secrets which are not available. Information on actual costs has been obtained from shipowners only in 27 cases. The estimations of various costs are, therefore, based mainly on published sources. All costs quoted are 1980 prices and expressed in Finnish marks (mk).

5.2 Identification of the Costs

The cost of accidents falls both on the shipowners, e.g. through loss of revenue and insurance rates, and on society, e.g. through loss of life and damage to property. The total financial loss of a marine accident in a general case can be divided into parts which belong to the categories given in the following:

a. Deaths and injuries to persons
   crew, passengers, workers, general public

b. Damage to property
   - vessels, cargo
   - facilities: piers, wharves, terminals, bridges

c. Damage to the marine environment
- water pollution by oil or chemicals:
  effects on fishery, tourism, seabirds, etc.

d. Loss of function
- vessel out of operation
- delays in delivering cargo

5.2.1 Value of Life

Any attempt to put a value on human life runs into a number of difficulties, the most fundamental of which is the objection that the value of life cannot be measured in monetary terms. Oscar Wilde is reported to have said that "Who knows the price of anything knows the value of nothing". However, as a part of everyday functioning of both the legal system and the insurance industry, such evaluations must be, and are regularly carried out. There exists an extensive literature on the value of human life [43], and only the adequate price estimates will be quoted here.

In [15] the value of British human life is measured in two ways: in terms of a person's expected lifetime earnings and in terms of industry's expenditure on safety measures per life saved. The first method gives an estimated value of the life of a seaman to be about 1.2 million mk; the second method estimates the value to be 1.4 million mk.

The value of human life lost in a road accident in Finland is calculated [45] to be 1.9 million mk. The differences in the three estimates given manifest the nature of the problem: the value set on a human life is largely a matter of opinion or definition. As a compromise, the mean value 1.5 million mk will be used here.

The cost of injuries are less a matter of opinion than the value of a life. However, the lack of knowledge on the distribution of the severity of injuries makes a detailed analysis impossible_ A rough average estimate from [45] is 50000 mk per injury. When using this estimate it is assumed that the severity distribution of injuries in maritime casualties is the same as in road accidents.

By using the estimates given above, the expected monetary loss through deaths and injuries in a given casualty type can be calculated: expected monetary loss is

$$1.5 \times 10^6 \times m_l + 50 \times 10^3 m_i,$$

where m_l and m_i are the expected or mean number of deaths and injury per casualty, which are given in Tables 30 and 31. The calculated values are presented in Table 34.

TABLE 34. Expected monetary loss in a casualty through deaths and injuries

	mean value per casualty	number of casualties	total [10^6 x mk]
foundering, capsizing	1 830 000	23	42.1
fire, explosion	580 000	8	4.6
collision	90 000	81	7.3
ramming	400	120	0.05

The total cost of deaths and injuries in the sample is thus about 54 million mk.

5.2.2 Value of Damage to Property

Total losses

The second-hand market value is generally assumed to be the best indication of the value of a vessel [16]. This viewpoint is adopted here and the values of ships totally lost are taken to be equal to their second-hand prices.

Published ships sales in the second-hand market were collected from [46][47][48]. The ships totally lost in the Baltic were found to be on the average much older and smaller than the ships whose sales are reported worldwide. Therefore, the regression formulas calculated from the published data did not give good estimates of the second-hand prices of the ships totally lost and the formulas could not be used.

The number of total losses is only **15,** and it was practical to assess the second-hand value of each ship separately by taking the known prices of ships of the same type and about the same age and size and then taking the average. The sum of estimated prices of the ships totally lost was found to be about 90 million mk.

Repair costs

Accurate information on repair costs was obtained only in the case of **27** damages, of which 16 were groundings, 9 collisions and 2 rammings. Because the repair cost sample is small, only rough average estimates of repair costs can be calculated, and it is necessary to make many assumptions.

It is assumed that the repair cost on the average is directly proportional to the severity of the hull damage. In groundings the following mean repair costs per casualty in the three severity categories were found: slight hull damage 285000 mk, moderate 1 911 000 mk and severe 3 450 000 mk. In collisions repair costs of only slight hull damages were obtained, the mean is 224000 mk.

The expected or mean repair costs per grounding is calculated with the help of the severity distribution of hull damages in groundings depicted in Fig.19. The following formula is applied:

$$(0.3p_1 + 2.0p_2 + 3.5p_3) \cdot 10^6 \text{mk},$$

where p_1, p_2 and p_3 are the proportions of slight, moderate and severe hull damages, respectively; $p_1 = 0.49$, $p_2 = 0.20$ $p_3 = 0.08$ and the mean repair costs have been rounded. The formula gives the mean repair cost per grounding to be 0.80 million mk.

Information obtained on repair costs of damages in other casualty types, and of damages to facilities is scarce. Therefore, no direct estimates can be obtained.

It is reasonable to assume that the ratios of the mean repair cost per casualty in different casualty types to the mean repair cost per grounding are the same as the corresponding ratios in the claims to insurance companies in partial losses. These calculated ratios are given in the first column of Table 35, the figures are based on the claims paid by Finnish insurance companies in the years 1979-1980 [49]. Taking the ratios and the mean value of repair costs in a grounding, 0.8 million, to be representative, the values of mean and total repair costs in different casualty types shown in Table 35 are obtained.

TABLE 35. Repair costs of different casualty types

	ratio	mean cost per casualty [10^6mk]	number of ships	total [10^6mk]
groundings	1	0.80	216	173
collisions	0.4	0.32	137	44
rammings	0.2	0.16	119	19
ice damages	0.4	0.32	16	5
heavy weather damages	0.3	0.24	3	1
fires and explosions	0.7	0.56	7	4
				246

It can be seen that on the average a grounding is the most expensive. Total repair costs of the ships of the sample in the casualty types given in Table 35. are thus estimated to be 246 million mk.

It has not been possible to estimate the following repair costs: founderings and capsizings which are not total losses; damages to facilities.

Cargo damages

There is not enough information on the cargo damages to assess their cost. The market value of the oil spilled, 22000 t, can be estimated to be about 20 million mk.

5.2.3 **Value of Environmental Damage**

The determination of the economic value of damage to the maritime environment through an oil or chemical discharge is a very difficult task in the present state of knowledge. A detailed analysis of each case should take into account e.g. the following constituents [SO]: physical effects on the biological environment; lost recreational values; effects on the tourist industry; economic consequences for the fishing industry; cost of restoration measures.

Information obtained on the economic consequences of the oil spills which have taken place in connection with the ship casualties of the sample is scarce and no detailed analysis is possible at this stage.

Cleanup costs give an indication of the magnitude of the economic values involved. Estimates on cleanup costs were available in five cases where a total of about 5500 t oil was spilled. The total cleanup costs were about 125 million mk, of which about 112 million mk were through one tanker grounding.

5.2.4 **Value of Loss of Function**

The cost of not delivering the cargo is very difficult to quantify and it will be neglected here, though it has to be identified as a potential source of cost.

When a ship is out of operation through a casualty, the shipowner loses the revenue, but he has to pay the fixed costs, of which the greatest are the capital and crew costs. The loss thus comprises the profit and fixed costs.

No attempt will be made here to estimate the values of profit of individual ships. It is assumed that the profit is generally of a smaller order of magnitude than the fixed costs and can be neglected.

The fixed costs consist of the following costs [51]: capital cost, crew costs, insurance, maintenance and general administration. The actual values and the proportions of these constituents differ much according to the type and age of the ship and the country of registration. It is assumed here that the fixed costs of Finnish ships are on the average representative.

The following least-square equations for the fixed cost C were obtained by applying regression analysis to the fixed cost data of Finnish ships [52]:

dry cargo ship: $C = 10.46 + 3.197d - 0.03755\ d^2$
bulk carrier: $C = 18.37 + 1.360d - 6.535 \cdot 10^{-3}d^2$
tanker: $C = 17.62 + 1.424d - 7.235 \cdot 10^{-3}d^2$

C is the fixed cost per day in 10^3 mk, d is deadweight tons in 10^3 t.

Using these equations, the fixed costs of the ships of the three types in the sample were calculated. The mean values for the fixed cost per day were the following: general cargo ship 22500 mk; bulk carrier 42000 mk; tanker 33500 mk.

Information on the number of days lost through casualties was obtained in the case of 33 groundings, 22 collisions and 21 rammings, but only in 8 cases of other casualties. Therefore, only the three most common casualty types can be considered here. The mean number of days lost were the following: in groundings 9.7 days; in collisions 1.7 days; in rammings 0.6 days.

Table 36 shows the number of general cargo ships, bulk carriers and tankers in groundings, collisions and rammings. Using these numbers and the mean values given above the expected cost through the days lost in casualties can be estimated. For instance, in a grounding the mean cost is

$$(100 \times 22.5 + 29 \times 42.0 + 37 \times 33.5)\ \frac{9.7 \times 10^3}{166}\ \text{mk}$$

$$= 275\ 000\ \text{mk}.$$

In a collision the mean cost is 46300 mk, in a ramming 16900 mk.

TABLE 36. Number of ships by casualty type

	general cargo	bulk carrier	tanker	total
groundings	100	29	37	166
collisions	67	14	18	99
rammings	64	22	11	97

The number of general cargo ships, bulk carriers and tankers in groundings, collisions and rammings is 362. Using the mean costs of days lost, the total sum of the losses of these ships is 52 million mk. These ships constitute about 70 percent of the sample. Assuming that the value of the days lost in the rest of the sample is the same as above, the total sum of the costs through days out of operation is 75 million mk.

5.3 Remarks on the Cost Estimates

The following list summarizes the economic estimates of the losses in the casualties of the sample:

a. Deaths and injuries to persons: 54 million mk.
b. Damage to property: 356 million mk
   – not included: cargo damages, damages to facilities
c. Damage to environment: –
d. Loss of function: 75 million mk.

The total sum is 485 million mk or 162 million mk per year, damage to environment excluded.

The estimation procedures have out of necessity been based on small cost data samples. This means that many of the cost variables entering into the calculations are subject to a high level of uncertainty. Therefore, the estimates presented have to be considered as first approximations.

The purpose of the cost estimation here has been to find the right order of magnitude of the losses. Therefore, the procedures based on a single value estimates can be considered to be an adequate method to use here. A more sophisticated cost analysis method [53] would take into account the uncertainty surrounding the key cost variables. This could be done by using the probability distributions of the cost variables and computer simulation.

6. CONCLUSIONS

A presentation is made in this paper of the results obtained by a statistical analysis of 471 ship casualties in the Baltic Sea in the years 1979-1981. From the information presented the following conclusions are made:

(a) The Poisson distribution is useful as a first approximate model to describe casualty frequencies in a short interval.

(b) The number of casualties per year seems to vary considerably from year to year.

(c) Groundings, rammings and collisions constitute 90 percent of the casualties. Most of the groundings and collisions occurred in narrow waterways.

(d) The seasonal distribution of the number of the casualties shows a clear periodic feature, with a maximum in the winter and minimum in the summer. This indicates the importance of the environmental conditions as contributory causes of casualties.

(e) In groundings and collisions no watch or day is significantly more prone to accidents than others. More rammings than expected take place between 8 a.m. and 4 p.m., and lesser than expected on Sundays. These features can be explained by the variations in the amount of traffic.

(f) Most flags have a casualty rate which does not differ significantly from the average. Greek ships have a higher than average rate, and evidently also Liberian, Panamanian and Singaporean ships.

(g) The ages of ships in casualties do not on the average differ from the ages of the whole ship population. The ages of ships in groundings are significantly higher than in rammings and almost significantly higher than in collisions. In general the ships in groundings are on the average older and smaller than those involved in collisions and rammings.

(h) Ship speeds in collisions and rammings are exponentially distributed.

(i) Environmental conditions are often present as important causes of casualties in the Baltic Sea. Especially heavy ice conditions are frequently present in rammings and collisions. A storm, a narrow channel and poor marking of the fairway are important causal factors in groundings.

(j) A technical failure is very seldom a cause of a grounding or collision. In fires, founderings and heavy list a technical failure is the most common causal factor leading to a casualty.

(k) Human factors or errors are dominant causal factors in groundings: an improper msnoeuvre, a miscalculation of the position and a misobservation are the most frequent reasons for groundings.

(l) A foundering, capsizing or fire are the greatest threat to the lives of seamen.

(m) A slight hull damage is the most common consequence of **a** grounding, collision or ramming.

(n) The size range of oil spills in connection with the casualties is extremely large and most spills are small. Most of the oil spilled is spilled in a few very large spills.

(o) A lower limit for the average costs of the casualties in the sample per year are estimated to be in total about 160 million mk when the costs of environmental damage are excluded.

(p) The lack of knowledge on the basic traffic features in the Baltic Sea forms a great obstacle to a casualty analysis. Information on the number of ships and their tracks, sizes, speeds, types, cargo and nationalities is needed.

(q) The analysis of the compiled casualty data shows clearly the limited capability of the statistical approach. A vast number of conceivable cause relationships, a small sample and the difficulties in obtaining relevant information on each case make it very difficult to measure quantitative and analyse the causal relationships.

7. ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the personnel of the Ship Hydrodynamics Laboratory at the Helsinki University of Technology for their contribution. The kind co-operation of Maritime Administrations, numerous shipowners and masters made it possible to compile the necessary data. The investigation has been financially supported by the Baltic Marine Environment Protection Commission. The member states of the Commission have made some valuable comments on the manuscript of the study, causing some changes. The comments, and especially those of Mr. Huber of Deutsches Hydrographisches Institut, are greatly acknowledged.

References

[1] Toyoda S. & Fujii Y., Marine Traffic Engineering. The Journal of Navigation, Vol. 24, No 1, 1971

[2] Fujii Y., Development of Marine Traffic Engineering in Japan. The Journal of Navigation, Vol. 30, No. 1, 1977

[3] Jurdzinski M. & Starośćiak J., Navigation Problems on Southern Baltic. A paper presented in the Fourth International Symposium on Vessel Traffic Services, Bremen 1981

[4] Hollingdale S. H. (ed), Mathematical Aspects of Marine Traffic. Academic Press 1979.

[5] Glansdorp C. C. (ed), Marine Traffic Systems. Delft University Press 1976.

[6] Drager K. H., The need for national and IMCO Ship Casualty statistics. Veritas No 103, 1981.

[7] Kostilainen V. & Hyvärinen M., Ship Casualties in the Baltic, Gulf of Finland and Gulf of Bothnia in 1971-75. Helsinki University of Technology, Ship Hydrodynamics Laboratory, Report No 10, Otaniemi 1976.

[8] Cashman J. D., Analysis of World Ship Losses 1967-1975, Second West European Conference on Marine Technology. London 1977.

[9] Drager K. H., Sluttrapport. Det norske Veritas, Report No 80-1147, Oslo 1980.

[10] Paffett J. A. H., Recent Developments in Marine Simulation. The Journal of Navigation, Vol. 34, No 2, 1981.

[11] Hagart J. & Barratt M. J., Personality Factors and Ship Handling Behavior. As [10].

[12] Gardinier J. S., Toward a Science of Marine Safety. in [5].

[13] Stratton A. & Silver W. E., Operational Research and Cost Benefit Analysis on Navigation with Particular Reference to Marine Accidents. The Journal of Navigation, Vol. 23 No 3, 1970

[14] Fujii Y., The Estimation of Losses Resulting from Marine Accidents. The Journal of Navigation, Vol. 31, No 1. 1978.

[15] O'Rathaille M. & Weidemann P., The Social Cost of Marine Accidents and Marine Traffic Management Systems. Man & Navigation, The Royal Institute of Navigation 1979.

[16] Giziakis K., Economic Aspects of Marine Navigational Casualties. The Journal of Navigation, Vol. 35, No 3, 1982

[17] Reymond R. D., Benefit/Cost Analysis Applied to Loran-C Expansion. Navigation, Vol. 29, No 1, 1982

[18] Kostilainen V., Analysis of Casualties to Tankers in the Baltic, Gulf of Finland and Gulf of Bothnia in 1960-69. Helsinki University of Technology, Ship Hydrodynamics Laboratory, Report No 5, 1971

[19] Kostilainen V. & Hyvärinen M., Ship Casualties in the Baltic, Gulf of Finland and Gulf of Bothnia in 1971-72. The Journal of Navigation, Vol. 27, No 2, 1974.

[20] Kostilainen V., Draft Programme Studies on Ship Casualties in the Baltic. Helsinki University of Technology, Ship Hydrodynamics Laboratory, M-77, 1979.

[21] Kostilainen V. & Tuovinen P., Amendment to Draft Programme Studies on Ship Casualties in the Baltic. M-80, 1979.

[22] Moon J. R. & Higgins J., Mathematical Aspects of Marine Traffic Casualty Statistics. In [4].

[23] Hammer W., Handbook of System and Product Safety. Prentice-Hall 1972.

[24] Nie - Hull - Jenkins - Steinbrenner - Bent, SPSS: Statistical Package for Social Sciences 2nd ed. McGraw-Hill 1975.

[25] Hull - Nie, SPSS Update 7-9. McGraw - Hill 1981.

[26] O'Muircheartaigh C. & Francis D. P., Statistics - a dictionary of terms and ideas. Arrow Books 1981.

[27] Grimes C., A Survey of Marine Accidents with Particular Reference to Tankers. Journal of Navigation, Vol. 25, No 4, 1972.

[28] Lindgren B. W., Statistical Theory (3rd Edition). Collier Macmillan Publishers 1976.

[29] Siegel S., Nonparametric Statistics. McGraw-Hill 1956.

[30] Sjöfartsverket: Anslagsframställning 1981/82. Norrköping 1980.

[31] Navigation. Official Statistics of Finland I B: 62-63 and monthly bulletins. 1979-81.

[32] Seewirtschaft. Vol 11-14.

[33] Seeschiffahrt. Monthly bulletins 1979-81. Statistisches Bundesamt Wiesbaden.

[34] Rother D, Ship Casualties - An Analysis of Causes and Circumstances. Institute of Shipping Economics Bremen, Lectures and Contributions, No 28, 1980.

[35] Sprent P., Quick Statistics. Penguin Books 1981.

[36] Tanker Casualties Report. IMCO, London 1978.

[37] Lloyd's Register Of Shipping Statistical Tables 1980. London 1980.

[38] Sjöfart 1980. Stockholm 1982.

[39] Yeomans K. A., Statistics for the Social Scientist: 2 Applied Statistics. Penguin Books 1979.

[40] Bulmer M. G., Principles of Statistics. Dover Publications 1979.

[41] Valsgård S. & Pettersen E., Simplified nonlinear analysis of ship/ship collisions. Norwegian Maritime Research, No 3, 1982.

[42] Devanney III J. W. & Steward R. J., Bayesian Analysis of Oil Spill Statistics. Marine Technology, Oct. 1974.

[43] Faragher W. E., Pizzo J. T., Rausch A. H., Commercial Vessel Safety Study, Vol II. Washington D. C. 1979. AD A077628.

[44] Mishan, E. J. The Value of Life. In Layard, R., ed. Cost Benefit Analysis, Penguin Books 1972.

[45] Tieliikenteen ajokustannukset vuonna 1982. Tie- ja vesirakennushallitus 1982.

[46] Hansa. 1979-81.

[47] Navigator. 1979-81

[48] The Swedish Shipping Gazette. 1979-81.

[49] The Insurance Companies. Official Statistics of Finland XXII A:85-86. 1979&1980.

[50] Lidgren K. & Norrby S., Oil and Chemical Pollution from Ships. The Ministry of Agriculture, Sweden 1980.

[51] Branch A. E., Economics of Shipping Practice and Management. Chapman and Hall, London 1982.

[52] Meriväylien syvennyshankkeiden kuljetustaloudellinen merkitys. TVH 753849. Helsinki 1981.

[53] Klausner R. F., The Evaluation of Risk in Marine Capital Investment. Marine Technology. Oct. 1970.

No. 9 SECOND BIOLOGICAL INTERCALIBRATION WORKSHOP
Marine Pollution Laboratory and Marine Division of the National Agency of Environmental Protection, Denmark, August 17-20, 1982, Rønne, Denmark
(1983)

No. 10 TEN YEARS AFTER THE SIGNING OF THE HELSINKI CONVENTION
National Statements by the Contracting Parties on the Achievements in Implementing the Goals of the Convention on the Protection of the Marine Environment of the Baltic Sea Area
(1984)

*Appendix A - l

HELSINKI UNIVERSITY OF TECHNOLOGY
SHIPHYDRODYNAMICS LABORATORY
SF-02150 ESPOO 15 FINLANO
TELEX NO 121591 tkk sf

SHIP
CASUALTY
CARD
NO

THIS PART CF THE QUESTIONNAIRE TO BEFILLED OUT BY THE LABORATORY

FILL OUT THE BLANKS AND UNDERLINE APPROPRIATE ALTERNATIVES

PLACE OF CASUALTY . . . . LAT . . . . LONG 1 2

OPEN SEA / OPEN COAST / SOUND, PASSAGE / APPROACH TO THE PORT / PORT AREA 3

DATE OF CASUALTY . . . . LOCAL TIME / GMT . . . . O'CLOCK 4 5

NAME OF THE SHIP . . . . FLAG . . . .

SHIPOWNER 6 7

CLASSIFICATION SOCIETY 8

TYPE OF THE VESSEL: ORDINARY ORY CARGO SHIP / ROLL ON - ROLL OFF SHIP / 9
CONTAINER SHIP/BULK CARRIER / TANK&R / PASSENGER SHIP/ CAR FERRY /
FISHING VESSEL / TUG / LIGHTER / OTHER: . . . .

LENGTH BETWEEN PERPENDICULARS L = ... m. MOULDED BREADTH B = ... m 10 11

MOULDED DEPTH D = ... m. DRAUGHT BEFORE CASUALTY : AMIDSHIPS T = ... m 12 13
FORE . . . . m AFT . . . . . . m

YEAR OF BUILD . . . . , TDW/GT 14 15

LOADING CONDITION: 100 PER C&NT LOAD/ . . . . PER CENT LOAD / BALLAST 16 17

WIND . . . . m/s AND SEA STATE NUMBER . . . . AT THE TIME OF CASUALTY. 18 19

SPEED OF SHIP AT THE TIME OF CASUALTY . . . . KNOTS. 20

NUMBER OF DECK OFFICERS ON THE BRIDGE AT THE TIME OF CASUALTY 21

WAS PILOT ON THE BRIOGE AT THE TIME OF CASUALTY? YES/NO 2

CASUALTY INVOLVED THE LOSS OF . . . . LIFES. NUMBER Of INJURED . . . .

VESSEL WAS TOTALLY LOST: f&S/NO. CARGO DAMAGES: SEVERE / MODERATE / SLIGHT

HULL DAMAGES: S&V&R& / MODERATE / SLIGHT. ENGINE DAMAGES: SEVERE / MODERATE /

SLIGHT, PROPELLER DAMAGED: YES/NO RUDOER DAMAGED: YES /NO 9 30

TOTALLY . . . . TANKS WERE DAMAGED. THESE TANKS CONTAINED . . . . TONS 1 52
CRUDE OIL, ... TONS DIES&L OIL, LIGHT FUEL OIL, ... TONS HEAVY 3 34
FUEL OIL, ... TONS GASOLINE ANO . . . . TONS OTHER CHEMICAL(S); 5 36
STAT& THE NAME(S) OF THE CHEMICAL(S) 7

APPROX. . . . . TONS OF OIL AND . . . . TONS OF CHEMICALS LEAKED INTO THE S&A. a 39

IN CASE OF COLLISION, WHEN THE OTHER SHIP OR OBJECT WAS DETECTED,
THE DISTANCE WAS . . . . MILES 0

INITIAL DETECTION OF THE OTHER OBJECT WAS MADE BY DIRECT SIGHTING / RAOAR /
SOUND SIGNALS/RADIO OR 2AOIOTELEPHONE. 1

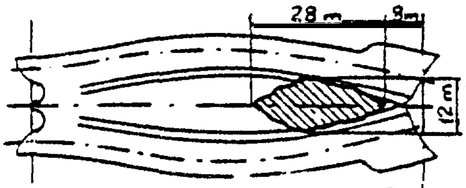
SPEED OF OTHER SHIP . . . . KNOTS. 2

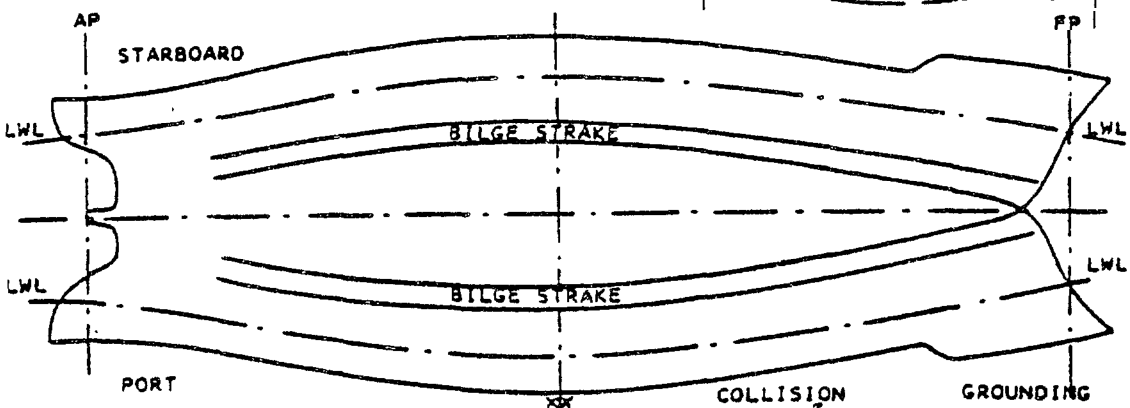
IN CASE OF GROUNDING, WAS THE UNSAFE POSITION OF THE SHIP DETECTED BEFORE
IMPACT? YES / NO. DETECTION WAS MAOE BY DIRECT SIGHTING / RADAR / 3
ECHO SOUNDING / BY OTHER MEANS 4
DETECTION WAS MADE . . . . MILES BEFORE THE IMPACT. 5

A - 2

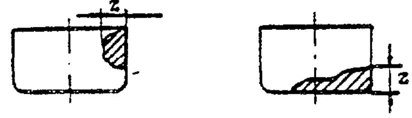
ADDITIONAL INFORMATION IN CASE OF COLLISION OR GROUNDING

LOCATION ANO DIMENSIONS OF DAMAGES
ARE TO BE OUTLINED ON THE SCHEMATIC
DRAWINGS BELOW. SEE EXAMPLE.





46 x
47 l
48 b
49 h



MAXIMUM PENETRATION OF DAMAGE z = ... m

DAMAGES IN THE BULKHEADS: YES / NO. 50

DAMAGES IN THE TANK YOP: YES / NO. 51

ADDITIONAL INFORMATION IN CASE Of FIRES AND EXPLOSIONS 52

NATURE: FIRE / FIRE AND EXPLOSION(S) / EXPLOSION(S) ANO FIRE / EXPLOSION(S) 53 Y

ORIGINAL SEAT OF THE FIRE OR-EXPLOSIONS: ACCOMMODATION / GALLEY / PAI NT 54
STORE / ENGINE STORE / ENGINE ROOM / BECK CARGO / CAR60 TANK NO .... /
CARGO HOLD NO .... / FUEL OIL TANK NO .... / OTHER ....

FIRE WAS DETECTED BY MEANS of DIRECT SIGHTING / AUT O MAT IC ALARM 55

FIRE WAS DETECTED BY A MEMBER OF DECK CREW / ENGINE CREW / 56
OECK OFFICER / ENGINEER / PASSENGER / OTHER ....

ADDITIONAL INFORMATION IN CASE OF ACCIDENTAL DISCHARGE OF OIL OR CHEMICAL

DISCHARGED AMOUNT APPROX. .... TONS OF CRUDE OIL / DIESEL OIL, LIGHT 57
FUEL OIL / HEAVY FUEL OIL / GASOLINE / OTHER CHEMICAL, *STATE* THE NAME OF 58
THE CHEMI CALS 59

. WAS NE OUTFLOW OF CARGO RAPID / SLOW.

ADDITIONAL INFORMATION ON THE MEASURES TAKEN ON BOARD DAMAGED SHIP
TO STOP OR DIMINISH THE OUTFLOW OF OIL OR CHEMICAL

WHAT MEASURES 010 YOU TAKE TO PREVENT OR REDUCE LEAKAGE OF OIL OR CHEMICALS? 60
.... 61
....

62

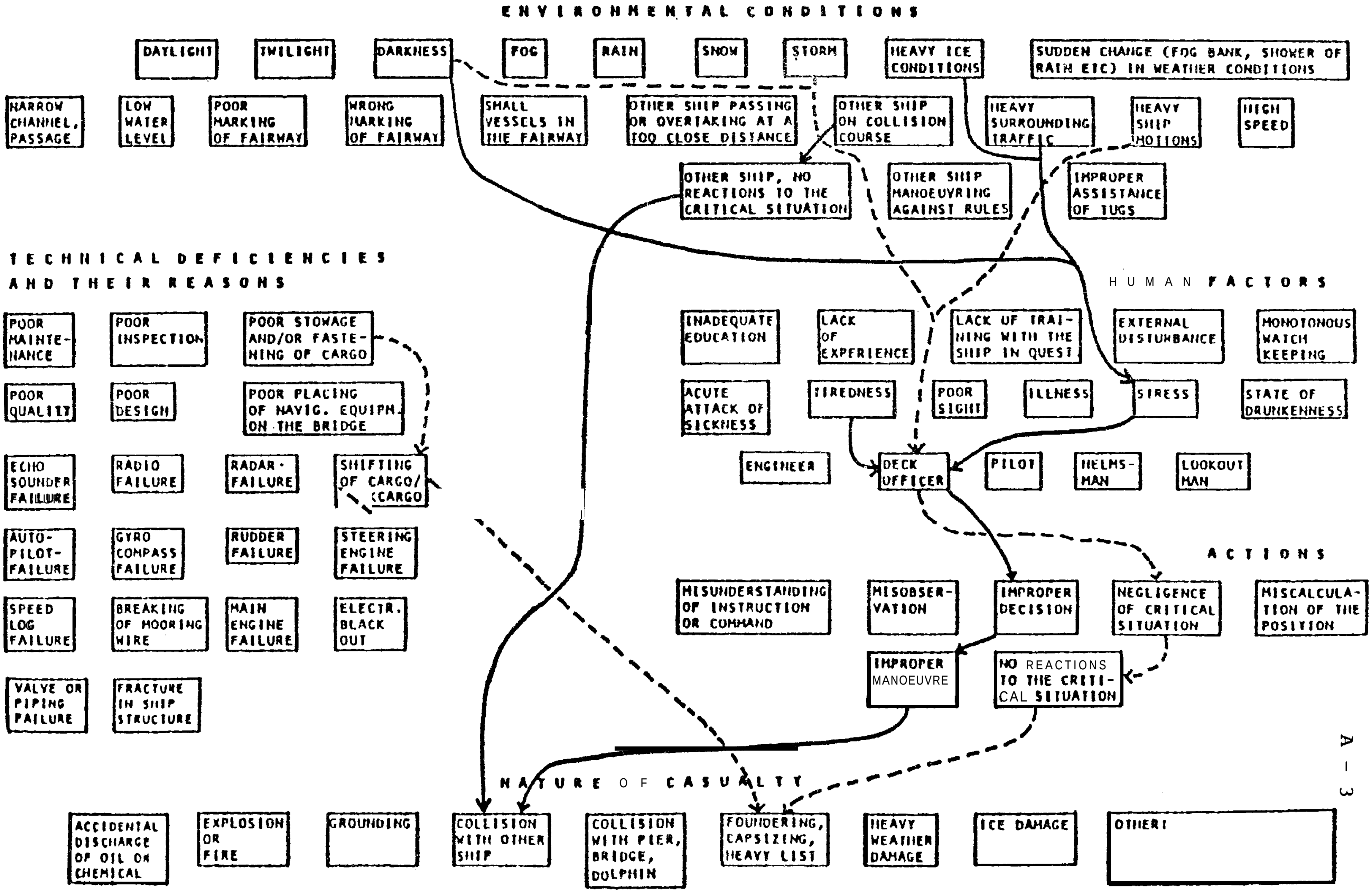
HOW LONG DID IT TAKE BEFORE LIGHTENING OF CARGO FROM DAMAGED TANKS COULO BE 63
COMMENCED?.. 64

COULD SHIP'S *CARGO* PUMPS BE USED FOR LIGHTENING OR INTERNAL TRANSFER OF CARGO? 65
YES / NO. WHAT OTHER MEANS WERE USED? 66

WHEN ANO TO WHOM DID YOU REPORT THE LEAKAGE? DATE .... LOCAL TIME /
GMT .... O'CLOCK, AUTHORITY ....*..............

FIND OUT THE RELEVANT SEQUENCE OF EVENTS OF THE CASUALTY BY CONNECTING THE APPROPRIATE BLOCKS WITH LINES.
ADD YOUR OWN BLOCKS IF NECESSARY.
FOR FURTHER ADVICE SEE ATTACHED EXAMPLES.

SHIP HYDRODYNAMICS LABORATORY
HELSINKI UNIVERSITY OF TECHNOLOGY
SF-02150 ESPOO 15 FINLAND



A - 4

HELSINKI UNIVERSITY OF TECHNOLOGY
SHIP HYDRODYNAMICS LABORATORY
SF-02150 ESPOO 15 FINLAND
TELEX NO 121591 tkksf

REPORT OF MARITIME OIL OR CHEMICAL SPILLAGE

THIS PART OF THE QUESTIONNAIRE TO BE FILLED OUT BY THE LABORATORY

FILL OUT THE BLANKS AND UNDERLINE APPROPRIATE ALTERNATIVES

AUTHORITY 1 2

GENERAL INFORMATION

NAME(S) OF THE SHIP(S) 3

PLACE OF THE CASUALTY 4

DATE OF THE CASUALTY ....

NATURE OF THE CASUALTY: ACCIDENTAL DISCHARGE OF OIL OR CHEMICAL / EXPLOSION OR FIRE / GROUNDING / COLLISION WITH OTHER SHIP / COLLISION WITH PIER, BRIDGE, DOLPHIN / FOUNDERING, CAPSIZING, HEAVY LIST / HEAVY WEATHER DAMAGE / ICE DAMAGE / OTHER 5 6 7 8

TYPE(S) AND AMOUNT(S) OF SPILLED OIL OR CHEMICALS? .... TONS CRUDE OIL, ... TONS DIESEL OIL, ... TONS HEAVY FUEL OIL, ... TONS GASOLINE AND .... TONS OTHER CHEMICAL(S); STATE THE NAME(S) OF THE CHEMICAL(S) 9 10 11

WHEN AND BY WHOM WERE YOU INFORMED OF THE SPILLAGE? DATE .... TIME .... O'CLOCK BY 12 13 14

DAMAGE TO THE ENVIRONMENT

LENGTH OF THE POLLUTED COAST-LINE .... m 15

IS / WAS IT POSSIBLE TO REMOVE ALL OIL OR CHEMICALS? YES / NO, ... % OF OIL OR CHEMICALS. 16 17

HAS THE LEAKAGE CAUSED, IN YOUR OPINION, DAMAGE TO BIRDS / FISH / SEALS / FLORA? SEVERE / MODERATE / SLIGHT / NO DAMAGE. 18

EXPENSES OF THE SPILLAGE

PROTECTION AND CLEANING:

THE TOTAL EXPENSES BECAUSE OF PROTECTION AND CLEANING OPERATIONS 19 20

THE AMOUNT OF THESE EXPENSES PAID BY YOUR OFFICE 21

OTHER EXPENSES:

DO YOU HAVE KNOWLEDGE OF OTHER FINANCIAL CLAIMS TO THE SHIPOWNER(S) E.G. BY FISHERY OR TOURISM? BY WHOM AND HOW MUCH 22 23

BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 1 JOINT ACTIVITIES OF'THE BALTIC SEA STATES WITHIN THE FRAMEWORK OF THE CONVENTION ON THE PROTECTION OF THE MARINE ENVIRONMENT OF THE BALTIC SEA AREA 1974-1978
(1979)*

No. 2 REPORT OF THE INTERIM COMMISSION (IC) TO THE BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
(1981)

No. 3 ACTIVITIES OF THE COMMISSION 1980
- Report on the activities of the Baltic Marine Environment Protection Commission during 1980
- HELCOM Recommendations passed during 1980
(1981)

No. 4 BALTIC MARINE ENVIRONMENT BIBLIOGRAPHY 1970-1979
(1981)

No. 5A ASSESSMENT OF THE EFFECT'S OF POLLUTION ON THE NATURAL RESOURCES OF THE BALTIC SEA, 1980
PART A-l: OVERALL CONCLUSIONS
(1981)

No. 5B ASSESSMENT OF THE EFFECTS OF POLLUTION ON THE NATURAL RESOURCES OF THE BALTIC SEA, 1980
PART A-l: OVERALL CONCLUSIONS
PART A-2: SUMMARY OF RESULTS
PART B: SCIENTIFIC MATERIAL
(1581)

No. 6 WORKSHOP ON THE ANALYSIS OF HYDROCARBONS IN SEAWATER
Institut für Meereskunde an der Universität Kiel, Department of Marine Chemistry, March 23 - April 3, 1981
(1982)

No. 7 ACTIVITIES OF THE COMMISSION 1981
- Report of the activities of the Baltic Marine Environment Protection Commission during 1981 including the Third Meeting of the Commission held in Helsinki 16-19 February 1982
- HELCOM Recommendations passed during 1981 and 1982
(1982)

No. 8 ACTIVITIES OF THE COMMISSION 1982
- Report of the activities of the Baltic Marine Environment Protection Commission during 1982 including the Fourth Meeting of the Commission held in Helsinki l-3 February 1983
- HELCOM Recommendations passed during 1982 and 1983
(1983)

------
* out of print

Baltic Marine Environment
Protection Commission
Eteläesplanadi 22 C 43
SF-W 130 Helsinki 13

ISSN 0357-2994

Helsinki 1984. Government Printing Centre