Ship incident risk in the areas of Tubbataha and Banc d'Arguin: A case for designation as Particular Sensitive Sea Area?

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Abstract

Since the early 1990's, the International Maritime Organization (IMO) has designated fourteen sea areas as Particular Sensitive Sea Areas (PSSA) that enjoy special protection because of their various important attributes and vulnerability to potential harm by increasing shipping activities. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has identified two possible sites for possible designation as PSSA under IMO: the *Banc d'Arguin National Park* (Mauritania) and the *Tubbataha Reef National Park* (Philippines). This article presents an integrated framework for the estimation of total risk exposure due to shipping activities and various risk measures for ships trading in the areas of interest. Using a unique and comprehensive combination of data, we test whether ship specific risk increased over time. The results confirm an increase in the considered risk measures of ships trading through or nearby West Africa (*Banc d'Arguin*) and South-East Asia (*Tubbataha*) in general and also close to both regions and therefore support the recommendation for an increased level of protection.

Keywords

Incident probability, ship specific risk, total risk exposure, binary logistic regression, change of risk over time, observation frequency

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[2] Disclaimer for Knapp, Henderson and Kleverlaan: 'The views expressed in this article represent those of the authors and do not necessarily represent those of the Australian Maritime Safety Authority (AMSA) and the International Maritime Organization (IMO).'

1. Introduction

In 1972, the United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted the Convention concerning the Protection of the World Cultural and Natural Heritage. In 1994, the World Heritage Committee (WHC) launched a strategy to include exceptional marine features. Currently, there are 46 marine World Heritage sites in 35 countries. Since the early 1990's, the International Maritime Organization (IMO) has designated fourteen sea areas as Particular Sensitive Sea Area (PSSA), starting with the Great Barrier Reef. PSSAs enjoy special protection because of their significance for recognized ecological, socio-economic, or scientific attributes. These attributes may be vulnerable to damage by shipping. As shipping activities have more than tripled since 1970 (UNCTAD, 2011), the risk to marine ecosystems from pollution, shipping incidents, and spills has increased.

In general, for an area to be identified as a PSSA, three elements must be present. First, the area must have certain significant attributes: ecological, socio-economic, or scientific. Second, it must be vulnerable to damage by international shipping activities. And third, there must be at least one associated protective measure (APM) with an identified legal basis that can be adopted by IMO to prevent, reduce, or eliminate risks from these activities. A PSSA may include the territorial sea of states as well as sea areas beyond national jurisdiction. Proposals for a new PSSA must be submitted in accordance with the IMO rules and procedures set out in IMO Assembly resolution A.982(24) (IMO 2005). If approved by IMO, the end result will be an area designated as a PSSA with one or more IMO-adopted (protective) measures for ships to follow. IMO is the only international body responsible for assessing proposals for and designating areas as PSSA and for adopting measures applicable to international shipping.

While an inscription on the World Heritage List is only one step toward safeguarding these marine areas for future generations, many stressors, such as international shipping, could threaten their conservation. It is with this in mind that WHC has identified the World Heritage sites *Banc d'Arguin National Park* (Mauritania) and *Tubbataha Reef National Park* (Philippines) as priority areas for possible designation as PSSA. The location and passing ship traffic densities are shown in Figure 1.

The Banc d’Arguin Park has a total area of 1,989 km^2 with 54% marine area. It is a major breeding site for migratory birds. The surrounding waters are some of the richest fishing waters in western Africa and serve as nesting grounds for the entire western region. It has at its northern extremity a fishing port that is recently expanding rapidly due to the growing oil and gas exploration and exploitation industry off the coast of Mauritania. The area is also adjacent to a major south-north oil transport shipping route. The Tubbataha Reef Park has an area of 968 km^2 and is listed as a Wetlands of International Importance under the Ramsar Convention. It is considered to be a global center of marine biodiversity containing more than 600 fish species, 360 coral species, 11 shark species, 13 dolphin and whale species, and 100 bird species. These reefs also serve as a nesting ground for hawksbill and green sea turtles. Tubbataha Reef lies at the crossroads of several major shipping routes, including a major east-west archipelagic sea lane in the Philippines.

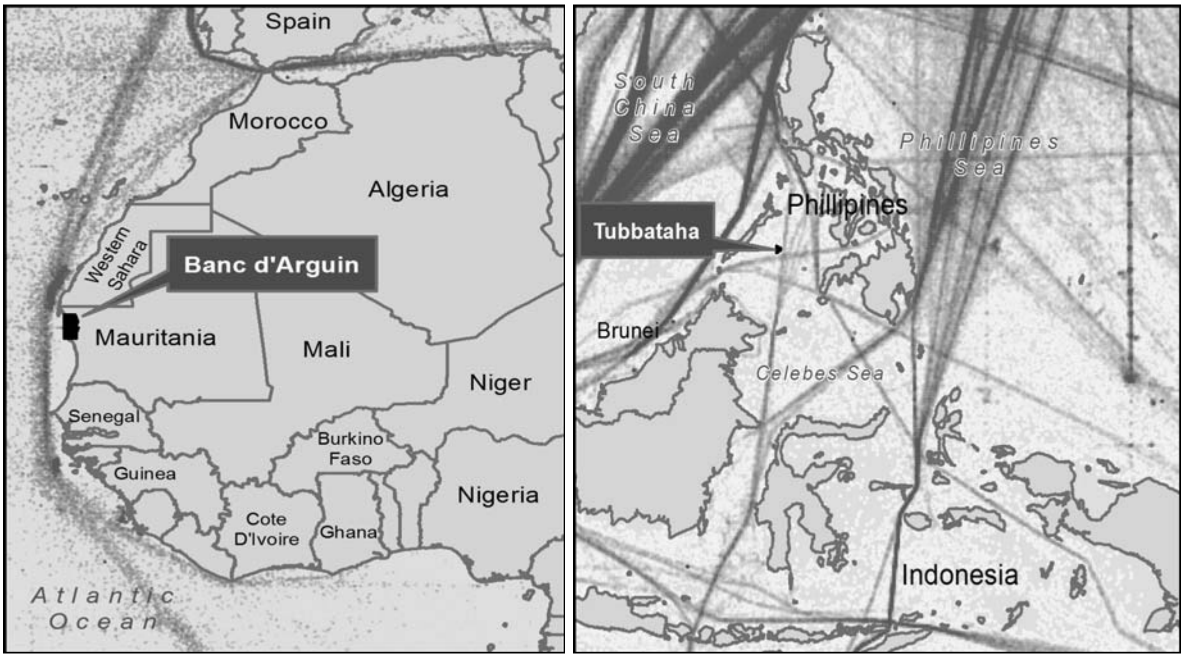

Figure 1: Location of Banc d'Arguin and Tubbataha Reef, with ship traffic routes

To assess whether a certain area is vulnerable to damage due to shipping activity, several risk components need to be considered. Figure 2, taken from Knapp (2013), presents an overview of all these components. Risk exposure integrates risk at the individual ship level with risk due to vessel traffic densities and physical environmental criteria (such as wind and waves). Risk exposure combined with (socio-economic and ecological) sensitivities can be used to quantify total risk exposure, which represents the potential harm to property, life, and the marine environment. These risks can be reduced by risk control measures, such as those associated with a PSSA. A comprehensive and robust risk exposure metric can assist maritime administrations to enhance mitigation of potential harm, to reduce vulnerability to the marine environment, and to safeguard lives and property. Incidents in shipping can result in high economic costs and damage to the marine environment (Grigalunas and Opaluch, 1988).

In studies that associate risk with areas (Eide et al., 2007, Admiral Danish Fleet, 2012, Det Norske Veritas, 2013), individual ship risk levels are normally not taken into account or all ships are treated equally. This is not realistic, and in this article we investigate in which way ship specific risk profiles changed over time for vessels that trade in the areas of interest. In our risk assessment, we also account for physical environmental criteria. We build on Knapp et al. (2011a) who tested for the change and effect of environmental criteria such as wind speed and significant wave height in the North Atlantic region.

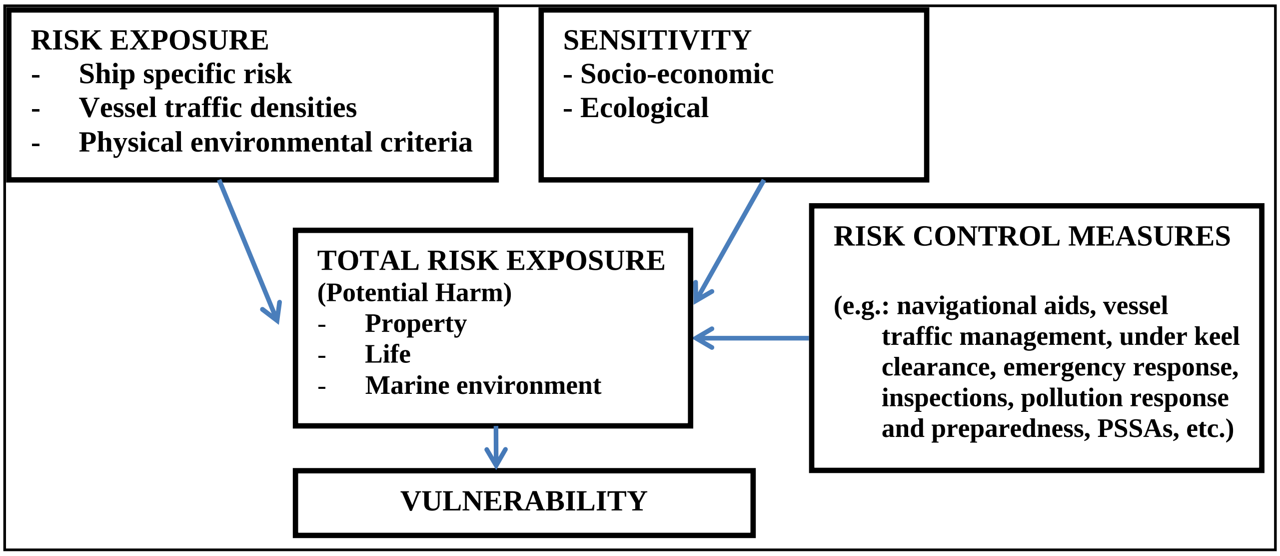

Figure 2: Factors affecting risk exposure, sensitivity, and vulnerability

We will not account for risk due to vessel traffic densities due to data limitations, since higher frequency data would be needed to establish ship tracks. We will also not account for environmental sensitivities, since data to quantify socio-economic and ecological sensitivities are not available for the areas under investigation. We therefore concentrate on ship specific risk of ships trading in the regions, taking some of the underlying location specific physical environmental criteria into account. We test whether ship specific risk has increased over time in terms of incident probabilities and risk exposure in monetary terms.

This report has the following structure. The data are described in Section 2, and Section 3 presents the risk measures and models. Risk developments in recent years, as compared to a base period, are evaluated in Section 4, and Section 5 evaluates the yearly risk in monetary terms. Conclusions and recommendations are given in Section 6, followed by the reference list. Technical details of data transformations are in Appendix A, and Appendix B contains supplementary tables.

2. Data and data treatment

The time frame for this analysis is for the time period from 1979 to 2007. The underlying dataset combines vessel positions, underlying physical environmental data (wind strength and significant wave height), ship particular data and their changes over time, ship incident data, ship safety inspection data, and ship economic cycles. The various data sources were merged using the IMO vessel number as link. Ship types are grouped into six main categories: general cargo, dry bulk, container, tanker, passenger, and all other ship types.

Vessel positions and physical environmental conditions during the voyage have been obtained from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). This database is the largest available compilation of surface meteorological observations from Voluntary Observing Ships (VOS). The ICOADS dataset contains latitude/longitude information for each observation. We zoom into two areas of interest, South-East Asia (South China Sea and the Philippines) for Tubbataha and the West African region for Banc d'Arguin. Ships' observations are usually made every six hours and reported at the standard synoptic hours of 0000, 0600, 1200 and 1800 UTC, but observations at intermediate reporting times of 0300, 0900, 1500 and 2100 UTC are also observed. Other vessels report less frequently, once a day or at irregular reporting intervals.

Table 1 provides an overview of the mean number of vessels per year in the database for the various regions of interest. As compared to the base period (1979-1998), recent years (1999-2007) show smaller world-wide participation rates in the VOS system (from 9% to 7%). The share of vessels in our database as part of the total VOS fleet has also declined somewhat (from 29% to 21%). Within our database, the share of vessels passing the heritage regions remained rather constant at a level of about nine percent.

The oceanographic data consist of wind speed and wave and swell data. These variables need to be corrected for biases due to differences in measurement techniques. For the wind data, the method described by Thomas et al. (2005) is used to homogenize wind speeds. The correction formula given by Gulev and Grigorieva (2006) is used to correct the wave and swell data and to calculate the significant wave height.

The ICOADS data is merged with an incident dataset at individual ship level for the same time period. The main data sources for the incident data are Lloyd's Register Fairplay (LRF), Lloyd's

Maritime Intelligence Unit (LMIU), and IMO. Incident data can be classified according to their seriousness or according to the type of incident or insurance relevance. It is important to mention that incident data are limited, since commercial data providers such as LRF and LMIU use different classification of incidents and seriousness. The data were therefore manually reclassified for compatibility with the internationally agreed definitions used by IMO (IMO, 2000) for three categories: very serious (including total loss), serious, and less serious incidents. We extend the incident types of Knapp et al. (2011a), where only weather related incidents were considered. In our analysis, we account for all incidents that can lead to pollution, such as collisions, contact, stranding and groundings, main engine blackouts (which can lead to drift grounding), capsizing, hull-related failures, flooding, and foundering. These incidents are classified as either serious or very serious. Less serious incidents are not considered.

Table 1: Mean number of individual ships per year

Period	1979-2007	1979-1998	1999-2007
Number of individual ships			
World commercial fleet	82,018	78,141	90,635
Voluntary Observing Ships (VOS)	6,859	7,162	6,185
South-East Asia	915	1,031	657
West Africa	944	1,070	664
South-East Asia and West Africa	1,859	2,101	1,321
Tubbataha	83	94	57
Banc d'Arguin	85	96	59
Tubbataha and Banc d'Arguin	167	190	116
Percentage shares			
VOS (of Total)	8.47	9.20	6.87
SE Asia and W Africa (of Total)	2.33	2.72	1.47
SE Asia and W Africa (of VOS)	26.84	29.25	21.46
Tubbataha (of SE Asia)	8.99	9.18	8.57
Banc d'Arguin (of W Africa)	8.98	9.10	8.72

"Number of individual ships" is the mean number of different vessels per year.
"Percentage shares" show the percentage share of number of vessels between regions.
Data for the world commercial fleet are from IHF-Fairplay.

Another important aspect of the dataset consists of accounting for characteristics reflecting the safety quality of a vessel. For this purpose, we use ship particulars from IHS Fairplay, ship safety inspections (Bijwaard and Knapp, 2009), relevant industry vetting inspections, and ship economic cycles. Changes in ship particulars (flag, class, ownership) are taken into consideration for 360 days prior to the incident. The same applies for previous inspection history in terms of detentions, deficiencies, port state control inspections, and ISM audits. Ship economic cycles are represented by average earnings for each ship type, which are available at a monthly basis from the Shipping Intelligence Network of Clarksons. The earnings information is corrected for inflation and it is merged to each individual observation in the dataset based on month, year, and ship type. The data are filtered by restricting attention to ships trading in the areas of interest: the South East Asia region around the Philippines, which contains the Tubbataha Reef, and West Africa that contains the park of Banc d'Arguin. The position reports in the ICOADS data (based on latitude and longitude) are used to distinguish between vessels that navigate outside or within a maximum of 100 nautical miles (1 nautical mile is 1,852 meters) to the shoreline of Tubbataha or Banc d'Arguin. The range of 100 nautical miles provides a five-day intervention time of oil spill response vessels in case of an incident. The better the region is equipped, the faster one can intervene in case of a spill, and we believe that 100 nautical miles are reasonable for both regions of interest. The resulting dataset contains 905,601 observations, 471,127 for South-East Asia and 434,474 for West Africa. Of these observations, 16,872 fall within the 100 nautical mile zones, 8,549 for Tubbataha and 8,323 for Banc d'Arguin.

3. Methodology to estimate risk measures at ship level

To estimate risk exposure, we construct six risk measures at individual ship level. These risk measures consist of incident probabilities (very serious, serious, pollution alone) and the monetary value at risk (MVR, based on Heij and Knapp, 2012). MVR quantifies risk in monetary terms, accounting for the possible consequences of incidents that are of interest for policy decisions. We also use a variation of MVR in Section 5 where we give an estimate of the yearly magnitude of total risk exposure. We also consider the risk of ships that trade within 100 nautical miles of the regions of interest: Tubbataha and Banc d'Arguin. Table 2 lists the variables used in models to estimate the probability of incidents. The models are estimated per ship type (6 types) and per region (2 regions), for each incident type: very serious (VS), serious (S), and pollution (POL). Pollution incident models were estimated for tankers for both regions, and for general cargo ships and dry bulk carriers only for South-East Asia. The total number of models is therefore twenty-eight. We used binary logistic regression, with general model equation $P(y_i = 1 \mid x_i) = \exp(x_i\beta) / (1+ \exp(x_i\beta))$, where "$y_i = 1$" denotes the occurrence of an incident for vessel observation "i" and where "$x_i\beta$" is a weighted combination of incident risk factors:

$$
\begin{aligned}
x_i\beta = {} & \beta_0 + \beta_1 \ln(\mathrm{AGE}_i) + \beta_2 \ln(\mathrm{SIZE}_i) + \sum_{k=1}^{2} \beta_{3,k}\,\mathrm{CL}_{k,i} + \sum_{k=1}^{3} \beta_{4,k}\,\mathrm{FS}_{k,i} + \beta_5\,\mathrm{CLCh}_i + \beta_6\,\mathrm{FSCh}_i \\
& + \beta_7\,\mathrm{OwnCh}_i + \beta_8\,\mathrm{Earn}_i + \beta_9\,\mathrm{PSC}_i + \beta_{10}\,\mathrm{Ind}_i + \beta_{11}\,\mathrm{FSInsp}_i + \beta_{12}\,\mathrm{ISM}_i + \beta_{13}\,\mathrm{Det}_i \\
& + \beta_{14}\,\mathrm{Def}_i + \beta_{15}\,\mathrm{SWH}_i + \beta_{16}\,\mathrm{WS}_i + \sum_{k=1}^{11} \beta_{17,k}\,\mathrm{M}_{k,i}
\end{aligned}
$$

The weight parameters β change per model type. The probabilities are estimated at the individual ship level and depend on the factors explained in Table 2. The coefficients are estimated by the method of quasi-maximum likelihood (QML, Greene, 2008). Some model summary statistics are presented in Table B-1 in Appendix B. Because of the large amount of models and variables per model, we do not present detailed model results (which are available from the authors upon request).

Table 2: Overview of variables

Code	Variable description	Type
Ln(AGE)	Vessel age at the time of incident (in logs)	C
Ln(SIZE)	Vessel size in gross tonnage (in logs)	C
CL	Classification society at time of incident (grouped)	D
FS	Flag state at the time of incident (grouped)	D
CLCh	Changes of class within 360 days prior to incident	C
FSCh	Changes of flag state within 360 days prior to incident	C
OwnCh	Changes in ownership within 360 days prior to incident	C
Earn	Earnings to account for ship economic cycles	C
PSC	Lagged PSC inspection history (360 days)	C
Ind	Lagged industry inspection history (360 days)	C
FSInsp	Lagged flag state inspection history (360 days)	C
ISM	Lagged ISM audits history (360 days)	C
Det	Lagged detention history (360 days)	C
Def	Lagged deficiency history (360 days)	C
SWH	Significant wave height (in meter)	C
WS	Wind strength (in kilometer per hour)	C
M	Monthly dummies	D

Type C is for continuous variables, and D for categorical variables; the number of categories is 3 for CL, 4 for FS, and 12 for M.

The monetary value at risk (MVR) provides an estimate of the expected total monetary value lost because of five potential types of damage: hull and machinery, cargo, third party liability, pollution, and loss of life. This expected value takes into account both the unconditional probability of an incident (VS, S, or POL) and the conditional probability of each damage type if an incident occurs. The formula is MVR= $p_{inc} \times \sum_{j=1}^{5} p_j V_j$, where p_{inc} is the probability of an incident (VS, S, or POL separate) obtained from the models above, p_j is the conditional probability of damage type j in case of an incident, and V_j is the monetary value of this damage type (j = 1, …, 5). The conditional probabilities and the values of the five damage types are obtained from Knapp et al. (2011b). The values V_j are based on the value of assets and cargo, third party liability limits, maximum insurance coverage for oil pollution, and insured value of life. The sum total of these five values ($\sum_{j=1}^{5} V_j$) reflects the total insurable value (TIV) for each vessel. In Section 5, we will use TIV instead of MVR to evaluate risk exposure in case of total loss of all value.

In order to analyze whether the risk measures changed over time and to compute combined risk exposure of ships trading in a particular area, we need to account and correct for biases in the dataset. These biases are due to the construction of the database used to estimate the incident probabilities and resulting MVR. The data from ICOADS were taken to estimate the probabilities, as relevant oceanographic variables such as wind and wave are location specific and should not be aggregated since local weather conditions can change frequently. The observations of the merged database of ICOADS data and incident data are of very mixed frequency, and the number of observations per vessel varies widely. As a consequence, the obtained logit incident probabilities do not refer to a common time scale of incident risk. The probabilities of the 28 models are transformed to a common time scale by correcting for the average observation frequency per model (see Appendix A for details). In this way, risks can be compared across periods, regions, and ship types. As the common time scale does not refer to an easily identifiable clock-time period, risks are compared in Section 4 on a relative scale, that is, risks are expressed relative to an initial base period. By making some additional assumptions in Section 5, the risks can be expressed on a yearly basis to evaluate the risk exposure per year in monetary terms.

4. Change of risk over time

As the number of available data for the zones within 100 nautical miles of the heritage regions is rather limited, we will focus mostly on the risk in the larger areas around these two regions. Figures 3 and 4 show the development of incident risk and MVR (on the vertical axis) for the regions of South-East Asia and West Africa for six consecutive periods (on the horizontal axis). These two risk measures are expressed as indices, relative to mean risk in the five-year base period (Jan 1979 – Dec 1983). Index values are obtained for the mean risk in five later periods: 1984–1988, 1989–1993, 1994–1998, 1999–2003, and January 2004 through July 2007. The last period lasts for less than five years as no data are available after July 2007. Because of the data limitations discussed before, the probability of pollution incidents is available for tankers and, for South-East Asia, also for general cargo and dry bulk vessels. The MVR of pollution risk is available only for tankers in both regions. Incident risks and monetary values at risk both show a tendency to increase over time, although the trends are discontinuous and quite mixed in some cases, especially for the class of other ship types.

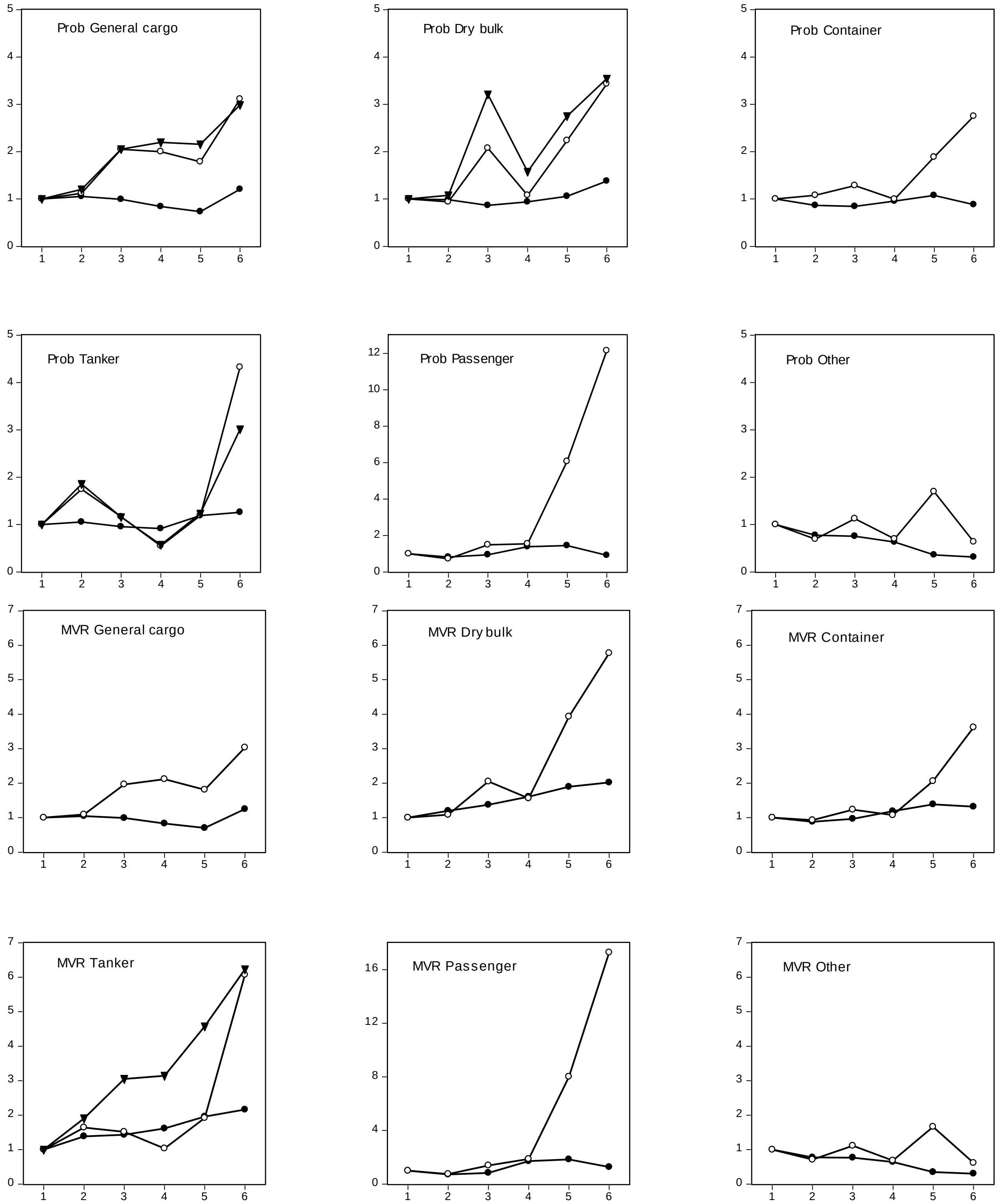

Figure 3: Region South-East Asia, mean incident probability index ("Prob") and mean monetary value at risk index (MVR) per ship type for six periods (index base period 1 is 1979-1983; period 2 is 1984-1988, 3 is 1989-1993, 4 is 1994-1998, 5 is 1999-2003, and 6 is 2004-July 2007); closed bullet for very serious incidents, open bullet for serious incidents, and triangle for pollution incidents. Vertical axis scale for the probability indices is the same for all ship types, except for passenger ships, and the same applies for the MVR indices.

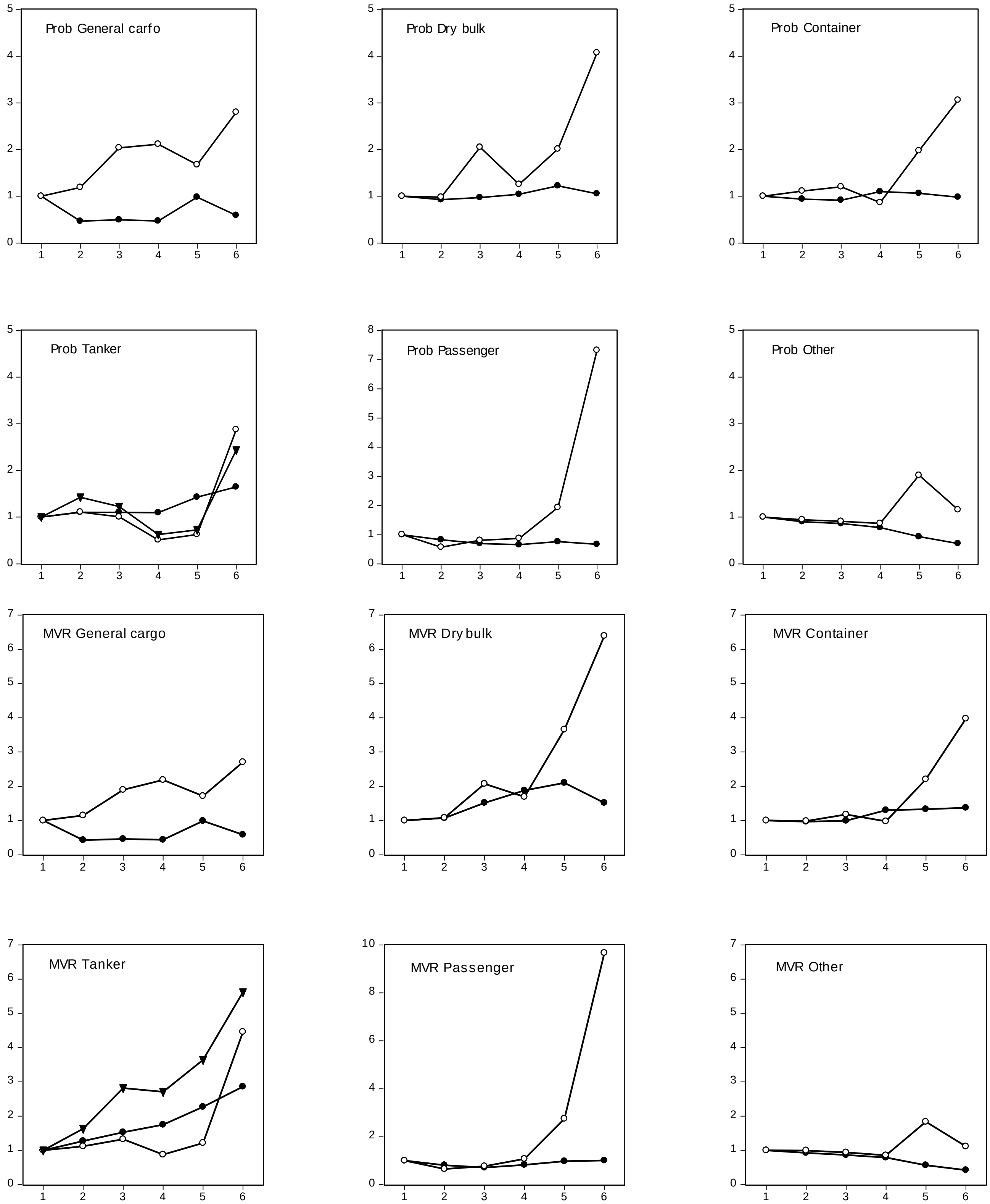

Figure 4: Region West Africa, mean incident probability index ("Prob") and mean monetary value at risk index (MVR) per ship type for six periods (index base period 1 is 1979-1983; period 2 is 1984-1988, 3 is 1989-1993, 4 is 1994-1998, 5 is 1999-2003, and 6 is 2004-July 2007); closed bullet for very serious incidents, open bullet for serious incidents, and triangle for pollution incidents. Vertical axis scale for the probability indices is the same for all ship types, except for passenger ships, and the same applies for the MVR indices.

The most consistent increases in risk are found for general cargo and dry bulk vessels, container ships, and tankers. Pollution risk is of special importance as potential hazard to the heritage regions. The probability of pollution incidents has increased substantially in recent periods, and the monetary value of pollution risk of tankers has increased throughout the time period of observation. The risk for serious incidents rose most dramatically for passenger ships, but these figures may be less reliable due to the relatively small number of passenger ship observations in the database (2% for South-East Asia and also for West Africa). More detailed information on the mean risk figures per sub-period can be found in Appendix B, see Tables B-3 and B-4 for South-East Asia and West Africa, and Tables B-5 and B-6 for Tubbataha and Banc d'Arguin. We tested for significance of the differences between the risk levels in the six periods under consideration, both by parametric (ANOVA) tests and by non-parametric (Kruskal-Wallis) tests. Not surprisingly, the differences are significant in almost all cases, that is, for almost all ship types in both regions, with respect to both the incident probability and the MVR.

As a next step in our risk evaluation, we consider whether the risk has increased significantly in recent years. For this purpose, we aggregate the six periods considered before to get two periods, a base period consisting of the first four periods (1979–1998) and a recent period (January 1999 through July 2007). The resulting relative risk measures are shown in Table 3. Mean values of incident probabilities and of monetary values at risk in the recent period are expressed relative to the twenty-year base period, so that values above 1 (below 1) indicate an increase (decrease) of risk for recent years as compared to the past. Results per ship type are presented for the larger regions of South-East Asia and West Africa, and for vessels that trade within 100 nautical miles of the two heritage regions we show results for all ship types combined and for tankers. The outcomes for the heritage sites are somewhat less reliable due to the relatively small sample sizes.

Nearly all risks measures have increased over time and the increases in MVR are more substantial than those in the incident probabilities. Of particular interest is the risk for pollution, which has increased by about 60% for South-East Asia and 25% for West Africa. The associated MVR for tankers has even doubled for both regions. The increase of pollution risk for the two heritage sites is even more substantial, in terms of pollution incident probabilities as well as the associated monetary value at risk.

Most increases of risk seem substantial, and we test whether the changes could be purely due to chance. The results of conventional comparison-of-mean t-tests for the two periods are in Table 4. Nearly all values of incident probabilities and monetary values at risk have increased.

Table 3: Relative mean risk per ship type, regions South-East Asia and West Africa

		Probability			MVR		
	Count	VS	S	POL	VS	S	POL
South-East Asia	471,127						
General cargo	122,087	0.913	1.551	1.607	0.915	1.552	
Dry bulk	60,690	1.220	1.955	1.639	1.445	2.989	
Container	105,811	1.092	2.053		1.321	2.538	
Tankers	116,361	1.242	2.023	1.603	1.465	2.526	2.157
Passenger	9,376	1.240	7.683		1.622	10.199	
Other	56,802	0.440	1.434		0.421	1.404	
All types	471,127	1.013	1.721	1.611	1.285	2.202	
All Tubbataha	8,549	0.883	1.859	5.895	1.017	1.919	
Tankers Tubbataha	1,497	1.265	13.040	10.690	1.119	8.766	4.422
West Africa	434,474						
General cargo	138,362	1.367	1.387		1.436	1.413	
Dry bulk	55,555	1.195	1.874		1.369	2.871	
Container	75,868	1.035	2.320		1.239	2.804	
Tankers	98,773	1.392	1.596	1.250	1.732	2.164	2.009
Passenger	8,872	0.888	5.149		1.178	6.536	
Other	57,044	0.593	1.714		0.567	1.620	
All types	434,474	1.164	1.512		1.453	1.968	
All Banc d'Arguin	8,323	0.977	2.170		1.073	2.696	
Tankers Banc	1,409	0.996	4.545	3.214	1.083	6.776	4.673

Count is the number of observations for VS and S (fewer for POL for general cargo and dry bulk), for the combined data period Jan 1979 - Jul 2007. Data from estimated logit models are adjusted as follows:
A: Data from logit models per region and ship type are corrected for observation frequency.
B: Individual data are down-weighted by their specific IMO-day observation frequency.
C: Mean is for recent period (Jan 1999 - Jul 2007) relative to the base period (Jan 1979 - Dec 1998).

For the far majority of cases, the increase of incident probabilities and MVR in recent years is highly significant. A significant decrease is found only for the class of other ship types, and this may be caused by changes in composition of this class over time. For the two heritage sites, risk increased significantly for serious incidents and for pollution incidents. Notwithstanding small sample sizes, these risk increases are significant even for the class of tankers passing through the heritage sites.

5. Estimate of magnitude of risk

The previous section evaluated the relative increase of risk over time, that is, the risk relative to that in the base period, in terms of incident probabilities and MVR. We next consider the risk level in two periods, recent years (1999-2007) and the preceding twenty years (1979-1998). The actual risk exposure contains four dimensions, namely, the time period of exposure, the vessels passing the region of interest in that time period, the probability of an incident of each vessel within that time period, and the yearly value at risk by vessel in case of an incident. The latter value is of interest to indicate the magnitude of risk exposure.

Table 4: Tests for increase of risk per ship type, regions South-East Asia and West Africa

		Probability			MVR		
		VS	S	POL	VS	S	POL
South-East Asia							
General cargo	factor	0.913	1.551	1.607	0.915	1.552	
	significance	x	+++	+++	x	+++	
Dry bulk	factor	1.220	1.955	1.639	1.445	2.989	
	significance	++	+++	+++	+++	+++	
Container	factor	1.092	2.053		1.321	2.538	
	significance	+	+++		+++	+++	
Tankers	factor	1.242	2.023	1.603	1.465	2.526	2.157
	significance	+++	+++	+++	+++	+++	+++
Passenger	factor	1.240	7.683		1.622	10.199	
	significance	x	+++		++	+++	
Other	factor	0.440	1.434		0.421	1.404	
	significance	---	+		---	x	
All types	factor	1.013	1.721	1.611	1.285	2.202	
	significance	x	+++	+++	+++	+++	
All Tubbataha	factor	0.883	1.859	5.895	1.017	1.919	
	significance	x	++	++	x	+++	
Tankers Tubbataha	factor	1.265	13.040	10.690	1.119	8.766	4.422
	significance	x	+	+	x	++	++
West Africa							
General cargo	factor	1.367	1.387		1.436	1.413	
	significance	+	+++		+++	+++	
Dry bulk	factor	1.195	1.874		1.369	2.871	
	significance	+++	+++		+++	+++	
Container	factor	1.035	2.320		1.239	2.804	
	significance	x	+++		+++	+++	
Tankers	factor	1.392	1.596	1.250	1.732	2.164	2.009
	significance	+++	+++	++	+++	+++	+++
Passenger	factor	0.888	5.149		1.178	6.536	
	significance	x	+++		x	+++	
Other	factor	0.593	1.714		0.567	1.620	
	significance	---	++		---	+++	
All types	factor	1.164	1.512		1.453	1.968	
	significance	+++	+++		+++	+++	
All Banc d'Arguin	factor	0.977	2.170		1.073	2.696	
	significance	x	+++		x	+++	
Tankers Banc d'Arguin	factor	0.996	4.545	3.214	1.083	6.776	4.673
	significance	x	x	+	x	+	+

Test is the non-paired t-test for equal means (equal variances not assumed) in the two sub-periods.
+++ indicates p-value < 0.0005, ++ < 0.005, + < 0.05, x > 0.05 for increase (factor > 1);
--- indicates p-value < 0.0005, -- < 0.005, - < 0.05, x > 0.05 for decrease (factor < 1).

As reliable traffic intensity data are not available to us, we consider the mean yearly risk of an incident, that is, the yearly incident probability averaged over the involved vessels. To obtain these yearly probabilities, we need to estimate the time period that the probabilities of the previous section (after correcting for differing observation frequencies) refer to. This time period is calibrated by relating the database probabilities (for each of the 28 models, per incident type, ship type, and region) to the empirical yearly incident rates for the world fleet. Details of the calibration method can be found in Appendix A and correction factors in Table A-1 and Table B-2.

Let the resulting yearly probability of an incident be denoted by P, then the yearly vessel risk exposure in case of an incident (VREI) is P×TIV, where TIV denotes the total insured value, that is, the sum total of the values of the five damage components (TIV = $\sum_{j=1}^{5} V_j$). The difference between MVR used in the previous section and VREI is that the damage components are summed to get TIV, instead of weighted by conditional damage probabilities as is done to get MVR. For the incident probability P, we consider two types of incident, very serious (including total loss) and pollution. This risk indicator is an approximation, because it involves both over-estimation aspects (because not all insurable value may be lost at each very serious incident) and under-estimation effects (as it neglects the damage of serious incidents that do not qualify as very serious). For pollution incidents, only the insurance coverage for oil pollution is taken into account for the insured value.

Table 5 shows yearly averages of VREI risk, both for recent years and for the base period. In South-East Asia, this monetary risk has increased most notably for the pollution risk of tankers, where the yearly VREI per tanker increased from about $25,000 in the base period to over $45,000 in recent years. This increase is due both to increased incident risk (from 0.163% per year to 0.229% per year) and to higher insurable value (from 10.7 to 13.1 million dollar). In West Africa, the VREI risk has increased for nearly all ship types. For pollution risk, the yearly VREI per tanker increased from about $12,000 in the base period to about $17,000 in recent years, because of increases in both the incident risk (from 0.149% per year to 0.184% per year) and the total insurable value (from 6.1 to 7.9 million dollar).

The VREI in West Africa is smaller than in South East Asia, because the values of both TIV and the incident probabilities are relatively lower for West Africa. For all ship types aggregated, vessels travelling through South-East Asia have 30% higher value and nearly twice as high incident probability as compared to West Africa. For recent years, the average VREI for all ship types combined is $255,000 for South-East Asia and $105,000 for West Africa, and the average TIV is respectively 47.7 and 36.6 million dollar.

Table 5: Mean yearly vessel risk exposure in case of an incident (VREI)

			Very serious incident			Pollution only		
	Variable	N	TIV	P	VREI	V-POL	P-POL	$VREI_{pol}$
	Units	1	1,000,000	0.001	1,000	1,000,000	0.001	1,000
South East Asia								
General cargo	base	99,714	50.15	9.00	472.92	10.38	0.53	3.85
	recent	22,373	54.00	7.85	408.78	11.95	0.76	4.48
Dry bulk	base	44,838	46.65	2.82	122.48	10.44	0.24	2.58
	recent	15,852	49.64	3.29	167.56	11.70	0.44	4.88
Container	base	71,368	49.58	4.98	249.95			
	recent	34,443	53.64	5.25	284.21			
Tankers	base	90,655	44.23	5.40	231.82	10.73	1.63	25.42
	recent	25,706	52.77	5.69	300.12	13.09	2.29	46.08
Passenger	base	7,900	61.05	3.80	239.43			
	recent	1,476	76.07	3.67	240.16			
Other	base	39,016	40.93	1.26	51.70			
	recent	17,786	16.93	1.24	19.04			
All	base	353,491	47.30	5.51	269.91	10.88	1.02	8.72
	recent	117,636	47.71	4.95	255.01	11.34	1.48	13.06
Tubbataha all	base	7,028	48.16	5.55	249.55	10.96	0.47	1.52
	recent	1,521	41.81	5.16	198.31	9.31	2.73	19.09
West Africa								
General cargo	base	113,617	39.87	3.52	140.69			
	recent	24,745	42.18	4.18	160.48			
Dry bulk	base	41,500	32.67	1.31	42.42			
	recent	14,055	34.02	1.48	48.84			
Container	base	51,444	33.31	2.34	75.54			
	recent	24,424	40.63	2.31	90.01			
Tankers	base	75,796	34.24	3.34	115.25	6.06	1.49	12.20
	recent	22,977	39.43	4.19	164.19	7.94	1.84	17.26
Passenger	base	7,555	39.45	1.34	55.89			
	recent	1,317	56.53	1.11	57.57			
Other	base	40,786	30.72	0.40	13.01			
	recent	16,258	18.49	0.43	9.73			
All	base	330,698	35.52	2.59	94.71	5.71	0.89	3.98
	recent	103,776	36.57	2.75	104.67	5.99	1.22	5.23
Banc d'Arguin	base	6,900	37.42	2.23	87.97	6.09	0.56	0.73
	recent	1,423	32.97	2.17	75.62	4.45	1.24	1.40

Table reports weighted mean values, correcting for varying observation frequencies in the database.
Base is the base period (Jan 1979 - Dec 1998), and recent is the period Jan 1999 - Jul 2007.
N is the total number of observations in the database.
TIV is the total monetary insurable value (in million USD) of vessels in case of a very serious incident (assuming total loss) of all values: hull and machinery, third party liabilities, passenger life, pollution, and insurable cargo.
P is the yearly probability (multiplied by 1,000) of a very serious incident (assuming total loss).
VREI shows the mean of the database products of TIV and P, that is, the yearly vessel risk exposure in case of a very serious incident, per year per vessel (in thousand USD).
For pollution, P-POL is the yearly probability (multiplied by 1,000) of a pollution incident, V-POL is the total insurable value of pollution costs, and $VREI_{pol}$ is the expected yearly vessel risk exposure for pollution only.

Of special interest are trends for VREI for ships trading within 100 nautical miles of the two heritage regions. Because these regions are relatively small, the numbers of vessels per ship type are too small to allow for a reliable analysis. Therefore, we consider all ship types combined, giving on average slightly less than 100 different vessels per year for each heritage region (see Table 1). The results in Table 5 show that the risk does not increase for very serious incidents, whereas pollution risk has increased, mainly because of increased pollution incident probabilities. The results for the two heritage regions are not very reliable, not even after aggregating over ship types, as the number of observations is still relatively small. With more accurate vessel traffic density data, such as AIS (automated identification system) data, one could estimate the combined risk exposure of all ships trading in a particular area by multiplying the number of vessels trading in that area in a year by the VREI for each ship type. Our data are too limited for this purpose and do not enable us to provide a reliable estimate of the combined risk exposure of all ships.

6. Conclusions and policy recommendations

This article presented a general framework to estimate total risk exposure due to shipping activities taking into account various components, such as ship specific risk, risk due to vessel traffic densities, and underlying environmental physical criteria and sensitivities (socio-economic and ecological). Due to data limitations, not all components of this general framework could be considered here. We concentrated therefore on ship specific risk and underlying physical environmental criteria such as wind and waves, and we tested whether ship specific risk increased over time. We feel that ship specific risk can serve as an indicator to determine whether risk increased over time, as it reflects the safety quality of vessels trading in the areas of interest and it represents one of the criteria for the designation of a Particular Sensitive Sea Area (PSSA): the area under consideration must be vulnerable to damage by international shipping activities.

In our analysis, we could not account for increased risk due to traffic densities, because of declines both in the participation in the VOS and in the share of VOS reports available in our database. In the future, data from AIS (automated identification system) could be used to quantify increase in risk due to traffic densities, which would add another dimension of risk. In our current analysis, historical AIS data for traffic densities were not available. Finally, we could also not account for environmental sensitivities, although we did account for incident consequences indirectly via the monetary value at risk (MVR) and the yearly vessel risk exposure in case of an incident (VREI) to demonstrate magnitude of risk.

We tested for significant increases in the risk levels over time, in terms of the relative risk in recent years as compared to a base period. The results show consistent increases in incident probabilities and monetary value at risk (MVR) for dry bulkers, container ships, and tankers. This finding applies for ships trading in the areas of South-East Asia and West Africa, but also within the 100 nautical mile zones of Tubbataha and Banc d'Arguin. Of particular interest for the decision to designate a heritage area as PSSA under IMO is pollution risk. As compared to the base period (1979-1998), the increase in pollution probability in recent years (1999-2007) is about 60% for South-East Asia and 25% for West Africa, and the associated MVR for tankers has even doubled for both regions. The increase of pollution risk for the two heritage sites is even more substantial.

For the magnitude of risk expressed by the yearly vessel risk exposure in case of an incident (VREI), we find for very serious incidents in recent years of all ship types combined an average yearly figure of $255,000 for South-East Asia and $105,000 for West Africa. The average total insured value (TIV) is respectively 47.7 and 36.6 million dollar. The VREI for pollution has also increased over time, as a combination of increases both in the yearly probability of pollution (from 0.163% to 0.229% per tanker per year for South-East Asia and from 0.149% to 0.184% for West Africa) and changes in TIV reflecting partly the increase in vessel size over time.

The results indicate that the safety quality of vessels trading in both areas has decreased over time. The upward trend in risk due to increased ship specific risk is expected to be magnified by higher traffic densities, which is an additional source of risk that was not quantified in our analysis. The outcome of our analysis leads to the recommendation of an increased level of protection for both heritage areas in order to mitigate potential risk increases. Another possible policy implication is to improve the targeting for high risk vessels trading in the areas of concern via existing port state control mechanisms.

For ships passing mainly through these areas, monitoring of high-risk vessels could be improved by linking AIS data with risk indicators at the individual ship level, such as the incident probabilities estimated in our analysis and potential consequences expressed in terms of the monetary value at risk (MVR) and the vessel risk exposure in case of incidents (VREI). The use of such integrated data information would not only lead to improved risk surveillance across areas of particular interest but also for all coastal areas in general, which is in line with the general framework of total risk exposure introduced at the beginning of this report.

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Appendix A: Correction factors for observation frequencies and participation rates

The observations of the merged database are of mixed frequency. Vessels participating in the VOS system report at different frequencies, and many incident data consist of a single observation for the vessel. We discuss three consequences of these differences in reporting frequencies: the effect on the mean level of model-based risk rates, the correction for these differences among the various models, and the computation of mean risk.

First we consider the effect on the model-based risk rates. For both regions and for each of the six ship types and the three risk types, a logit model is estimated from the relevant subset of the database. The data are used as reported, because the relevant oceanographic variables like wind and wave are location specific and cannot be aggregated. The amount of observations per vessel varies widely: a single observation for the whole time period, irregular observations with varying time gaps of several days or months, or high frequency observations with up to more than six observations per day. As a consequence, the obtained logit probabilities do not refer to a common time scale, as is best illustrated by a simple example. Suppose that the database consists of two groups of vessels, denoted by A and B. Let the number of vessels in each group be denoted by n_A and n_B, their daily observation frequencies by f_A and f_B, and their daily risk by p_A and p_B. The actual daily risk rate for the combined data is equal to $(n_A p_A+n_B p_B)/(n_A+n_B)$. For a period of D observation days, we have in total $D\times(n_A f_A+n_B f_B)$ observations and, on average, $D\times(n_A p_A+n_B p_B)$ incidents. This means that the risk rate in the database, that is, the total number of incidents divided by the total number of observations in the database, is (on average) equal to $(n_A p_A+n_B p_B)/(n_A f_A+n_B f_B)$. The logit model has the property that this database risk rate is equal to the mean of the estimated risk probabilities (Greene, 2008, p. 778), $(n_A p_A+n_B p_B)/(n_A f_A+n_B f_B)$ on average. This expression differs from the actual daily risk rate unless $f_A=f_B=1$, that is, unless both observation frequencies are the daily. For example, if $n_A = n_B$, $f_A = 1$, and $f_B = 0.1$, then the required correction factor to get the actual risk is $(n_A f_A+n_B f_B)/(n_A+n_B) = 0.55$.

Our combined dataset merges very low-frequency incident data (often with a single observation in 28 years, with an average observation frequency of 1/14 years) with non-incident data of mixed and much higher frequencies (often with 4 or more observations per day). With an average of 224 operational days per year, the latter observation frequency is about 4×224×14 or more than 12,500 times as large as that of the incident data. As a consequence, for our database with very complex observation frequency structure, we obtain logit risk probabilities that do not refer to a clearly identified unit of time. As the model is estimated for the full data period, the probabilities can be compared among sub-periods, as they share the common time unit that is the mixture of all observation frequencies. We therefore report the risks in Section 4 relative to an initial base period.

Second, we consider the correction for differences in observation frequencies among the various models. For both regions and for each ship type, we obtain model-based risk estimates that refer to different units of time. The differences in mean observation frequencies per day vary between 0.6 and 7.6, see Table A-1. If these model-based risks are analyzed jointly, we first have to transform them to a common unit of measurement time. Let q denote the risk for a single unit of time, then the risk p for T units of time is obtained as follows. The probability not to have an incident in a single unit of time is 1-q, and the probability not to have an incident in T units of time is $(1-q)^T$. Therefore, $1 - p = (1-q)^T$, and hence $p = 1 - (1-q)^T$. The value of q is small in our applications, so that $(1-q)^{\mathrm{T}} \approx 1 - Tq$ and $p \approx Tq$, in accordance with (slightly inaccurate) intuition. The model-based risks q are transformed by the factors T shown in Table A-1. In this way, the risks for all combinations of region and ship type refer to a comparable time unit of risk. As Table A-1 contains the average daily observation frequencies, it might be tempting to interpret the resulting risks as daily risks. This is, however, incorrect, as many incident data have much lower observation frequency (down to once in 14 years, or over 3,000 operational days).

Table A-1: Factors to correct for varying observation frequencies

	South-East Asia	West Africa
General cargo	2.008	1.078
Dry bulk	3.032	0.638
Container	2.633	2.105
Tanker	2.811	0.951
Passenger	1.950	0.828
Other	7.588	2.844

Table shows mean daily observation frequency per vessel per region and ship type.

Third, we discuss the computation of mean risk. Clearly, if a vessel has a relatively high (low) daily observation frequency, it has a relatively too large (too small) weight in non-weighted means and sums. We apply as weights the inverse of the number of observations per day. Let f_{jd} be the number of observations of vessel "j" on day "d", then the values x_{jd} of any variable of interest (such as risk probability and monetary value at risk) in the database are replaced by $x^*_{\mathrm{jd}} = x_{\mathrm{jd}}/f_{\mathrm{jd}}$. In this way, the observations obtain a (combined) weight of 1 per vessel per day. This kind of weighting is correct for the far majority of the data, that is, for the VOS data. If a vessel appears only once in the database, as is the case for many incident data, we cannot determine the appropriate weighting factor due to missing (non-incident) data for this vessel, and the weight is taken as 1. Note that this does not mean that the weighted average risk is under-estimated, as the model-based risk probabilities were obtained jointly for the merged VOS and incident data so that these risks are taken into account also in the VOS observations. Further note that weighted risks, where x_{jd} is a model-based probability, do not refer to daily risks, as the time risk unit of x_{jd} is unknown, as discussed before.

Appendix B: Supplementary tables

Table B-1: Model summary statistics

	South-East Asia			West Africa		
	VS	S	POL	VS	S	POL
General cargo						
Total observations	681,538	681,538	681,538	346,876	346,876	n/a
Incident observations	1,790	1,466	194	330	383	
Cut-off value	0.0026	0.0022	0.0003	0.0009	0.0001	
HL test p-value	0.000	0.000	0.726	0.001	0.197	
Hit rate (% correct)	72.31	72.97	71.61	81.85	82.88	
Dry bulk						
Total observations	333,959	333,959	333,959	76,889	76,889	n/a
Incident observations	306	419	50	140	269	
Cut-off value	0.0009	0.0013	0.0001	0.0018	0.0034	
HL test p-value	0.003	0.439	0.738	0.215	0.905	
Hit rate (% correct)	80.63	81.93	81.57	50.39	86.35	
Container						
Total observations	458,269	458,269	n/a	237,994	237,994	n/a
Incident observations	95	198		31	46	
Cut-off value	0.0002	0.0004		0.0001	0.0002	
HL test p-value	0.345	0.725		0.618	0.001	
Hit rate (% correct)	81.56	83.05		90.23	86.68	
Tanker						
Total observations	476,468	476,468	476,468	172,309	172,309	172,309
Incident observations	531	494	230	110	140	43
Cut-off value	0.0011	0.0010	0.0004	0.0006	0.0008	0.0002
HL test p-value	0.010	0.241	0.479	0.421		0.890
Hit rate (% correct)	86.39	99.81	85.71	99.88	55.60	80.99
Passenger						
Total observations	76,728	76,728	n/a	27,572	27,572	n/a
Incident observations	122	172		16	28	
Cut-off value	0.0015	0.0022		0.0005	0.0010	
HL test p-value	0.000	0.000		1.000	0.091	
Hit rate (% correct)	85.20	88.17		88.31	87.09	
Other						
Total observations	365,576	365,576	n/a	179,640	179,640	n/a
Incident observations	73	58		17	18	
Cut-off value	0.0002	0.0002		0.0001	0.0001	
HL test p-value	0.003	0.692		0.000	0.395	
Hit rate (% correct)	84.02	84.13		86.47	83.16	

Pollution models "n/a" are not applicable, as too few observations were available for estimation.

Table B-2: Correction factors for yearly incident probabilities

	Risk probability (*1,000)			Transformation factor	
	Empirical	South-East Asia	West Africa	South-East Asia	West Africa
General cargo					
Very serious	9.30	2.96	1.36	3.15	6.85
Serious	12.49	3.89	4.19	3.22	2.99
Pollution	0.73	0.74	0.77	0.98	0.94
Dry bulk					
Very serious	2.81	3.36	1.55	0.83	1.81
Serious	5.62	4.17	4.20	1.35	1.34
Pollution	0.36	0.51	0.54	0.72	0.67
Container					
Very serious	4.25	3.48	1.54	1.22	2.77
Serious	9.42	1.14	1.26	8.32	7.48
Tanker					
Very serious	4.90	2.20	1.44	2.23	3.40
Serious	7.01	2.85	2.54	2.47	2.77
Pollution	2.44	1.30	1.11	1.88	2.20
Passenger					
Very serious	3.23	1.38	0.44	2.34	7.27
Serious	8.23	9.67	8.35	0.85	0.99
Other					
Very serious	0.52	3.30	1.24	0.16	0.42
Serious	0.83	1.37	1.04	0.61	0.80

The risk probabilities are multiplied by 1,000.
"Empirical" shows the empirical risk probabilities, that is, the total number of incidents in the period 1979-2007 divided by the sum of the twenty yearly total number of vessels.
The risk probabilities for SE Asia and W Africa are the mean database probabilities obtained after correcting for different observation frequencies (see Table A-1).
The transformation factors are obtained as follows: let q be the mean database probability and p the empirical risk; then the probability of not having an incident in a period of one year is 1-p; the period of time (1/T years) that q refers to is estimated by requiring equal probability of having no incident in one year, that is, in T periods; so 1-p = (1-q)^T, and T = ln(1-p) / ln(1-q). For example, for very serious general cargo incidents in SE Asia we get T = ln(1-0.00930) / ln(1-0.00296) = 3.15 (a bit rougher approximation is T = p/q = 3.14).

Table B-3: Relative mean risks for six periods, per ship type, region South-East Asia

				Probability			MVR		
Ship type	Period	Count	Count (rel)	VS	S	POL	VS	S	POL
General cargo	79-83	26,146	1	1	1	1	1	1	
	84-88	33,166	1.268	1.054	1.120	1.202	1.047	1.090	
	89-93	22,728	0.869	0.993	2.051	2.055	0.989	1.963	
	94-98	17,674	0.676	0.840	1.999	2.200	0.829	2.118	
	99-03	14,362	0.549	0.733	1.785	2.158	0.702	1.808	
	04-07	8,011	0.306	1.205	3.110	2.986	1.252	3.033	
Dry bulk	79-83	7,196	1	1	1	1	1	1	
	84-88	11,865	1.649	0.985	0.939	1.078	1.200	1.085	
	89-93	12,659	1.759	0.864	2.076	3.208	1.372	2.048	
	94-98	13,118	1.823	0.939	1.079	1.578	1.604	1.563	
	99-03	11,535	1.603	1.058	2.236	2.747	1.895	3.932	
	04-07	4,317	0.600	1.381	3.432	3.543	2.018	5.774	
Container	79-83	11,062	1	1	1		1	1	
	84-88	16,034	1.449	0.868	1.079		0.881	0.927	
	89-93	20,455	1.849	0.844	1.285		0.966	1.233	
	94-98	23,817	2.153	0.955	0.998		1.189	1.073	
	99-03	19,704	1.781	1.077	1.886		1.386	2.062	
	04-07	14,739	1.332	0.883	2.750		1.316	3.619	
Tanker	79-83	18,469	1	1	1	1	1	1	1
	84-88	22,331	1.209	1.056	1.744	1.858	1.388	1.642	1.905
	89-93	24,997	1.353	0.955	1.164	1.157	1.434	1.514	3.054
	94-98	24,858	1.346	0.917	0.548	0.575	1.615	1.034	3.145
	99-03	17,126	0.927	1.192	1.189	1.230	1.960	1.920	4.576
	04-07	8,580	0.465	1.262	4.322	3.012	2.162	6.076	6.234
Passenger	79-83	2,414	1	1	1		1	1	
	84-88	2,519	1.043	0.822	0.719		0.727	0.751	
	89-93	1,685	0.698	0.950	1.495		0.845	1.387	
	94-98	1,282	0.531	1.387	1.542		1.719	1.874	
	99-03	891	0.369	1.445	6.071		1.845	8.003	
	04-07	585	0.242	0.914	12.151		1.268	17.273	
Other	79-83	7,639	1	1	1		1	1	
	84-88	11,562	1.514	0.773	0.692		0.775	0.712	
	89-93	10,187	1.334	0.754	1.123		0.767	1.112	
	94-98	9,628	1.260	0.630	0.697		0.644	0.680	
	99-03	10,158	1.330	0.362	1.698		0.351	1.665	
	04-07	7,628	0.999	0.315	0.634		0.303	0.614	

Count is the number of individual observations in the database for VS and S (fewer observations for POL).
The counts for the last period (Jan 2004 - Jul 2007) are relatively small (43 instead of 60 months); the reported averages automatically correct for this difference in length of observation period.
Risk data from estimated logit models per ship type are adjusted as follows:
A: Logit probabilities are corrected for varying observation frequency.
B: Individual data are down-weighted by their specific IMO-day observation frequency.
C: The resulting data are averaged per period (for 6 periods).
D: Finally, the period means are scaled to have value 1 in base period 1 (Jan 79 - Dec 83).

Table B-4: Relative mean risks for six periods, per ship type, region West Africa

				Probability			MVR		
Ship type	Period	Count	Count (rel)	VS	S	POL	VS	S	POL
General cargo	79-83	30,221	1	1	1		1	1	
	84-88	37,023	1.225	0.466	1.191		0.430	1.149	
	89-93	25,936	0.858	0.494	2.037		0.460	1.896	
	94-98	20,437	0.676	0.469	2.114		0.439	2.183	
	99-03	15,902	0.526	0.980	1.677		0.991	1.717	
	04-07	8,843	0.293	0.591	2.804		0.589	2.708	
Dry bulk	79-83	6,414	1	1	1		1	1	
	84-88	11,308	1.763	0.928	0.979		1.072	1.080	
	89-93	11,718	1.827	0.974	2.050		1.514	2.073	
	94-98	12,060	1.880	1.043	1.256		1.882	1.693	
	99-03	10,336	1.611	1.222	2.013		2.099	3.658	
	04-07	3,719	0.580	1.055	4.074		1.516	6.391	
Container	79-83	8,117	1	1	1		1	1	
	84-88	11,882	1.464	0.941	1.112		0.967	0.986	
	89-93	14,694	1.810	0.913	1.202		0.994	1.177	
	94-98	16,751	2.064	1.100	0.864		1.300	0.975	
	99-03	14,627	1.802	1.062	1.975		1.330	2.201	
	04-07	9,797	1.207	0.980	3.063		1.375	3.977	
Tanker	79-83	14,347	1	1	1	1	1	1	1
	84-88	18,169	1.266	1.104	1.106	1.425	1.270	1.122	1.631
	89-93	21,252	1.481	1.101	1.006	1.227	1.526	1.326	2.820
	94-98	22,028	1.535	1.097	0.513	0.628	1.751	0.876	2.708
	99-03	14,949	1.042	1.428	0.628	0.724	2.270	1.215	3.644
	04-07	8,028	0.560	1.649	2.877	2.436	2.862	4.456	5.621
Passenger	79-83	2,130	1	1	1		1	1	
	84-88	2,160	1.014	0.824	0.569		0.804	0.651	
	89-93	1,855	0.871	0.695	0.805		0.707	0.765	
	94-98	1,410	0.662	0.655	0.871		0.823	1.069	
	99-03	776	0.364	0.757	1.928		0.974	2.750	
	04-07	541	0.254	0.666	7.320		1.009	9.667	
Other	79-83	7,630	1	1	1		1	1	
	84-88	12,080	1.583	0.903	0.945		0.924	0.993	
	89-93	10,752	1.409	0.862	0.911		0.867	0.940	
	94-98	10,324	1.353	0.777	0.866		0.793	0.854	
	99-03	9,410	1.233	0.583	1.899		0.565	1.836	
	04-07	6,848	0.898	0.436	1.159		0.422	1.112	

Count is the number of individual observations in the database for VS and S (fewer observations for POL).
The counts for the last period (Jan 2004 - Jul 2007) are relatively small (43 instead of 60 months); the reported averages automatically correct for this difference in length of observation period.
Risk data from estimated logit models per ship type are adjusted as follows:
A: Logit probabilities are corrected for varying observation frequency.
B: Individual data are down-weighted by their specific IMO-day observation frequency.
C: The resulting data are averaged per period (for 6 periods).
D: Finally, the period means are scaled to have value 1 in base period 1 (Jan 79 - Dec 83).

Table B-5: Relative combined risk exposure for six periods, per ship type, region Tubbataha

				Probability			MVR		
Ship type	Period	Count	Count (rel)	VS	S	POL	VS	S	POL
General cargo	79-83	932	1	1	1	1	1	1	
	84-88	1,252	1.339	1.690	2.611	4.519	1.846	2.738	
	89-93	733	0.805	0.990	2.252	4.583	1.107	2.428	
	94-98	467	0.595	0.521	1.657	7.986	0.594	2.038	
	99-03	392	0.517	0.535	1.082	3.670	0.567	1.362	
	04-07	218	0.534	0.512	2.257	21.261	0.562	2.940	
Dry bulk	79-83	63	1	1	1	1	1	1	
	84-88	116	1.837	2.836	18.485	71.722	1.800	13.344	
	89-93	65	1.054	0.499	19.851	33.807	0.367	16.992	
	94-98	45	0.846	0.366	3.187	5.166	0.327	4.034	
	99-03	103	1.982	0.587	10.563	40.813	0.424	6.785	
	04-07	26	0.913	0.650	4.571	11.671	0.410	8.165	
Container	79-83	190	1	1	1		1	1	
	84-88	198	1.041	0.427	2.332		0.416	2.029	
	89-93	263	1.408	0.949	5.851		1.077	5.174	
	94-98	282	1.764	1.108	2.238		1.203	2.619	
	99-03	227	1.460	1.283	29.867		1.241	24.252	
	04-07	130	1.550	1.105	33.936		1.147	34.202	
Tanker	79-83	384	1	1	1	1	1	1	1
	84-88	416	1.081	1.089	2.097	1.527	0.781	2.017	1.460
	89-93	252	0.665	0.833	2.319	1.808	0.915	3.086	3.905
	94-98	328	1.014	0.871	2.386	2.232	2.129	4.991	9.216
	99-03	86	0.272	0.410	4.037	2.259	0.447	4.732	3.796
	04-07	31	0.195	0.128	11.732	9.071	0.137	9.025	5.195
Passenger	79-83	74	1	1	1		1	1	
	84-88	124	1.669	3.407	0.050		3.084	0.052	
	89-93	18	0.246	0.284	0.013		0.288	0.013	
	94-98	17	0.271	0.327	0.044		0.416	0.050	
	99-03	9	0.150	0.055	0.043		0.071	0.048	
	04-07	4	0.141	0.039	0.011		0.068	0.022	
Other	79-83	262	1	1	1		1	1	
	84-88	326	1.239	1.038	1.187		1.086	1.390	
	89-93	157	0.607	0.460	0.529		0.467	0.819	
	94-98	64	0.290	0.093	0.204		0.098	0.203	
	99-03	98	0.468	0.105	0.981		0.106	1.101	
	04-07	197	1.902	0.317	0.519		0.316	0.515	

Count is the number of individual observations in the database for VS and S (fewer observations for POL).
The counts for the last period (Jan 2004 - Jul 2007) are relatively small (43 instead of 60 months); the reported sums are corrected for this difference in length of observation period (see E below).
Risk data from estimated logit models per ship type are adjusted as follows:
A: Logit probabilities are corrected for varying observation frequency.
B: Individual data are down-weighted by their specific IMO-day observation frequency.
C: The resulting data are summed per period (for 6 periods).
D: The sums are scaled up by dividing by average VOS participation rate per period.
E: As period 6 has 43 months instead of 60, its sums are further upscaled by the factor 60/43.
F: Finally, the period sums are scaled to have value 1 in base period 1 (Jan 79 - Dec 83).

Table B-6: Relative combined risk exposure for six periods, per ship type, region Banc d'Arguin

				Probability			MVR		
Ship type	Period	Count	Count (rel)	VS	S	POL	VS	S	POL
General cargo	79-83	954	1	1	1		1	1	
	84-88	1,181	1.234	0.942	2.003		1.129	2.044	
	89-93	603	0.641	0.528	1.903		0.598	1.958	
	94-98	468	0.583	0.550	1.761		0.759	2.242	
	99-03	432	0.558	0.641	1.330		0.769	1.626	
	04-07	213	0.504	0.408	3.332		0.513	4.175	
Dry bulk	79-83	35	1	1	1		1	1	
	84-88	94	2.675	1.644	14.197		1.681	18.916	
	89-93	59	1.713	0.600	5.111		0.628	7.159	
	94-98	39	1.311	0.396	2.920		0.406	3.278	
	99-03	67	2.333	0.716	12.584		0.893	14.793	
	04-07	15	0.984	0.851	5.977		0.984	11.620	
Container	79-83	134	1	1	1		1	1	
	84-88	172	1.281	1.367	4.822		1.419	4.682	
	89-93	198	1.506	1.282	14.069		1.142	11.751	
	94-98	244	2.167	2.043	4.605		2.146	6.082	
	99-03	178	1.626	1.924	27.373		1.816	27.652	
	04-07	92	1.536	1.295	77.555		1.211	90.849	
Tanker	79-83	310	1	1	1	1	1	1	1
	84-88	408	1.314	1.368	1.541	1.291	1.110	1.348	1.008
	89-93	246	0.806	0.568	3.219	3.367	0.666	3.881	3.135
	94-98	304	1.164	0.700	2.268	1.728	1.512	3.882	3.129
	99-03	107	0.419	0.347	3.166	1.995	0.436	5.402	2.962
	04-07	34	0.268	0.256	3.052	2.160	0.312	6.527	3.867
Passenger	79-83	66	1	1	1		1	1	
	84-88	107	1.616	13.712	1.912		10.346	1.549	
	89-93	16	0.243	0.267	0.088		0.198	0.080	
	94-98	22	0.396	0.172	1.423		0.217	1.560	
	99-03	15	0.279	2.474	1.883		3.011	2.629	
	04-07	2	0.071	0.004	0.008		0.005	0.013	
Other	79-83	192	1	1	1		1	1	
	84-88	722	3.743	6.216	3.843		6.987	4.370	
	89-93	223	1.168	1.984	1.051		2.032	1.108	
	94-98	103	0.637	1.359	0.477		1.387	0.492	
	99-03	105	0.689	0.446	0.207		0.433	0.208	
	04-07	163	2.090	1.673	3.028		1.624	3.039	

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Risk data from estimated logit models per ship type are adjusted as follows:
A: Logit probabilities are corrected for varying observation frequency.
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C: The resulting data are summed per period (for 6 periods).
D: The sums are scaled up by dividing by average VOS participation rate per period.
E: As period 6 has 43 months instead of 60, its sums are further upscaled by the factor 60/43.
F: Finally, the period sums are scaled to have value 1 in base period 1 (Jan 79 - Dec 83).