Image Cover Sheet

CLASSIFICATION UNCLASSIFIED	**SYSTEM NUMBER** 504203

TITLE

SEABED OBJECT SIZE DISTRIBUTION

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

Deliver to:

National Defence
Research and
Development Branch

Défense nationale
Bureau de recherche
et développement

TECHNICAL MEMORANDUM 97/214
February 1997

SEABED OBJECT
SIZE DISTRIBUTION

R.H. Poeckert

Defence
Research
Establisnment
Atlantic

Centre de
Recherches pour la
Défense
Atlantique

Canada

DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

9 GROVE STREET

P.O. BOX 1012
DARTMOUTH, N.S.
B2Y 3Z7

TELEPHONE
(902) 426-3100

CENTRE DE RECHERCHES POUR LA DÉFENSE ATLANTIQUE

9 GROVE STREET

C.P. BOX 1012
DARTMOUTH, N.É.
B2Y 3Z7

National Defence
Research and
Development Branch

Défense nationale
Bureau de recherche
et développement

SEABED OBJECTS

SIZE DISTRIBUTION

R.H.Poeckert

February 1997

Approved by R.E. Erickson *Signiture on File*
Head/Electromagnetics Section

TECHNICAL MEMORANDUM 97/214

Defence
Research
Establishment
Atlantic

Centre de
Recherches pour la
Défense
Atlantique

Canada

ABSTRACT

A 2 km^2 area of seabed in Juan de Fuca Strait was surveyed in 1993 with a Mesotech 972 sidescan sonar. The area has significant mine-sized clutter including rocks and boulders up to several meters across. The sonar data were geocoded and mosaiced into one geographically correct image. The mosaic was scanned for objects greater than 0.5 m in diameter. This report presents an analysis of the size distribution of objects in this area and the implications for mine detection in cluttered seabeds.

RÉSUMÉ

Une superficie du fond de la mer d'une grandeur de 2 km^2 du détroit de Juan de Fuca a été relevée en 1993 au moyen d'un sonar à balayage latéral Mesotech 972. Cette région contient du fouillis significatif de la grandeur de mines, y compris des rochers et des boulders, jusqu'à plusieurs mètres de largeur. Nous avons géocodé et mosaïqué les données du sonar pour en faire une image géographiquement correcte. Nous avons balayé la mosaïque pour détecter des objets d'un diamètre en-dessus de 0.5 m. Ce rapport présente une analyse de la distribution d'objets, par rapport à leur grandeur, dans cette superficie, ainsi que les implications pour la détection de mines dans des fonds de mer caractérisés de fouillis.

DREA TM/97/214

SEABED OBJECT SIZE DISTRIBUTION

by R.H. Poeckert

EXECUTIVE SUMMARY

INTRODUCTION The Canadian Navy is developing a route survey/mine hunting capability based on a towed sidescan sonar. The sonar provides route survey data, which is essentially a detailed map of the seabed. These data are used to determine whether objects detected during a mine hunting mission are new, that is, are not in the route survey database. Such new objects could constitute threats, possible mines. Any objects appearing in both the route survey data and the mine hunting data would be deemed harmless. Thus route survey data can significantly reduce the false alarm rate and allow mine hunting operations in areas with clutter densities well beyond what is currently feasible with conventional mine hunting techniques. If the objects can be catalogued in an object database, as opposed to an image database, it is possible to detect new objects (possible mines) in real-time. In this report the size distribution of mine-sized clutter is examined and the effect of size estimation error on the utility of a route survey object database is explored.

PRINCIPAL RESULTS Sidescan sonar data covering a large boulder were geocoded and assembled into a mosaic covering 2.4 km^2. Another, less cluttered region was also mapped. These data were examined and the location and size of every object were noted. The size of the objects in these areas was found to follow a power law distribution. It was also possible to estimate the detection probability of the sonar system, a Mesotech 972, by examining several independent seabed maps. For objects >1 m in size the detection probability is essentially 1. It was also possible to determine the precision of the sonar system in measuring object size. The system tended to overestimate size by 0.3 m with an error of ±0.2 m.

SIGNIFICANCE OF THE RESULTS The rather steep power law distribution combined with the error in size estimation means that a route survey object database will have to be much larger than expected. During mine hunting it is likely that a size threshold will be used to decide if an object is potentially a mine. The route survey object database will have to include many objects of a smaller size in order to accommodate the error in size estimation. This diminishes the capability of an object database and may require very cluttered areas to be analyzed using an image comparison technique, which is unlikely to be conducted in real-time.

FUTURE PLANS The Maritime Coastal Defence Vessel (MCDV) route survey payload, a multi-beam sidescan sonar, is expected to be delivered in 1997. An assessment of the size estimation error of this system will be undertaken. This assessment will define the extent to which an object database can be used for mine hunting.

Table of Contents

List of Figures

1. INTRODUCTION

The Mine Countermeasures (MCM) Group of the Defence Research Establishment Atlantic (located at the Esquimalt Defence Research Detachment) conducted a number of sidescan sonar seabed surveys in the straits around southern Vancouver Island. These surveys were intended to explore aspects of route survey/mine hunting which consists of comparing archival (pre-mining) seabed imagery with newly acquired images, and checking for new objects (possible mines) on the seabed. A major concern in mine hunting is the density of naturally occurring mine sized objects, termed "clutter" is this report. (The term "size" as used in this report will refer to the cross-section or diameter of an object.) Given the current state of the art in mine-sized object classification using high frequency sonars, a highly cluttered area generally results in an unacceptably high false alarm rate leading the area to be considered as "unhuntable". Using archived imagery it is hoped that the false alarm rate can be reduced significantly. This report deals with the size distribution of mine-sized objects in an area of high clutter and explores the problems likely to be faced during mine hunting.

2. THE SURVEYS

For several years, areas off southern Vancouver Island, British Columbia have been surveyed using a sidescan sonar. All of these areas were at some time covered in glaciers during the last ice age, and all exhibit some degree of clutter in the form of boulders on the seabed. Two areas of interest are discussed in this report. Area "A" was selected for intensive coverage for this study because of the density of mine-sized objects. While this area has a relatively high object density, ~10000/km^2, it is possible to distinguish individual objects in the sonar images. There are areas in the surveyed regions in which the object density is even higher, but in these areas it is often impossible to identify individual objects. Area "B" was selected since it is part of an on-going study and data on objects in this area were already available.

The areas in question were surveyed using a Mesotech 972 sidescan sonar. The sonar frequency was 330 kHz, the range was 75 m and the ping rate was ~8 Hz. The nominal resolution of the system is ~0.1 m across track and ~0.35 m along track. The nominal towing speed was ~2 meters per second, resulting in an along-track sampling interval of ~0.25 m. The geographic position of the towfish was estimated by first determining the position of the tow vessel using differential GPS. The position of the towfish relative to the tow ship was estimated using a Trackpoint II acoustic positioning system. The towfish track was estimated using a modified dead-reckoning algorithm (Poeckert 1993) and the sonar data were geocoded using the EDRD Sonar Image Processing System (SIPS, Desandoli 1989).

For area A the system was set to provide a 150 m wide swath of data along the towfish track. Twelve nominally parallel tracks were made such that a 500 m wide 4 km long area was completely covered with at least two "looks" at each object. The tracks provided for sufficient overlap such that the poorly imaged area directly along the towfish track was imaged on an adjacent track. The geocoded data were co-registered and mosaiced. Two mosaics were constructed, one with east looking beams and the other with west looking beams. The absolute positional accuracy in the resultant mosaics is ±10 m. The relative positional accuracy is estimated at ~2% of separation or ~0.6 m, whichever is greater. The pixel size in the mosaic is 0.2 m, although the nominal resolution of the data, is closer to 0.4 m. Figure 1 shows a typical excerpt from the mosaic. The largest object in this scene is a 5.5 m diameter boulder.

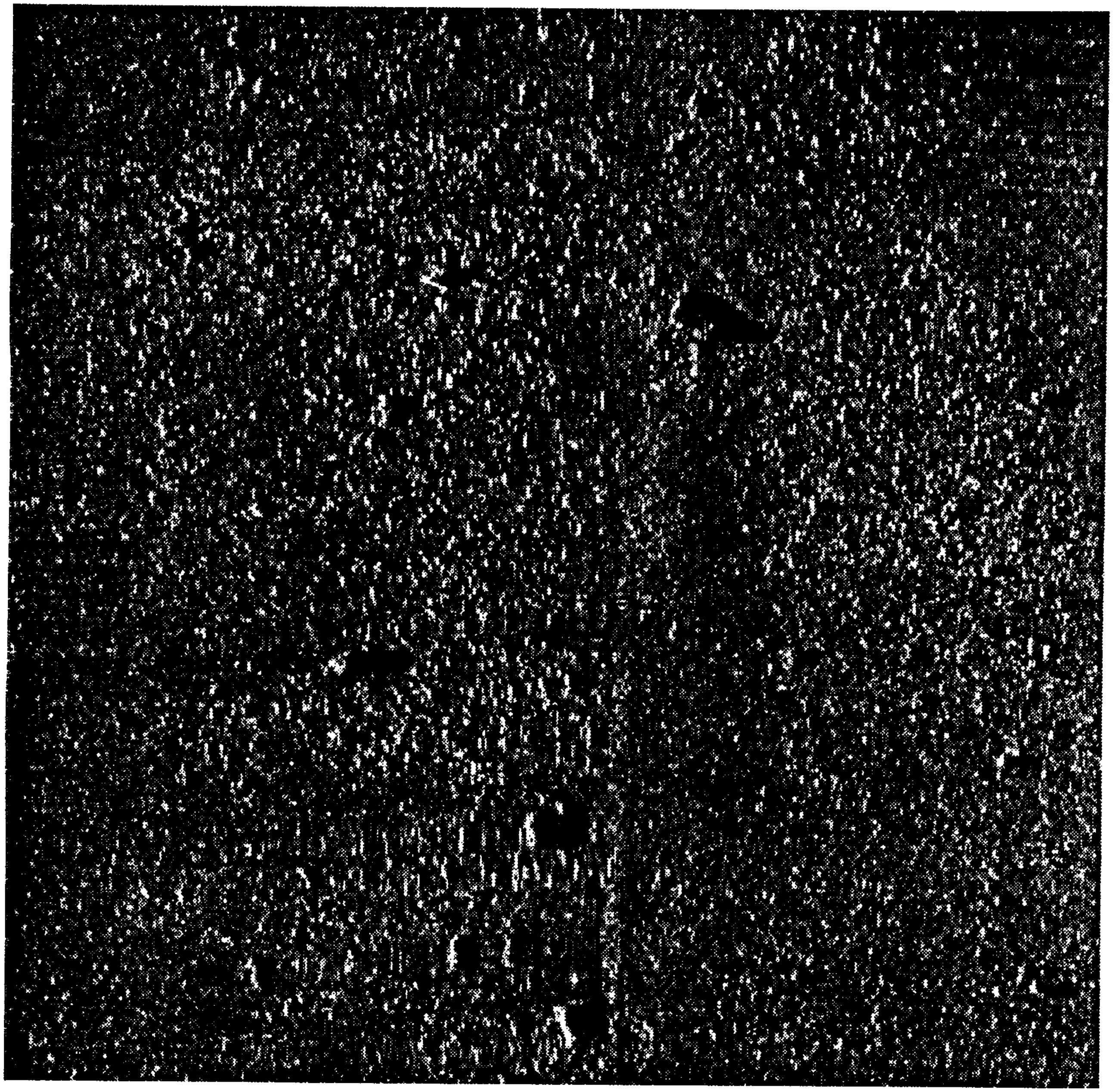

Figure 1. A 100 X 100 m extract from the mosaic of area A. The figure includes data from three overlapping passes with all the object shadows (dark areas) to the right.

For area B the system was set to provide a 200 m wide swath. The data consist of approximately 56 km of linear track covering ~10 km^2. Note that the coverage estimate makes allowance for the poorly imaged area directly beneath the towfish, by neglecting it and reducing the corresponding coverage. The absolute positional accuracy is ±15 m while the relative accuracy is comparable to that in area A.

3. OBJECTS

The seabed image data, the area A mosaic and all 56 km of the linear survey of area B, were scanned visually and the location and size of every object between 0.4 m to 30 m diameter were noted. For area A this portion of the work was carried out under contract (Barrodale 1994) as part of an investigation into real time object identification. To count the objects, small portions of a geocoded image (100 X 100 m) were displayed to an operator. The operator selected objects by positioning a cursor at the extreme ends of each object's highlight (area of elevated backscatter) or shadow (area with no backscatter). The average of the two cursor positions indicated the location of the object. The difference between cursor positions gave the size of the object. The shape of an object was not considered and only the longest linear dimension was measured. In the case of objects that had a highlight and a shadow, only the highlight size was considered. Most of the surveyed area has a seabed which exhibits moderate backscatter with almost no texture and object shadows are easily detected.

All "recognizable" objects were counted. That is, if a feature was recognizable to the operator it was counted, regardless of shape, size, brightness, and thus the count is somewhat subjective, especially for the smaller or fainter objects. A total of 23000 objects, the largest being 7 m in size, were identified in the "east-beam" mosaic of area A! A total of 1100 objects were counted in area B. Small portions of the mosaic were examined by several operators, and also by the same operator several weeks apart. There was considerable variation in the number and location of small objects as determined by these operators. Consistency was achieved with objects spanning at least 6 pixels, or about 1.2 m in size, or larger. This suggests that the detection probability for small objects, <1.2 m in size, is < 1.

In order to better understand the consistency problem, a small portion of the mosaic, 100 X 100 m, was examined in greater detail. Three independent images of this area were analyzed and compared. An object size distribution was determined by combining the counts from all three images with objects common to two or more images counted only once. The object size distribution from this analysis as well as for the mosaic and the linear survey are shown in Figure 2.

Assuming that the error in object size determination, discussed below, does not seriously affect the overall distribution, it is possible to determine the "detection probability" of objects of a given size. It can be shown that the cumulative detection probability is given by

$$P_n = 1 - (1 - p)^n \quad ,$$

where n is the number of times an area has been surveyed and p is the single pass detection probability. It is possible to estimate p by comparing the object size distribution of the mosaic (equivalent to a single pass) to the data from the 100X 100 m area, where 3 passes are involved. The number of unique objects detected is given by

$$N_1(s) = N_T(s)\, P_1(s) \qquad ,$$

$$N_3(s) = N_T(s)\, P_3(s) \qquad ,$$

where $N_T(s)$ is the total number of objects of size s, $N_1(s)$ is the number of objects of size s detected during one pass over an area and $N_3(s)$ is the number of unique objects of size s detected after three passes over an area. Thus, the detection probability for objects of size s is given by

$$p(s) = 1.5 - \sqrt{2.25 + N_3/N_1 - 3} \qquad .$$

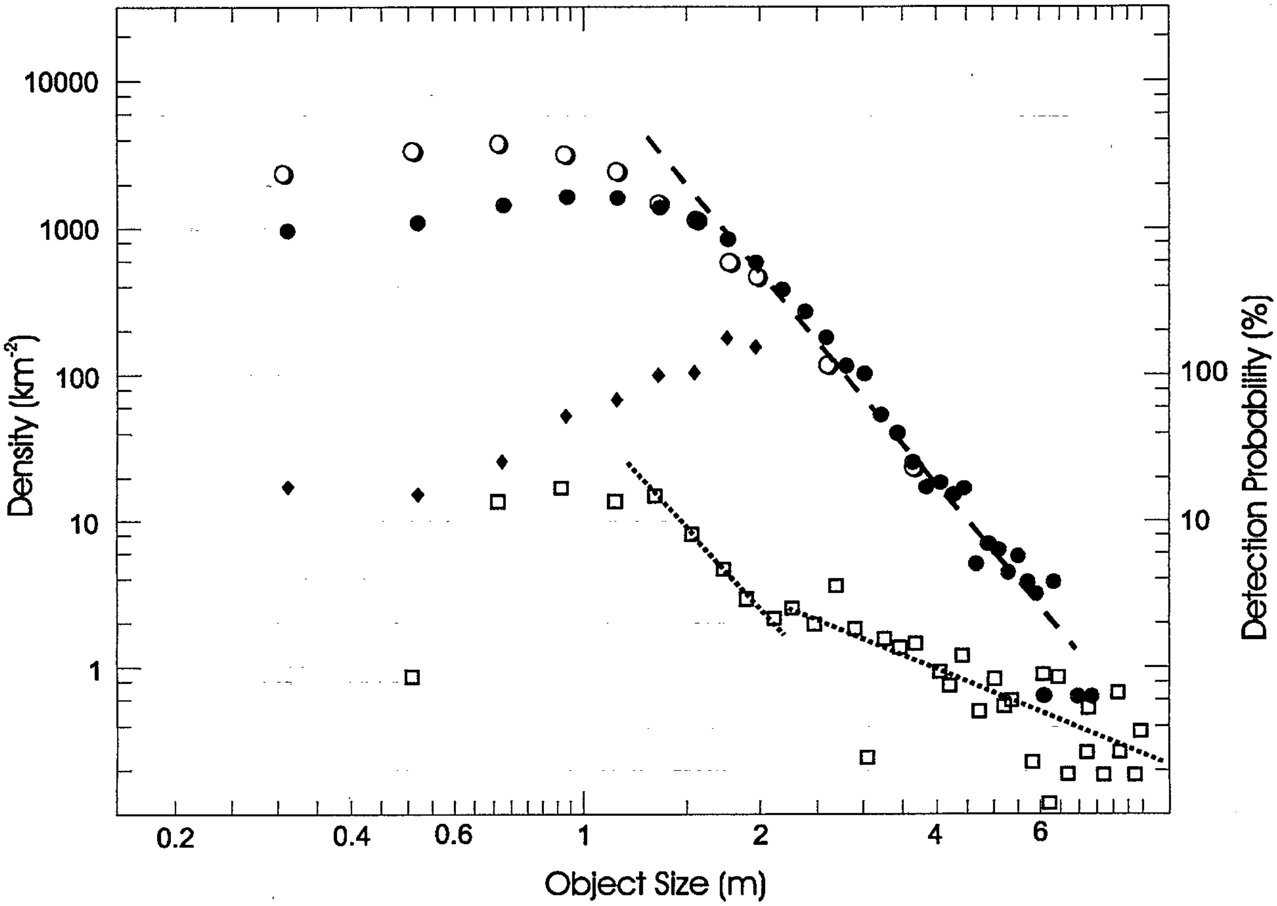

Figure 2. Object size distribution. The filled circles (●) show the object size distribution for the entire mosaic of area A (2 km^2) while the open circles (○) show the distribution of the 100 X 100 m area based on cumulative data from three images. The diamonds (◆) denote the estimated detection probability.. The open squares (□) show the distribution for area B. The dashed and dotted lines indicate the linear fits.

Figure 2 shows the single pass detection probability as a function of object size. It should be noted that this is only a measure of the consistency of the technique used to detect objects in the mosaic. There is no independent measure of the actual number of small objects in the area and therefore it is not possible to determine the actual detection probability and false alarm rate of the system as a whole (the "system" in this case consists of the sonar, navigation systems and all the subsequent processing). Given the performance of the system on a test area where 15 known objects, 1 to 2 m in size, have been imaged numerous times on several sea trials, and from the analysis of the data in Figure 2, it is safe to assume that the detection probability for objects of size >1 m is 100%.

The distribution of objects in the mosaic, between 1.3 and 7 m, appears linear in the log-log plot shown in Figure 2. A least squares linear fit to the data (shown in the figure) between these limits indicates that the distribution of object sizes is given by

$$N(s) = A\, s^{-4.7}$$

where N is the number objects of a given size, s, in meters, and A is a scaling factor. In the mosaic A = 15000.

The object size distribution appears to be bi-modal in area B. A linear fit to the overall data, 1.3 to 10 m, gives an index of -1.8, while linear fits to the 1.3 to 2.3 m and 2.3 to 10 m size ranges give indices of -4.5 and -1.6, respectively. The size distribution for the smaller objects is very close to that found in area A. The cause of this bi-modal distribution is the presence of logs on the seabed in the area B. Logs are easy to identify in that they are long and narrow. All the large objects in area A appear to be spherical and not cylindrical in appearance (based on the shadow outlines).

The size of an object in a sonar image depends a great deal on the accuracy to which the initial time-based data can be converted into spatial data and on aspect angle. An asymmetrical object, for example a cylinder, could present a beam-on aspect or an end-on aspect, and the size ascribed to the object might be quite different. In the case of boulders, which tend to be rounded and not elongated, aspect is not a critical factor.

To convert the sonar data from a time-based regime to a spatial regime requires a knowledge of the sound speed and the position and attitude of the sonar. The data in this case were all geocoded prior to analysis for objects. The geocoding process resamples the raw sonar image data and converts it into a spatial format. The consistency of the geocoded image depends on the accuracy of the position and attitude data (Preston and Poeckert 1993). This process is helped significantly if the towfish is itself stable and not prone to wild gyrations or accelerations.

The test area mentioned above has in it 6 upright cylinders and 9 horizontal cylinders of a known size and aspect, and has been imaged numerous times since 1988. The data from this area can be used to assess the accuracy of the size estimates. Over 100 individual size estimates were made using geocoded data from over 20 images. The difference between estimated size and true size is 0.3±0.2 m. The system tends to consistently overestimate size.

Also, the area A mosaic area has significant and variable currents (~4 knots) and towfish stability was significantly worse than for the area B survey and the test area. This has a deleterious effect on the estimation of sizes of objects in the images. A comparison of images derived from data obtained several hours apart suggest that the size error is likely twice that estimated from the data from the test area, or about ±0.4 m. Again, there is no independent measure of any of the objects in the mosaiced area, so this is only an estimate of consistency.

4. MINE DETECTION

Detecting a mine in a very cluttered area is difficult unless some way is found to virtually eliminate the false alarms, i.e. rocks or logs that are deemed to be mines. If one assumes that each mine-like object (MLO) will have to be prosecuted, a diver or submersible investigates the object and identifies it as either a mine or a non-mine, then the length of time require to clear a square kilometer can be estimated by

$$T_C = T_P\, N\, P_{fa} + T_m$$

where T_C is the time in hours required to clear the area, T_P is the time required to prosecute one MLO, N is the number of mine-sized objects, P_{fa} is the probability of false alarm and T_m is the time required to map the area (detect and classify all mine-sized objects).

The Maritime Coastal Defence Vessel (MCDV) will have the capability of mapping the seabed at a rate of 2 km^2/hr. A remote mine hunting system being developed for the Canadian Forces (CF) will have comparable capability. Assuming that mine sized objects can be detected and classified in real time, $T_m = 0.5$ hr. The prosecution time, T_P, can be optimistically estimated at 0.5 hours. This is typical of a very efficient deployment of a submersible. In the region studied in this report, the density of objects between one and two meters is 4785 km^{-2}. Thus

$$T_C = 2393\, P_{fa} + 0.5 \quad \text{(hours)}$$

If we require the region to be cleared at a rate of 1 km^2/day, then $P_{fa} \approx 0.01$. For an MCDV type system the equivalent false alarm rate would be, $R_{fa} \approx 50$/hr.

Systems that depend on an object's characteristics, beyond its size, to determine whether an object is an MLO or a non-mine-like object (NOn Mine Bottom Object, NOMBO) are unlikely to achieve this level of performance. Route survey offers the possibility of reducing the P_{fa} to the levels required (cf. Preston 1992). In route-survey assisted mine hunting, maps of the seabed are used to locate all naturally occurring mine-sized objects. Any new mine-sized objects found during mine hunting are considered MLOs, regardless of other characteristics. The Real Time Control Point Matching (RTCPM) program (Barrodale 1994) uses a pattern matching technique to detect new objects by comparing archival data with new data. Tests of the RTCPM program using object data from the region under discussion, limited to object sizes > 1 m (so that the detection probability is at or near 1), have resulted in $P_{fa} \sim 0.03$. The higher quality data that the MCDV system is likely to produce, both in terms of navigation error and resolution, should reduce the P_{fa} even further.

Given that there will be errors in the object size determination, a route survey assisted mine hunting system will have to consider objects that are somewhat smaller than the anticipated lower limit to mine size. For example, assume that only objects between 1 and 2 m in size are of interest, and the size estimation error for both the "new" and archival data sets is 0.2 m. Then the system should at least include as possible mines all objects between 0.8 and 2.2 m in size (the upper and lower bounds $\pm 1\sigma$). Now consider a 0.8 m "new" object which is to be matched to archival objects. Since the archival data set also has a size estimation error, archival objects <0.8 m in size must be considered as possible matches. It can be shown that the archival data set must include objects between 0.7 and 2.3 m, if the size error in the two data sets is comparable.

The ratio of archived objects to sensed objects in a route survey mine hunting system is given by

$$K = \frac{\int_{L-\sqrt{2}\sigma}^{U+\sqrt{2}\sigma} S^{-4.7}\,dS}{\int_{L-\sigma}^{U+\sigma} S^{-4.7}\,dS} = \frac{(L-\sqrt{2}\sigma)^{-3.7} - (U+\sqrt{2}\sigma)^{-3.7}}{(L-\sigma)^{-3.7} - (U+\sigma)^{-3.7}}$$

where S is the object size, L is the lower size limit, U is the upper size limit and σ is the size estimation error. It is assumed that both the archived and sensed data sets have the same size estimation error. If U>>L, then the terms involving U can be ignored and the ratio becomes

$$K \cong \left(\frac{L-\sqrt{2}\sigma}{L-\sigma}\right)^{-3.7} = \left(\frac{1-\sqrt{2}\beta}{1-\beta}\right)^{-3.7}$$

where $\beta = \sigma/L$.

Similarly it can be shown that, for a given lower limit to the mine size, the increase in the number of sensed objects required to account for the error in size estimation is given by

$$M \cong (1-\beta)^{-3.7}$$

Figure 3 shows the values of M and K for a reasonable range in β.

The consequences of this are that for typical values, L = 1 m and $\sigma = 0.2$ m, K = 1.5. In this case the archive object data set will have to contain 50% more objects than the sensed object data set.. The probability that a new object is associated with an archive object increases with an increase in archived objects and this can lead to missed mines. It is therefore important to have a seabed imaging system that has accurate size estimation. This in turn requires good relative navigational accuracy.

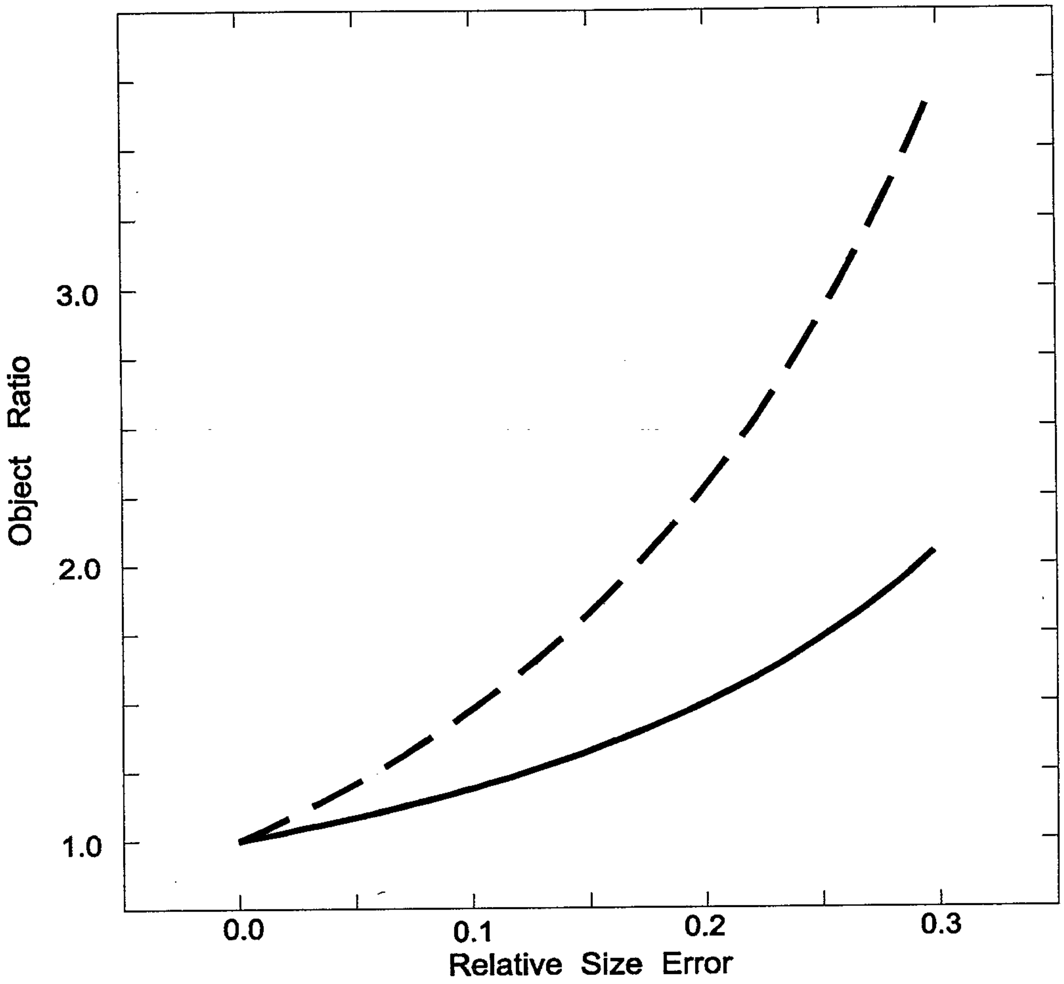

Figure 3. The relative increase in the number of sensed objects needed, M (solid line) and the ratio between sensed and archive objects needed, K (dashed line) to accommodate a given size estimation error.

5. Conclusions

It has been shown that the size distribution of objects in a boulder field follows a relatively steep power law distribution. The consequence of this for a route survey/mine hunting system is that an error in object size estimation requires the number of objects in an archive data set to be significantly larger than would be the case without size errors. For example, assume that objects ≥1 m in size are considered mine sized and that the system has a 10% error in size estimation, which in the case of the MCDV system is equivalent to a ~1 pixel error. To accommodate the size error the number of objects that must be included as mine-sized is 40% larger in the sensed (new) data and 67% larger in the archived data, than would be the case with no size error.

With current technology it is possible to do object matching in real-time in areas with mine-sized clutter up several thousand objects per km^2. The effect of size error is that there are a large number of smaller-than-mine-sized objects in the database which could be associated with a new object (a potential threat). Consequently the utility of an object database is diminished in that it cannot be used safely in very cluttered areas. Such areas will have to be examined carefully using an image comparison approach. It is unlikely that this can be done by an operator in real-time.

The size distribution of boulders has the same power law distribution in at least two separate geographical areas. Since virtually all Canadian waters were once covered by glaciers this distribution may be a common one. The presence of other sources of mine sized objects, such as logs, can alter the distribution significantly.

6. REFERENCES

Barrodale, I., 1994, “Real Time Control Point Matching Program”, DREP Contractor's Report 94-150

Desandoli, M., and Taylor, J., 1989, "Sonar Image Processing System II, High Level Design, Functional Specifications", MacDonald Dettwiler and Associates, Contractor's Report (limited circulation).

Preston, J.M., 1992, “An Application of the Minefield Clearance Simulation Model: Benefits of Route-Survey Databases in Minehunting”, DREP Technical Memorandum 92-51.

Preston, J.M., and Poeckert, R.H., 1993, “Distortion and Break-up of Sidescan Images - Criteria and Reconstruction by Geocoding“, Proceedings Oceans’93, Vol. I, pp 371-377.

Poeckert, R.H., 1991, "An Algorithm for Estimating Towfish Position", DREP Technical Memorandum 91-12.

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

Esquimalt Defence Research Detachment
Defence Research Establishment Atlantic

2. SECURITY CLASSIFICATION (Overall security of the document including special warning terms if applicable.)

Unclassified

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

Seabed Object Size Distribution

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

POECKERT Roland H.

5. DATE OF PUBLICATION (Month and year of publication of document.)

February 1997

6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)

15

6b. NO. OF REFS. (Total cited in document.)

5

6. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

DREA Technical Memorandum

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the reseach and development. include the address.)

Defence Research Establishment Atlantic
P.O. Box 1012, Dartmouth, N.S. B2Y 3Z7.

9a. PROJECT OR GRANT NUMBER (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

1da

9b. CONTRACT NUMBER (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number mrst be unique to this document.)

DREA Technical Memorandum 97/214

10b. OTHER DOCUMENT NUMBERS (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; futher distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic annoucement of this document. This will normally correspond to the Document Availability (11). However, where futher distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

Unlimited

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

DCDO3 2/06/87

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

A 2 km^2 area of seabed in Juan de Fuca Strait was surveyed in 1993 with a Mesotech 972 sidescan sonar. The area has significant mine-sized clutter, rocks and boulders up to several meters across. The sonar data were geocoded and mosaiced into one geographically correct image. The mosaic was scanned for objects greater than 0.5 m in diameter. This report presents an analysis of the size distribution of objects in this area and the implications for mine detection in cluttered seabeds.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title).

Sidescan Sonar, Seabed Images, Mine-sized Objects