PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

A DESCRIPTION OF A SIMULATION PROGRAM FOR NORWEGIAN FISHERIES WITH SPECIAL EMPHASIS ON WEATHER SIMULATION.

Emil Aall Dahle, res. eng., lic. techn. and Henrik Schaathun, ass. res. eng., 3F-research project, The Technical University of Norway, Trondheim.

CONTENTS

1. SUMMARY.

It is customary to construct a mathematical or a physical model of a construction in order to study its behaviour under various conditions.

In this paper some technological aspects regarding the construction of a mathematical model of a fishing vessel in its natural environment is discussed. The model consists partly of analytical descriptions regarding the vessel, and partly of stochastic descriptions of the environment.

The economic part of the model is developed at the 3F-research project at The Fishery Directorate in Bergen, and will not be dealt with here. At the present the model is used for studies on long-lining in Arctic waters. A flow diagram of the simulation computer program is presented in Appendix 1 at the end of the paper.

2. INTRODUCTION.

One of the main objectives of the 3F-research project at The Technical University of Norway, is to undertake a technical and economical study of the operation of Norwegian fishing vessels in the length range 30' - 150'.

As a tool in this work it was decided to develop a simulation program, based on the computer language SIMULA, which has been developed at The Norwegian Computer Centre in Oslo. The use of simulation programs is not new in the fishing industry. A model of the Polish "Atlantic" trawler has been tested in a program. For several other countries some reports of simulation studies are listed at the end of the paper (Ref. 1, 2, 3, 4 and 5). The list does not pretend to be extensive.

3. ENVIRONMENT STUDY.

During the construction of a realistic model one must pass several steps. The first and most important is to undertake a study on the subjects, as stated in Table 1, page 3 and Table 2, page 4.

The environment study as indicated in Table 1 may be simplified by using published, historical data and statistics.

For the long-lining in Arctic waters, however, statistics for each individual vessel was not published. However, two skippers had made exact notes for several years. These data were analyzed at the 3F-research project, resulting in frequency distributions. An example is shown in fig. 1, page 5.

ENVIRONMENT STUDY

Fishing grounds	Fishing ports	Weather
- Location and extension - Catch statistics for relevant fish types for each relevant fishing gear for every month of the year	- Location - Limitations imposed on vessels (draft, type etc.) - Unloading speed for various vessels - Fuelling speed - Maximum acceptable vessel queue inside the harbour - Arrival frequency of various vessel types	- Location - Statistics for wave height and main direction of waves for every month of the year

Table 1.

Also shown in fig. 1 is the two-parameter Gauss- and the Erlang (Gamma) - distribution, with the same mean and variance as the empirical distribution. Also the one-parameter Rayleigh distribution is shown. In the specific case shown in fig. 1, the Chi-square test did not indicate acceptable accordance between the theoretical and the empirical distribution, although this was not a general rule. The Erlang distribution gave the closest fit.

One must always use common sense regarding the "tails" of theoretical distributions when applying such to physical situations. In the case of long-lining for inst., a theoretical catch giving more than one large fish on each hook is noncence.

The next crucial point is to arrive at fishing statistics for the future. It is probably wise to construct sets of statistics, and use those in a sensitive analysis. Before drawing conclusions the statistics used should be compared with biological prognoses. The 3F-research project is following closely the work in this field.

In order to limit the amount of data, the Erlang distribution is presently used for representing catch rates. A sensivity analysis as indicated above is then

VESSEL AND FISHING GEAR STUDY

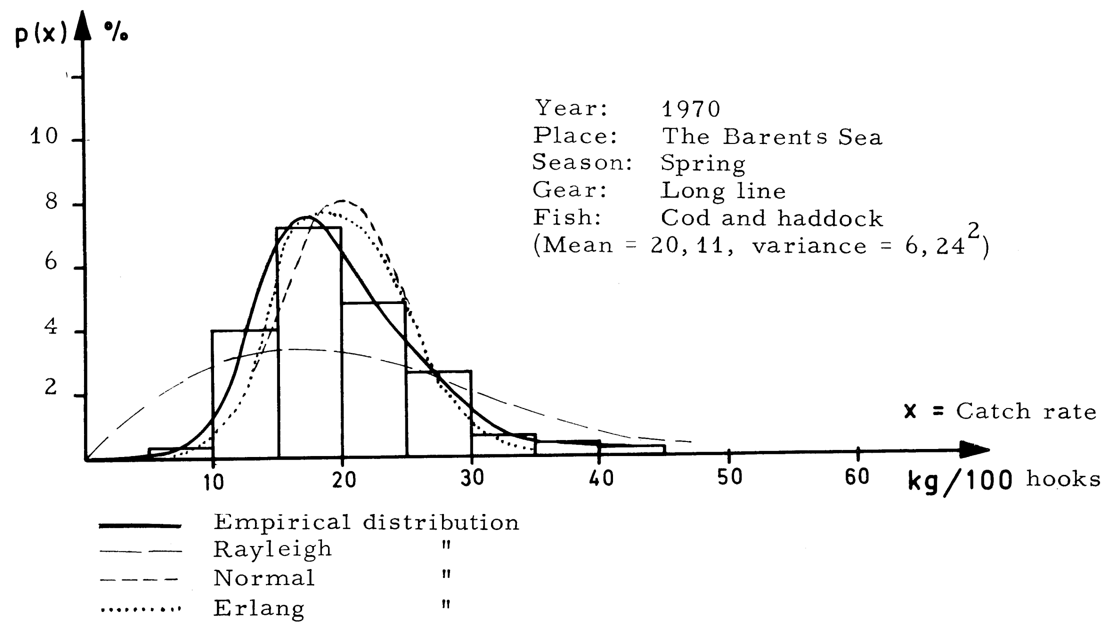
Technical parameters	Economical parameters	Decision parameters
<u>Vessel</u> - Geometrical data - Propulsive data including performance in bad weather - Fishing gear machinery data - Electronic searching instrument data - Fish handling machinery data - Data regarding overhaul and wear	<u>Vessel</u> - Initial cost of hull, machinery, electronic equipment and hydraulic equipment - Depreciation of above mentioned components - Costs associated with wear - Data for several costs not mentioned here	<u>Vessel</u> - Number of crew Rules for ; - Distribution of income and cost between owner and crew - Length of fishing cycle - actions taken due to weather - which fishing gear to use, - which fishing ground to exploit, - which fishing port to go to after each fishing cycle
<u>Gear</u> - Geometrical data - Hydrodynamical data - Other data for calculating fishing power	<u>Gear</u> - Initial cost - Depreciation - Costs associated with wear	<u>Gear</u> - Actions taken due to weather - effective fishing time pr. cycle (gives fishing effort)

Table 2.

easily carried out by changing the mean, the variance or both in some specified manner.

Concerning necessary data for the fishing ports (see Table 1) these have been obtained by interviews. Future data of fishing ports may be arrived at by studying long term plans and budgets. It must, however, be admitted that such material is often nonexistent.

Fig. 1. Frequency distribution of long-lining catch rate.



Of the environment data, only the weather statistics may be regarded as stationary. For smaller fishing vessels, the weather is of dominant importance. This is indicated in the list of decision parameters of Table 2.

The parameter under consideration, for inst. wave height, is drawn from the cumulative distribution in the following manner, called the Monte-Carlo method.

- A random number A between 0 and 100 is drawn from a uniform distribution. The A is set equal to F(x) %.

- The corresponding x is used as parameter in the simulation.

For a large number of drawings, the use of the Monte-Carlo method will supply a parameter sample with statistic properties corresponding to those of the distribution from which the cumulative distribution is evaluated. In the study the "weather" is defined by waves and wind.

4. DECISION PARAMETERS.

The various decisions taken onboard a fishing vessel have a very important impact on the economical result, as discussed by Chaplin and Haywood in Ref. 3. Some of the more important decisions are listed in Table 2, page 4.

The actions taken regarding handling of the fishing gear in relation to weather have been studied by Schaathun (Ref. 6) and for long-lining by Karlsen (Ref. 7). Some of Schaathun's results are presented in Table 3.

RANGE FOR USE OF VARIOUS FISHING GEARS
BASED ON SIGNIFICANT WAVE HEIGHT.

Gear type	$H_{1/3}$ (m)	
Long line	3,0 - 3,5	Very wave-sensitive
Tangling net	2,5 - 3,0	Medium "
Hand line	2,0 - 2,5	Not very "
Purse seine	1,5 - 2,0	Very "
Seine net	1,5 - 2,0	Very "

TABLE 3.

The handling of the vessel in rough weather varies widely. However, criteria for staying in the harbour have been studied as well as the engine rating usually used in rough weather. This latter subject is well covered in the literature for larger vessels, and is treated f. inst. by Gerritsma in Ref. 8. Several institutions have constructed computer programs for calculation of sea speed based on slamming and green water occurrence criteria.

The simulation computer program is constructed in such a manner that the important decision parameters can be spesified in the input. At the present the decisions are adjusted to correspond to those of an average skipper, although special studies on the impact of other decisions on the final economic result may be undertaken later.

5. DETERMINATION OF WAVE HEIGHT AND DIRECTION DISTRIBUTIONS.

In this study meteorological observations data from 15 lighthouses along the Norwegian coast have been analyzed. The data consist of visual sea state observations, instrumentally recorded wind force and direction, and sea surface air pressure. They have been taken 4 times daily over a period of 20 years from 1949 to 1968, and have been punched on cards by the Meteorological Institute of Norway. The statistical analysis of the data has been undertaken in co-operation with The Department of Port and Ocean Engineering of the Technical University of Norway.

The method used is based on the assumption, arrived at by visual judgement, that the wave height distribution can be closely approximated by the negative exponential distribution,

$$p(H) = \frac{1}{a} \exp\left(-\frac{H}{a}\right) \tag{1}$$

The cumulative distribution of (1) is

$$P(H) = 1 - \exp\left(-\frac{H}{a}\right) \tag{2}$$

where "a" is estimated by

$$a = \frac{\Sigma H}{N} \tag{3}$$

and where N = number of observations
H = wave height
a = estimated mean wave height.

In similar studies, it has been common to evaluate the cumulative distribution by means of plotting the wave height versus the number of exceedences on semi-logaritmic paper and then to draw the best straight line through the data points. It seems, however, logical to state a priori that the wave height follows an exponential distribution and calculate the estimator for "a" directly from the data. If a statistical test gives acceptable confidence limits, a method as described seems to be preferable for use of the statistic with short-term aspects as in this case. Long-term aspects (study of extreme) is a scientific field for itself, and is usually not taken into account in a simulation study of the kind described in this paper.

The Chi-square test has been carried out on a uniform sample, each of 100 observations from 3 different populations. Using the criterion of Bevington (Ref. 9, page 190) and estimating "a" from the populations, the test gives acceptable results.

It should finally be mentioned that the estimator for "a" has been evaluated for each month of the year. The trend is quite similar for all stations.
The mean value "a" for May, June and July is in the range of 0,2 - 1,2 m,

whereas for December and January "a" is in the range of 0,77 - 2,10 m. A full report of the study is given by Schaathun in Ref. 10.

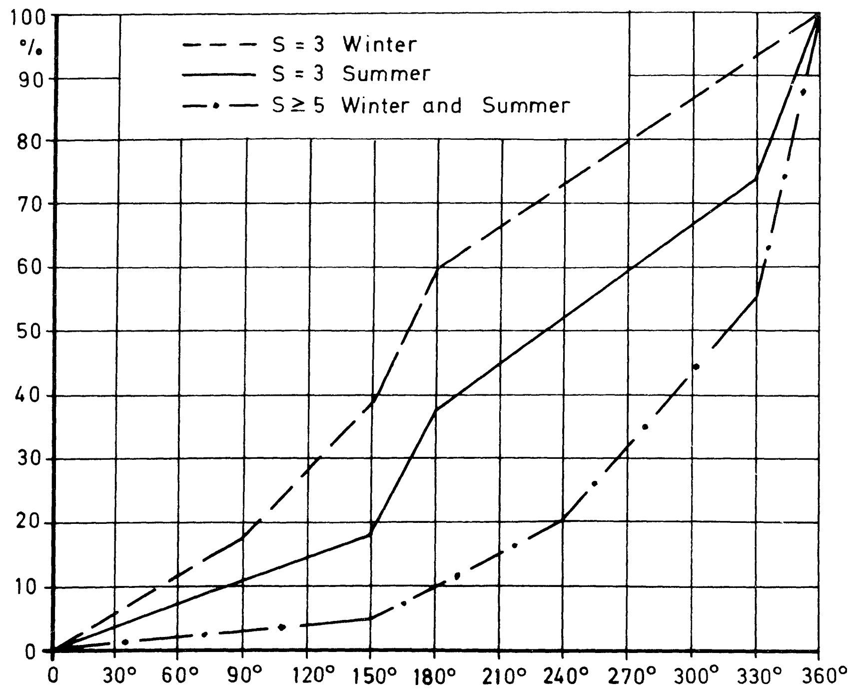
Wave direction is not observed at the lighthouses. As a crude estimate the observed wind direction is regarded as equal to the wave direction. The following five direction-distributions have been computed for each of the lighthouses:

- Summer distribution of sea state 3 (0,5 - 1,25 m)
- Winter " " 3 (0,5 - 1.25 m)
- Summer " " 4 (1,25 - 2,5 m)
- Winter " " 4 (1,25 - 2,5 m)
- Whole year distribution of sea state 5 and higher (over 2,5 m)

"Summer" is defined as 1st April to 30th September, whereas "winter" is the rest of the year.

It has not been considered to represent these cumulative distributions with theoretical distributions. Therefore, they are approximated by 4 straight lines as indicated in fig. 2.

Fig. 2 Direction distribution (cumulative) "UTSIRA LIGHTHOUSE".



Apart from criteria for use of the fishing gear as given in Table 3, page 6, and criteria for staying in the harbour or lying heave to the weather, the observed wave height is used for constructing wave spectra. The observers at the lighthouses are instructed to report the significant wave height, Ref. 12. The postulate that the observers have succeeded is accepted in this study.

The two-parameter spectrum recommended by ISSC in 1964, has been chosen among several others. The lacking parameter T_z is calculated according to Scott, Ref. 11.

$$T_z = 4.80 \, (H_{1/3})^{1/3} \tag{4}$$

with T_z = average zero crossing period (sec.)
$H_{1/3}$ = significant (= observed) wave height (m)

Then the spectrum used is expressed by

$$S(\omega) = \text{function of } (H_{1/3}, T_z) \tag{5}$$

where $S(\omega)$ = spectrum energy density as a function of frequency (ω) (m^2 sec. /rad.).

Transfer functions for added power in waves for various longitudinal weight distributions for a typical fishing vessel have been found experimentally at the 3F-research project. Using the linear super position principle, with the spectrum transformed to correspond to the actual speed and course, the speed in the actual weather is found through successive iteration using a special sub-program.

Other statistical parameters for the vessels' performance can also be found by using the super position principle provided that the corresponding transfer functions (waves/ship) are known.

The weather simulation as described is rather crude. One important reason for this is that the drawings of wave height is independent of the wave height the days before. A more sophistical weather model could be constructed by using Markov chains (Ref. 13). Nevertheless, using data for every month instead of one distribution for the whole year, is a substantial improvement.

6. CONCLUSIONS.

In order to arrive at a mathematical model it is necessary to simplify without over-simplifying. It is also necessary to use numerical values and not only theory. Consequently a model will remain a compromise. As such it could link the theoretical and the practical man and might in the future serve both as a tool for decisions.

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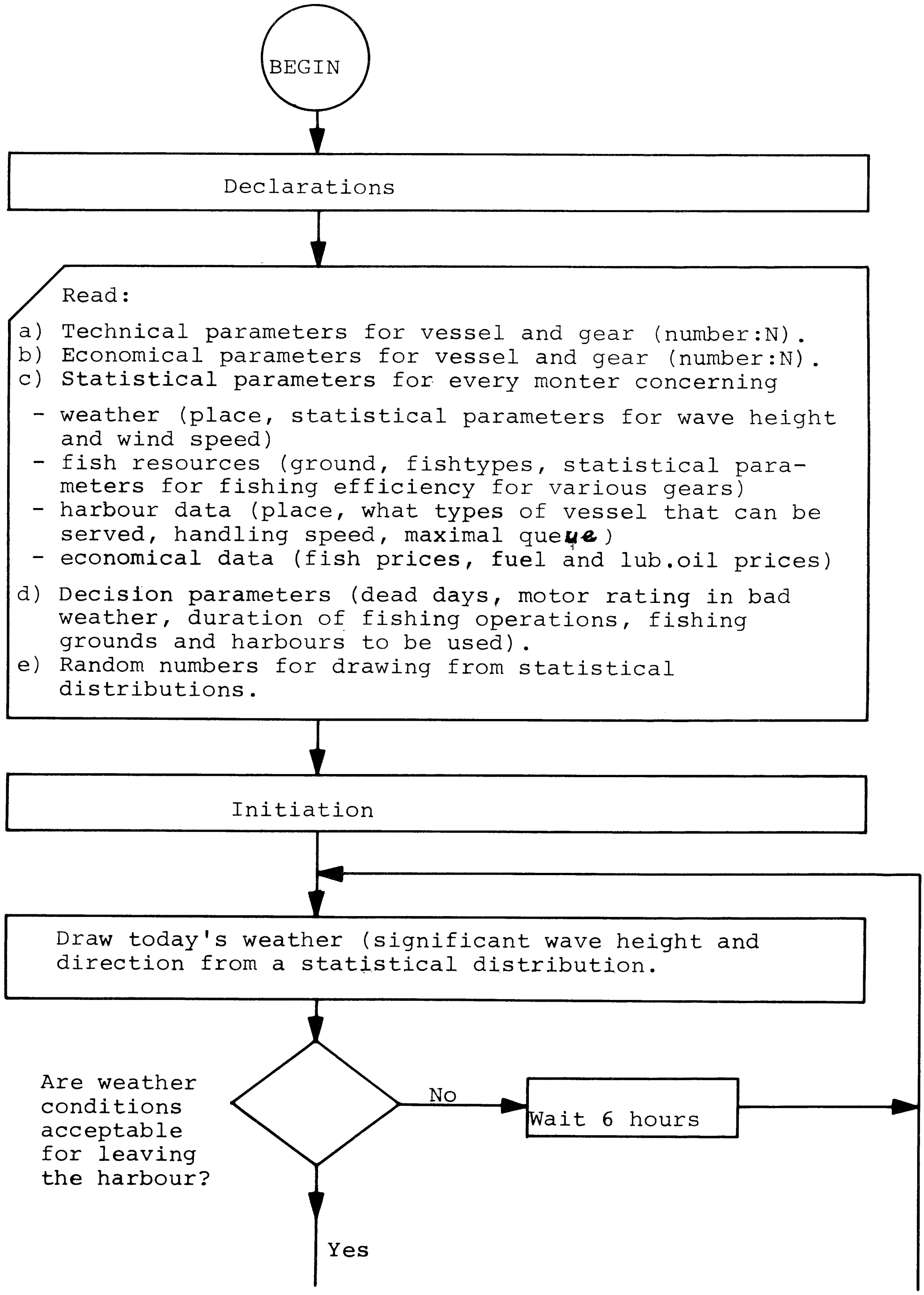
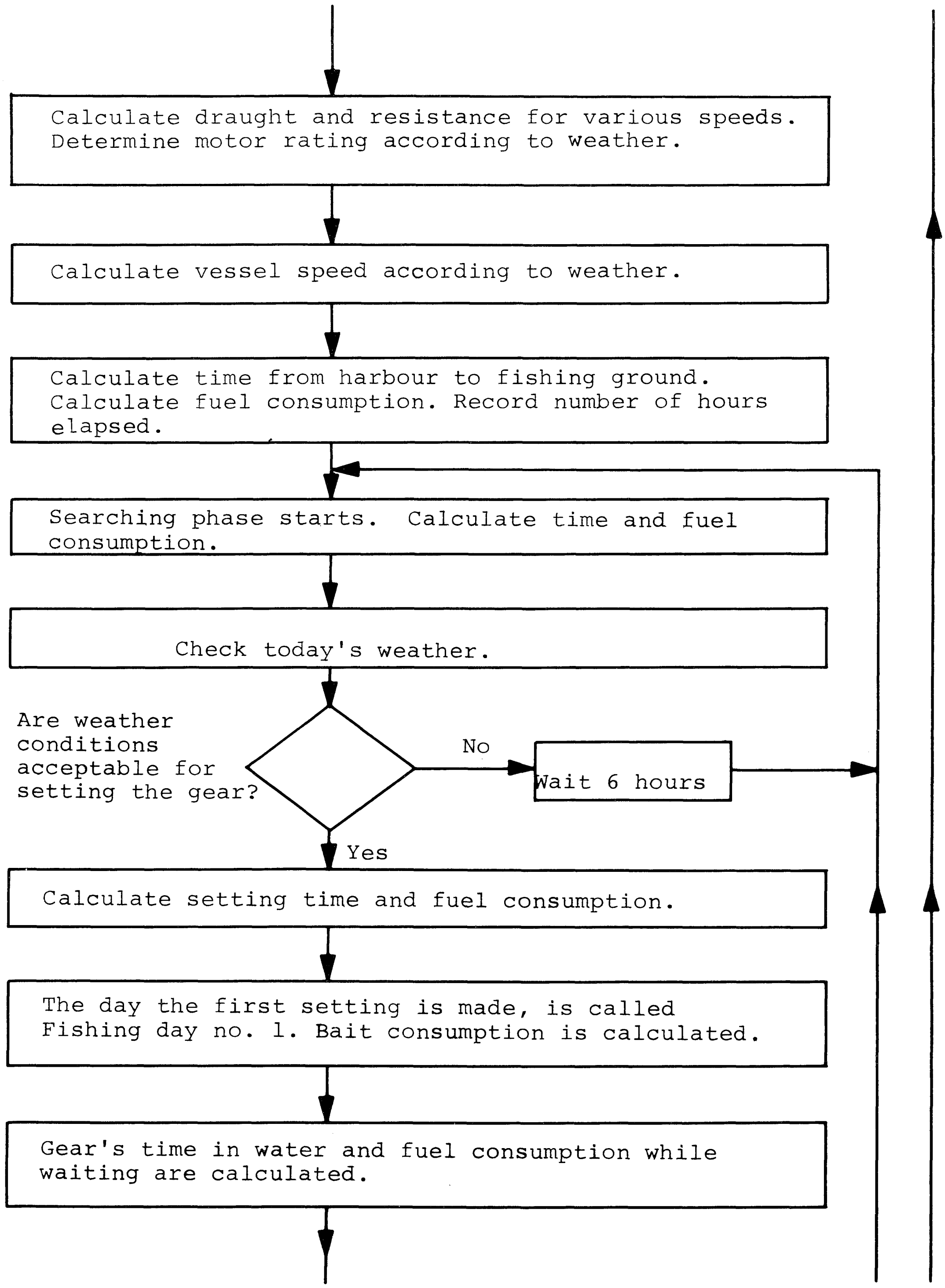
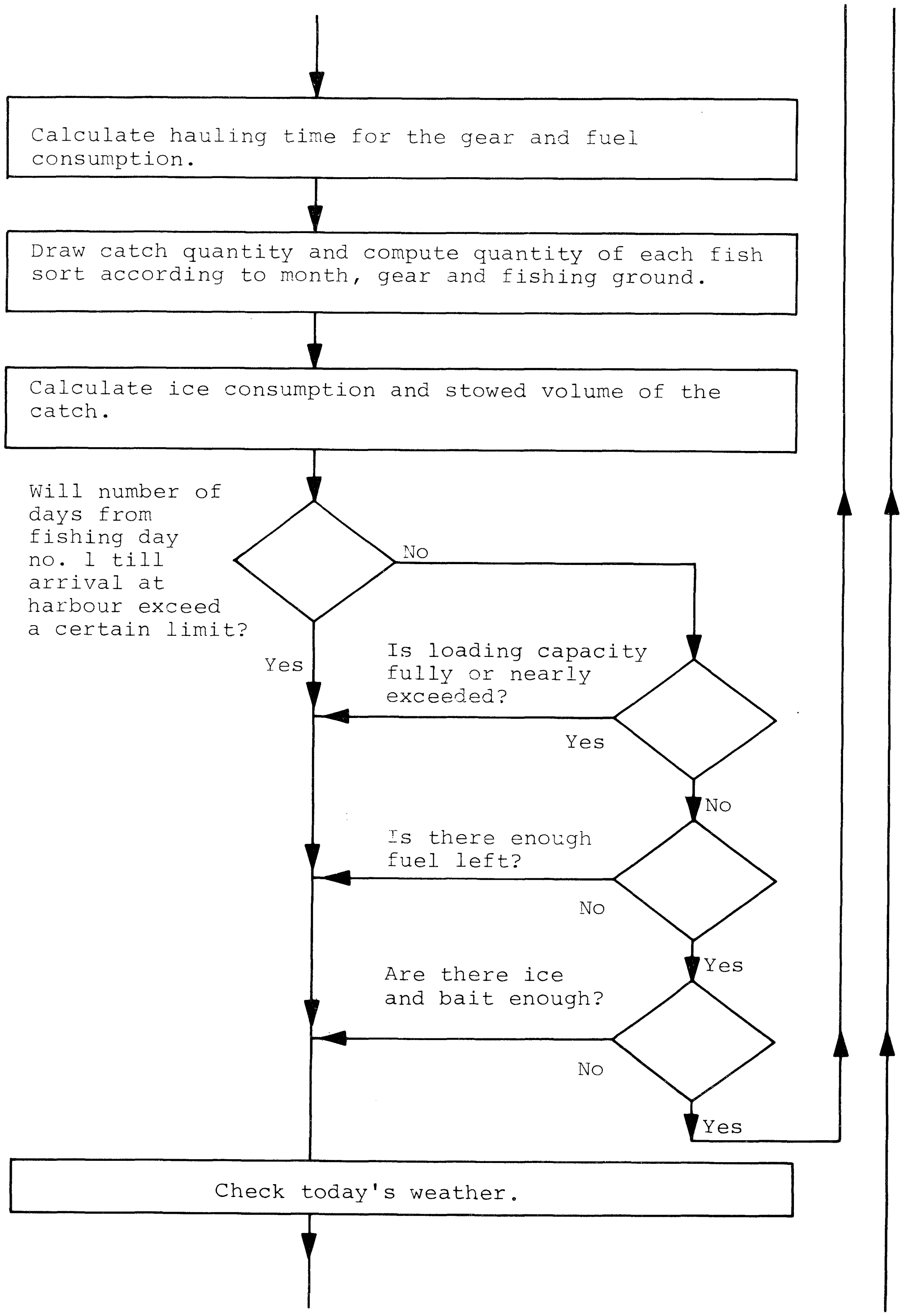
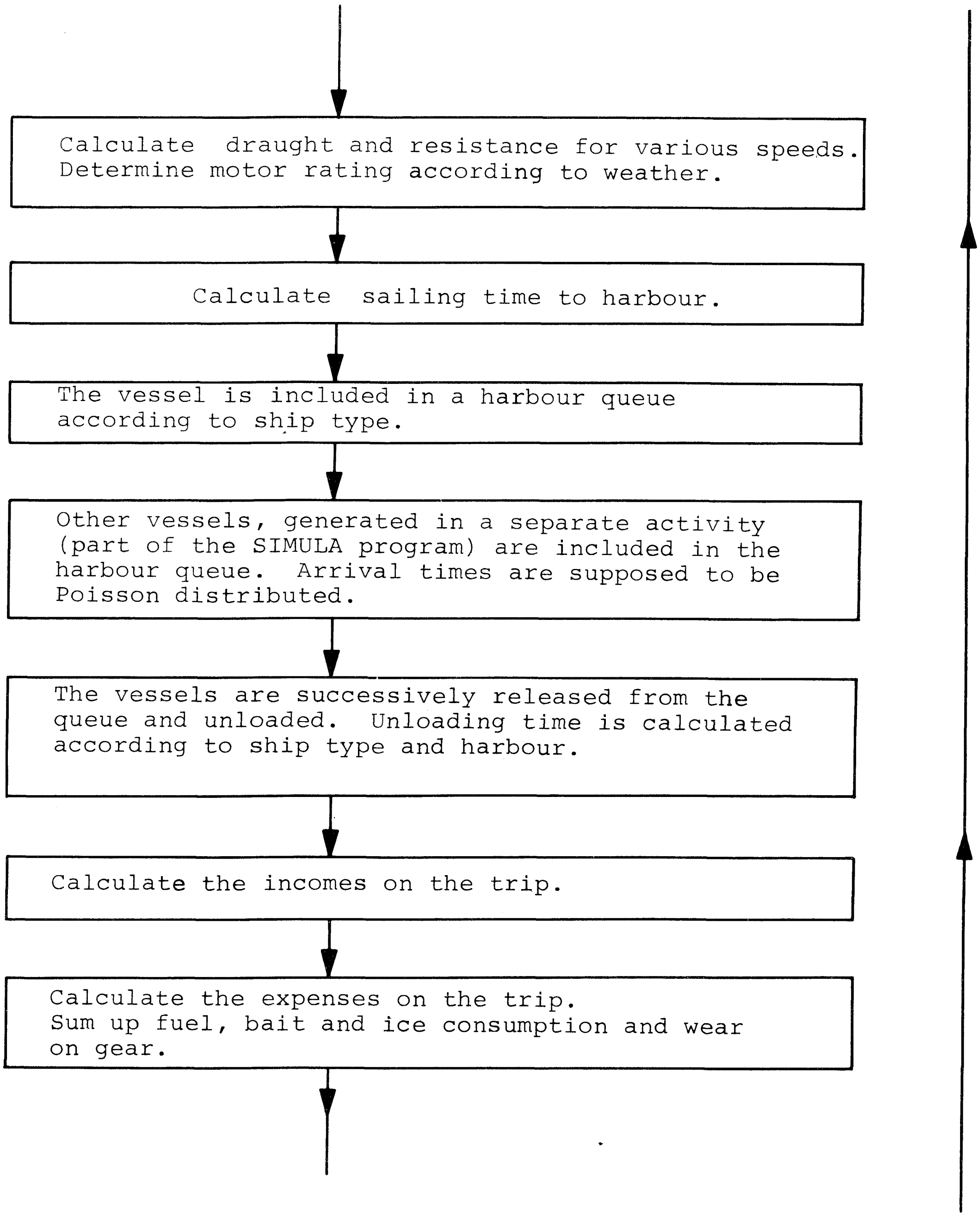
Appendix 1.

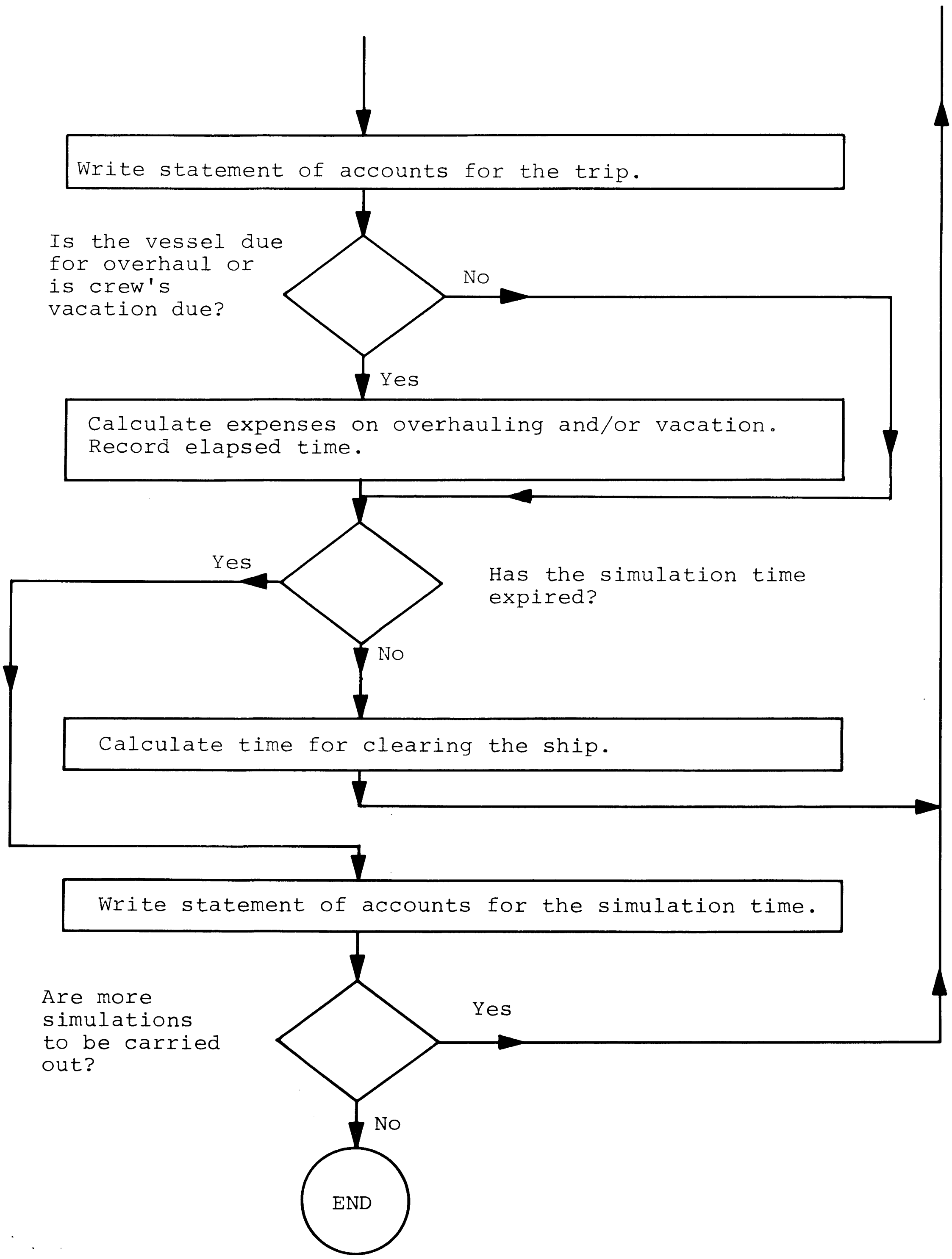
FLOW CHART




Calculate draught and resistance for various speeds. Determine motor rating according to weather.
Calculate vessel speed according to weather.
Calculate time from harbour to fishing ground. Calculate fuel consumption. Record number of hours elapsed.
Searching phase starts. Calculate time and fuel consumption.
Check today's weather.
Are weather conditions acceptable for setting the gear?
No
Wait 6 hours
Yes
Calculate setting time and fuel consumption.
The day the first setting is made, is called Fishing day no. 1. Bait consumption is calculated.
Gear's time in water and fuel consumption while waiting are calculated.


Calculate hauling time for the gear and fuel consumption.
Draw catch quantity and compute quantity of each fish sort according to month, gear and fishing ground.
Calculate ice consumption and stowed volume of the catch.
Will number of days from fishing day no. 1 till arrival at harbour exceed a certain limit?
No
Yes
Is loading capacity fully or nearly exceeded?
Yes
No
Is there enough fuel left?
No
Yes
Are there ice and bait enough?
No
Yes
Check today's weather.


Calculate draught and resistance for various speeds.
Determine motor rating according to weather.
Calculate sailing time to harbour.
The vessel is included in a harbour queue according to ship type.
Other vessels, generated in a separate activity (part of the SIMULA program) are included in the harbour queue. Arrival times are supposed to be Poisson distributed.
The vessels are successively released from the queue and unloaded. Unloading time is calculated according to ship type and harbour.
Calculate the incomes on the trip.
Calculate the expenses on the trip.
Sum up fuel, bait and ice consumption and wear on gear.


Write statement of accounts for the trip.
Is the vessel due for overhaul or is crew's vacation due?
No
Yes
Calculate expenses on overhauling and/or vacation. Record elapsed time.
Yes
Has the simulation time expired?
No
Calculate time for clearing the ship.
Write statement of accounts for the simulation time.
Are more simulations to be carried out?
Yes
No
END