COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 54

# THE ESTIMATION OF SURFACE CURRENTS FROM SHIPS' SET

By M. A. Greig

Marine Laboratory
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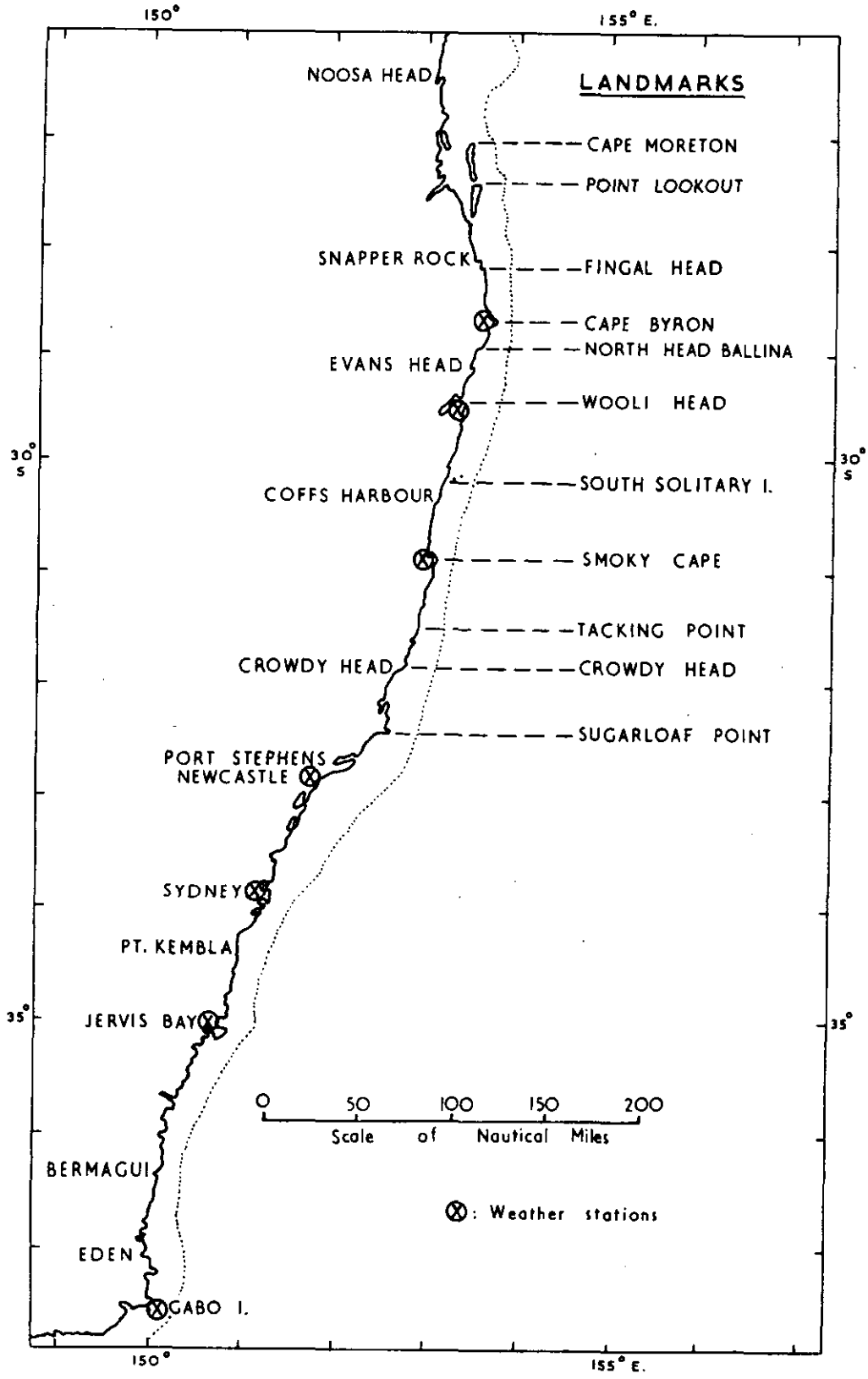


Fig. 1 Sketch showing the position of land marks between which currents were estimated.

# THE ESTIMATION OF SURFACE CURRENTS FROM SHIPS' SET

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## INTRODUCTION

During the course of a project designed to obtain the relationship between variation in sea level and current off the east coast of Australia, we used the normal navigational observations from merchant ships to compute the currents encountered by them during their passage between Cape Moreton off the Queensland coast, and Sugarloaf Point some 350 miles further south (Fig. 1).

This method of measuring ocean currents by comparing distance run by log readings with distance made good over the ground has been used for many years, the systematic collection and charting of the data having been started by Lt. Maury U.S.N. in the middle of the last century. However, most previous measurements have been derived from observations taken over a fairly long period, usually from noon to noon. In our work, the emphasis has been on monitoring currents over shorter distances and times.

The east coast of Australia between Cape Moreton and Sugarloaf Point was chosen for a number of important reasons, the chief of these being, the presence of the variable East Australian Current, the large number of ships making this passage, (some quite regularly) and the ease with which ships can fix their position precisely at any time in all but the most adverse weather conditions. In addition, it had already been demonstrated (Hamon & Kerr 1968) that this method could produce useful current measurements over this section of the coast.

This report sets out the technical details of the methods used to compute the currents, and includes details of data collection, editing, and smoothing. A paper giving the overall results of the project will be published separately.

## COLLECTION OF DATA

Companies operating ships along the selected section of the coast were asked to cooperate in the project by allowing their officers to provide navigational data. All companies asked indicated their willingness to help and ships' officers were asked to provide the following details:

CSIRO DIVISION OF FISHERIES AND OCEANOGRAPHY, CRONULLA. EAST AUSTRALIAN CURRENT PROJECT.

LOG TYPE _____
LOG MAKER _____

VESSEL MANOORA (Office use only: MANOORA48)

PAGE ___ OF ___ PAGES

Master B 1
Detail B 2

FROM ENDEAVOUR ON 030173 TO BRISBANE ON 100273

| DATE | | | SHIP TIME | | ZONE | LOG READING | ENGINE REVS. | OLD COURSE | NEW COURSE | OBSERVED LAND MARK (CODE) | L' MARK BEARING | LAND MARK DISTANCE | WIND | | SEA | SWELL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | MONTH | DAY | HOUR | MIN | | | | | | | | | DIRECT'N | FORCE | | |
| 73 | 01 | 09 | 09 | 12 | 1000 | 403.5 | | | 013 | STE | 293 | 13.4 | | | | |
| | | | 10 | 30 | | 425.9 | | 023 | 002 | SUG | 317 | 14.8 | | | | |
| | | | 12 | 00 | | 451.6 | | | | | | | 040 | 05 | 4 | 1 |
| | | | 12 | 15 | | 456.1 | | 002 | 034 | | | | | | | |
| | | | 13 | 04 | | 470.0 | | | | CRB | 304 | 1.8 | | | | |
| | | | 13 | 20 | | 474.8 | | 034 | 018 | | | | | | | |
| | | | 14 | 00 | | 485.6 | | 018 | 014 | | | | | | | |
| | | | 16 | 00 | | 519.5 | | | | | | | 040 | 04 | 3 | 1 |
| | | | 16 | 52 | | 534.0 | | 014 | 012 | SMB | 283 | 1.8 | | | | |
| | | | 19 | 40 | | 558.1 | | 012 | 021 | SSB | 282 | 1.0 | | | | |
| | | | 20 | 00 | | 568.7 | | | | | | | 030 | 02 | 3 | 1 |
| | | | 22 | 48 | | 603.1 | | 021 | 003 | | | | | | | |
| | | | 23 | 44 | | 617.7 | | 003 | 354 | | | | | | | |
| | | 10 | 00 | 44 | | 635.3 | | 354 | 019 | WBB | 262 | 2.3 | | | | |
| | | 09 | 24 | 00 | | 657.0 | | 019 | 018 | | | | | | | |
| | | 09 | 24 | 00 | | 657.0 | | | | | | | 310 | 02 | 3 | 1 |
| | | 10 | 00 | 30 | | | | 018 | 016 | | | | | | | |
| | | | 01 | 00 | | 675.5 | | 016 | 002 | NHB | 244 | 3.2 | | | | |
| | | | 04 | 50 | | 689.0 | | 002 | 160 | BYR | 272 | 1.4 | | | | |
| | | | 04 | 50 | | 706.4 | | 160 | 155 | | | | | | | |
| | | | 03 | 10 | | 719.6 | | | | FSW | 266 | 5.7 | | | | |
| | | | 00 | 10 | | 728.5 | | | | | | | 330 | 03 | 3 | 1 |
| | | 06 | 20 | 18 | | 772.1 | | 356 | 342 | LBB | 270 | 4.0 | | | | |
| | | 07 | 05 | 40 | | 792.7 | | | | MBR | 253 | 4.2 | | | | |

FO.23. 5/72

First Code Letter in this column please.

Fig. 2 Example of navigational data form completed by ships' officers.

(a) at each navigational fix:

- time of fix
- course
- distance and bearing of land mark from ship
- log reading at time of fix
- name of landmark in a code provided.

(b) at each change of watch:

- time
- log reading
- weather and sea state
- engine revolutions.

(c) at each alteration of course:

- time
- log reading
- old course
- new course.

The end-of-watch readings were used to provide a check on readings taken during each watch.

The above information was entered on printed forms which we supplied. These forms, when completed by ships' officers were collected from some 40 ships by our agent who visited each ship each time it called at Sydney. These visits, which also provided a valuable link between us and those who supplied the data, were instrumental in maintaining continued interest in the project.

An example of a data form, completed by ships officers, is shown in Figure 2.

## PROCESSING OF DATA

*Editing*

Before the data were punched onto cards for processing in the C.D.C. 6600 computer, the completed sheets were edited to the extent that voyages which could not be computed because too much information was missing were rejected. The usual reasons for rejection at this stage were the absence of log readings or the omission of major alterations of course. These rejections amounted to 7 per cent of the 750 voyage logs received during the period May 1971 to November 1972.

Also at this stage, fixes given on landmarks other than the eleven "Standard" landmarks shown in Figure 1 were, if necessary, replotted. A bearing and distance to the nearest standard landmark was then taken off the chart and used in the computer program.

| YR | MTH | DAYTIME | LAND MARK | BNG | DIST | LOG | LOG INTER | CRSE | REVS | WATER SPEED | CURRENT SPD. | CURRENT DRN. | CURR N | COMPS. E | ALONG TRACK | ACROSS TRACK | MILES DELN | BET. DELE | FIXES DELD | LOG DELD | TIME DIFF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 1 | 2 2242 | MOR | 256. | 4.8 | 3.5 | 3.1 | 166 | 111 | Ø.Ø | 1.8 | 213.9 | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.ØØ | A |
| 73 | 1 | 3 ØØ16 | LOO | 256. | 6.2 | 24.5 | 24.3 | | 111 | 13.4 | 2.2 | 175.1 | 2.2 | .2 | 2.1 | .3 | 23.8 | 5.4 | 24.4 | 21.Ø | 1.57 | 167. |
| 73 | 1 | 3 Ø325 | DAN | 276. | 16.Ø | 67.Ø | 66.9 | 18Ø | 111 | 13.5 | 1.8 | 178.2 | 1.8 | .1 | 1.8 | .4 | 47.Ø | 1Ø.5 | 48.1 | 42.5 | 3.15 | 167. |
| 73 | 1 | 3 Ø5ØØ | BYR | 27Ø. | 11.2 | 88.Ø | 88.1 | | 111 | 13.3 | 3.7 | 181.6 | 3.7 | -.1 | 3.7 | .1 | 26.8 | -.2 | 26.8 | 21.Ø | 1.58 | 18Ø. |
| 73 | 1 | 3 Ø512 | | | | 9Ø.5 | 9Ø.8 | 186 | 111 | 12.5 | 3.7 | 181.6 | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | 2.5 | Ø.ØØ | |
| 73 | 1 | 3 Ø554 | NHB | 276. | 13.3 | 99.3 | 1ØØ.1 | | 111 | 12.6 | 4.4 | 171.2 | 4.4 | .7 | 4.3 | -1.1 | 15.2 | -.3 | 15.2 | 8.8 | .9Ø | 181. |
| 73 | 1 | 3 Ø753 | WOO | 266. | 22.Ø | 126.7 | 126.4 | 197 | 111 | 13.8 | 1.9 | 184.2 | 1.9 | -.1 | 1.9 | -.1 | 31.1 | -3.1 | 31.2 | 27.4 | 1.98 | 186. |
| 73 | 1 | 3 113Ø | SSOL | 287. | 1Ø.6 | 174.6 | 174.4 | | 111 | 13.2 | 1.4 | 2Ø8.6 | 1.2 | -.7 | 1.4 | .3 | 5Ø.3 | -16.4 | 52.9 | 47.9 | 3.62 | 198. |
| 73 | 1 | 3 133Ø | | | | 2ØØ.6 | 2ØØ.7 | 188 | 112 | 13.Ø | 1.4 | 2Ø8.6 | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | 26.Ø | Ø.ØØ | |
| 73 | 1 | 3 1417 | SMO | 278. | 7.3 | 21Ø.7 | 211.Ø | | 112 | 12.9 | 2.7 | 2Ø6.2 | 2.4 | -1.2 | 2.5 | .8 | 41.6 | -12.3 | 43.4 | 1Ø.1 | 2.78 | 196. |
| 73 | 1 | 3 1618 | TAC | 278. | 1Ø.6 | 237.4 | 237.7 | | 112 | 13.2 | 3.5 | 185.2 | 3.5 | -.3 | 3.5 | -.2 | 33.6 | -4.4 | 33.8 | 26.7 | 2.Ø2 | 187. |
| 73 | 1 | 3 1734 | | | | 254.8 | 255.1 | 196 | 112 | 13.7 | 3.5 | 185.2 | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | 17.4 | Ø.ØØ | |
| 73 | 1 | 3 1753 | CRO | 286. | 16.8 | 259.3 | 259.4 | | 112 | 14.2 | 2.3 | 179.9 | 2.3 | .Ø | 2.2 | -.6 | 25.3 | -3.7 | 25.5 | 4.5 | 1.58 | 188. |
| 73 | 1 | 3 2ØØØ | SUG | 283. | 16.4 | 288.5 | 288.5 | | 112 | 13.8 | 3.5 | 2Ø2.8 | 3.3 | -1.4 | 3.5 | .4 | 35.Ø | -11.Ø | 36.6 | 29.2 | 2.12 | 197. |
| 73 | 1 | 3 2Ø12 | | | | 291.Ø | I | 255 | 112 | 12.5 | 3.5 | 2Ø2.8 | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | Ø.Ø | 2.5 | Ø.ØØ | |
| 73 | 1 | 3 222Ø | STE | 315. | 15.4 | 317.Ø* | 32Ø.5 | | 112 | 12.2 | 2.4 | 211.5 | 2.1 | -1.3 | 2.4 | -.6 | 25.6 | -22.Ø | 33.8 | 26.Ø | 2.33 | 221. |

MEAN CURRENT ALONG TRACK (WEIGHTED) = 2.52

Fig. 3 Printout of the first calculation of the currents encountered by one ship during one south bound voyage, together with the components of those currents and, for checking purposes the mileage between fixes and times of fixes.

Finally, each voyage was given a code number consisting of a part of the ship's name together with the sequence number of the voyage of that ship.

*Computation*

The initial calculation of current encountered by the ships was made using a program developed earlier for a similar project (Hamon & Kerr 1968).

This program first calculates the ship's true position (latitude and longitude) at each fix on a standard landmark. It then computes the ship's dead-reckoning (D.R.) position at the same instant using courses steered and distances run by log from the last true position. The difference between these two positions is, at this stage, attributed to the current encountered, currents towards the South and East being reckoned as positive. The current found in this manner is then further resolved into two components, along and across the ship's track. It is the "along-track" component with which we are concerned in this paper, although we hope to use the "across-track" components later.

The printout of this computation (Fig. 3) is used to detect errors, which show up at this stage as inconsistent water speeds, excessive currents, or large differences between course steered and course made good, the course made good being shown in the right hand column of Figure 3. Large differences between these two courses also show up as large east-west or across-track components.

Another check on the data is provided in column 9 headed "LOG INTER". This column contains a calculated log reading obtained by interpolation between adjacent change of watch log readings. Should this calculated value differ from the recorded value by more than two miles an asterisk is printed alongside the recorded value.

Errors detected in these checks have been found to be due mainly to transcription mistakes, these being:

- errors in the recorded time of the fix,
- wrong landmark shown on data sheet,
- errors in the log reading, usually in the hundreds column.

After this editing, and the correction of obvious mistakes, the program is rerun, this time to produce a punch card for each fix to make the output available for further computation.

The punch cards contain this information:

- date
- time
- this landmark (present fix)
- last landmark (previous fix)
- current encountered along track and across track from the previous fix to the present fix

- distance from last fix
- an indicator to give the direction of the voyage, (north bound or south bound)
- Modified Julian Day Number * (M.J.D.) of the day the ship enters the section of coast between Cape Moreton and Sugarloaf Point (this date is not changed during the 1½-2 day passage).
- course steered when approaching present fix
- weighted mean of currents encountered between Cape Moreton and Sugarloaf Point**
- distance offshore at the present fix.

** The weighted mean current is the mean of the currents found in all sections, the section current being weighted in proportion to the length of the section.

* The Modified Julian Day number is the last 3 digits of the number of whole days elapsed since 0000 hours on the 17th November 1858.

## ESTIMATION OF THE LOG ERROR

The "along-track" current components obtained as output from the current program contain uncertainties due to the presence of unknown errors in the ship's log. We have been able to estimate the size of this error for each ship and apply a correction to the computed (along-track) current to obtain the true current. Before this estimate is made the output cards on which the along-track component is punched are divided into two sets, one containing the results from all south bound voyages, the other the results from north bound voyages. This grouping separates current estimates obtained in the strong currents near the two hundred metre line (obtained from south bound ships) from the estimates obtained in the weaker close inshore currents encountered by ships travelling northwards. See Figures 4, 7, and 8.

The log error for a particular ship is computed by finding the difference between the mean of all currents (along-track components) encountered during all voyages of all ships travelling in one direction over a 30 day period, and the mean of all currents encountered by this ship during this voyage in the same direction. The difference in knots, which is one of many estimates of this ship's log error, is plotted as a function of time to detect any change in its value. After inspection of the plot, all differences calculated for this ship (for both south bound and north bound voyages) since the beginning of the project or since the last change, are averaged to give the log error.

Most of the errors in a ship's log are proportional to the speed of the vessel and the error is therefore usually expressed as a percentage of the ship's speed, which in the case of vessels supplying us with data, varied from 12 to 25 knots. The estimate of the log error which we obtain is expressed in knots, and applies only to the speed at which the vessel traversed this section of the coast. We have found very little variation in the speed at which any ship makes successive passages.

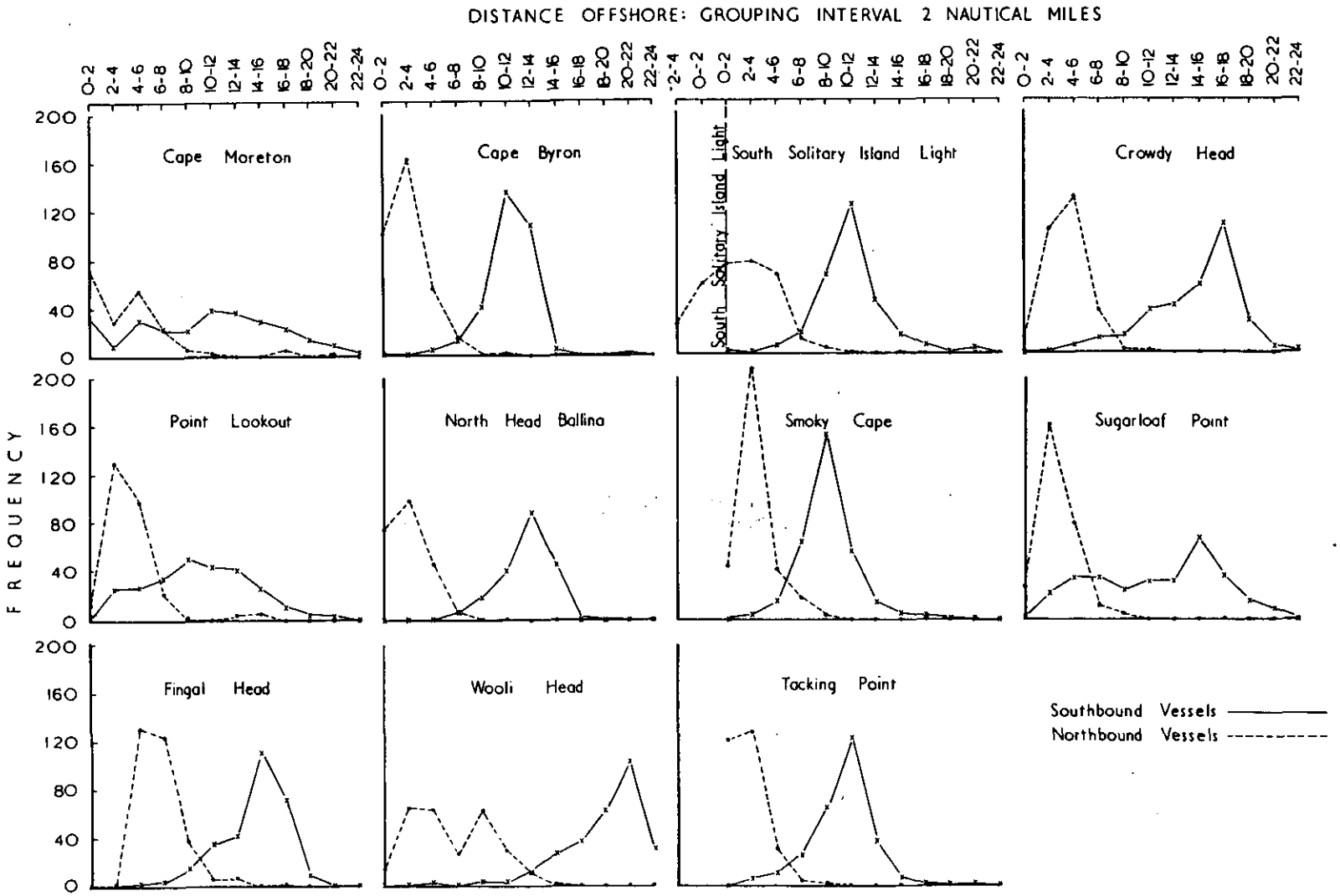


Fig. 4 Diagram showing the frequency distribution of distance offshore of vessels when abeam of land marks.

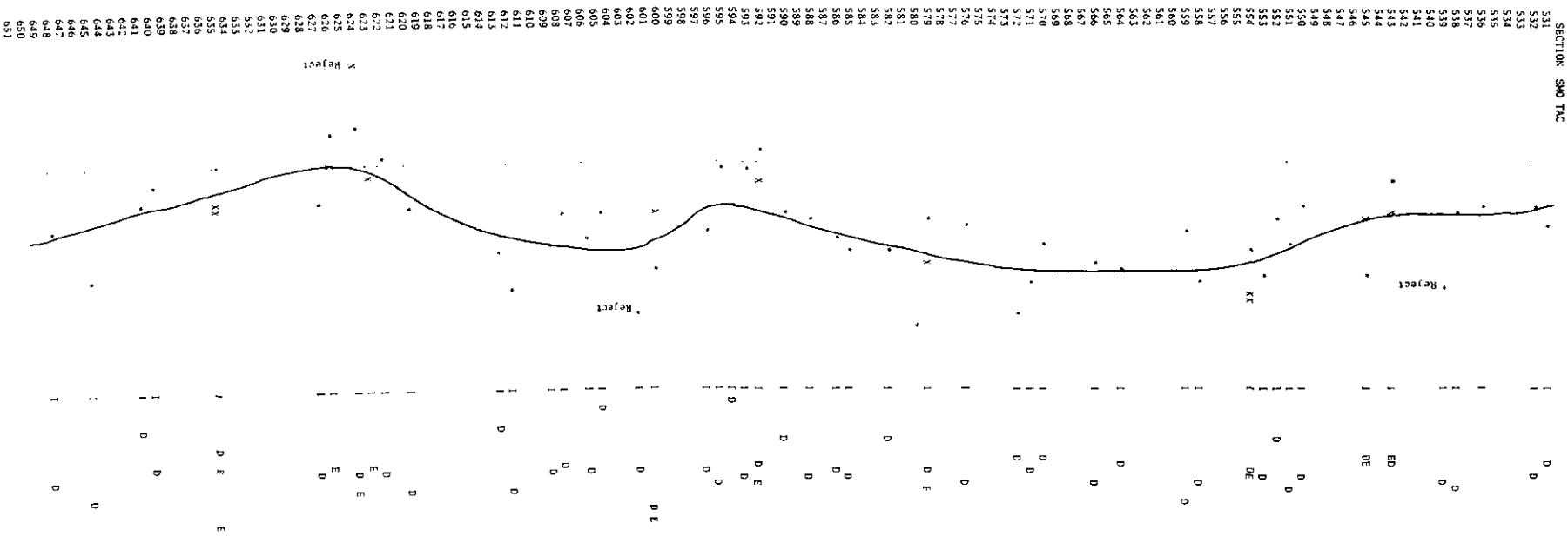


Fig. 5 Line printer plot of the corrected along-track current between Smoky Cape and Tacking Point. The current is plotted on a scale of 2 knots to 1 inch, the distance offshore on a scale of 7.5 miles to 1 inch. The numbers along the bottom of the figure are Modified Julian Day numbers.

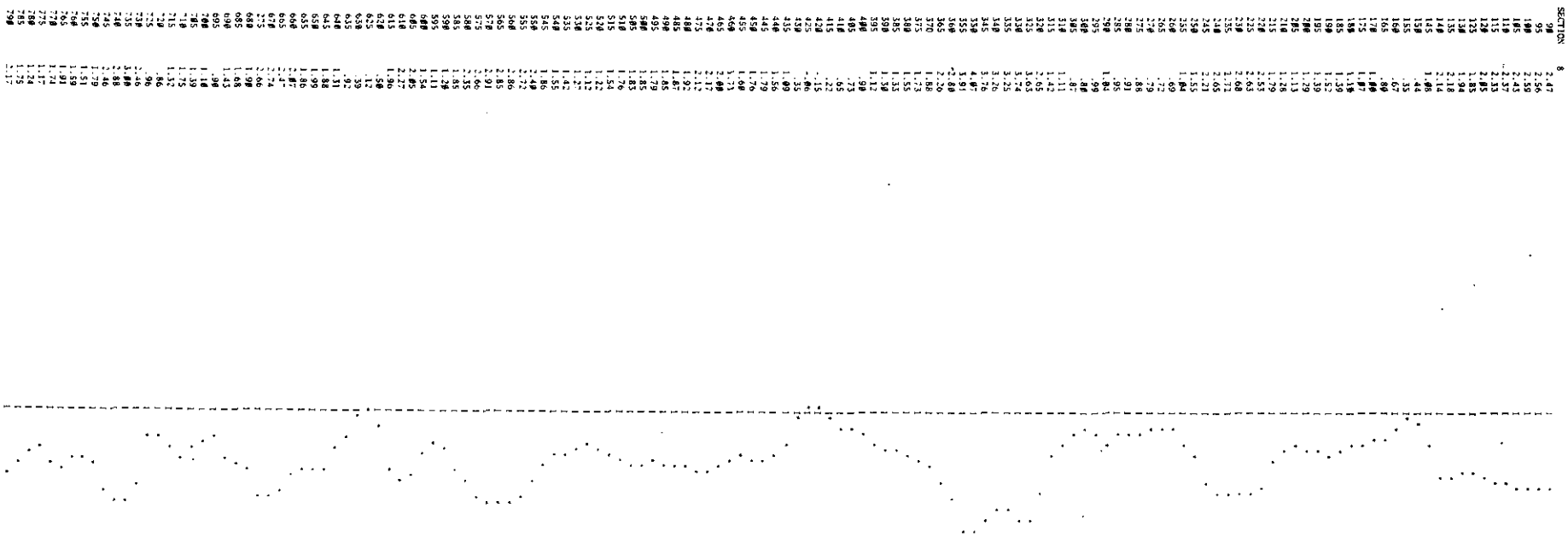

Fig. 6 Line printer plot of 5 day mean currents (along-track) in section 8, Smoky Cape to Tacking Point. The numbers along the bottom of the figure are Modified Julian Day numbers, the numbers above these are the value of the 5 day mean current in knots. The current is plotted on a scale of 2 knots to 1 inch.

## COMPUTATION AND PLOT OF CORRECTED CURRENT

The computed currents, corrected for log error, are plotted on a line printer as shown in Figure 5. The numbers along the abscissa are Modified Julian Day Numbers, the ordinate is current in the range -5 to +15 knots on a scale of 1 inch to 2 knots. The first current measurement on a particular day is printed as an asterisk, subsequent measurements on that day being shown by an X. One plot is produced for each of the 10 sections of coast. If a fix on one standard landmark is missed, the mean current over the two adjacent sections is plotted in each section. If there are two or more fixes missing in succession, no values are plotted in these sections.

The upper part of Figure 5 is a plot of the distance offshore of the ship when abeam of the landmark at the start of the section. Here the scale is 7.5 miles to one inch, "D" represents the offshore distance of the first ship and "E" that of subsequent ships on any one day.

A number of these current plots were examined to determine the spread of the measurements. After this examination an estimate of the standard deviation of the measurements was adopted and a rejection criterion fixed at three standard deviations. The standard deviation was found to be about 0.6 knots, and in practise we reject any measurement which is two or more knots away from a curve hand drawn through the mean of the series of measurements in the plot. It should be noted that this curve is for quality control purposes only - an objective filtering step is used later to give mean currents at 5 day intervals.

It has sometimes been possible to find the cause of outlying values and to correct them by, for example, omitting one bad fix, but generally this is not possible.

The program to plot currents also produces a set of punch cards which makes the corrected current available for further calculation. Each card gives:

- Modified Julian Day Number
- Corrected current in each of the 10 sections.

After inspection of the plot these output cards are corrected, whole voyages being rejected or some few section current values altered as explained above.

Finally the corrected output cards are run to produce 5 day mean currents using the LANCZOS taper filter;

$$w_j = \frac{\text{Sin } \frac{\pi j}{m}}{\frac{\pi j}{m}}, \quad j = -(m-1),-(m-1)+1,\ldots,-1,0,1,\ldots(m-1)$$

for m = 10. A line printer plot of the 5 day means so far calculated for Section 8, Smoky Cape to Tacking Point, is shown in Figure 6.

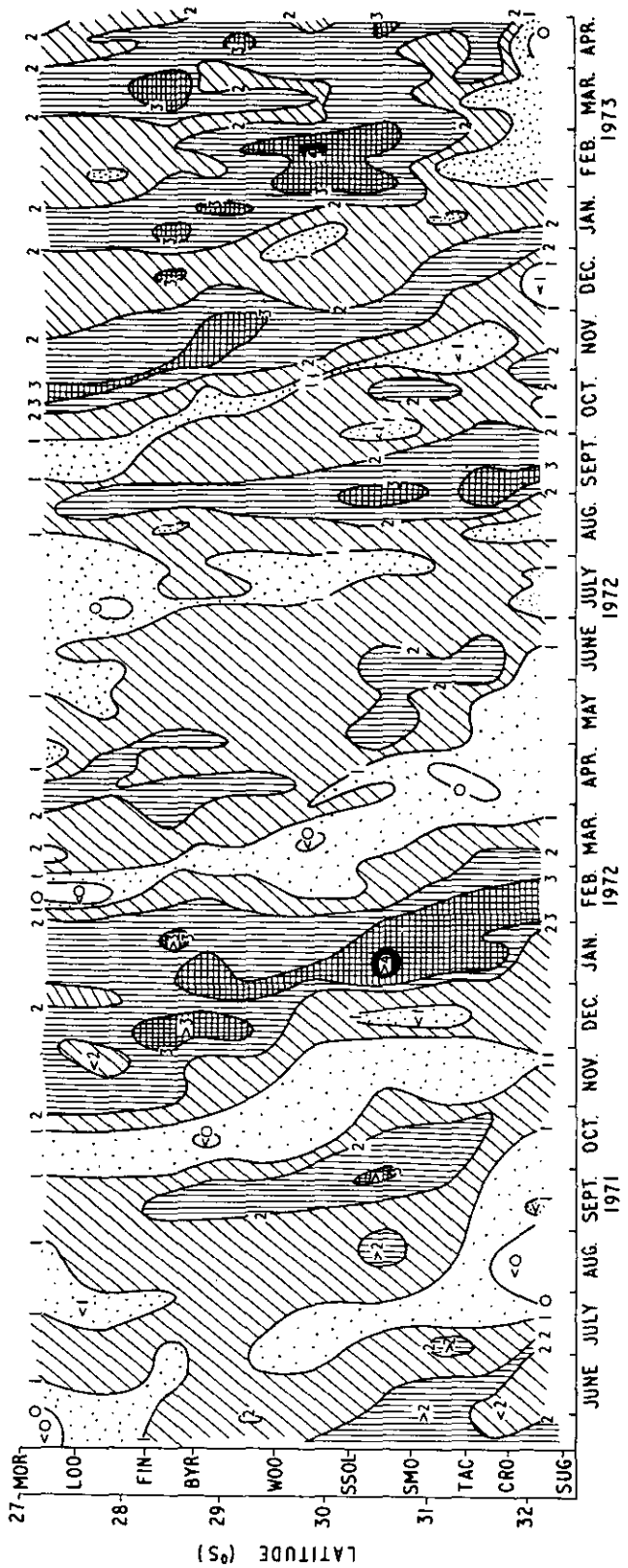


Fig. 7 Along-track currents from south bound ships as a function of latitude and time. Contour interval 1 knot. Currents are towards the south except in parts marked "<0", where the currents are between 0 and 1 knot to the north.

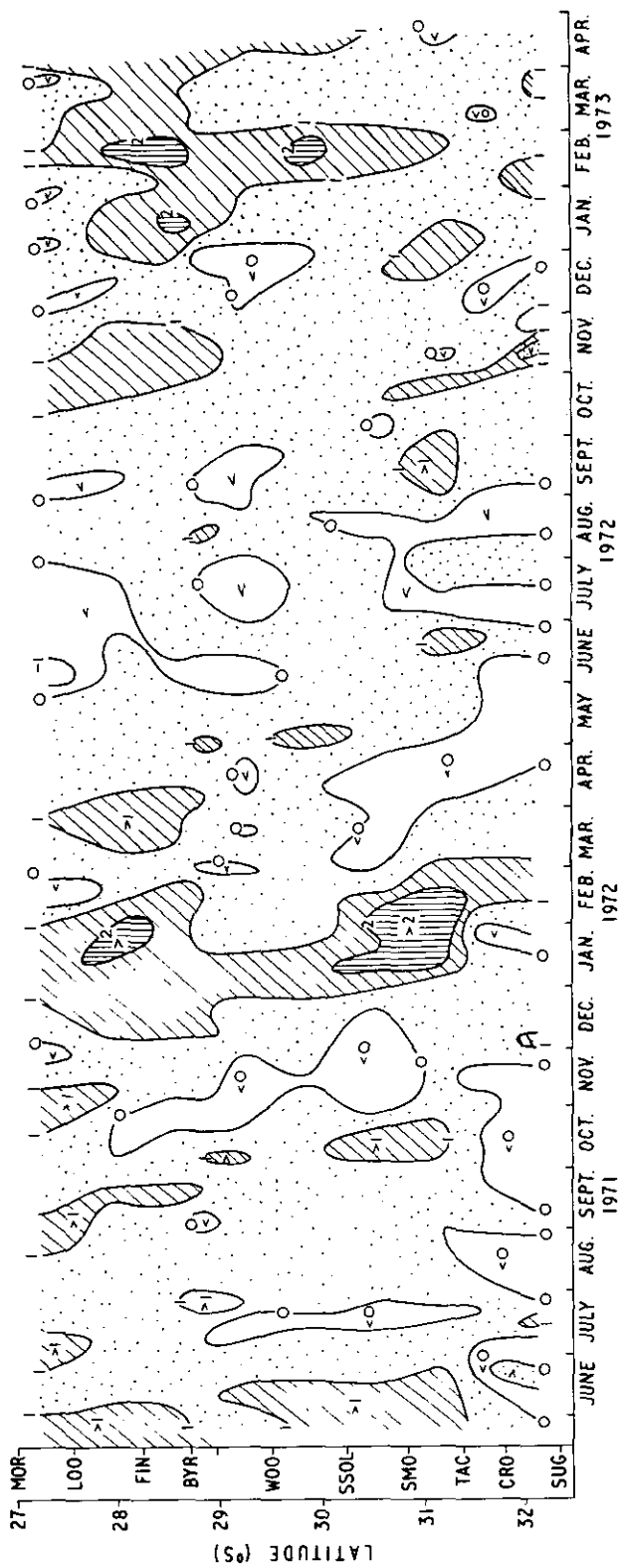


Fig. 8 Along-track currents from north bound ships as a function of latitude and time. Contour interval 1 knot. Currents are towards the south except in parts marked "<0", where the currents are between 0 and 1 knot to the north.

The filtered values (5 day means) are defined, for each section of coast, by

$$\overline{C}_i = (\Sigma w_j C_{i-j})/(\Sigma w_j)$$

where,

$\overline{C}_i$ = mean current on day number i (i a multiple of 5)

$C_{i-j}$ = observed current on day (i-j)

$w_j$ = filter weight

Since the $C_{i-j}$ are not uniformly spaced, both the summations are taken over all available current observations that come within the range of the filter i.e. $-9<j<9$.

There were no gaps in the series of 5 day means, since there were no periods as long as 19 days in which there were no current observations. Of course, the reliability of a given 5 day mean value depends on the number of observations used in computing it.

This program also prints the values of the 5 day mean currents using one line for each set of 10 section values of the current. These current values are printed across the page, the spacing being proportional to the length of the section between standard landmarks on a scale of 40 miles to one inch.

These numbers are contoured to give a picture of the variation with time of the current along the coast. Examples of this contoured plot for both south bound and north bound voyages are given in Figures 7 and 8.

## DISCUSSION

We have been able to monitor variations in the East Australian Current over a distance of 350 miles for a period of two years and with an estimated accuracy in the 5-day mean currents of 0.2 knots.

The measurements we have made are summarized in Figures 7 and 8 where the variation with time of the pattern of currents along the coast is clearly seen. From the general slope of the isolines it can be seen that the pattern moves southwards at some 5 miles a day.

It will also be seen that there is good agreement in pattern between Figures 7 and 8, showing that the currents found near the edge of the continental shelf are also found much closer inshore. These inshore currents are much weaker and negative values (current setting to the north) do happen, but the average inshore set is certainly to the south.

We believe that this method of monitoring currents could be extended to cover any region where relatively strong currents exist close to a shore well served by shipping, and also to cover currents encountered during ocean passages as more ships are fitted with precise electronic or satellite navigation equipment.

## REFERENCES

HAMON, B.V., and KERR, J.D. (1968).- Time and space scales of variations in the East Australian Current, from merchant ship data. *Aust. J. mar. Freshwat. Res.* 19, 101-106.

TAYLER, R.J. (1970).- Julian day numbers for the years 1700-1999. National Institute of Oceanography U.K. Internal Report No. N21.

# APPENDIX

*Computer Programs*

None of the programs used in this project is a general purpose program and some, especially BDGELØG, are rather long and need to be rewritten. For these reasons the program listings are not included in this report. The programs, were written in Fortran Extended by Mr D. Crooks and Mr B.V. Hamon of the CSIRO, Division of Fisheries and Oceanography.

The programs are on file in the Division.

BDGELØG : A program to compute currents encountered by merchant ships between successive fixes on coastal landmarks.

LØGERR : A program to compute the error in ships' logs using the output of BDGELØG.

SECTCUR : A program to correct the current computed in BDGELØG for log errors, and to plot this corrected current. This program also prints and plots the distance offshore of each vessel at each landmark.

FILCUR : A program to compute and plot 5 day mean currents from the corrected current computed in SECTCUR.