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Special Study on Sediment Discharge and Its Consequences (SedSS)

Technical Report Number 3

SIDE-SCAN SONAR AND ECHO-SOUNDING SURVEYS AT THE SOUTHERN END OF LAKE TANGANYIKA

by

R W Duck and S F K Wewetzer

1999

Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)

Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)

Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement (PNUD)"	The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme.

Burundi: Institut National pour Environnement et Conservation de la Nature
D R Congo: Ministrie Environnement et Conservation de la Nature
Tanzania: Vice President's Office, Division of Environment
Zambia: Environmental Council of Zambia

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SIDE-SCAN SONAR AND ECHO-SOUNDING SURVEYS AT THE SOUTHERN END (ZAMBIAN WATERS) OF LAKE TANGANYIKA, AUGUST 1998

Report for the Lake Tanganyika Biodiversity Project

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1. INTRODUCTION

This report describes a series of side-scan sonar and echo-sounding surveys carried out during August 1998 in the southern, Zambian waters of Lake Tanganyika as part of the Lake Tanganyika Biodiversity Project (LTBP). The principal aims of the surveys were:

- To map the bottom sediment and bedform distribution at the southern end of the lake using side-scan sonar, augmented with direct sampling, in areas being sampled principally by the Sedimentation Special Study (SedsSS) team but also by the Pollution (PolSS) and Biodiversity (BioSS) Special Study teams.

- To carry out bathymetric surveys using echo-sounding of the offshore zones and deltas developed off the mouths of the principal rivers draining into the Zambian waters of the lake, i.e. those influents being studied by the SedsSS, PolSS and BioSS teams.

As detailed in the Back to Office Report (Duck, 1998), failure of the side-scan sonar equipment precluded the completion of the work to the extent that was originally intended. The following surveys were, however, successfully completed and detailed descriptions of these follow:

(i) Side-scan sonar survey of Musende Bay between the LTBP Station and Kasakalawe Point, together with a programme of bottom sediment sampling to aid the interpretation of sonographs.

(ii) Bathymetric survey of Musende Bay to augment the side-scan sonar survey.

(iii) Bathymetric survey of the delta of the Lunzua River, together with a programme of bottom sediment sampling.

2. EQUIPMENT AND METHODS

All surveys were conducted from the Zambian Department of Fisheries research vessel, the *Silver Shoal,* with position fixing by means of the LTBP hand-held, Magellan® GPS. Side-scan sonographs were obtained using a Waverley 3000 system (operating frequency 100 kHz) from the University of Dundee, Scotland, and echograms using a Lowrance recording echo-sounder (operating frequency 192 kHz) from the Institute of Freshwater Ecology (IFE), Penicuik, Scotland. Bottom sediment samples were collected by means of the LTBP's Windermere Grab deployed from the stern winch on the *Silver Shoal*. These were described visually in the field (Tables 1 and 2), then stored in plastic containers prior to analysis the laboratory. Survey and sampling fixes were plotted onto tracings photo-expanded from 1: 50 000 scale maps of the lake (Sheets 0831C1 and 0831C3) obtained from the Survey Department in Lusaka.

3. MUSENDE BAY

3.1 Bathymetric survey

The bathymetric survey of Musende Bay was carried out on 24th August 1998. A total of 18 traverse lines (Figure 1), incorporating 140 GPS fixes, formed the basis for the construction of the bathymetric chart presented in Figure 2. The datum to which depths have been reduced is 774 m above mean sea level.

The bathymetry of Musende Bay is relatively simple, with the isobaths essentially following the line of the shore, the water depth reaching over 28 m in the central part of the surveyed area (Figure 2). Underwater slope angles of <1º are present off the eastern part of the bay, whereas steeper underwater slopes (>1º) characterise the area off Tanganyika Lodge and Kasakalawe Point (Figure 2).

3.2 Side-scan sonar survey

The Musende Bay area was initially chosen for survey by side-scan sonar because of:

- Its proximity to Mpulungu affording ready access by the *Silver Shoal.*

- Paul Tierney had identified the site as important for the BioSS: his programme formalised fortnightly dives by the BioSS team to map and census Kasakalawe Point/Tanganyika Lodge. This was viewed as a preparation for the commencement of SedsSS *in situ* field experiments on species extinction and recolonisation to be supervised by Ken Irvine (KI).

- The site off Tanganyika Lodge is reported (by Dr Sigal Balshine-Earn of the Taborsky Research Project to Paul Tierney in May 1998) to have changed "radically" after the rains of 1997/98 and a recent storm with the elimination of the *Eretmodus cyanosticus* (cichlidae) population and the exposure of a "sand-sub-stratum".

- A side-scan sonar survey (calibrated by the collection of bottom sediment samples) was seen as providing important base line data on the site, of value to both SedsSS and BioSS.

The following survey lines were successfully completed on 10th August 1998:

- One long (trial) line from Kasakalawe Point to the Department of Fisheries, Mpulungu.

- Four, fully GPS fixed traverse lines in Musende Bay, one long, shore parallel line (GPS Fixes 1-25) from Tanganyika Lodge to the Fisheries Station and three shorter lines (GPS Fixes 26-37), as shown in Figure 3. The locations of these lines were chosen to coincide with areas in which the SedsSS team had sampled previously (K. Kaoma, pers. comm.).

To aid the interpretation of sonographs, sediment samples were collected at 13 sites chosen after initial interpretation of the latter: 6 samples were collected on 13th August 1998 (Table 1 and Figure 4) with a further 7 samples being recovered on 14th August 1998 (Table 1 and Figure 4).

3.2.1 *Sonograph interpretation*

A diagrammatic interpretation of the Musende Bay sonographs is presented in Figure 5. This should be consulted in conjunction with the map of traverse lines and GPS fixes (Figure 3).

Between GPS Fixes 2 and 5, sonographs revealed alternations of shore-parallel, laterally continuous bands of high and low tonal intensity (Figure 6). These are interpreted as shore parallel terraces and segments of terraces developed principally in cobble deposits (sediment samples S1, S12 and S13, together with the cobble beaches on the shore, confirm the occurrence of cobbles in this area). A sequence of 4 major terrace segments was recorded shown by the high acoustic backscatter from the ‘risers’ and the low backscatter from the ‘treads’. The latter generally appear as a mottled backscatter pattern in which point targets can be identified and which are interpreted as boulders. At GPS Fix 3, some small, 20 x 20 m, patches of lower backscatter were recorded, which are interpreted as veneers of finer sediment. The terraces are believed to have formed through wave erosion at former depressed water levels and it is suggested that they could form important microhabitats.

At GPS Fix 5 a transition from low acoustic backscatter to generally higher backscatter was recorded. This is interpreted as the transition from marginal cobble deposits along the shore into shelly sands, as also confirmed by sediment sampling (S11). However, the high backscatter level reveals a different acoustic signature than that recorded in the cobbly area. A small number of point targets can be identified suggesting there are a few isolated boulders present amongst the finer sediment around GPS Fix 6. The bed topography in the area around GPS fix 6 is flat. However, low relief (<1 m) mounds and depressions were recorded on both sides of the survey line.

Between GPS Fixes 7 and 8 the acoustic signature suggests that the bottom deposits continue to consist of shelly sands towards GPS fix 8 where small-scale relief patterns (<1m) were recorded.

Between GPS Fixes 10 and 11 the shoreline, which is marked by a characteristic diffuse and broken echo caused by fringing reed stands (*Phragmites mauritanus*), appears again on the sonograph. In the region of GPS Fixes 9 and10 numerous point targets, mainly with acoustic shadows, were recorded. Due to the acoustic shadows, these features are of positive relief and are interpreted as boulders of the order of 1-2 m in diameter. Nearer to the shore a clear sequence of areas of high backscatter followed by areas of low backscatter was recorded. These are interpreted as three shore parallel terraces (again possibly forming significant microhabitats), with the strong reflections being returned from the 'risers' (Figure 7). The step closest to the shore is probably sloping lakeward and therefore gives a better backscatter level due to the angle of beam incidence than middle step which probably slopes slightly towards the shore. From GPS Fix 9 towards GPS Fix 10 and continuing to GPS Fix 11, fewer point targets (boulders) were recorded but cobbles are believed to dominate this area.

It is suggested that the 'step' or 'tread' of the uppermost terrace (as imaged between GPS Fixes 11 and 13) step represents the normal, dry season minimum water level. The two 'steps' of the lower terraces (between GPS Fixes 9 and 11) are believed to represent the remains of shore parallel terraces eroded by waves at extreme low stands of the lake. By reference to Verburg (1997), it is suggested that these could have been formed in the years 1929 and 1950.

Between GPS Fixes 10 and 16 a dominant set of small-scale ridges with a north-west to south-east orientation were recorded along the near shore zone. At GPS Fix 12 a secondary orientation at right angles to the above was recorded, giving an interference pattern (Figure 8). This pattern is interpreted as being due to the presence of wind generated wave ripples characterising this zone, formed by winds blowing dominantly from the north-east and subordinately from the north-west. The ripples have a crest-to-crest spacing of the order of 3-4 m and are dominantly straight crested. Some evidence of crest bifurcation is apparent, especially at GPS Fix 14. The presence of these bedforms implies that the bottom sediments are mobile; shelly sand is characteristic of this area.

Point targets on the 'tread' of the middle of the three terraces look like they are caused by isolated boulders, however, the angle of incidence is very low so this interpretation is questionable. Bottom sediment sample S9 retrieved medium sand with a small amount of shell fragments which provides the characteristic acoustic signature recorded at GPS Fix 12 (Figure 8). Here the lakeward (below wave base) section of the sonograph shows patchy backscatter levels that are interpreted as being due to different concentrations of living molluscs, mainly bivalves, which can reach dimensions of 10-12cm by 4-6cm but are, on average, 4 cm in length.

Sediment sample S8, collected in the lacustro-littoral zone between GPS Fixes 16 and 17, consisted of fine to medium sand with a low shell content, similar to that of sample S4 collected between GPS Fixes 17 and 18. Such materials would account for the low backscatter levels recorded on the sonographs of these areas.

The characteristic acoustic signature of the shoreline due to reeds is lost close to GPS Fix 18 but appears again on the sonograph near GPS Fix 20. The signal is lost again near to GPS Fix 21, where the survey line continued further offshore.

Between GPS Fixes 18 and 19 patches of strong acoustic backscatter (Figure 9) were recorded. These are interpreted as shell beds, i.e. localised concentrations of whole and fragmental shelly deposits; probably both living and dead organisms are present.

The tonal intensity variations recorded between GPS Fixes 22 and 25 are not believed to be indicative of relief effects and are therefore interpreted as the result of substrate changes (sediment type or density). These ill defined patches are of the order of 50 m in dimension and are characterised by lower acoustic backscatter which are believed to be the signature of finer grained sediments.

The area between GPS Fixes 26 and 28 shows the diffuse broken echoes that are the characteristic signature of reed beds. The light tonal intensities of the inshore side of the sonograph suggest the accumulation of fine material, which is probably derived from land drainage. The offshore side of the sonograph reveals varying backscatter levels, which are interpreted as being due to small-scale variations in sediment type and shell content.

The mottled texture recorded in the area from GPS Fix 29 to Fix 33 is also believed to be due to variations in the shell content of the bottom sediments.

3.2.2 *Discussion*

This survey is believed to be the first use of side-scan sonar in the Zambian waters of Lake Tanganyika. Despite its small spatial coverage a number of important observations have emerged from it which have implications for the LTBP. It is suggested that the most important are:

- The discovery of a suite of shore parallel terraces that may be linked with former, dated low stands of the lake.

- The possible existence of microhabitats within the ‘treads’ and ‘risers’ of the near-shore terraces.

- The imaging of the patchy zonation of sediment types, the zonation typically indicative of variations in the shell content of living and dead molluscs.

- The observation of near shore sets of interfering wave ripples indicative of the movement of mobile sands by winds blowing dominantly from the north-east and subordinately from the north-west.

It was observed by Coulter (1991) that the nature of the bottom of Lake Tanganyika appears to be the principal physical factor determining the distribution of gastropods and bivalves. The degree of exposure to water turbulence nearshore is also important. Coulter (1991) also reported that gastropods and bivalves in the lake tend to be localised in optimal habitats, mainly in relation to these factors, and their distribution tends to be 'patchy' rather than zoned. The small-scale, patchy distribution of shelly sands in Musende Bay has been indicated by the side-scan sonar observations, as described above, and confirms in the small area of Musende Bay the generic observations of Coulter (1991).

4. LUNZUA DELTA

4.1 Bathymetric survey

The bathymetric survey of The Lunzua Delta was carried out on 25th August 1998. A total of eight traverse lines (Figure 10), incorporating 96 GPS fixes, formed the basis for the construction of the bathymetric chart presented in Figure 11. As for the chart of Musende Bay, the datum to which depths have been reduced is 774 m above mean sea level. The sediments of the delta, sampled in conjunction with this work (Figure 12), are described in Table 2.

The morphology of the delta is relatively simple and characterised by gentle slopes away from the river mouth. Nearshore the slopes are slightly steeper than offshore, however, in the surveyed area, slope angles do not exceed 0.5º. Depths of c. 20 m are not encountered until about 3 km offshore. This broad flat shelf is indicative of a large zone of sediment accumulation. At the time of the survey (during the dry season), a well-defined plume of turbid water could be seen extending from the moth of the Lunzua into the lake for about 500m. Beyond this plume the water was clear, suggesting that dense waters laden with sediment were, at this point, plunging beneath the main water mass. It was anticipated that the presence of delta distributary channels would be identified from echograms recorded approximately parallel with the shoreline. However, this was not the case. Indeed, no cleanly defined offshore channels could be identified associated with the mouth of the Lunzua. This is manifest by the generally regular trend (i.e. curving parallel with the form of the delta) of the isobaths in Figure 11. The fluctuations in these, e.g. in the 11, 12 and 13 m contours, may define a shallow channel within the delta deposits but further work would be needed to confirm this.

5. REFERENCES

Coulter, G.W. 1991. Composition of the flora and fauna. Chapter 9, In: Coulter, G.W. (Ed.) Lake Tanganyika and its life. Oxford University Press.

Duck, R.W. 1998. Back-to-office report on visit to Lake Tanganyika (Mpulungu, Zambia), 3 to 29 August, 1998. 13pp. For NRI/LTBP, Consultant Ref. No.: 1198, Project Number: K0027.

Verburg, P. 1997. Water level of Lake Tanganyika. LTR Newsletter, **22**, 14-15.

Table 1: Musende Bay Sediment Samples

Sample No.	Date	GPS Fix	Water Depth	Field Description of Sample
S1	13.8.98	08º46.738'S 31º04.993'E	7.0m	Medium sand with whole and broken mollusc shells
S2	13.8.98	08º46.700'S 31º05.436'E	16.5m	Repeatedly failed sampling site – cobbly substrate suggested (?)
S3	13.8.98	08º46.704'S 31º05.755'E	11.5m	Muddy sand, poorly sorted with shell fragments of gastropods and bivalves
S4	13.8.98	08º46.544'S 31º06.109'E	6.3m	Fine sand with shell fragments
S5	13.8.98	08º46.334'S 31º06.413'E	2.5m	Fine sand with plant organics and 1-2 cm whole gastropod shells
S6	13.8.98	08º46.171'S 31º06.517'E	4.5m	Poorly sorted, fine to granular sand with high proportion of shell debris and small whole gastropods
S7	14.8.98	08º46.113'S 31º06.575'E	4.2m	Fine sand with coarse shell debris and weeds
S8	14.8.98	08º46.628'S 31º06.575'E	4.3m	Well sorted fine to medium sand with low content of shell debris (cf.S6 and S7)
S9	14.8.98	08º46.747'S 31º05.789'E	7.2m	Well sorted, medium sand with small amount of shell fragments

continued/

Table 1 continued

S10	14.8.98	08º46.649'S 31º05.731'E	12.0m	Medium sand to gravel with shell debris, whole bivalve (2cm) and gastropods (0.5-1cm)
S11	14.8.98	08º46.772'S 31º05.317'E	14.5m	Well sorted fine sand with shell fragments 1-4mm in size (no whole shells)
S12	14.8.98	08º46.784'S 31º04.950'E	4.8m	Repeatedly failed sampling site – cobbly substrate suggested by analogy with shore line materials
S13	14.8.98	08º46.693'S 31º04.849'E	10.5m	Repeatedly failed sampling site – cobbly substrate suggested (?)

Table 2: Lunzua Delta Sediment Samples

Sample No.	Date	GPS Fix	Sample Depth	Field Description of Sample
1	20.8.98	08º44.303'S 31º10.292'E	10.0m	Mud with leaf debris and plant fibres, bivalves, up to 1.5cm
2	20.8.98	08º44.129'S 31º10.415'E	15.5m	‘Old looking’, brown, whole gastropod shells, up to 5cm; small amount of mud
3	20.8.98	08º43.860'S 31º10.589'E	19.5m	Very fine sand/mud with live shrimps and ‘old’, whole gastropod shells
4	20.8.98	08º43.430'S 31º10.789'E	23.0m	‘Old looking’, brown, whole gastropod shells, up to 5cm; small bivalves and live shrimps
5	20.8.98	08º44.473'S 31º10.164'E	4.7m	Mud with leaves, plant stems and root fibres

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Figure 6. Sonograph between GPS Fix 3 (right) and Fix 5 (left edge) looking upslope towards the lake shore, showing shore parallel terraces developed in cobble deposits. Note strong reflections (dark tones) from the 'risers' and weaker reflections (lighter tones) from the 'treads'. Distance between range lines = 15 m.

Figure 7. Sonograph between GPS Fix 10 (right) and 12 (left), looking upslope towards the lake shore. The present shoreline is marked by the diffuse echoes to the top left of the figure, the character of which is due to fringing reed beds. The two shore-parallel dark echoes are believed to be from wave cut 'risers' delimiting lower stands of the lake. See text for details. Distance between range lines = 15 m.

Figure 8. Sonograph between GPS Fix 12 (right) and Fix 14 (left edge), looking upslope towards the lake shore, showing interference bedforms in the near shore zone. See text for details. Note the diffuse echoes from the fringing reed beds causing the shore line to appear indistinct. Distance between range lines = 15 m.

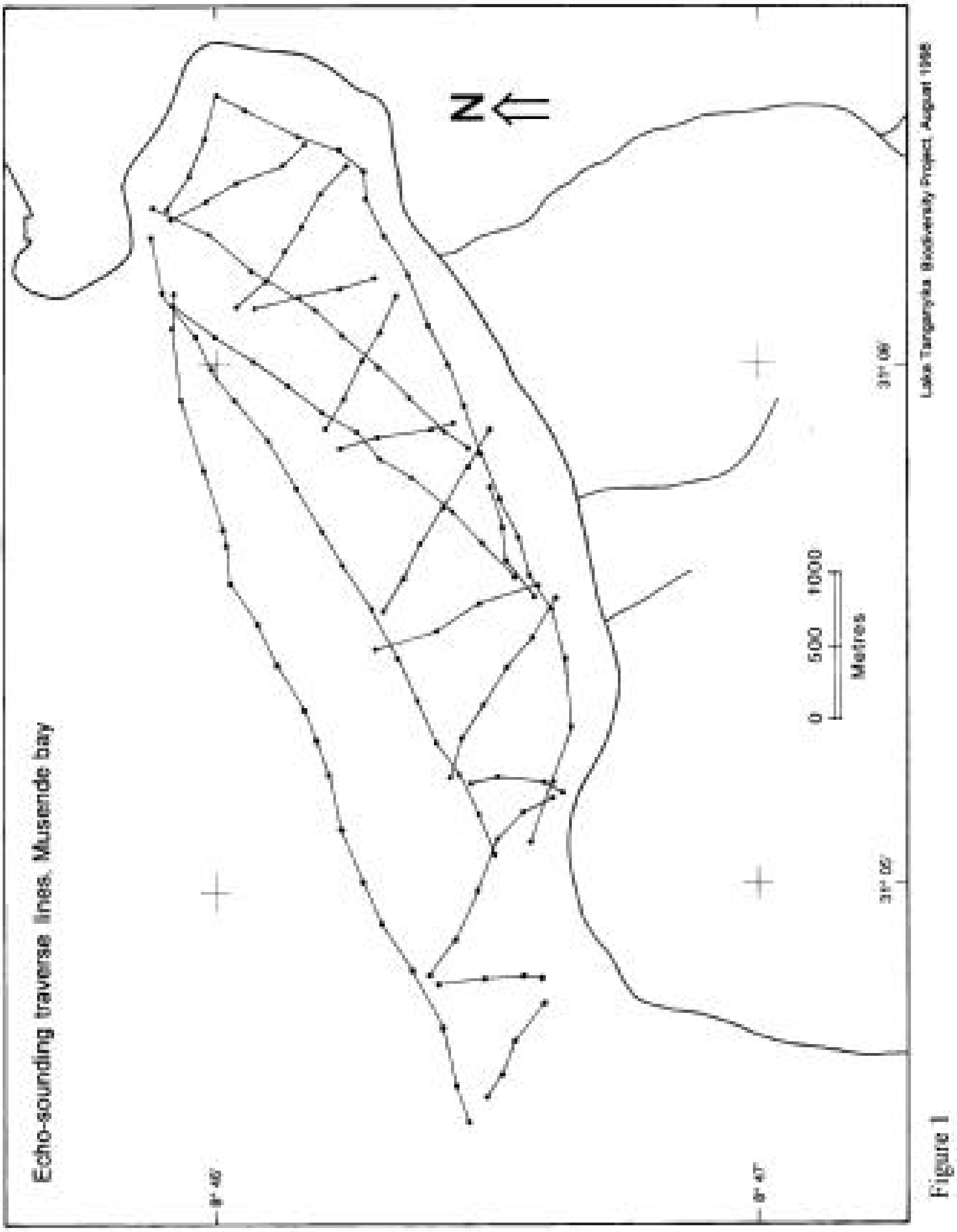
Figure 9. Sonograph from GPS Fix 18 (right) to midway between Fixes 19 and 20 (left edge) showing 'patches' with dark tonal intensity indicative of high acoustic backscatter. These are interpreted as shell beds. See text for details. Distance between range lines = 15 m.

Figure 10. Echo-sounding traverse lines, Lunzua Delta.

Figure 11. Bathymetric map of the Lunzua Delta.

Figure 12. Sediment sampling localities, Lunzua Delta.

Figure 1


Echo-sounding traverse lines, Musende bay
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1000
Metres
Figure 1

Figure 2

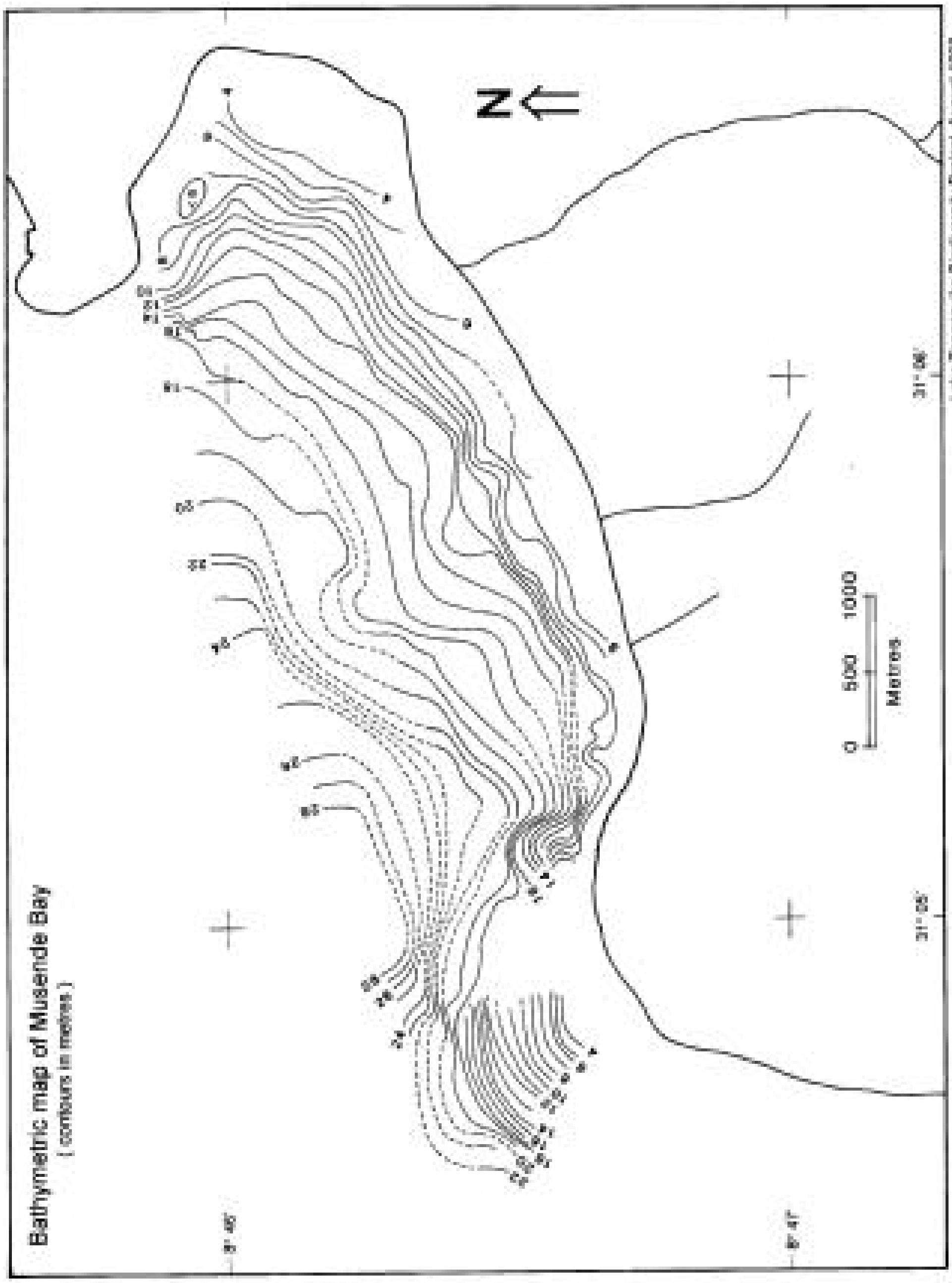

Figure 2

Figure 3

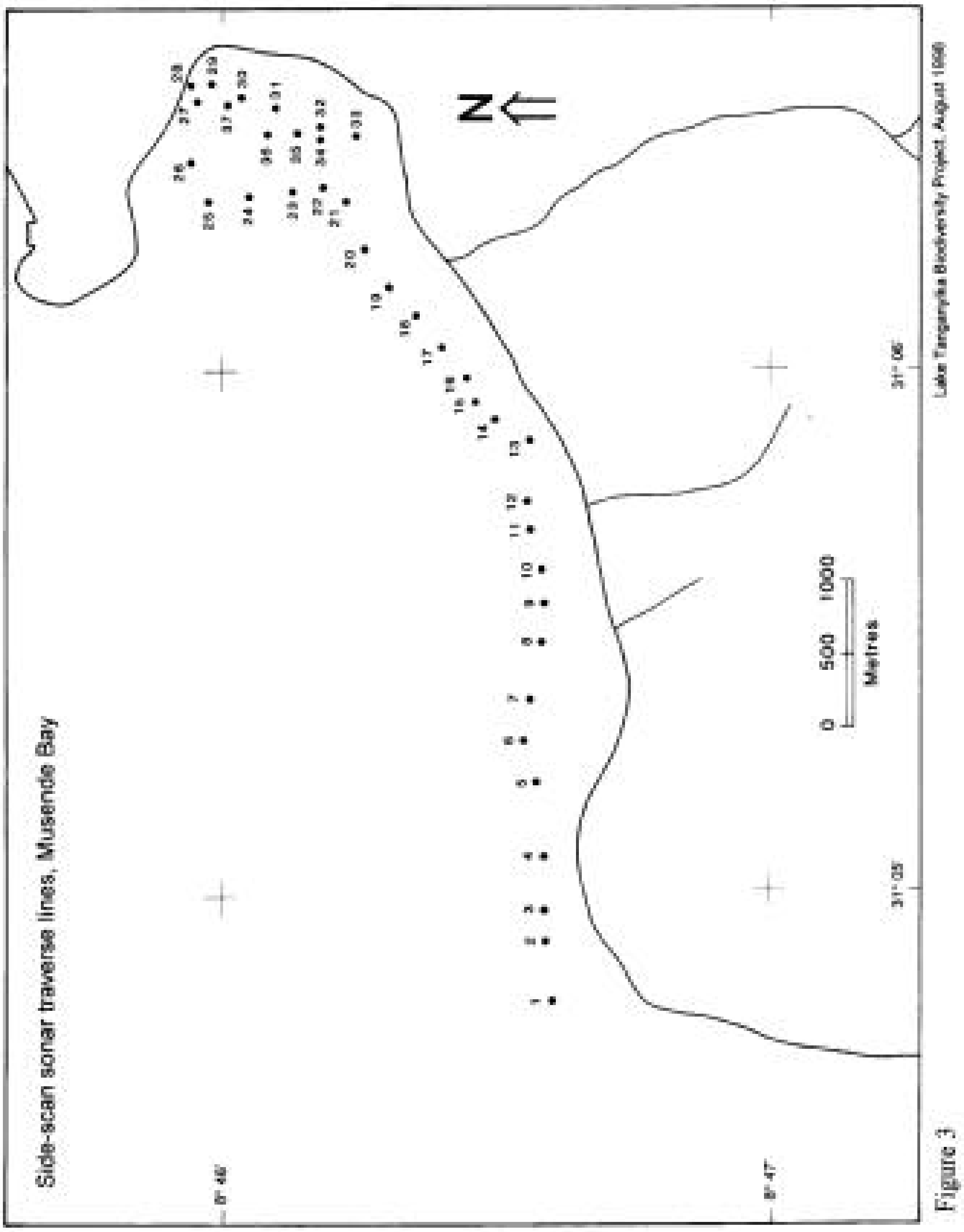

Figure 3

Figure 4

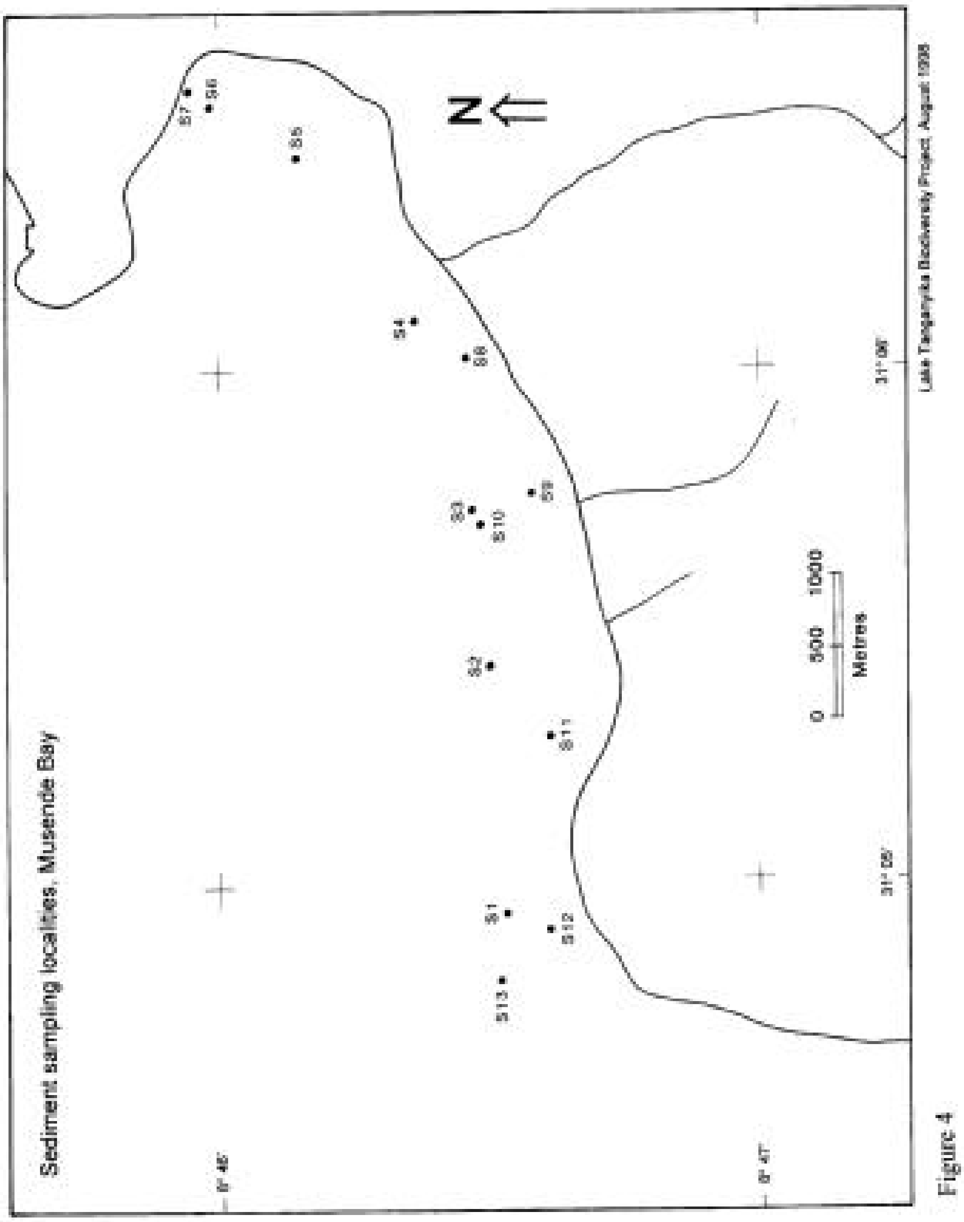
Sediment sampling localities, Musende Bay
Lake Tanganyika Biodiversity Project, August 1998
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
N
0 500 1000
Metres
8° 46'
8° 47'
31° 05'
31° 06'
Figure 4

Figure 5

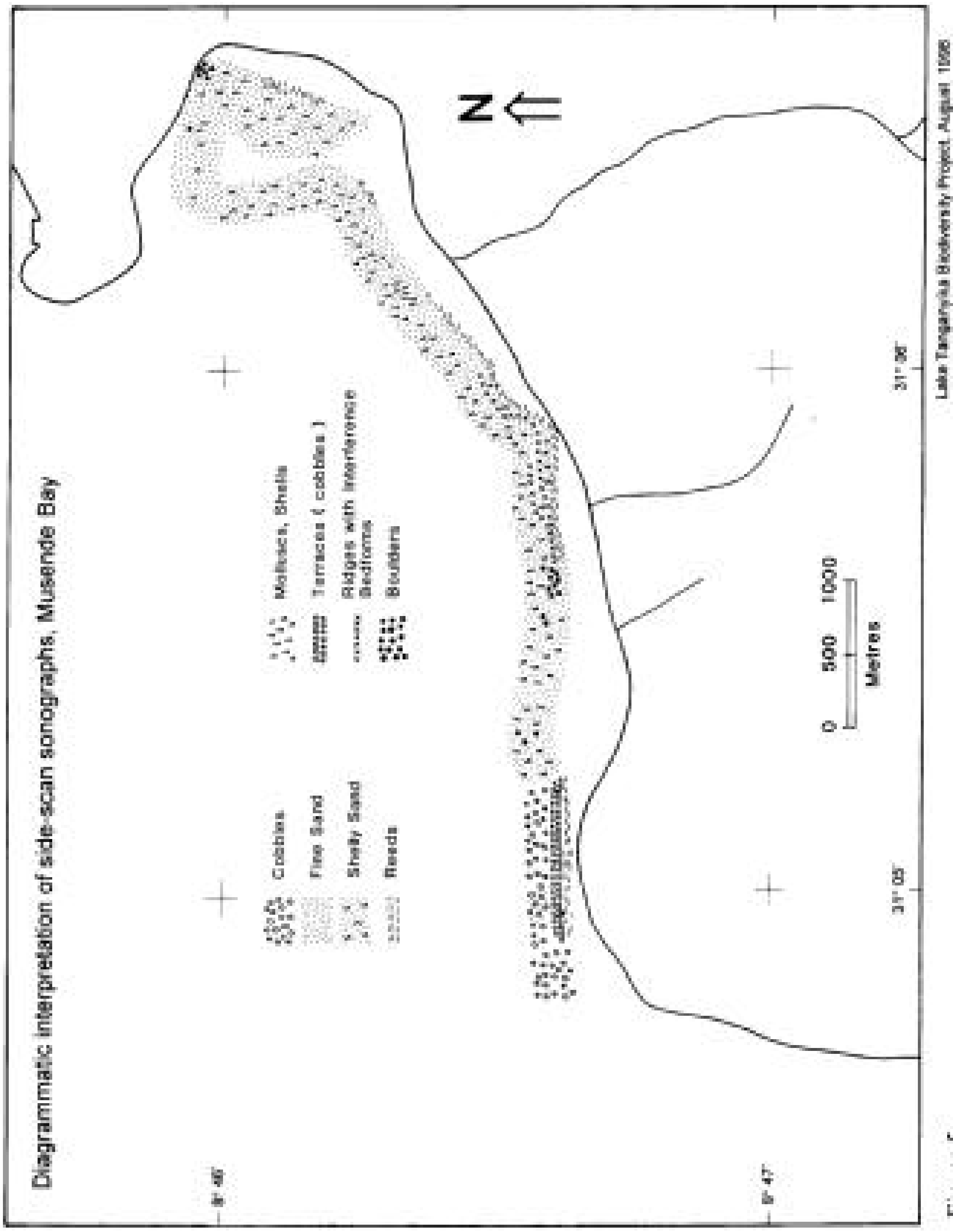

Figure 5

Figure 6

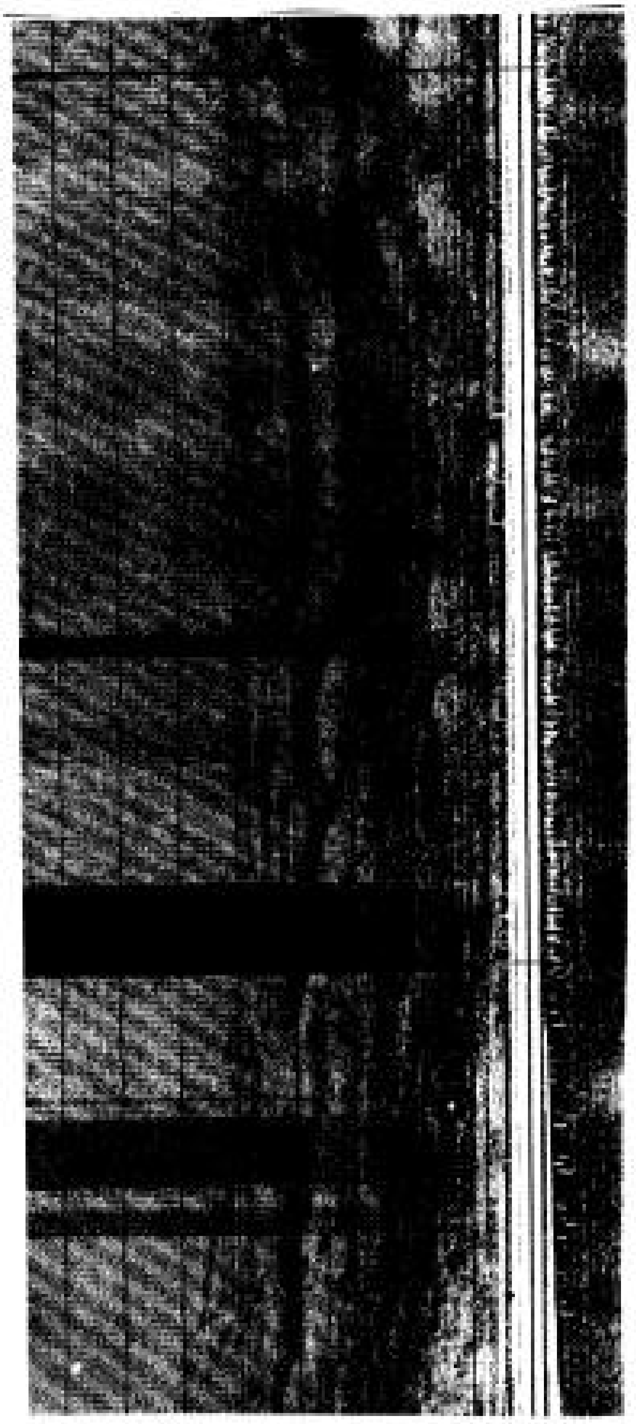

Figure 6. Sonograph between GPS Fix 3 (right) and Fix 5 (left edge) looking upslope towards the lake shore, showing shore parallel terraces developed in cobble deposits. Note strong reflections (dark tones) from the 'risers' and weaker reflections (lighter tones) form the 'treads'. Distance between range lines = 15 m.

Figure 7

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Figure 8

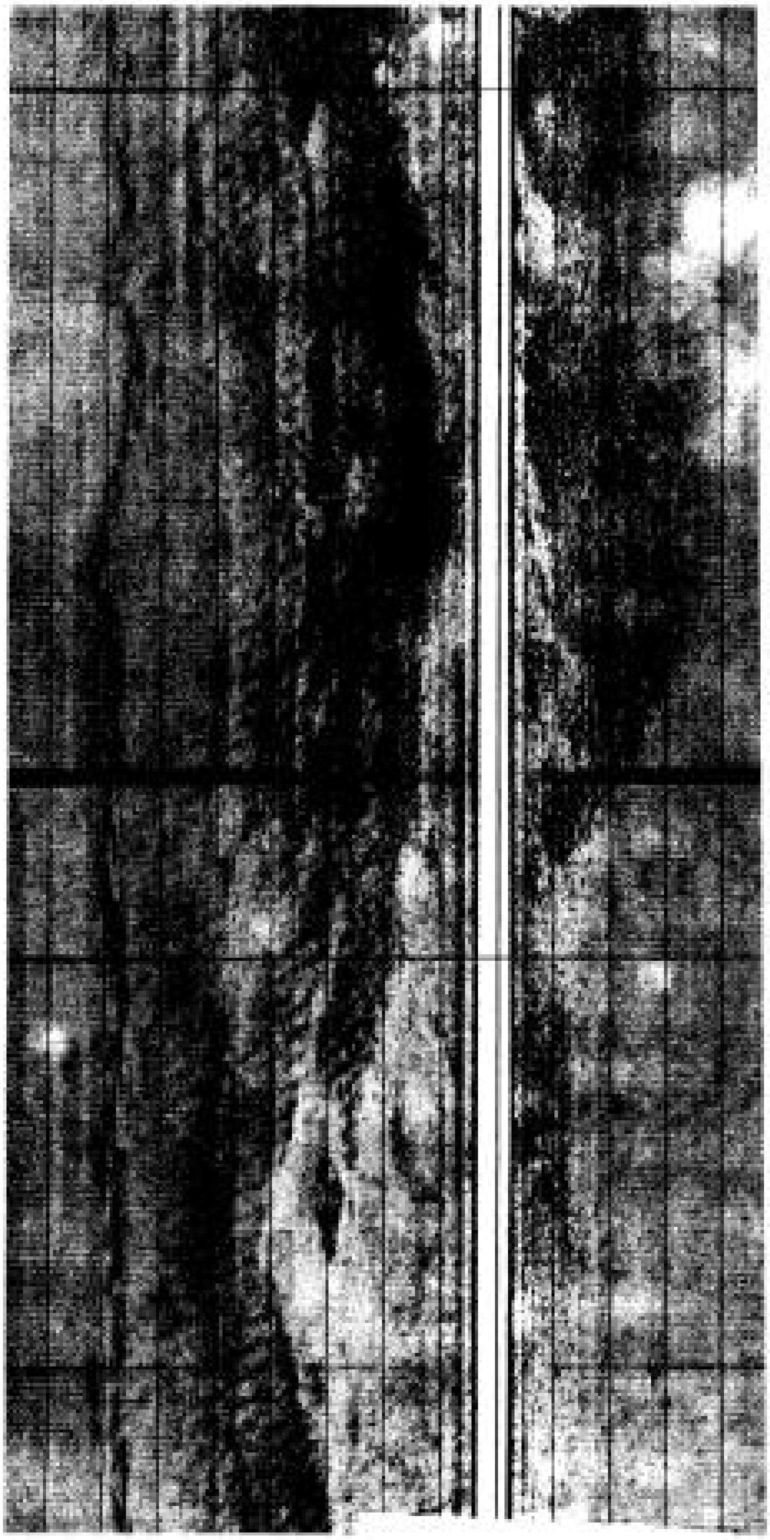

Figure 8. Sonograph between GPs Fix 12 (right) and Fix 14 (left edge), looking upslope towards the lake shore, showing interference bedforms in the near shore zone. See text for details. Note the diffuse echoes from the fringing reed beds causing the shore line to appear indistinct. Distance between range lines = 15 m.

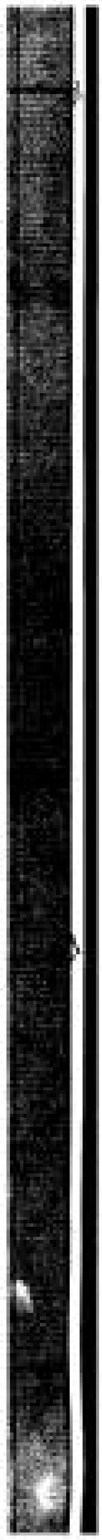

Figure 9

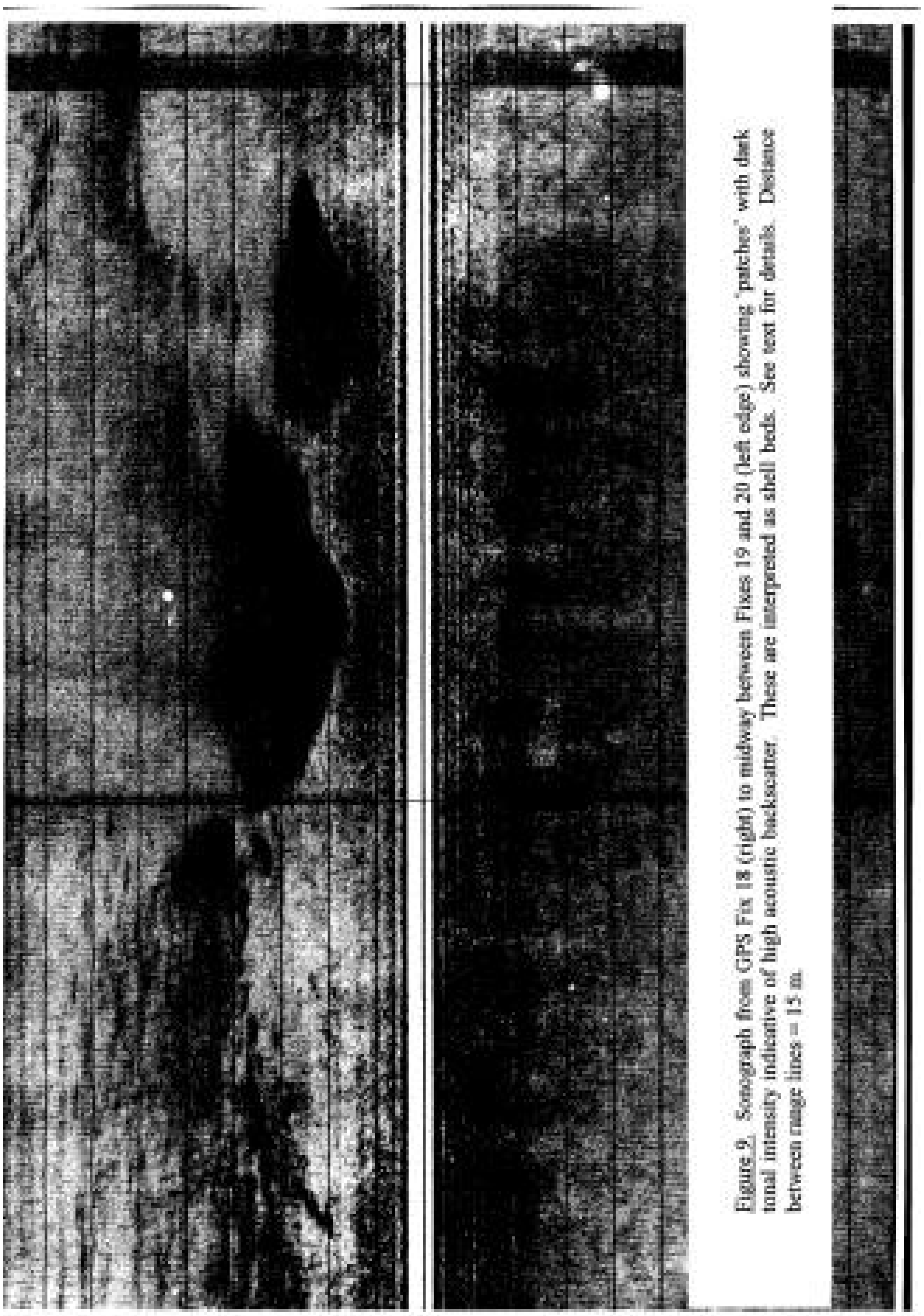

Figure 9. Sonograph from GPS Fix 18 (right) to midway between Fixes 19 and 20 (left edge) showing 'patches' with dark tonal intensity indicative of high acoustic backscatter. These are interpreted as shell beds. See text for details. Distance between range lines = 15 m.

Figure 10

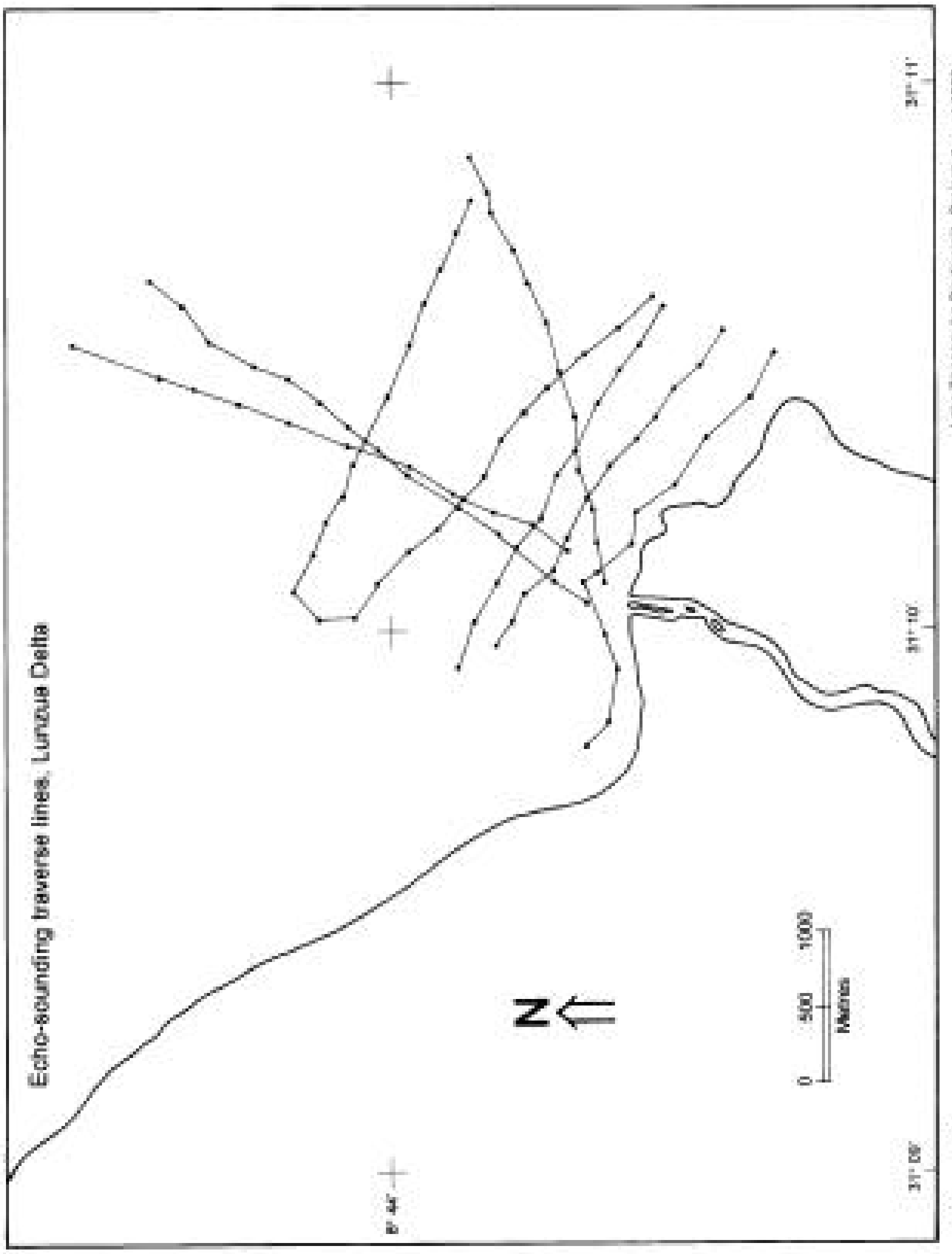

Figure 10

Figure 11

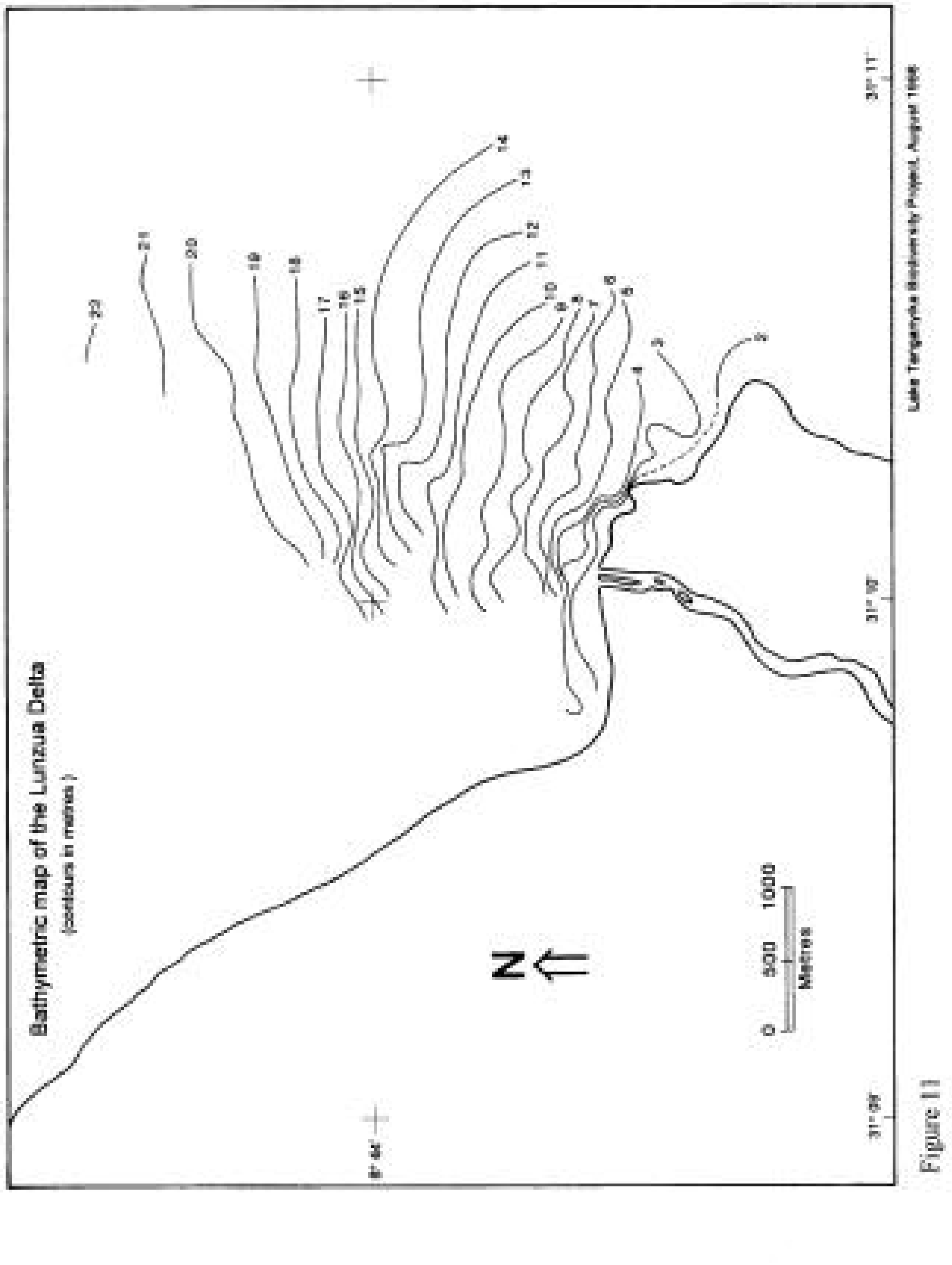
Bathymetric map of the Lunzua Delta
(contours in metres)
N
0 500 1000
Metres
Figure 11

Figure 12

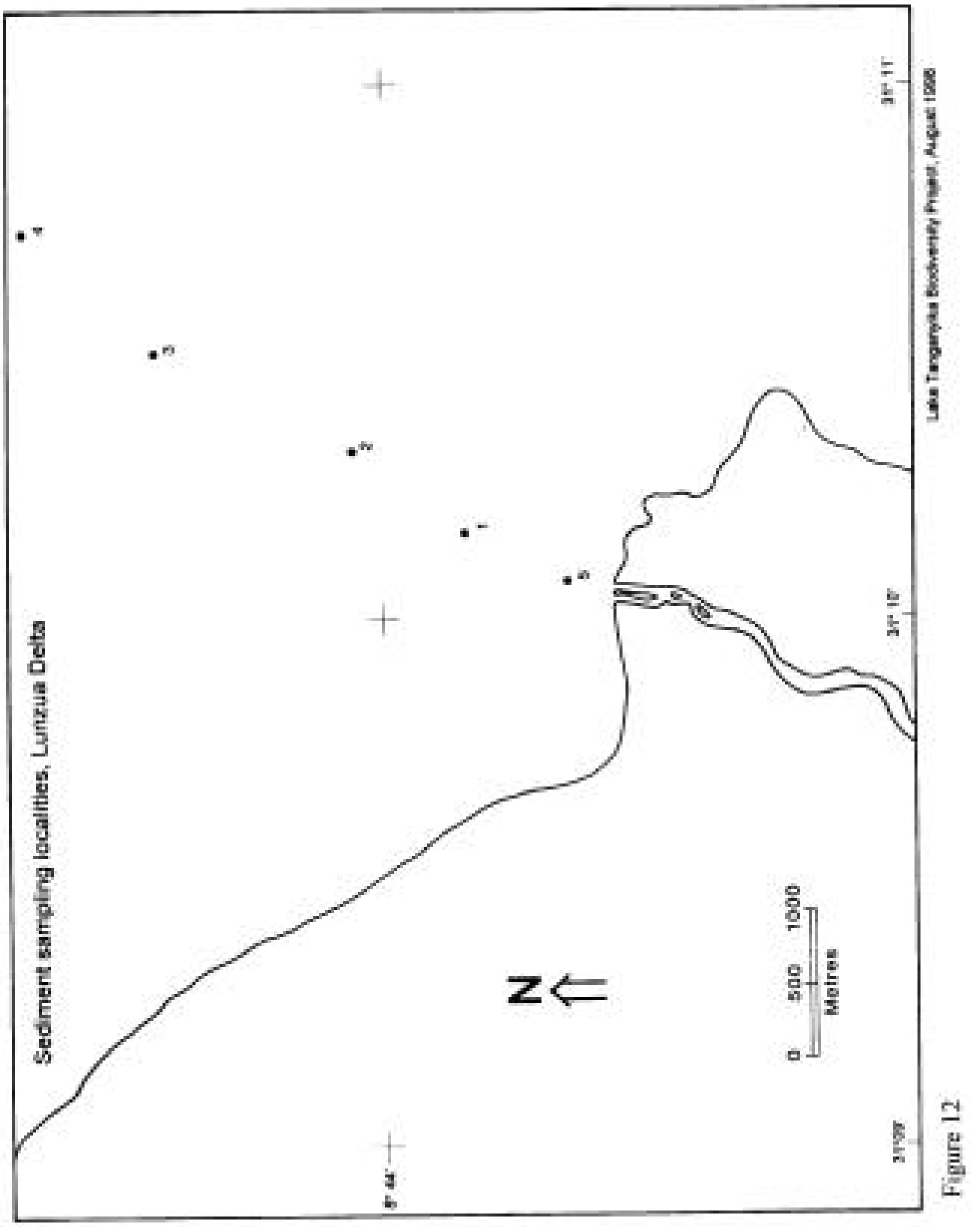
Sediment sampling localities, Lunzua Delta
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Figure 12