MARINE MANAGEMENT SUPPORT:
NINGALOO & OCEANIC SHOALS

WATER TEMPERATURE TIME SERIES DATA COLLECTED AT NINGALOO MARINE PARK, ROWLEY SHOALS MARINE PARK AND MERMAID REEF MARINE NATIONAL NATURE RESERVE (December 2000 – October 2001)

Data Report: MMS/NIN,OSS/NIN,RSH – 35/2001

A collaborative project between the Marine Conservation Branch, Exmouth District and West Kimberley District of the Department of Conservation and Land Management

Prepared by
J.A. Davidson and N. D'Adamo
February 2002

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry St
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- Dr Chris Simpson - Manager, Marine Conservation Branch (MCB), Nature Conservation Division.

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- Roland Mau – Conservation Officer (Marine), Exmouth District.
- Adam Meyer – Reserves Officer (Marine), Exmouth District.

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SUMMARY

This report presents water temperature data collected in Ningaloo Marine Park between 28th December 2000 and 8th October 2001 and Rowley Shoals Marine Park between 2nd December 2000 and 10th September 2001. These data were collected as part of the 2001/2002 Marine Conservation Branch (MCB) project titled*: Establishment of an ocean temperature monitoring capability in existing tropical marine reserves – Stage 2*. This project was coordinated by the MCB of the Department of Conservation and Land Management and conducted in collaboration with the Department's Exmouth District and West Kimberley District.

The objective of this project is to collect water temperature data over long time scales, as relevant to the management of the State's existing tropical marine conservation reserves, namely Ningaloo Marine Park and Rowley Shoals Marine Park, and the Commonwealth vested Mermaid Reef Marine National Nature Reserve. The data collected in Mermaid Reef (Mermaid Reef Marine National Nature Reserve) have not been presented in this data report for reasons which are explained within this report. The temperature monitoring program for Mermaid Reef was originally established as an opportunistic initiative when a charter vessel carrying staff from the Department, who were engaged to deploy temperature loggers in Rowley Shoals Marine Park, also visited Mermaid Reef as part of the charter routing. The Mermaid Reef loggers will be maintained to provide the Commonwealth with information relevant to the management of the area and to provide a data set complementary to those being collected in Rowley Shoals Marine Park.

The data acquired during this project will be used to conduct a correlation analyses between the water temperature data collected in-situ during this project and those derived by satellite-based sensors for the oceanic areas adjacent to the respective marine conservation reserves. An assessment of the suitability of using satellite derived sea surface temperature as an indicator of lagoonal water temperatures in existing tropical marine conservation reserves is a key requirement for management of these areas.

This project comprises part of the development of a statewide ocean temperature monitoring capacity in Western Australia's existing tropical marine conservation reserves, required by the Department for the characterisation and modelling of key ecological processes and for the on-going management of these areas.

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1 INTRODUCTION

This report presents water temperature data collected in Ningaloo Marine Park between 28th December 2000 and 8th October 2001 and Rowley Shoals Marine Park between 2nd December 2000 and 10th September 2001. These data were collected as part of the 2001/2002 Marine Conservation Branch (MCB) project titled*: Establishment of an ocean temperature monitoring capability in existing tropical marine reserves – Stage 2*. This project was coordinated by the MCB of the Department of Conservation and Land Management and conducted in collaboration with the Department's Exmouth District and West Kimberley District.

1.1 GENERAL BACKGROUND

Ningaloo Reef and the Rowley Shoals are pristine examples of Western Australia's system of tropical marine ecosystems. In order to protect the important ecological and socio-economic values of these coral reefs, the Ningaloo Marine Park, Rowley Shoals Marine Park and Mermaid Reef Marine National Nature Reserve were established in 1987, 1990 and 1991, respectively. Many of the management strategies identified in the respective management plans and draft management plans can only be achieved with a comprehensive knowledge of the physical environment within the marine reserves.

This project was established to collect water temperature data over long time scales, as relevant to the management of the State's existing tropical marine conservation reserves, namely Ningaloo Marine Park and Rowley Shoals Marine Park, and the Commonwealth vested Mermaid Reef Marine National Nature Reserve. The data collected in Mermaid Reef (Mermaid Reef Marine National Nature Reserve) have not been presented in this data report for reasons which are explained within this report. The temperature monitoring program for Mermaid Reef was originally established as an opportunistic initiative when a charter vessel carrying staff from the Department, who were engaged to deploy temperature loggers in Rowley Shoals Marine Park, also visited Mermaid Reef as part of the charter routing. The Mermaid Reef loggers will be maintained to provide the Commonwealth with information relevant to the management of the area and to provide a data set complementary to those being collected in Rowley Shoals Marine Park.

The data acquired during this project will be used to conduct a correlation analyses between the water temperature data collected in-situ during this project and those derived by satellite-based sensors for the oceanic areas adjacent to the respective marine conservation reserves. An assessment of the suitability of using satellite derived sea surface temperature as an indicator of lagoonal water temperatures in existing tropical marine conservation reserves is a key requirement for management of these areas.

This project comprises part of the development of a statewide ocean temperature monitoring capacity in Western Australia's existing tropical marine conservation reserves, required by the Department for the characterisation and modelling of key ecological processes and for the on-going management of these areas.

2 PURPOSE

The purpose of this report is to:

(i) present information, in the form of time series graphs, of the water temperature variation at:

- Tantabiddi, Ningaloo Marine Park, between 28th December 2000 and 8th October 2001.
- Clerke Reef, Rowley Shoals Marine Park, between 2nd December 2000 and 10th September 2001.

(ii) Report on the calibration of the temperature loggers used in this project, and;

(iii) Report any amendments that were made to the raw data.

3 METHODS

3.1 STUDY AREA

There are two study areas within this project:

- Ningaloo Marine Park, which is broadly described as the State Territorial Waters from Bundegi Reef, 5 km north of Exmouth, to Amherst Point (Figure 1), and;

- The Rowley Shoals, which includes the areas of the Rowley Shoals Marine Park and Mermaid Reef Marine National Nature Reserve. The Rowley Shoals are positioned approximately 260 km west north west of Broome lying between 17°07' S, 119°36' E and 17°35' S, 118°56' E (Figure 2).

3.2 SITE SELECTION

3.2.1 Ningaloo Marine Park

Two sites within Ningaloo Marine Park were selected for the deployment of water temperature loggers. Site NO1 was established using the existing Department of Conservation and Land Management mooring at Tantabiddi on 28th July 2000 (Figure 3). Site N48 was established at an existing MCB habitat monitoring site (see Cary *et al.,* 2000) in Bills Bay on 3rd January 2001 (Figure 4). These sites were selected to assist in characterising the annual temperature extremes of the lagoonal areas north and south of Point Cloates. It is expected that the largest temperature variations in Ningaloo Marine Park will occur within the lagoons. Recent studies suggest that the physical presence of Point Cloates provides a latitudinal transition in the general features of the oceanic hydrodynamics of Ningaloo Reef (D'Adamo and Simpson, 2001) and this further motivated the positioning of the loggers to the north and south of Point Cloates.

3.2.2 Rowley Shoals

Two sites within the Rowley Shoals were selected for the deployment of water temperature loggers. One site was established using the existing 'True North' mooring line in Clerke Reef on 2nd December 2000 (Figure 5). Another site was established in Mermaid Reef using a mooring constructed by Mike Lapwood (West Kimberley District) on 4th December 2000 (Figure 6). These sites were selected to assist in characterising the annual temperature extremes in the lagoonal areas of the Rowley Shoals. The site within Mermaid Reef Marine National Nature Reserve was established as an opportunistic initiative and will provide a data set complementary to those being collected in the Rowley Shoals Marine Park.

3.3 SAMPLING METHODS

StowAway Tidbit temperature loggers (Onset Computer Corporation; www.onset.com) were used to record water temperature data at pre-specified time intervals. All loggers for these deployments were set to record instantaneous temperature data at 30 minute intervals.

Note that advice from the manufacturer indicates that *StowAway Tidbit* temperature loggers immersed in water for a continuous period of 8 weeks or more at temperatures above 30 ^{o}C have a susceptibility to temperature drift. The only way to avoid this would be to waterproof the loggers by, for example, deploying them within waterproof containers. However, the absence of suitable containers (in respect of thermal lag response times between the outside water and inner air of the container) resulted in deployment without the protection of waterproof containers in this instance. The data has been appropriately scrutinised for the possibility of excessive temperature effects (see Section 3.5).

3.3.1 Ningaloo Marine Park

On 28th December 2000 two loggers were deployed at site NO1, Tantabiddi, Ningaloo Marine Park. Deployment details are presented in the field programme report by D'Adamo and Davidson (2001a) and are briefly described below in Table 1. The loggers were positioned side by side on the anchor (large wheel) of the existing Department of Conservation and Land Management mooring, using plastic electrical ties. The heights of the loggers were therefore maintained at approximately 30 cm above the seabed for the entire data collection period. The loggers were retrieved on 8th October 2001. Retrieval details are presented in the field programme report by Davidson and D'Adamo (2001) and are briefly described below in Table 2.

On 3rd January 2001 one logger was deployed at site N48, Bills Bay, Ningaloo Marine Park. Deployment details are presented in the field programme report by D'Adamo and Davidson (2001a) and are briefly described below in Table 1. The logger was secured, using metal wire, to a steel star picket encased by PVC piping, which was positioned among corals. The logger was positioned near the bottom of the water column (approximately 1 m from seabed). An attempt to retrieve the logger was made in early September 2001 and again on 18th December 2001 and, unfortunately, the logger was not found. The wire that the logger had been secured to was found in an unwound and straightened state, implying that it had been unraveled and the logger removed by force (suggesting vandalism).

Table 1: Deployment details for StowAway Tidbit temperature loggers at Ningaloo Marine Park

Name	Logger 1	Logger 2	Logger 3
Serial number	299266/2199	304276/0699	304285/6099
Activity	Deployment	Deployment	Deployment
Site name	NO1 (Tantabiddi)(i)	NO1 (Tantabiddi)(i)	N48 (Bills Bay)(ii)
Date	28/12/00	28/12/00	03/01/01
Time	1255 hrs	1255 hrs	Not recorded
Latitude(iii)	21.91181	21.91181	23.14127
Longitude(iii)	113.97354	113.97354	113.76938
Water depth (m) at time of deployment	Approx. 3 m	Approx. 3 m	Approx. 3 m
Position of logger in water column	Approx. 0.3 m above seabed	Approx. 0.3 m above seabed	Approx. 1 m above seabed (logger was positioned among coral)

(i) Site NO1 is the Department of Conservation and Land Management's mooring, which is located near the Tantabiddi boat ramp.
(ii) Site N48 is an existing MCB habitat monitoring site (see Cary *et al.*, 2000).
(iii) Latitude and longitude are presented in decimal degrees. They were recorded using a Garmin 12 GPS and the datum was WGS 84. The accuracy of these readings is ± 10 m.

Table 2: Retrieval details for StowAway Tidbit temperature loggers at Ningaloo Marine Park

Name	Logger 1	Logger 2	Logger 3
Serial number	299266/2199	304276/0699	304285/6099
Activity	Retrieval	Retrieval	Attempted retrieval (logger was not found)
Site name	NO1 (Tantabiddi)(i)	NO1 (Tantabiddi) (i)	N48 (Bills Bay) (ii)
Date	08/10/01	08/10/01	Early September 2001(iii)
Time	1505 hrs	1505 hrs	Not recorded
Latitude(iv)	21.91181	21.91181	23.14127
Longitude(iv)	113.97354	113.97354	113.76938
Water depth (m) at time of retrieval	Not recorded	Not recorded	Logger not retrieved
Position of logger in water column	Approx. 0.3 m above seabed	Approx. 0.3 m above seabed	Logger not retrieved

(i) Site NO1 is the Department of Conservation and Land Management's mooring, which is located near the Tantabiddi boat ramp.
(ii) Site N48 is an existing MCB habitat monitoring site (see Cary *et al.*, 2000).
(iii) Actual inspection date was not recorded, however advice from Roland Mau (Exmouth District) indicates that it occurred around early September 2001.
(iv) Latitude and longitude are presented in decimal degrees. They were recorded using a Garmin 12 GPS and the datum was WGS 84. The accuracy of these readings is ± 10 m.

3.3.2 Rowley Shoals

On 2nd December 2000 two loggers were deployed at Clerke Reef, Rowley Shoals Marine Park. Deployment details are presented in the field programme report by D'Adamo and Davidson (2001b) and are briefly described below in Table 3. The loggers were attached using stainless steel wire and a plastic electrical tie to the existing 'True North' mooring line. One logger was attached 1 m from the anchor and the other was attached 1 m from the surface float, both loggers were covered in 'gaffa' tape. The effect of tidal change and currents would have been such that the position (in the water column) of the bottom logger would have varied slightly with the tide, whereas the position of the top logger would have remained relatively constant (1 m under the surface).

The Clerke Reef loggers were retrieved by Ron Kitcher from the charter vessel 'Jodie Anne' on 10th September 2001. Unfortunately, the 'True North' mooring had lost its float and both loggers were found on the seabed still attached to the mooring chain. It is estimated that the damage to the mooring occurred on the 6th June 2001 (see Section 4). Retrieval details are presented in the field programme report by Davidson and D'Adamo (2001) and are briefly described below in Table 4.

On 4th December 2000 two loggers were deployed at Mermaid Reef Marine National Nature Reserve. Deployment details are presented in the field programme report by D'Adamo and Davidson (2001b) and are briefly described below in Table 3. The loggers were attached to a mooring constructed using approximately 10 m of rope, which was bouyed by a sub-surface float (approximately 1 m below the

surface) and anchored by a danforth anchor and chain. The loggers were attached in the same way as at Clerke Reef i.e. using stainless steel wire, plastic electrical ties and 'gaffa' tape. One logger was attached 1 m from the anchor and the other was attached 1 m from the sub-surface float. Tides and currents would have affected the position of both of the loggers in the water column.

An unsuccessful attempt to retrieve the Mermaid Reef loggers was made by Ron Kitcher on around the 10th September 2001. They were eventually retrieved on 17th October 2001. Unfortunately, the mooring to which the loggers were originally attached to, had lost its sub-surface float and both loggers were found to be lying on the seabed, covered by a thick layer of sand (approximately 5-20 cm deep). It is uncertain when this damage occurred and what effect the thick layer of sand would have on the data. Speculatively, the sand may have insulated the loggers and prevented them from recording accurately. As a result of this and other reasons which are explained in Section 3.5 the data collected from Mermaid Reef have not been presented in this report. Retrieval details are presented in the field programme report by Davidson and D'Adamo (2001) and are briefly described below in Table 4.

Table 3: Deployment details for StowAway Tidbit temperature loggers at the Rowley Shoals

Name	Logger 1	Logger 2	Logger 3	Logger 4
Serial number	299261/2199	304273/2199	304286/0699	298514/2199
Activity	Deployment	Deployment	Deployment	Deployment
Site name	Clerke Reef(i)	Clerke Reef(i)	Mermaid Reef(ii)	Mermaid Reef(ii)
Date	02/12/00	02/12/00	04/12/00	04/12/00
Time	0830 hrs	0830 hrs	0830 hrs	0830 hrs
Latitude(iii)	17.27916	17.27916	17.06562	17.06562
Longitude(iii)	119.36395	119.36395	119.6239	119.6239
Water depth (m) at time of deployment	11 m	11 m	12 m	12 m
Position of logger in water column	1 m from anchor	1 m beneath surface float	1m beneath sub-surface float	1 m from anchor

(i) Clerke Reef loggers were attached to the 'True North' mooring line (see D'Adamo and Davidson, 2001b).
(ii) Mermaid Reef loggers were attached to a mooring constructed by Mike Lapwood (West Kimberley District) specifically for the deployment of loggers (see D'Adamo and Davidson, 2001b).
(iii) Latitude and longitude are presented in decimal degrees. They were recorded using a Garmin 12 GPS and the datum was WGS 84. The accuracy of these readings is ± 10 m.

Table 4: Retrieval details for StowAway Tidbit temperature loggers at the Rowley Shoals

Name	Logger 1	Logger 2	Logger 3	Logger 4
Serial number	299261/2199	304273/2199	304286/0699	298514/2199
Activity	Retrieval	Retrieval	Retrieval	Retrieval
Site name	Clerke Reef(i)	Clerke Reef(i)	Mermaid Reef(ii)	Mermaid Reef(ii)
Date	10/09/01	10/09/01	17/10/01	17/10/01
Time	1115 hrs	1115 hrs	1745 hrs	1745 hrs
Latitude(iii)	17.27916	17.27916	17.06562	17.06562
Longitude(iii)	119.36395	119.36395	119.6239	119.6239
Water depth (m) at time of retrieval	12.4 m	12.4 m	10.7 m	10.7 m
Position of logger in water column	(iv)	(iv)	(v)	(v)

(i) Clerke Reef loggers were attached to the 'True North' mooring line (see D'Adamo and Davidson, 2001b), which was found to be damaged when the loggers were retrieved.
(ii) Mermaid Reef loggers were attached to a mooring constructed by Mike Lapwood (West Kimberley District) specifically for the deployment of loggers (see D'Adamo and Davidson, 2001b), this mooring was found to be damaged when the loggers were retrieved.
(iii) Latitude and longitude are presented in decimal degrees. They were recorded using a Garmin 12 GPS and the datum was WGS 84. The accuracy of these readings is ± 10 m.
(iv) The mooring was in a damaged state at the time of retrieval. Consequently, the loggers were resting on the seabed.
(v) The mooring was in a damaged state at the time of retrieval. Consequently, the loggers were lying on the seabed covered with a thick layer of sand (approximately 5-20 cm deep).

3.4 CALIBRATION

3.4.1 Pre-deployment calibration

StowAway Tidbit temperature loggers have an accuracy of ± 0.23 °C and must be calibrated against a thermometer, or any other temperature recorder with an accuracy much better than ± 0.23 °C, prior to all field deployments. For these deployments, calibration was performed using a scientific mercury thermometer (accuracy of ± 0.05 °C). The procedure for calibration was as follows:

(i) Temperature loggers were initialised to record instantaneous temperature data at 1 minute intervals;
(ii) The air temperature and time were recorded using a mercury thermometer and stop watch;
(iii) The loggers were placed in a bucket of water for approximately 20 minutes;
(iv) The water temperature and time were recorded several times during the calibration using the mercury thermometer and stop watch;
(v) The loggers were taken out of the water and dried;
(vi) The air temperature and time were recorded every 1 minute for approximately 5 minutes;
(vii) The information was downloaded from the loggers to check that the difference between the logger and thermometer water temperature readings was not greater than ± 0.23 °C.

All loggers were recording at an accuracy of better than ± 0.23 °C before their deployment. The calibration data for the Ningaloo Marine Park loggers has been recorded in the Marine Conservation Branch official file, number 1997F001167. In this instance, the calibration data for the Rowley Shoals loggers were not recorded.

3.4.2 Post-retrieval calibration

A post-retrieval calibration was performed to ensure that the loggers retained an accuracy of ± 0.23 °C. This calibration was carried out using the same procedure as the pre-deployment calibration (see Section 3.4.1). The calibration data has been recorded in the relevant Marine Conservation Branch official files, number 1997F001169 and number 1997F001167.

The results of the post-retrieval calibration showed that most of the loggers were recording at an accuracy of better than ± 0.23 °C. The bottom logger at Mermaid Reef (logger 4 serial number 298514) and the bottom logger at Clerke Reef (logger 1 serial number 299261) were consistently recording water temperatures under the thermometer by 0.63 °C and 0.3 °C, respectively. That is, they exceeded the allowable difference of ± 0.23 °C by 0.4 °C and 0.07 °C, respectively. It was decided that the data retrieved from the Mermaid Reef logger (logger 4 serial number 298514) would not be used due to the high error in the readings. The data retrieved from the Clerke Reef logger (logger 1 serial number 299261) would still be used, as the error was small.

One of the Ningaloo Marine Park loggers (logger 2 serial number 304276) was damaged during the deployment period and therefore was not calibrated after the retrieval. The logger was sent to Onset Computer Corporation who retrieved the data by interrogating the electronics of the logger. Comparisons with the data retrieved from the other Tantabiddi logger shows that they were both recording within ± 0.23 °C of each other for most of the time.

3.5 AMENDMENTS TO DATA

The raw temperature data collected from Ningaloo Marine Park and the Rowley Shoals were carefully scrutinised for erroneous data in the time series, such as:

- Electrical spikes, which are erroneous readings that appear as spikes in the time series graphs.
- Temperatures in excess of 30 °C for periods of 8 weeks or more, which may cause the logger to temperature drift.
- Temperature differences between two loggers that were positioned next to each other in the field, which may highlight errors in the readings.

No electrical spikes or temperatures in excess of 30 °C for periods of 8 weeks or more were found. The data collected by logger 1 (serial number 299266) and 2 (serial number 304276) at Ningaloo Marine Park and by logger 1 (serial number 299261) and 2 (serial number 304273) at Rowley Shoals Marine Park are considered to be 'good' data and no amendments were necessary.

The data recorded by logger 3 (serial number 304286) and 4 (serial number 298514) at Mermaid Reef Marine National Nature Reserve is considered to be erroneous data. The reasons for this being:

- The calibration data showed that logger 4 was consistently recording temperatures under the thermometer by 0.63 °C.
- The mooring to which the loggers were originally attached to, had lost its sub-surface float and both loggers were found to be lying on the seabed, covered by a thick layer of sand (approximately 5-20 cm deep). It is uncertain when this damage occurred and what effect the thick layer of sand would have on the data. Speculatively, the sand may have insulated the loggers and prevented them from recording accurately.
- The time series seemed to be 'smoother' that those recorded at Clerke Reef, indicating that the Mermaid Reef loggers were being insulated by the sand and were not recording diurnal water temperature changes.
- There were significant differences between the data retrieved from the two loggers. The bottom logger (logger 4) was consistently reading higher temperatures than the top logger (logger 3) and the magnitude of this difference increased from approximately 0.1 °C to 0.3 °C from the beginning to the end of the deployment.

Consequently, the data from the Mermaid Reef loggers has not been presented in this data report. It will be stored digitally at the Marine Conservation Branch at two locations:

1. The MCB server:
   144-mcb gis data on 'Calm-frem-1'
   [L:\MIS\Data\Development\Oceanography\Temperature\Calm]

2. MCB Server full backup DAT tape:
   [L:\MIS\Data\Development\Oceanography\Temperature\Calm]

4 RESULTS

The Ningaloo Marine Park and Rowley Shoals Marine Park water temperature data were plotted as time series graphs (Figure 7 – 15). Figures 7 and 12 present the data recorded by the loggers from deployment to retrieval at Tantabiddi and Clerke Reef, respectively. The time series have also been separated into summer (December – February), autumn (March – May), winter (June – August) and spring (September – November) and plotted as time series graphs for Ningaloo Marine Park (Figure 8 - 11) and Rowley Shoals Marine Park (Figures 13 - 15). The spring time series are incomplete as the Tantabiddi loggers were retrieved in October and the Clerke Reef loggers were retrieved in September.

Notable results in the data include:

- The highest recorded water temperature was 31.84 °C. This was recorded at Clerke Reef by logger 2 (serial number 304273) at 6:50 PM on 6th January 2001 and 5:50 PM and 7:20 PM on 20th January 2001.

- The lowest recorded water temperature was 18.37 °C. This was recorded at Tantabiddi by logger 2 (serial number 304276) at 12:05 PM on 3rd September 2001.

- The mooring that the Clerke loggers were originally attached to was damaged on approximately 6th June 2001. This is evident in the time series plot where both loggers started to record the same temperature (Figure 12). Prior to this date they were recording different temperatures as one was positioned near the surface and the other was positioned near the seabed.

Other notable results are presented in Table 5.

Table 5: Notable results in water temperature time series data collected at Ningaloo Marine Park and Rowley Shoals Marine Park

Logger/site	Max. temp. (°C)	Min. temp. (°C)	Mean temp. (°C)	Mean summer temp. (°C)	Mean winter temp. (°C)	Figure N°.	Instances of relatively rapid change in temperature (i.e. greater than normally expected due to tide and diurnal heating and cooling)
Logger 1 (serial # 299266) Tantabiddi, Ningaloo Marine Park Logger was positioned approx. 0.3 m above the seabed.	31.2	18.41	24.61	27.23	22.45	7-11	From 30/01/01 (5:34 PM) to 01/02/01 (7:04 AM) the temperature decreased from 30.26 °C to 24.37 °C. From 14/03/01 (6:04 PM) to 17/03/01 (7:04 AM) the temperature decreased from 30.82 °C to 24.2 °C. From 17/04/01 (5:04 PM) to 19/04/01 (9:34 AM) the temperature decreased from 29.14 °C to 23.86 °C. From 23/04/01 (5:04 PM) to 27/04/01 (6:34 AM) the temperature decreased from 29.69 °C to 23.17 °C. From 04/06/01 (9:04 PM) to 06/06/01 (3:34 AM) the temperature decreased from 24.89 °C to 18.89 °C. From 13/06/01 (10:04 AM) to 15/06/01 (6:04 PM) the temperature increased from 20.52 °C to 24.54 °C. From 19/07/01 (11:34 PM) to 20/07/01 (4:04 PM) the temperature increased from 19.87 °C to 23.68 °C. From 30/07/01 (10:04 PM) to 01/08/01 (12:04 PM) the temperature decreased from 24.54 °C to 20.19 °C. From 12/08/01 (10:04 AM) to 13/08/01 (4:04 PM) the temperature increased from 19.22 °C to 24.03 °C. From 15/08/01 (5:34 PM) to 16/08/01 (10:34 AM) the temperature decreased from 24.72 °C to 21.17 °C. From 29/08/01 (6:04 PM) to 31/08/01 (9:04 AM) the temperature decreased from 24.2 °C to 20.19 °C.
Logger 2 (serial # 304276) Tantabiddi, Ningaloo Marine Park Logger was positioned approx. 0.3 m above the seabed	31.37	18.37	24.67	27.34	22.45	7-11	From 30/01/01 (5:34 PM) to 01/02/01 (7:04 AM) the temperature decreased from 30.42 °C to 24.33 °C. From 14/03/01 (6:04 PM) to 17/03/01 (7:04 AM) the temperature decreased from 30.99 °C to 24.33 °C. From 17/04/01 (5:04 PM) to 19/04/01 (9:34 AM) the temperature decreased from 29.31 °C to 23.98 °C. From 23/04/01 (5:04 PM) to 27/04/01 (6:34 AM) the temperature decreased from 29.86 °C to 23.13 °C. From 04/06/01 (9:04 PM) to 06/06/01 (3:34 AM) the temperature decreased from 25.03 °C to 18.86 °C. From 13/06/01 (10:04 AM) to 15/06/01 (6:04 PM) the temperature increased from 20.47 °C to 24.68 °C. From 19/07/01 (11:34 PM) to 20/07/01 (4:04 PM) the temperature increased from 19.99 °C to 23.81 °C. From 30/07/01 (10:04 PM) to 01/08/01 (12:04 PM) the temperature decreased from 24.68 °C to 20.15 °C. From 12/08/01 (10:04 AM) to 13/08/01 (4:04 PM) the temperature increased from 19.18 °C to 23.98 °C. From 15/08/01 (5:34 PM) to 16/08/01 (10:34 AM) the temperature decreased from 24.86 °C to 21.13 °C. From 29/08/01 (6:04 PM) to 31/08/01 (9:04 AM) the temperature decreased from 24.33 °C to 20.15 °C.

Logger/site	Max. temp. (°C)	Min. temp. (°C)	Mean temp. (°C)	Mean summer temp. (°C)	Mean winter temp. (°C)	Figure N°.	Instances of relatively rapid change in temperature (i.e. greater than normally expected due to tide and diurnal heating and cooling)
Logger 1 (serial # 299261) Clerke Reef, Rowley Shoals Marine Park From deployment to 06/06/01 logger was positioned approx. 1 m above seabed. From 0606/01 to retrieval logger was positioned on seabed.	30.03	23.28	27.24	28.34	25.40	12-15	From 05/12/00 (7:20 PM) to 09/12/00 (7:20 AM) the temperature decreased from 29.11 °C to 26.23 °C. From 17/01/01 (2:50 PM) to 19/01/01 (12:20 AM) the temperature decreased from 29.84 °C to 27.66 °C. From 14/02/01 (7:50 PM) to 16/02/01 (1:50 AM) the temperature decreased from 29.29 °C to 27.12 °C. From 06/06/01 (5:20 PM) to 06/06/01 (9:50 PM) the temperature decreased from 26.94 °C to 24.49 °C.
Logger 2 (serial # 304273) Clerke Reef, Rowley Shoals Marine Park From deployment to 06/06/01 logger was positioned 1 m beneath surface float. From 0606/01 to retrieval logger was positioned on seabed.	31.84	22.88	27.45	28.71	25.41	12-15	From 05/12/00 (7:20 PM) to 09/12/00 (7:20 AM) the temperature decreased from 29.58 °C to 26.51 °C. From 17/01/01 (2:50 PM) to 19/01/01 (12:20 AM) the temperature decreased from 30.32 °C to 28.48 °C. From 14/02/01 (7:50 PM) to 16/02/01 (1:50 AM) the temperature decreased from 29.21 °C to 27.93 °C. From 06/06/01 (5:20 PM) to 06/06/01 (9:50 PM) the temperature decreased from 26.86 °C to 24.77 °C.

5 DATA MANAGEMENT

5.1 REPORT

Hard copies of this report will be held at three locations:

1. Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry St., Fremantle Western Australia, 6160. Ph: (08) 9432 5100 Fax: (08) 9430 5408.

2. Woodvale Library, Science and Information Division, Ocean Reef Rd., Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641.

3. Archives, Woodvale Library, Science and Information Division, Ocean Reef Rd., Woodvale, Western Australia, 6026. Ph: (08) 9405 5100 Fax: (08) 9306 1641.

The Marine Conservation Branch will hold digital copies of this report at the following:

1. The Marine Conservation Branch Server:
   Shareddata on 'Calm-frem-1' [T:\144-Marine Conservation Branch\Shared Data\Current_MCB_reports\MMS\mms_3501]

2. MCB Server full backup DAT tape:
   [T:\144-Marine Conservation Branch\Shared Data\Current_MCB_reports\MMS\mms_3501]

3. CD-ROM [MMS_3501]

5.2 OCEANOGRAPHIC DATA

A database of the oceanographic data will be stored digitally at two locations:

3. The MCB server:
   144-mcb gis data on 'Calm-frem-1'
   [L:\MIS\Data\Development\Oceanography\Temperature\Calm]

4. MCB Server full backup DAT tape:
   [L:\MIS\Data\Development\Oceanography\Temperature\Calm]

6 REFERENCES

D'Adamo, N. and Davidson, J. A. (2001a). Establishment of an oceanographic monitoring network in marine reserves: Stage 1. Temperature monitoring in Ningaloo Marine Park (July 2000 – January 2001). Field Programme Report: MMS/NIN/NIN–32/2001. Marine Conservation Branch, Department of Conservation and Land Management, Perth, Western Australia. (Unpublished report).

D'Adamo, N. and Davidson, J. A. (2001b). Establishment of an oceanographic monitoring network in marine reserves: Stage 1. Temperature monitoring in Rowley Shoals Marine Park (December 2000). Field Programme Report: MMS/OSS/RSMP–34/2001. Marine Conservation Branch, Department of Conservation and Land Management, Perth, Western Australia. (Unpublished report).

D'Adamo, N. and Simpson, C. J. (2001). Review of the oceanography of Ningaloo Reef and adjacent waters. Technical Report: MMS/NIN/NIN-38/2001. Marine Conservation Branch, Department of Conservation and Land Management, Perth, Western Australia. (Unpublished report).

Davidson, J. A. and D'Adamo, N. (2001). Temperature monitoring in Ningaloo Marine Park, Rowley Shoals Marine Park and Mermaid Reef Marine National Nature Reserve: Retrieval and deployment details of temperature loggers (September – October 2001). Field Programme Report: MMS/NIN,OSS/NIN,RSH – 51/2001. Marine Conservation Branch, Department of Conservation and Land Management, Perth, Western Australia. (Unpublished report).

Cary, J. L., Grubba, T.L., Mahendran, M. and Radford, B. J. (2000). Ningaloo Marine Park Monitoring Program: Benthic monitoring sites established in 1999. Data Report: MMS/PI/NMP-21/2000. Marine Conservation Branch, Department of Conservation and Land Management. Perth, Western Australia. (Unpublished report).

FIGURES

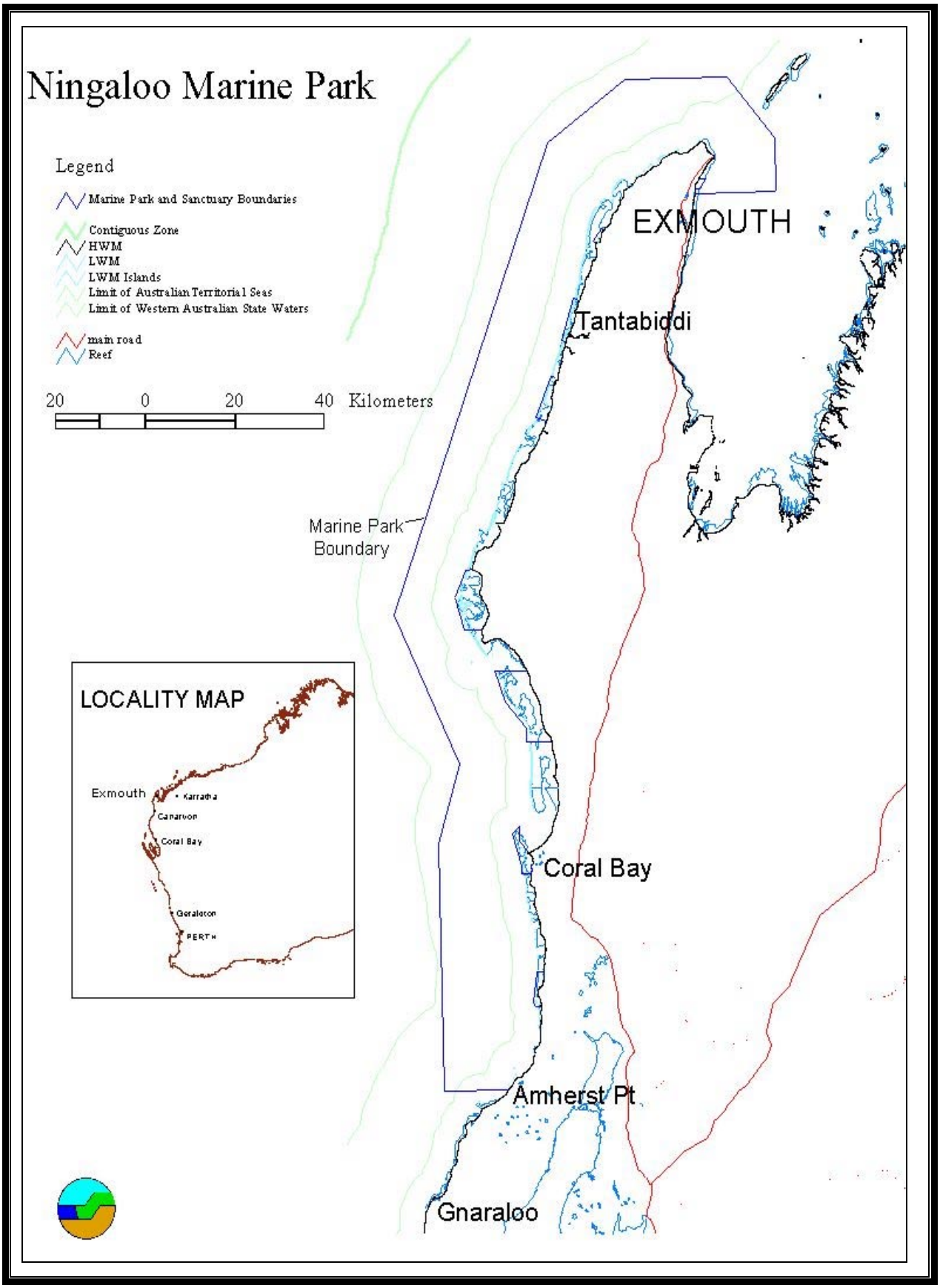

Figure 1: The Ningaloo Marine Park study area

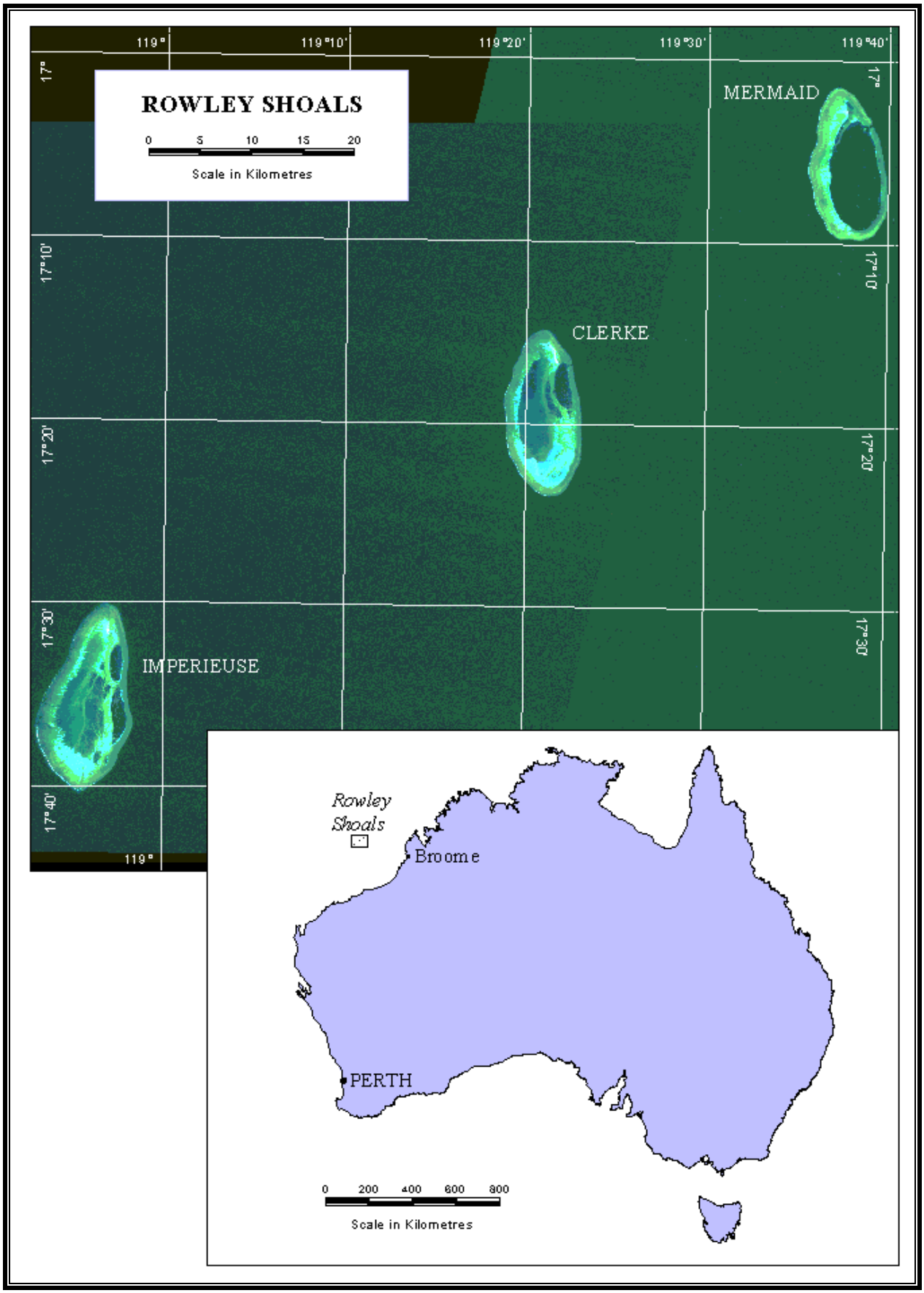

Figure 2: The Rowley Shoals study area

Figure 3: Approximate location of the water temperature monitoring site (NO1) at Tantabiddi, Ningaloo Marine Park

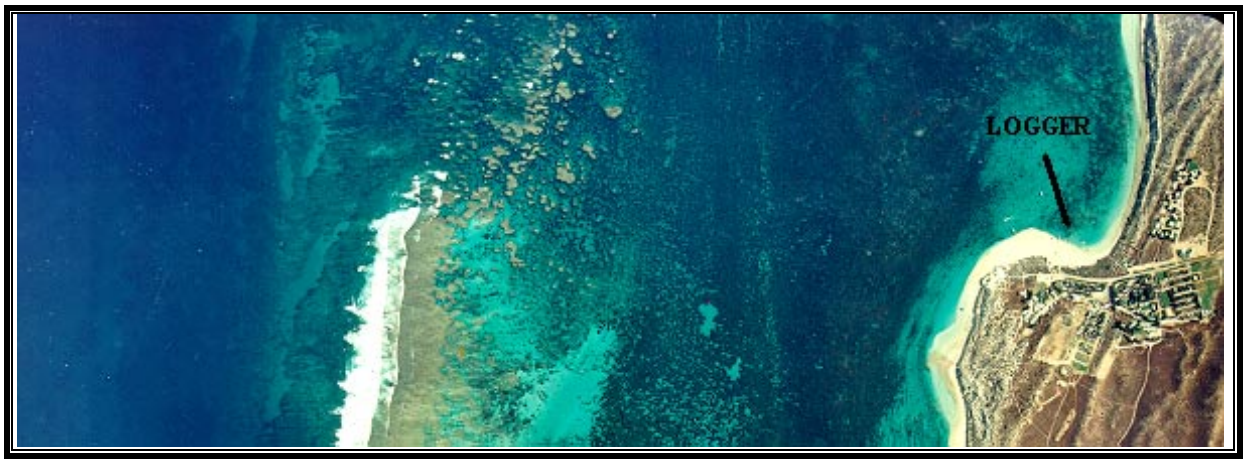

Figure 4: Approximate location of the water temperature monitoring site (N48) at Bills Bay, Ningaloo Marine Park

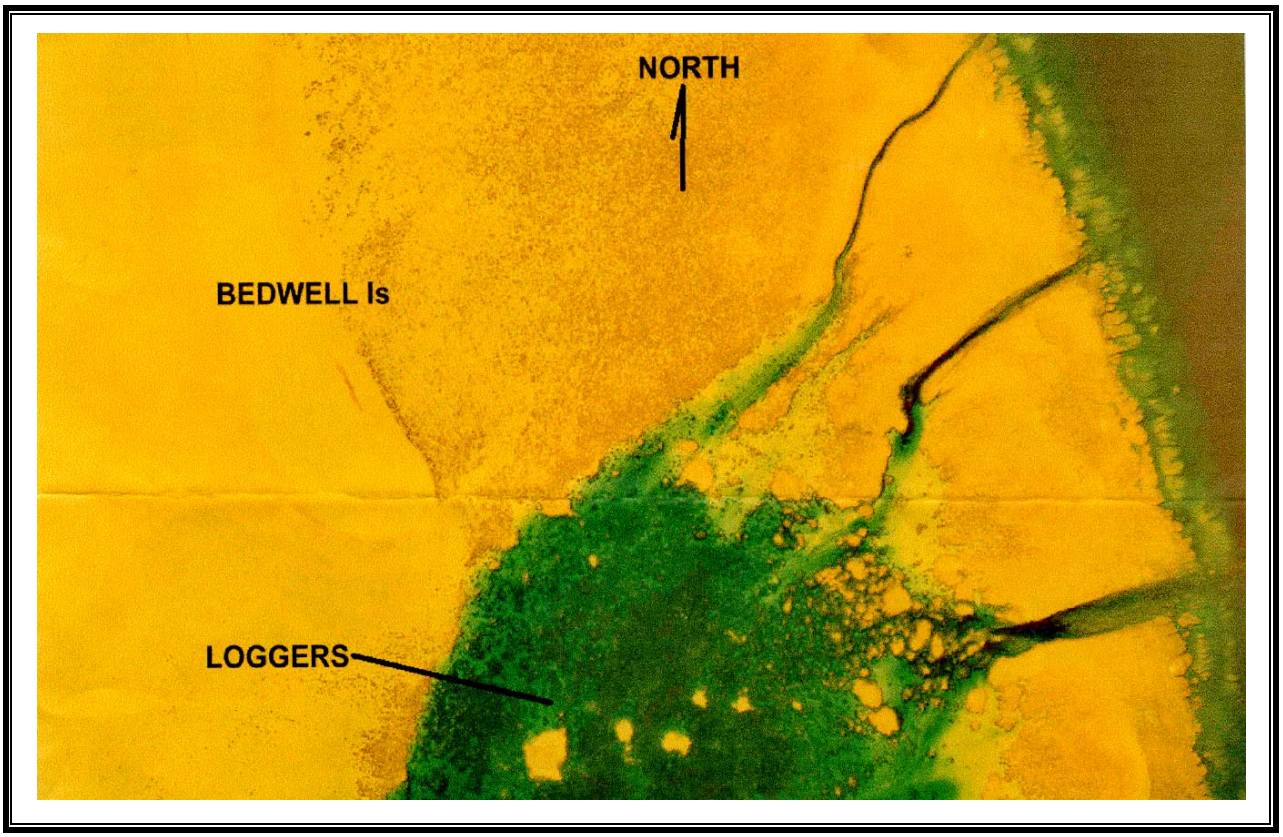

Figure 5: Approximate location of the water temperature monitoring site at Clerke Reef, Rowley Shoals Marine Park

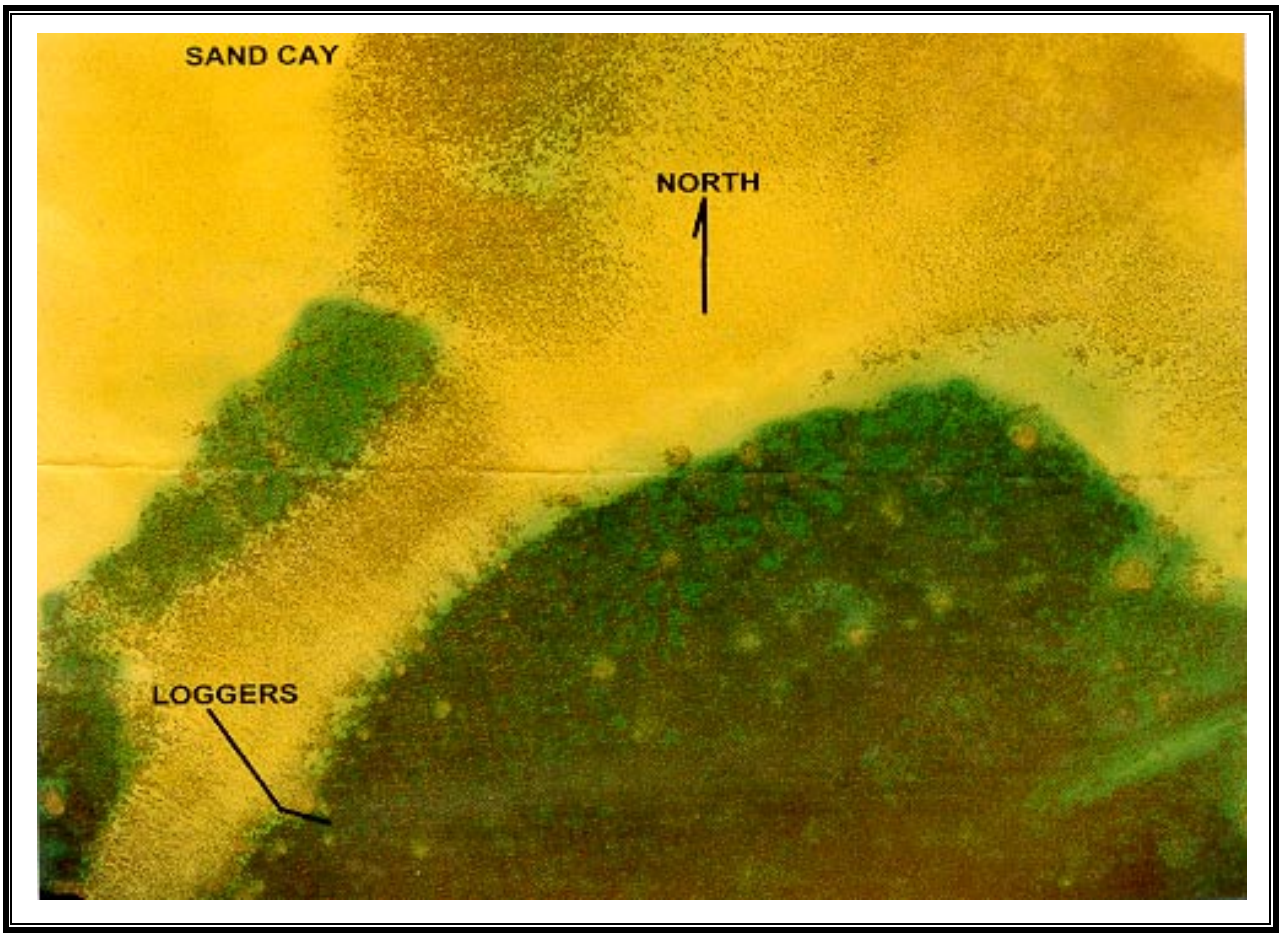

Figure 6: Approximate location of the water temperature monitoring site at Mermaid Reef, Mermaid Reef Marine National Nature Reserve

Figure 7: Water temperature time series from 28th December 2000 to 8th October 2001 at Tantabiddi, Ningaloo Marine Park, recorded by logger 1 (serial number 299266) and logger 2 (serial number 304276)

Figure 8: Water temperature time series from 28th December 2000 to 28th February 2001 at Tantabiddi, Ningaloo Marine Park, recorded by logger 1 (serial number 299266) and logger 2 (serial number 304276)

Figure 9: Water temperature time series from 1st March 2001 to 31st May 2001 at Tantabiddi, Ningaloo Marine Park, recorded by logger 1 (serial number 299266) and logger 2 (serial number 304276)

Figure 10: Water temperature time series from 1st June 2001 to 31st August 2001 at Tantabiddi, Ningaloo Marine Park, recorded by logger 1 (serial number 299266) and logger 2 (serial number 304276)

Figure 11: Water temperature time series from 1st September 2001 to 8th October 2001 at Tantabiddi, Ningaloo Marine Park, recorded by logger 1 (serial number 299266) and logger 2 (serial number 304276)

Figure 12: Water temperature time series from 2nd December 2000 to 10th September 2001 at Clerke Reef, Rowley Shoals Marine Park, recorded by logger 1 (serial number 299261) and logger 2 (serial number 304273)

Figure 13: Water temperature time series from 2nd December 2000 to 28th February 2001 at Clerke Reef, Rowley Shoals Marine Park, recorded by logger 1 (serial number 299261) and logger 2 (serial number 304273)

Figure 14: Water temperature time series from 1st March 2001 to 31st May 2001 at Clerke Reef, Rowley Shoals Marine Park, recorded by logger 1 (serial number 299261) and logger 2 (serial number 304273)

Figure 15: Water temperature time series from 31st June 2001 to 10th September 2001 at Clerke Reef, Rowley Shoals Marine Park, recorded by logger 1 (serial number 299261) and logger 2 (serial number 304273)