1.3. OBJECTIVES

- Collate available existing physical data relating to the seabed & water-column environment of the Torres Strait, eg. sediments, bathymetry, currents & stress, water physical & chemical attributes, ocean colour, trawl effort etc.

- Collate available existing biological data relating to the seabed environment of the Torres Strait, eg. habitat type, flora and fauna species distribution and abundance data.

- Conduct exploratory analysis of bio-physical relationships, spatial modelling and stratification based on available biological and physical data of the seabed & water-column from the Torres Strait.

- To the extent possible, characterise, describe & map patterns in seabed & water-column biological and physical attributes, including those potentially vulnerable to trawling and other seabed activities.

- Assess the current state of relevant knowledge of the seabed & water-column environment, habitats, and biological assemblages of the Torres Strait

- Identify key information needs, including areas of seabed & water-column where additional sampling / mapping / survey work is required and design a sampling strategy for that survey work (including PNG seabed in the Torres Strait);

- Provide a report and GIS information to the NOO and Torres Strait Reef CRC / Torres Strait Fisheries Scientific Advisory Committee to support the marine planning and research in the Torres Strait

2. METHODS & RESULTS

This Project characterised the major patterns in the seabed habitats & water-column of Torres Strait (Figure 2.0-1), at spatial scales relevant to regional conservation and management needs, and planning/design of future research surveys. The information included: seabed habitat distribution in inter-reef areas; water chemistry; and physical attributes that may drive patterns within the system.

The approach was to collate and integrate the available biological, habitat, physical and water-column data; analyse bio-physical relationships to identify important environmental variables; stratify the Torres Strait seabed based on these variables weighted by their biological importance; attempt spatial-prediction of seabed biological assemblage information to provide interim characterisation of the Torres Strait seabed and estimates of prediction uncertainty; design sampling for future seabed surveys to achieve representative inclusion of important biological components, major habitat strata, and areas of uncertainty.

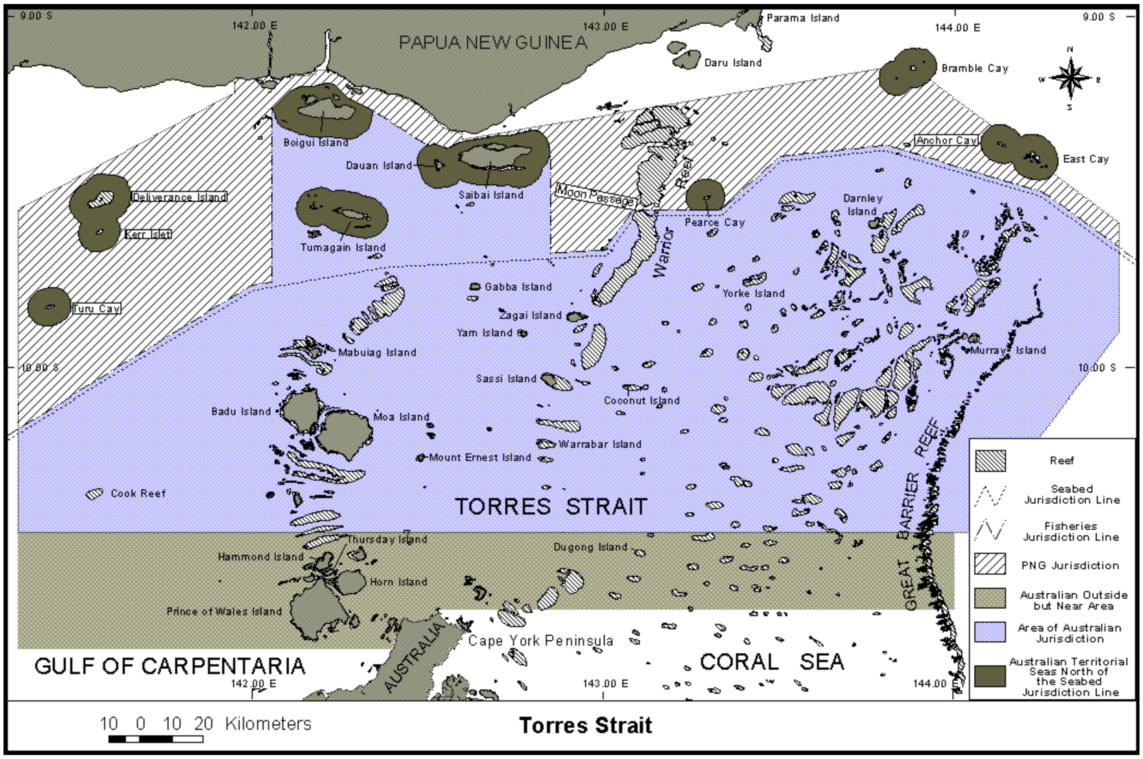

Figure 2.0-1 Map of Torres Strait showing the spatial scope of the Project, including all continental shelf marine seabeds and water column within the Torres Strait Protected Zone (corresponding to the scope of the CRC proposal) and relevant adjacent waters (extent indicated by map).

2.1. COLLATION OF AVAILABLE DATASETS

Available datasets of biological and physical data were collated from several internal & external sources. Some data was already held by CMR and simply needed to be mapped onto a 0.01º grid for analysis by this Project, some previously held data required updating before importing into GIS and mapping onto the grid, thirdly, some data needed to be sourced. These datasets included those outlined below.

2.1.1. Datasets Collated

- **Torres Strait Jurisdiction Zones**/Lines for Fisheries, Management, Protected Zone – these datasets were available from previous AFMA funded research in TS.

- **Bathymetry** – this dataset was updated from CMR (digital soundings & imagery) and GA sources, incorporated into GIS and modelled to produce a DEM and mapped onto a 0.01º grid. The coverage of the TS is extensive but not complete. Slope and aspect variables were derived.

- **Seabed sediment composition** – this dataset was updated from CMR and Ocean Sciences Institute (Chris Jenkins, formally OSI, Sydney University, auSeabed sediment database) sources, incorporated into GIS and mapped onto a 0.01º grid. Coverage is the most extensive available in TS, but is not complete. The dataset included: characteristic grain size (phi), sorting, %mud, %sand, %gravel, %rock, %carbonate, with varying degrees of spatial reliability.

- **Torres Strait Prawn Trawl Fishery Logbook** – this dataset was provided by Industry–QDPI/QFS and has been updated post 1997 to cover the years 1989-2002. TS trawl effort (boat-days) data has been summarised annually at 6' (0.1º) resolution (~11.1 km).

- **Seabed current-stress** – this dataset was provided by Bode & Mason (JCU/Reef-CRC). The data are root mean square (RMS) stress (Pascals (N/m^2)) output from a circulation model run over period of approx 6 months. The modelled coverage is for the entire TS region, at 1 minute of arc resolution (~1.8 km), but is dependent on bathymetry data (which is incomplete) and other model assumptions.

- **CSIRO Atlas of Regional Seas (CARS)** – this dataset is an Australia wide database of water-column physical and chemical attributes maintained by CMR. The dataset included temporal series at fixed stations in Torres Strait and additional data has been collated to provide broader spatial coverage. All available measurements of water column properties were mapped at the the near-surface and the seabed to provide full-coverage of the TS region at 1/8 degree resolution by weighted averaging that takes into account bathymetry and seasonality. Water properties evaluated included:
  - temperature - degrees C, mean and standard deviations
  - salinity - psu, mean and standard deviations
  - oxygen - ml/l, mean and standard deviations
  - silicate - uM, mean and standard deviations
  - phosphate - uM, mean and standard deviations
  - nitrate – uM, mean and standard deviations

- **Ocean Colour** – this dataset includes estimates of mean and standard deviations for chlorophyll concentration and turbidity, processed by CMR based on SeaWiFS satellite data and calibration and validation algorithms. The SeaWiFS coverage has been updated with more than a year of additional data (more than 4 years in total). Relative benthic irradiance has been calculated, based on K490, latitude, and depth. The data provides full coverage of the TS region, with 0.01º resolution ~(1.11 km).
  - chlorophyll-a (mg/m3) concentration, mean and standard deviations
  - K490 diffuse attenuation coefficient at wavelength 490nm, m-1, mean and standard deviations

- **Seabed substratum types and living habitat** – this dataset includes physical substratum, epibenthos, seagrass, algae from several CSIRO diver and towed-video surveys of western, central and southeast TS over the period 1987-2002. While some surveys provided species abundance or percent cover detail, this level of information was not available with sufficient spatial coverage for analysis and a common set of lower level information was extracted. Broad scale coverage was provided primarily by 6 Projects/Surveys:
  - Western TS Seagrass Survey 1987
  - Lobster Abundance Survey 1989
  - South Eastern TS Pipeline Survey 1996
  - Central TS Pipeline Survey 1997

- PNG Lobster Abundance Survey 1998
- Lobster Benchmark Abundance Survey 2002

The following common set of lower level data was available for all surveys:

- SUB_CODE classification: 1= >50% rocky, 2= 10-50% rock, 3= rubble, 4= sand, 5= mud
- BIO_CODE classification:
  1= dense epibenthos, fauna separated by a few metres or less, covering >50% of the transect
  2= sparse, fauna separated by more than a few metres, covering 10-50% of the transect
  3= very sparse, patches separated by 10s-100s of metres, covering <10% of the transect
  4= no epibenthos, virtually no epibenthic fauna present
- PA_ALGAE: Presence/Absence Algae
- PA_SEAGRASS: Presence/Absence Seagrass

A slightly higher level of information was available with somewhat reduced spatial coverage:

- PCT_TOT_ALG: Estimated total cover of all Algae on transect %
- PCT_TOT_SGRS: Estimated total cover of all Seagrass on transect %
- PCT_SUB_COMP: Estimated mud/silt, sand/gravel, rubble, consolidated, rock on transect %

- **Torres Strait Effects of Trawling Study** – this dataset includes seabed fish abundance by species by station from a series of trawl surveys conducted in the region of the trawl fishery in central eastern Torres Strait during the mid 1980s.

- **Acoustics** – this dataset includes RoxAn Hardness and Roughness indices (and Depth) acquired during various surveys conducted 1986-2002.

2.2. OCEANOGRAPHIC DATA

2.2.1. Tides and currents

The bathymetric complexity of Torres Strait severely limits exchanges of both water and wave energy between the Gulf of Carpentaria and Coral Sea. The semidiurnal and diurnal tides contain most of the tidal energy on both sides of the strait, the dominant constituents being O_1, K_1, M_2, S_2, and N_2. However, bottom friction within the straits dissipates much of the tidal energy. Sea-level is therefore not coherent across the strait and the spring-neap cycles are not aligned. This mismatch can result in sea-level differences across the strait of up to 6 m (Wolanski et al. 1988), which drives tidal currents of almost 2 m s^{-1} in the major shipping channel (Clarke 1990).

Non-linear interactions with tidal flows also cause significant dissipation of low-frequency (sub-tidal) signals through the straight. Low-frequency sea-level is incoherent across the strait with differences of up to 0.3 m (Wolanski et al. 1988). Residual currents through the strait are typically less than 0.15 m s^{-1} (Wolanski et al. 1988, Harris 1991). They also tend to reverse with the seasonal change from the summertime northwesterly monsoon winds to the winter south-easterly trade winds (Harris 1991). The long-term average currents may therefore be as small as 0.01 m s^{-1}, corresponding to a through strait transports as low as 10^4 m^3 s^{-1} (Wolanski et al. 1988).

Modelling of sea-level and currents in Torres Strait began with highly simplified "channel flow" models representing the balance between sea-level difference, bottom friction, and local acceleration.

While these models can yield realistic estimates of local tidal currents through tuning of bottom friction parameters (Clarke 1990), the inclusion of nonlinear interactions is critical in reproducing the observed increase in transmission through the strait with frequency (Wolanski et al. 1988). Depth-integrated nonlinear models appear to adequately reproduce tidal elevations throughout the strait (Bode and Mason 1995). However, more recent model development has focused on three-dimensional solutions of the full equations over realistic bathymetry (Hemer et al. 2003). This model included realistic wind and wave forcing. Freshwater inputs representative of the Fly River were also included, but surface freshwater and heat fluxes were neglected. The results showed good agreement with sea-level observations, although the observed currents were more difficult to reproduce.

2.2.2. Hydrographic conditions

Seasonal hydrographic conditions, such as temperature, salinity, dissolved oxygen, and nutrients, can be estimated for Torres Strait from historical cast data. A least-squares mapping of this data has recently been developed in the form of the CSIRO Atlas of Regional Seas or CARS (Ridgway et al. 2002). The mapping methodology explicitly accounts for separation of water masses by land and complex bathymetry (Dunn and Ridgway 2002), and is therefore well suited to regions such as Torres Strait. However, the spatial and temporal coverage of the data is quite restricted in the strait. For example, temperature and salinity casts were nearly all taken during the monsoon (mainly March) and there has very little nutrient or oxygen data collected in the local region (Figure 2.2-1).

Climatological temperatures from CARS show a broad peak over the summer monsoon period of between 29 and 30°C, with waters in the neighbouring Gulf of Carpentaria up to 1°C warmer than those in the northwestern Coral Sea (Figure 2.2-2 and Figure 2.2-3). During winter, a cold-water anomaly (≈ 25°C) forms over the shallow Torres Strait, presumably in response to local heat loss to the atmosphere.

Salinities from CARS fall quite rapidly from around 35 to 32 psu under the influence of the monsoon rains (Figure 2.2-2). A strong freshwater anomaly along the PNG coastline is evident during March (Figure 2.2-3), when the data coverage is relatively dense (Figure 2.2-1). While salinities gradually increase again following cessation of the monsoon, there is evidence that the trades can occasionally introduce freshwater from the Fly River plume to the northeast (Harris et al. 1993, Wolanski et al. 1995, Hemer et al. 2003). For example, low salinity water (24 psu) observed for around two weeks in the Great North East Channel was attributed to repeated exposure of Gulf of Papua coastal water to the Fly plume during reversals in the alongshore current, prior to being advected southwestward into Torres Strait (Wolanski et al. 1999). While the Fly plume generates a strong halocline in the Gulf of Papua (Wolanski et al. 1995), tidal mixing generally prevents the development of vertical stratification within Torres Strait.

CARS suggests that dissolved oxygen levels in the well-mixed waters of Torres Strait tend to be relatively high (Figure 2.2-3), with limited seasonal variability (Figure 2.2-2). However, the data coverage is extremely sparse (Figure 2.2-1) and local enhancements in northern Torres Strait and the Gulf of Papua are largely artefacts of the mapping (Figure 2.2-3).

Nitrate, phosphate, and silicate all follow a similar trend, increasing over the course of the monsoon, before diminishing under trade wind conditions (Figure 2.2-2). Such patterns are consistent with enhancement through riverine inputs. On the basis of these distributions, it might be concluded that nutrients are unlikely to limit primary productivity in Torres Strait at any time of the year. However, it should be emphasized that the existing data coverage (Figure 2.2-1) is insufficient to support the apparent enhancement of nitrate and phosphate in Torres Strait and further northwest relative to neighbouring Gulf of Carpentaria and Coral Sea waters (Figure 2.2-4).

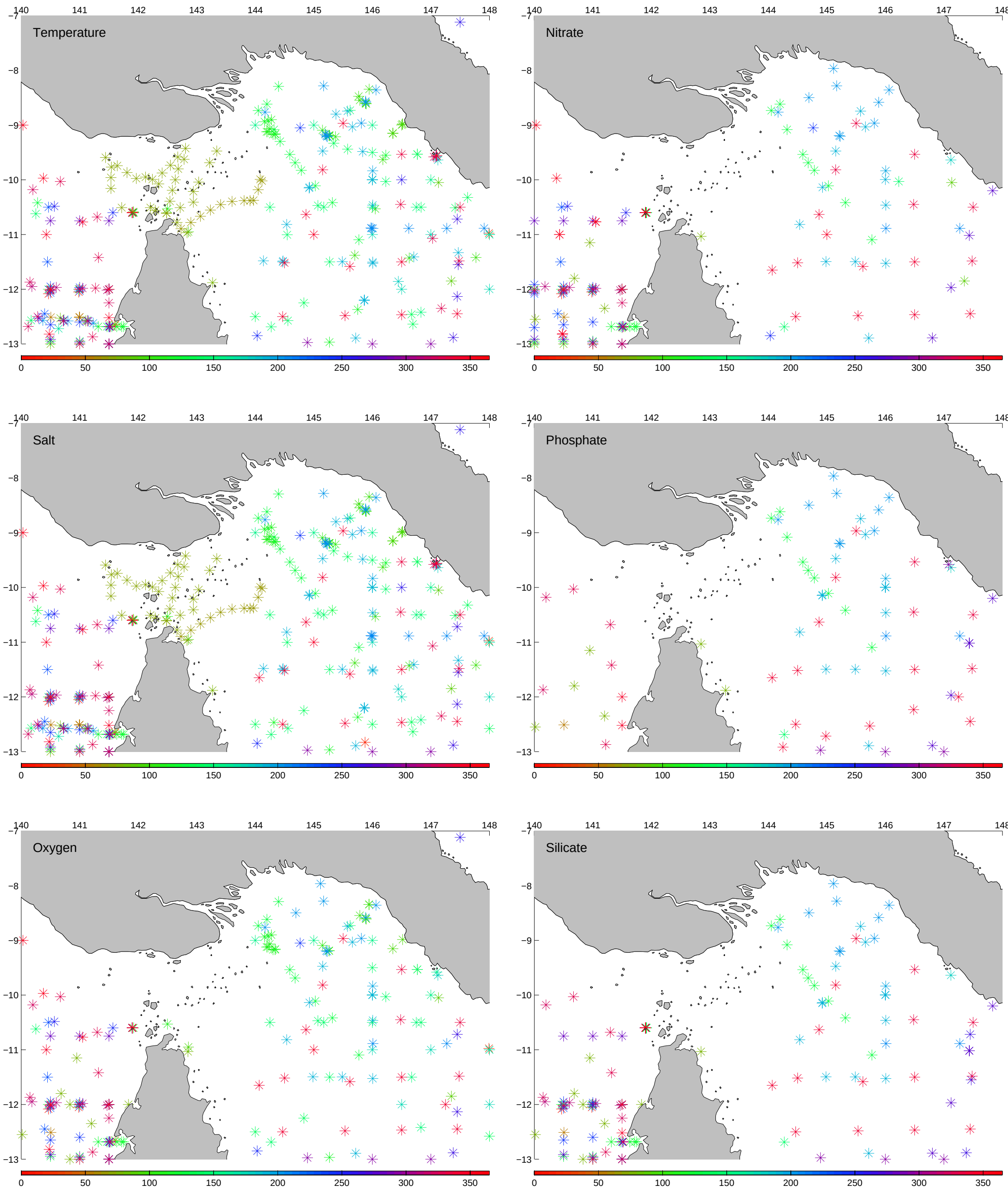

Figure 2.2-1 Distribution of hydrographic casts used to derive the CARS maps. The colours indicate the day of the year that individual casts were taken and thereby provide an indication of potential seasonal biases.

In southwestern Torres Strait, near Booby Island, a hydrographic station was regularly occupied from 1977 to 1983 as part of the CSIRO Coastal Monitoring Program. This data provides some insight into the interannual variability of the region (Figure 2.2-5). Temperature follows a very regular annual cycle over the monitoring period, which closely matches the seasonal trend estimated from CARS for the site. Salinity also tends to follow a regular seasonal pattern following CARS, although there is some evidence of low-salinity anomalies around the end of the monsoon in 1978 and slightly earlier in 1982. In contrast, salinities remained relatively high during the 1982-83 monsoon.

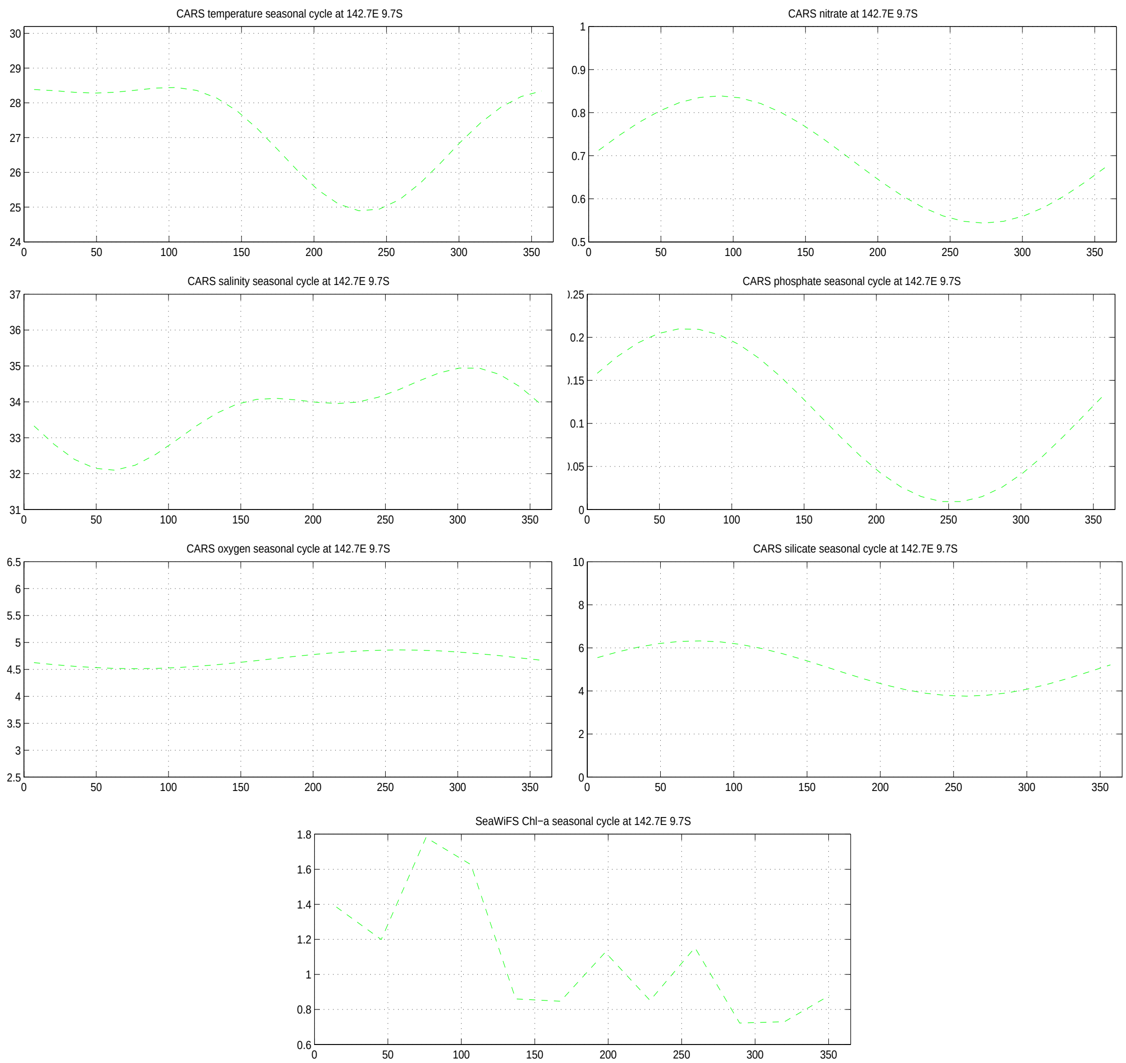

Figure 2.2-2 Seasonal trends in near-surface temperature (°C), salinity (PSU), dissolved oxygen (ml l^{-1}) (left) and nutrients (ml l^{-1}) (right) in central northern Torres Strait (142.7°E, 9.7°S) from CARS. Monthly averaged chlorophyll estimates based on SeaWiFS at the same location is also shown (mg m^{-3}) (bottom centre).

Dissolved oxygen exhibits much higher levels of interannual variability than temperature or salinity (Figure 2.2-5). While CARS correctly predicts that oxygen levels rise during the trade winds then fall during the monsoon, the observed range is at least three times that of CARS (even ignoring possibly suspect records from 1979). Nitrate levels also show high interannual variability, including an extended period of enhancement in 1977-78, and low values from late 1979 through 1980. With the exception of 1980, 1982 and 1983, strong peaks regularly occurred near the end of the monsoon period. The average seasonal trend confirms that the CARS nitrate distributions are not yet reliable in Torres Strait.

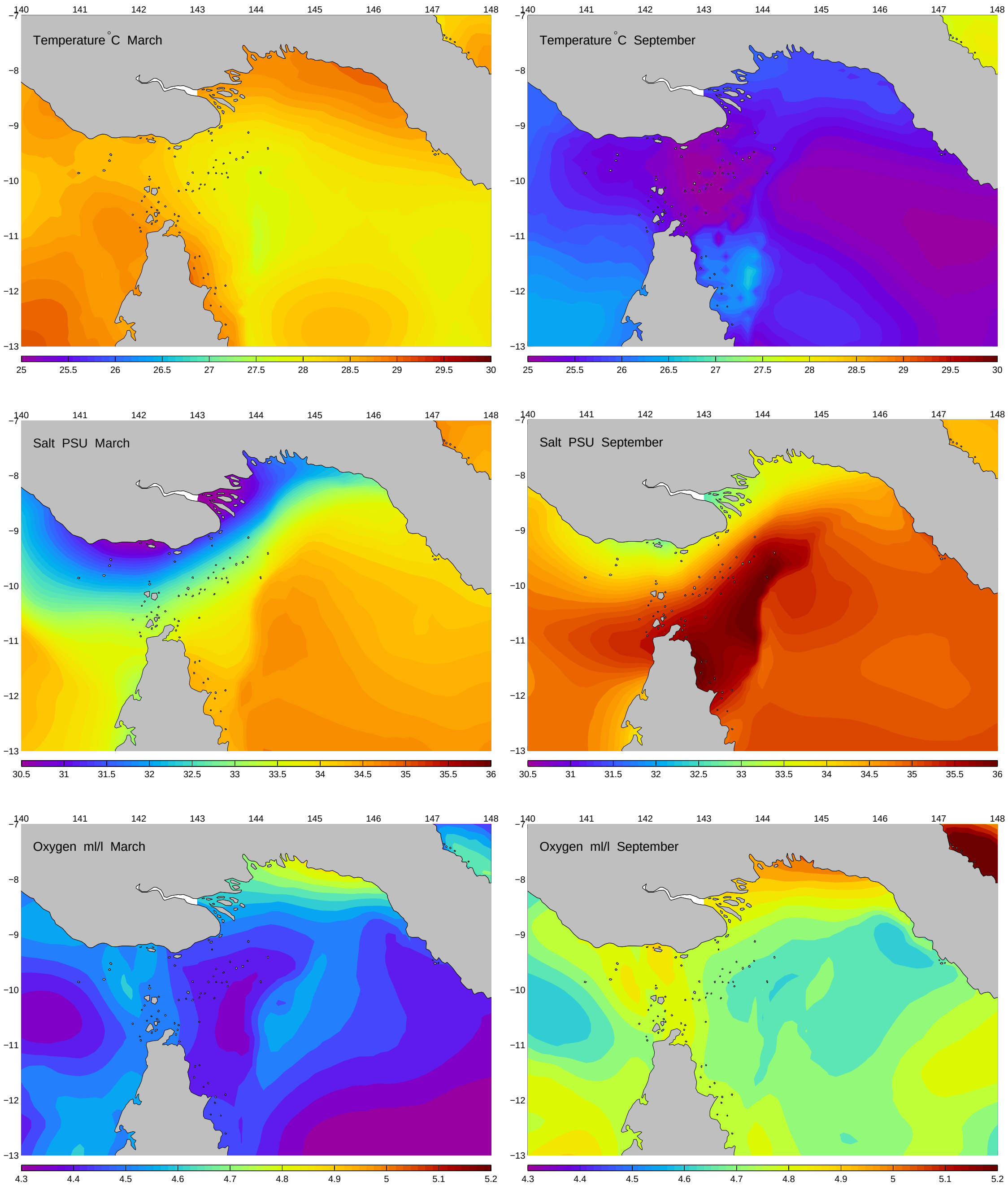

Figure 2.2-3 Seasonal maps of near-surface temperature (top), salinity (center), and dissolved oxygen (bottom) for March (left) and September (right) from CARS.

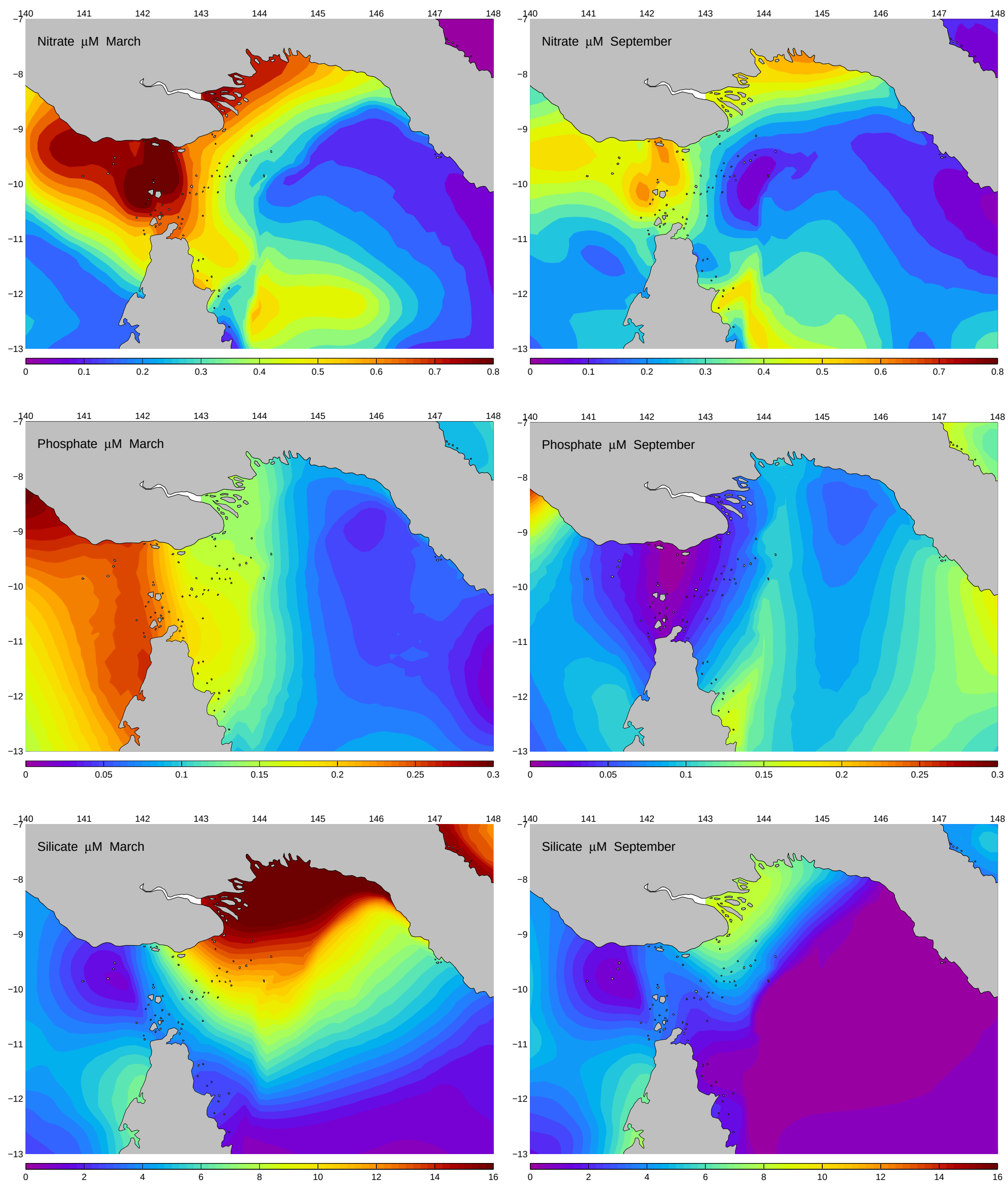

Figure 2.2-4 Seasonal maps of near-surface nitrate (top), phosphate (center), and silicate (bottom) for March (left) and September (right) from CARS. There are large uncertainties associated with nutrient distributions along the PNG coast and within Torres Strait due to the poor data coverage (Figure 2.2-1).

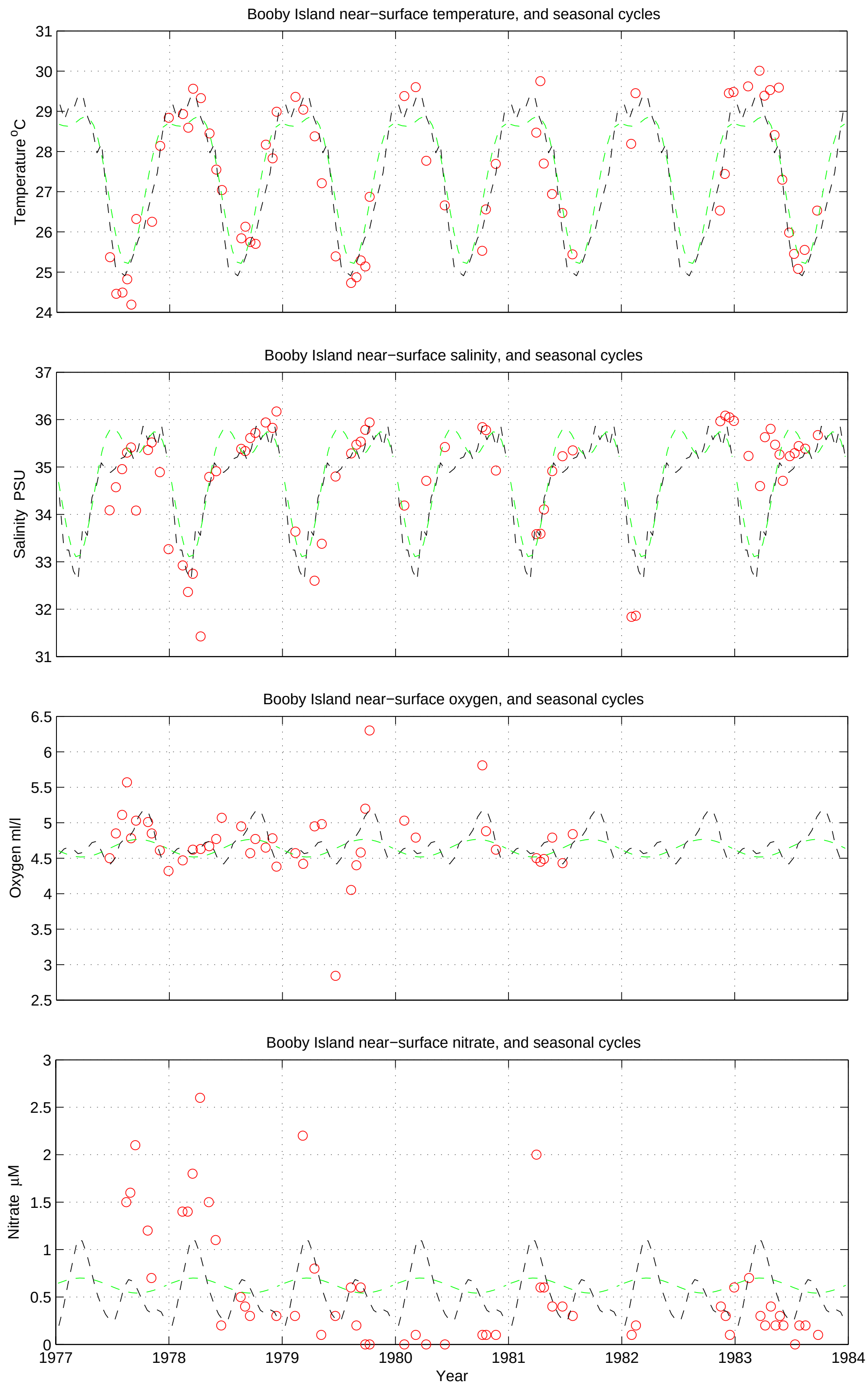

Figure 2.2-5 Measurements of temperature, salinity, dissolved oxygen, and nitrate from the Boobie Island Coastal Station (o), compared to the seasonal trend averaged across years using the same dataset (---), and CARS estimates for the same site (---). Note that the CARS analysis includes the Boobie Island data.

2.2.3. Suspended sediments

Tidal currents and locally generated surface waves are responsible for resuspension of sediments, giving rise to a turbidity maximum in central Torres Strait (Harris and Baker 1991). Suspended sediment concentrations in Missionary Passage have also been observed to increase from under 10 mg l^{-1} during neap tide to 20-30 mg l^{-1} during spring tide (Harris 1999). Model results suggest that sediments from the Fly River plume are likely to enter the strait, with increased loads during the trade-wind season (Hemer et al. 2003). This conclusion is consistent with observations of a low salinity event during September 1994 (Wolanski et al. 1999).

2.2.4. Chlorophyll

There are no in situ plankton measurements available from Torres Strait region. It is also likely that high suspended sediment loads, coupled with extensive regions of shallow water and persistent cloud cover, will introduce significant errors into chlorophyll estimates based on satellite ocean colour (Figure 2.2-6). Within these limitations, the seasonal trends in ocean colour suggest that highest chlorophyll levels occur during the monsoon season (Figure 2.2-2 and Figure 2.2-7). As winter approaches, chlorophyll peaks in the Gulf of Carpentaria (Burford and Rothlisberg 1999) and Coral Sea, but decreases in Torres Strait, where it remains relatively constant until the return of the monsoon (Figure 2.2-7).

There is currently insufficient information to determine what factors control primary production in Torres Strait. The seasonal peak in chlorophyll coincides with that in nutrients (Figure 2.2-2) and nitrate levels at the Boobie Island station are sometimes depleted (Figure 2.2-5). However, it seems likely that light availability will also be a factor in the turbid waters of Torres Strait, as found in the neighbouring waters of the Gulf of Carpentaria (Burford and Rothlisberg 1999). The phytoplankton community in Torres Strait may also have similarities to the Gulf (Rothlisberg et al. 1994). For example, the availability of both nitrate and silicate suggests that diatoms will form a major part of the phytoplankton biomass. However, there is currently no data available on the plankton community structure in Torres Strait.

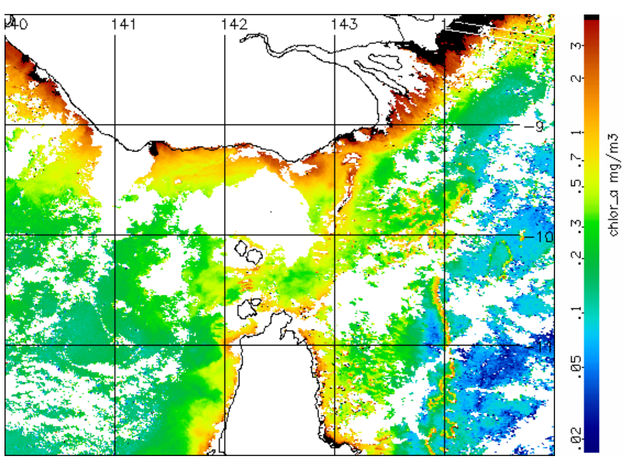

Figure 2.2-6 An example of chlorophyll distribution in Torres Strait derived from SeaWiFS ocean colour data (31 Mar 2000). The white patches over water correspond to unreliable data that has been excluded. For instance, the solid patches near the centre of the strait correspond to shallow water (< 15 m) where the bottom is likely to contribute to the signal, while the more diffuse patches indicate cloud cover. Despite this filtering major reefs, such as the northern Great Barrier Reef and Warrior Reefs, still appear as pseudo high chlorophyll patches.

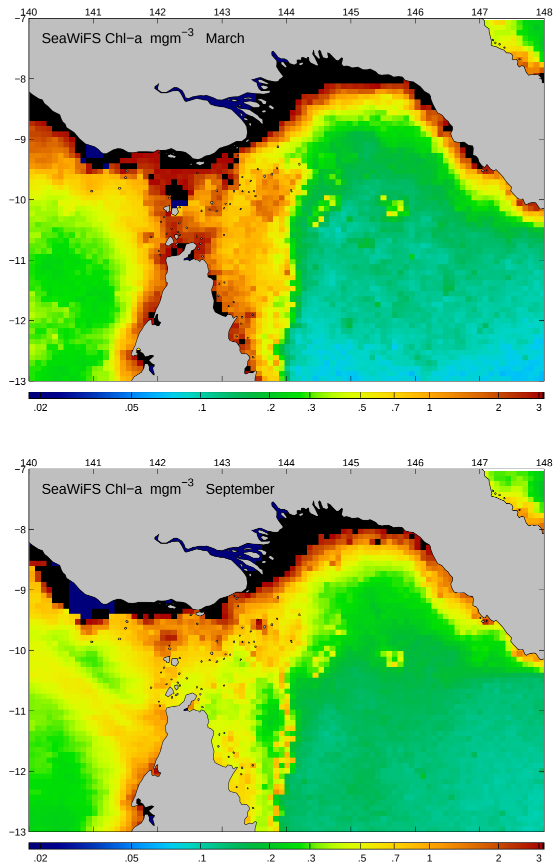

Figure 2.2-7 Seasonally averaged chlorophyll estimates derived from SeaWiFS ocean colour data for March, June, September, and December (mg m^{-3}). The black patches over water indicate that no reliable data was received for that location.