

Database documentation: ctd (Fisheries Oceanography)

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1 Introduction to the Database Document series

The National Institute of Water and Atmospheric Research (NIWA) currently carries out the role of Data Manager and Custodian for the fisheries research data owned by the Ministry of Fisheries (MFish).

The Ministry of Fisheries data set incorporates historic research data, data collected more recently by MAF Fisheries prior to the split in 1995 of policy to the Ministry of Fisheries and research to NIWA, and currently data collected by NIWA and other agencies for the Ministry of Fisheries.

This document is a brief introduction to the fisheries oceanography database **ctd**, and is part of the database documentation series produced by NIWA. It supersedes the previous documentation by Taylor (1993) on this database.

All documents in this series include an introduction to the database design, a description of the main data structures accompanied by an Entity Relationship Diagram (ERD), and a listing of all the main tables. The ERD graphically shows how all the tables link together and their relationship with other databases.

This document is intended as a guide for users and administrators of the **ctd** database.

Access to this database is restricted to specific nominated personnel as specified in the current Schedule 6 of the Data Management contract between the Ministry of Fisheries and NIWA. Any requests for data should in the first instance be directed to the Ministry of Fisheries.

2 Fisheries Oceanography Database

2.1 Data sources

The **ctd** (fisheries oceanography) database contains some physical oceanography data collected during voyages conducted by the Marine Research Group of the Ministry of Agriculture and Fisheries. Much of the data collected were obtained using a conductivity, temperature, and depth (CTD) probe, hence the name of the database. The data on the **ctd** database were collected during voyages conducted between 1982 and 1992. It may be necessary to alter the structure of the database later to allow for the storage of data from mechanical bathythermographs (MBT) and expendable bathythermographs (XBTs).

The database has been set up in accordance with Marine Research Computing database standards (Ng 1992).

2.2 Uses of the ctd Database

Physical oceanographic features such as thermoclines and upwellings affect the distribution and availability of fish. Data from the **ctd** database can be used to locate and study the nature of water masses, currents and temperature fronts. These data can also be used to describe the physical environment where fish are found.

The **ctd** database is designed to be used in conjunction with voyage data on catch rates, catch composition, etc, to assist in the interpretation of trends in abundance. Since these data also span a range of seasons and years in many areas of New Zealand they can also assist in planning voyages.

3 Data Structures

3.1 Table relationships

This database contains several tables. The ERD for **ctd** (Figure 1) shows the logical structure¹ of the database and its entities (each entity is implemented as a database *table*) and relationships between these tables and tables in other databases. This schema is valid regardless of the database system chosen, and it can remain correct even if the Database Management System (DBMS) is changed. Each table represents an object, event, or concept in the real world that has been selected to be represented in the database. Each *attribute* of a table is a defining property or quality of the table. All of the table's attributes are shown in the ERD. The underlined attributes represent the table's primary key².

Note that Figure 1 shows the main tables only. Note that most tables contain foreign keys³. These foreign keys define the relationships between the tables in **ctd**.

The **ctd** database is implemented as a relational database; i.e., each table is a special case of the mathematical construct known as a *relation* and hence elementary relation theory is used to deal with the data within tables and the relationships between them. There are three types of relationships possible between tables, but only one exists in **ctd**: one-to-many⁴. These relationships can be seen in ERDs by connecting a single line (indicating 'many') from the child table; e.g., *t_bottle_casts*, to the parent table; e.g., *t_stations*, with an arrowhead (indicating 'one') pointing to the parent.

Every relationship has a mandatory or optional aspect to it. If a relationship is mandatory, then it has to occur at least once, while an optional relationship might not occur at all. For example, in Figure 1, consider that relationship between the table *t_stations* and its child table *t_bottle_casts*. The symbol 'o' by the child *t_bottle_casts* means that a station can have zero or many bottle cast records, while the bar by the parent *t_stations* means that for every bottle cast record there must be a matching station record.

¹ Also known as a database *schema*.

² A primary key is an attribute or a combination of attributes that contains an unique value to identify that record.

³ A foreign key is an attribute or a combination of attributes that is a primary key in another table.

⁴ A one-to-many relationship is where one record (the *parent*) in a table relates to one or many records (the *child*) in another table; e.g., one landing in *t_catch_site* can have many samples in *t_sample* but one sample can only come from one catch site.

Physical Data Model		
Project : ctd		
Model : Fisheries Oceanography database		
Author : wjt	Version 1.0	12/7/00

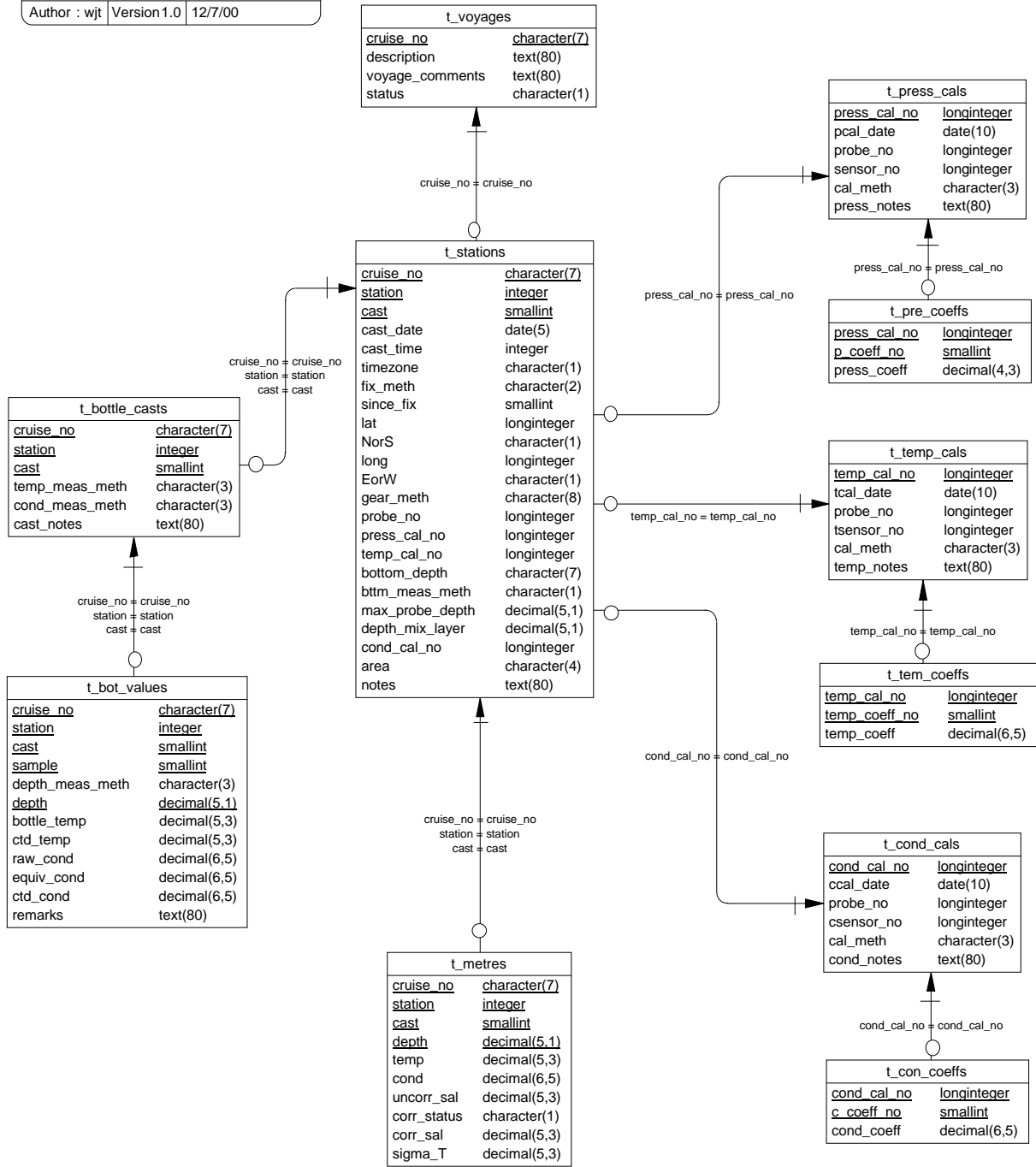


Table 1: Entity Relationship Diagram (ERD) for the ctd database.

These links are enforced by referential constraints⁵. Constraints do not allow *orphans* to exist in any table; i.e., where a child record exists without a related parent record. This may happen when: a parent record is deleted; the parent record is altered so the relationship is lost; or a child record is entered without a parent record

Constraints are shown in the table listings by the following format:

```
Referential:      constraint name (attribute[, attribute])  |INSERT|
                                                           |DELETE|
                   parent table (attribute[, attribute])
```

Note that the typographical convention for the above format is that square brackets [] may contain more than one item or none at all. Items stacked between vertical lines || are options of which one must be chosen.

For example, consider the following constraint found in the table *t_stations*:

```
Referential:      voycheck (cruise_no) INSERT t_voyages (cruise_no)
```

This means that the value of the attribute *cruise_no* in the current record must already exist in the parent table *t_voyages* or the record will be rejected and the following message will be displayed:

```
*** User Error: insert constraint 'voycheck' violation
```

For tables residing in external databases, the parent table name will be prefixed by the name of the database.

Section 5 lists all the **kina** tables as implemented by the Empress RDBMS. As can be seen in the listing of the tables, a table's primary key has a unique index on it. Primary keys are generally listed using the following format:

```
Indices:          UNIQUE index_name ON (attribute[, attribute])
```

where attribute(s) make up the primary key and the index name is the primary key name. These prevent records with duplicate keys from being inserted into the tables; e.g., a record with an existing sample number.

The database listing (Tables 1-5) show that the tables also have indices on many attributes. That is, attributes that are most likely to be used as a searching key have like values linked together to speed up searches. These indices are listed using the following format:

```
Indices:          NORMAL (2, 15) index_name ON (attribute[, attribute])
```

Note that indices may be simple, pointing to one attribute or composite pointing to more than one attribute. The numbers "... (2, 15) ..." in the syntax are Empress RDBMS default values relating to the amount of space allocated for the index.

⁵ Also known as integrity checks.

3.2 Database design

Physical oceanography data are collected from casts⁶ conducted at stations in a voyage.

The table *t_voyages* (Table 1) lists voyages during which oceanographic data were collected, with a brief description and the processing status for each voyage. The processing status indicates whether all relevant data that can be recovered from a voyage have been loaded into the database.

There is generally only one cast at each station, but occasionally, such as when there are comparisons between instruments or where there are gear problems, there can be more than one. For each cast data such as station position, date, time, gear methods used, bottom depth, maximum probe depth and mixed layer depth are recorded. These data are contained in table *t_stations* (Table 2). Records exist on *t_stations* for almost every voyage on *t_voyages*. However, there are voyages from which the data could not be recovered so there are no records on *t_stations* for these.

The type, amount and accuracy of data collected depend on the gear used in a cast. Vertical profiles of temperature can be obtained from each cast. Mechanical bathythermographs (MBTs) and expendable bathythermographs (XBTs) give continuous temperature profiles. From casts where a CTD probe is used or where water samples are collected, vertical profiles of salinity as well a temperature can be obtained.

The gear methods used in a cast are held in *gear_meth* on *t_stations*. This attribute is defined as a string of up to three two-digit code numbers, each code number being equal to and having the same meaning as a value of *code* in table *meth_codes*, the method codes table in the **rdb** database. This allows for situations where different gear methods were used during one cast. However, *gear_meth* cannot be a foreign key to *meth_codes* because it is defined as a string and may contain more than one code. This is a departure from third normal form. It would be possible to create a table with one record for each cast and gear method, but there would be difficulty in the selection of data where gear methods were specified and more than one method was used in a cast.

If a method of position fixing is known for a station the attribute *fix_method* must be a valid code equal to a value of *fix_method_code* in the table *t_fix_method_codes* on the **rdb** database. Similarly, if an area exists on a record on *t_stations*, then it must be a valid area code as listed in the table *area_codes* on the **rdb** database.

CTD probes provide effectively continuous temperature and conductivity data throughout a cast. Summarised temperature, conductivity, salinity and specific gravity anomaly (s_t) data at 1-metre depth intervals are on table *t_metres* (Table 3). This table is linked to *t_stations* and has a primary key of *cruise_no*, *station*, *cast*, and *depth*. It is a large table, with over 300,000 records. In many cases it is sufficient to obtain data from standard depths (ie. 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750 and 2000 metres). To obtain these data more quickly a view, *v_std_depths* (View 3.1), has been created on the table *t_metres* that contains the same data as *t_metres* but only at the standard depths listed above.

Discrete temperature and salinity data can be obtained by bottle hydrocasts. These casts are listed in *t_bottle_casts* (Table 4), which is linked to the table *t_stations* and has a primary key of *cruise_no*, *station*, and *cast*. Temperature data are collected using reversing thermometers. The mercury

⁶ A cast is an event where oceanographic instruments are deployed to obtain measurements at depth.

column of a reversing thermometer is broken by suddenly flipping the thermometer when it has reached the desired depth, thereby recording temperature at that depth. On many casts a CTD probe was also deployed so the more accurate temperature measurements would have come from the CTD. The more accurate method used to measure temperature in each bottle cast is held in *t_bottle_casts*. The accuracy of the measurement of the salinity (or conductivity) of water samples depends on the salinometer used, so this information is also contained in the table.

Temperature and conductivity values in bottle casts and the method for measuring depth at which each sample was taken are listed in *t_bot_values* (Table 5). This table has a primary key of *cruise_no*, *station*, *cast*, *depth* and *sample*, and is linked to the table *t_bottle_casts*. The accuracy of measurement of depth depends on the method by which depth was determined. The method of measuring depth may change during a cast so each record on *t_bot_values* has a code for depth measurement method. These methods are discussed in Appendix A. If a CTD probe was used with bottles, then CTD temperature and conductivity values corresponding to the depths at which water samples were taken are also listed on this table as are the conductivity values of the water samples, back-calculated to the pressures and temperatures at which the samples were obtained.

For voyages where casts used a CTD probe in association with bottle sampling, CTD conductivity can be calibrated against conductivity of the water samples, using values from *t_bot_values*. These calibrations may change between stations because occasionally the conductivity sensor response may change suddenly. For this reason *t_stations* has a foreign key, *cond_cal_no*, to table *t_cond_cals* (Table 6). The table *t_cond_cals* lists the date and method of each calibration of each conductivity sensor and is linked to *t_con_coeffs* (Table 7), which shows the conductivity correction coefficients derived from each calibration.

Pressure and temperature sensors are periodically calibrated in a laboratory. The correction coefficients from these calibrations are applied to the pressure and temperature as measured by the CTD probe when the data are being initially processed.

If a CTD probe was used in the cast, pressure and temperature calibration numbers (*press_cal_no* and *temp_cal_no*) will be listed. These are foreign keys to *t_press_cals* (Table 8) and *t_temp_cals* (Table 9) respectively. These tables provide information on calibration date and method and provide links to the tables *t_pre_coeffs* (Table 10) and *t_tem_coeffs* (Table 11), which list the pressure and temperature correction coefficients respectively. These coefficients are used to correct raw CTD pressure and temperature data when they are being summarised.

4 Table Summaries

The **ctd** database has 11 tables and one view. The tables are briefly described below:

1. **t_voyages** : Voyages where physical oceanography data were collected.
2. **t_stations** : Information on each station and cast in each voyage.
3. **t_metres** : Temperature, conductivity, salinity and specific gravity anomaly information for each 1 metre of depth in a cast producing nearly continuous data (downcast only).
There is a view on this table:
 - 3.1 **v_metres** : Contains data from *t_metres* at 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750 and 2000 metres.
4. **t_bottle_casts** : Casts using water sampling bottles and measurement methods used.
5. **t_bot_values** : Temperature and conductivity values from each sample in a bottle cast and, where applicable, CTD values from the same cast at the same depth.
6. **t_cond_cals** : Regressions (calibrations) of conductivity of water samples against conductivity as measured by CTD conductivity sensors.
7. **t_con_coeffs** : Conductivity correction coefficients from conductivity calibrations.
8. **t_press_cals** : Calibrations of CTD pressure sensors.
9. **t_temp_cals** : Calibrations of CTD temperature sensors.
10. **t_pre_coeffs** : Pressure correction coefficients from pressure calibrations.
11. **t_tem_coeffs** : Temperature correction coefficients from temperature calibrations.

5 ctd Tables

The following are listings of the tables in the **ctd** database, including attribute names, data types (and any range restrictions), and comments.

5.1 Table 1: t_voyages

Comment: Gives a brief description of each voyage where and/or salinity profiles were obtained. The description includes species being targeted (if any) and area. The table also contains comments on data and an indication of whether data have been loaded onto the database.

Attributes	Data Type	Null?	Comment
cruise_no	character(7,1) smatch "[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]"	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
description	text(75,0,75,1)		Brief description of purpose of voyage and area or areas surveyed during voyage.
voyage_comments	text(75,0,75,1)		Notes on processing of voyage data and/or reliability of data, including missing data and methods of calibration.
Status	character(1,1) smatch "[ny]"		Indicates whether loading of physical oceanography data (i.e., CTD or other data related to temperature and salinity casts) for this voyage has been completed y = all data for this voyage that can be recovered at time of processing have been loaded onto the database; n = loading of data has not been completed for this voyage.

Creator: wjt
Referential: statcheck (cruise_no) DELETE t_stations (cruise_no)
Indices: UNIQUE voyex ON (cruise_no)

5.2 Table 2: t_stations

Comment: Identifying and descriptive features of each station.

Attributes	Data Type	Null?	Comment
cruise_no	character(7,1) smatch "[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]"	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
station	integer	No	Sequential number for each station in the voyage.
cast	smallint		Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
cast_date	date(5)	No	Date of cast.
cast_time	integer range 0 to 2359	No	Time of cast in 24 hour format. This is usually the start time of the cast.
timezone	character(1,1) = "D" = "S"		D is NZDT, S is NZST
fix_meth	character(2,1)		Method of fixing position. For method codes please refer to rdb:t_fix_meth_codes
since_fix	smallint		Time between the last position fix made and the time the cast was performed, in minutes. This attribute is often null as the time since fix was often not noted.
lat	longinteger range 0 to 900000	No	Latitude expressed in format DDMMmm with implied decimal minutes; i.e., the last 4 digits are minutes and hundredths of minutes. Eg., 453480 is 45 degrees 34.80 minutes.
NorS	character(1,1) = "N" = "S"	No	Hemisphere - N = north, S = south.
long	longinteger range 0 to 1800000	No	Longitude expressed in format DDDMMmm; i.e., the last 4 digits are decimal minutes. E.g., 1743480 is 174 degrees 34.80 minutes.
EorW	character(1,1) = "E" = "W"	No	Hemisphere - E = east, W = west.

Attributes	Data Type	Null?	Comment
gear_meth	character(8,1)		Type of measurements made. This attribute can contain up to 3 method codes separated by commas. The codes are defined below: 80 = Nansen bottle hydrocast 82 = CTD only 83 = rosette only 84 = CTD and rosette 85 = MBT 86 = XBT 88 = MOCNESS CTD
probe_no	longinteger		Digits of serial number of CTD probe.
press_cal_no	longinteger		Identification number of pressure sensor calibration used for the CTD probe in the cast.
temp_cal_no	longinteger		Identification number of temperature sensor calibration used for the CTD probe in the cast.
bottom_depth	character(7,1)		Bottom depth in metres.
bttm_meas_meth	character(1,1)		Method used to measure bottom depth - S = echo sounder - often accurate to 1 metre. C = chart - often a rough estimate.
	= "C"		
	= "S"		
max_probe_depth	decimal(5,1)		Deepest depth reached in cast rounded down to the nearest metre. This is usually recorded only for CTD probes.
depth_mix_layer	decimal(5,1)		Depth of mixed layer, defined as the depth which the rate at which temperature decreases with depth equals or exceeds 0.5 degrees Celsius in 10 m. Generally, if this depth is less than 10 m then it is considered that no mixed layer exists and the attribute is null. However, there are exceptions to this, e.g. bays, sounds, etc.
cond_cal_no	longinteger		Identification number of conductivity correction used for cast. If this attribute is null and the CTD was used, only uncorrected salinity can be found.
area	character(4,1)		Area in which cast took place. This must be a valid 4 character area code as listed in the rdb:area_codes table. Areas are not well defined and for many stations this attribute is null.

Attributes	Data Type	Null?	Comment
notes	text(75,0,75,1)		Notes on data, methods or conditions at the station.

Creator: wjt

Referential:

```

area_check (area) INSERT rdb : area_codes (code)
press_check (press_cal_no) INSERT t_press_cals (press_cal_no)
temp_check (temp_cal_no) INSERT t_temp_cals (temp_cal_no)
cond_check (cond_cal_no) INSERT t_cond_cals (cond_cal_no)
wholecheck (cruise_no, station, cast) DELETE t_metres
(cruise_no, station, cast)
voycheck (cruise_no) INSERT t_voyages (cruise_no)
fix_check (fix_meth) INSERT rdb : t_fix_meth_codes
(fix_meth_code)
botcheck (cruise_no, station, cast) DELETE t_bottle_casts
(cruise_no, station, cast)

```

Indices:

```

NORMAL (2, 15) i_crustat ON (cruise_no)
NORMAL (2, 15) i_station ON (station)
NORMAL (2, 15) i_statcast ON (cast)
UNIQUE i_stat ON (cruise_no, station, cast)

```

5.3 Table 3: t_metres

Comment: Table of temperature, conductivity, salinity and sigmaT data in whole metre slices. Data is from downcast only.

Attributes	Data Type	Null?	Comment
cruise_no	character(7,1) smatch "[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]"	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
station	integer	No	Sequential number for each station in the voyage.
cast	smallint		Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
depth	decimal(5,1)	No	Depth in metres.
temp	decimal(5,3) range 1.000 to 30.000		Temperature in degrees Celsius.
cond	decimal(6,5) range 0.60000 to 1.20000		Conductivity ratio = conductivity of water in metre slice as measured by conductivity sensor : conductivity of standard seawater at 0m at 15 degrees Celsius.
uncorr_sal	decimal(5,3) range 25.000 to 36.000		Salinity according to International Practical Salinity Scale 78 (IPSS-78) without correction from calibration being applied.
corr_status	character(1,1) = "C" = "N" = "Y"	No	Status of correction of salinity data for cast. C = salinity corrected. N = salinity not corrected; i.e., calibration not possible or calibration not performed. Y = calibration possible but correction not applied as yet.

Attributes	Data Type	Null?	Comment
corr_sal	decimal(5,3)		Salinity according to International Practical Salinity Scale, after correction found by calibration has been applied. Except where otherwise stated, calibration is performed by back-calculating conductivities of water samples collected in bottles to conductivities at the pressures and temperatures when the samples were collected, and comparing these conductivities with in situ conductivities as measured by the CTD.
	range 25.000 to 36.000		
sigma_T	decimal(5,3)		Specific gravity anomaly. If both corrected and uncorrected salinities are available sigmaT is calculated using corrected salinity; otherwise uncorrected salinity is used to calculate sigmaT.
	range 20.000 to 30.000		
Creator:	wjt		
Referential:	wstatcheck (cruise_no, station, cast) INSERT t_stations (cruise_no, station, cast)		
Indices:	NORMAL (2, 15) i_wcruise ON (cruise_no)		
	NORMAL (2, 15) i_wstation ON (station)		
	NORMAL (2, 15) i_wcast ON (cast)		
	NORMAL (2, 15) i_wdepth ON (depth)		
	UNIQUE i_unidepth ON (cruise_no, station, cast, depth)		

The following listings are views of the table *t_metres*. These views are instances of *t_metres* where for selected depths. Each record has the temperature, conductivity, salinity and density anomaly information for each standard depth in a cast (downcast only). See above listing for a most complete description of the attributes.

5.3.1 v_std_depths

View: `select * from "t_metres" where (((((((((((((((((((((((((((((((((((((((attr "depth" = 10 or attr "depth" = 20) or attr "depth" = 30) or attr "depth" = 50) or attr "depth" = 75) or attr "depth" = 100) or attr "depth" = 125) or attr "depth" = 150) or attr "depth" = 200) or attr "depth" = 250) or attr "depth" = 300) or attr "depth" = 400) or attr "depth" = 500) or attr "depth" = 600) or attr "depth" = 700) or attr "depth" = 800) or attr "depth" = 900) or attr "depth" = 1000) or attr "depth" = 1100) or attr "depth" = 1200) or attr "depth" = 1300) or attr "depth" = 1400) or attr "depth" = 1500) or attr "depth" = 1750) or attr "depth" = 2000))`

Attributes	Data Type
cruise_no	character(7,1)
station	integer
cast	smallint
depth	decimal(5,1)
temp	decimal(5,3)
cond	decimal(6,5)
uncorr_sal	decimal(5,3)
corr_status	character(1,1)
corr_sal	decimal(5,3)
sigma_T	decimal(5,3)

Creator: wjt

5.4 Table 4: t_bottle_casts

Comment: Table listing rosette or Nansen bottle casts. The table gives methods used for measuring depth, temperature and salinity as well as notes on accuracy of data or variations in measuring depth.

Attributes	Data Type	Null?	Comment
cruise_no	character(7,1)	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number. smatch "[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]"
station	integer	No	Sequential number for each station in the voyage.
cast	smallint		Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
temp_meas_meth	character(3,1) = "CTD" = "TEM"		Method used to measure water temperatures during the cast. This attribute gives the more accurate method used if both CTD and reversing thermometers were used. Codes are: CTD = CTD TEM = reversing thermometers.
cond_meas_meth	character(3,1) = "FRC" = "NOI"		Salinometer used to determine salinity of seawater samples. Codes are: FRC = Autolab salinometer NOI = NZOI/MRC Guildline Autosol 8400 salinometer.
cast_notes	text(75,0,75,1)		Remarks on cast. These often include an indication of variation in methods used to measure depth during the cast, such as the use of protected and unprotected thermometers at given depths.

Creator: wjt

Referential: botvalcheck (cruise_no, station, cast) DELETE t_bot_values
(cruise_no, station, cast)
checkstat (cruise_no, station, cast) INSERT t_stations
(cruise_no, station, cast)

Indices: NORMAL (2, 15) i_botvoy ON (cruise_no)
NORMAL (2, 15) i_botstat ON (station)
NORMAL (2, 15) i_botcast ON (cast)
UNIQUE i_unicast ON (cruise_no, station, cast)

5.5 Table 5: t_bot_values

Comment: Table containing depth, temperature and conductivity data from Nansen bottle and rosette casts. Corresponding data from the CTD probe are also included where the CTD probe was used at the same position and time. These data can be used to calibrate CTD conductivity against conductivity of samples collected in sample bottles.

Attributes	Data Type	Null?	Comment
cruise_no	character(7,1) smatch "[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]"	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
station	integer	No	Sequential number for each station in the voyage.
cast	smallint		Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
sample	smallint		Number of sample at the give depth for a cast. There is usually only one sample for each depth in a cast, but occasionally more than one bottle may be tripped to collect samples.
depth_meas_meth	character(3,1) = "CTD" = "CWA" = "MBC" = "PUT"		Method of determining depth at which sample was taken and/or thermometers were reversed. Codes are: CTD = CTD probe (accurate to about 0.5 m over 1000 m, but greater accuracy at shallower depths). CWA = cosine of wire angle (accuracy in the order of metres). MBC = metre block counter reading (not as accurate as cosine of wire angle). PUT = determined from difference between readings of protected and unprotected thermometers (accuracy in the order of metres if thermometer readings are accurate).
depth	decimal(5,1)	No	Depth at which water samples were taken and/or thermometers tripped. Accuracy of depth is dependent on the measurement method used.

Attributes	Data Type	Null?	Comment
bottle_temp	decimal(5,3)		Temperature as measured by protected reversing thermometer after thermometer corrections (for index and expansion of mercury and glass) have been applied. Accuracy is at best + or - 0.01 degrees Celsius, but is often less.
	range		"1.000 to 30.000
ctd_temp	decimal(5,3)		Temperature as measured by CTD at depth given. This is usually done by interpolating data that are averages of temperature over depths of about 1 metre. Accuracy of the CTD temperature is about + or - 0.03 degrees Celsius.
	range		1.000 to 30.000
raw_cond	decimal(6,5)		Conductivity of hydrocast or rosette bottle sample water as measured by the salinometer (generally at 15 degrees Celsius near or at sea level).
	range		0.80000 to 1.20000
equiv_cond	decimal(6,5)		Conductivity of bottle sample back-calculated to the in situ pressure and temperature where the sample was collected. Some error may be introduced during back-calculation.
	range		0.60000 to 1.30000
ctd_cond	decimal(6,5)		Conductivity ratio as measured by CTD probe.
	range		0.60000 to 1.20000
remarks	text(75,0,75,1)		Notes on any errors that may occur (e.g. loose tops on salinity sample bottles), or on any change in method of determining values (e.g., finding raw conductivity by back-calculating salinity).

Creator: wjt

Referential: checkcast (cruise_no, station, cast) INSERT t_bottle_casts
(cruise_no, station, cast)

Indices: NORMAL (2, 15) i_valvoy ON (cruise_no)
NORMAL (2, 15) i_valstat ON (station)
NORMAL (2, 15) i_valcast ON (cast)
NORMAL (2, 15) i_valdepth ON (depth)
UNIQUE i_unival ON (cruise_no, station, cast, depth, sample)

5.6 Table 6: t_press_cals

Comment: Information about each pressure sensor calibration.

Attributes	Data Type	Null?	Comment
press_cal_no	longinteger	No	Identification number of pressure sensor calibration.
pcal_date	date(5)	No	Date of pressure calibration.
probe_no	longinteger	No	Serial number of probe to which the calibration relates.
sensor_no	longinteger	No	Serial number of pressure sensor that was calibrated.
cal_meth	character(3,1)	No	Site or organisation where pressure calibration was performed. MAN = manufacturer. PEL = former Physics and Engineering Laboratory. (now Industrial Research Ltd, Gracefield). NOI = NZ Oceanographic Institute.
press_notes	text(75,0,75,1)		Remarks about pressure calibration method, data or results.

Creator: wjt

Referential: statpress (press_cal_no) DELETE t_stations (press_cal_no)
press_coeff (press_cal_no) DELETE t_pre_coeffs (press_cal_no)

Indices: UNIQUE i_presscal ON (press_cal_no)\end{tabbing}

5.7 Table 7: t_pre_coeffs

Comment: Pressure corrections used in summarising raw CTD data are found by using a polynomial whose coefficients are listed in this table. The polynomial is of the form $P_c = p_0 + p_1Pr + p_2Pr^2 + \dots + p_nPr^n$ where:

P_c is corrected pressure

Pr is raw pressure and

p_0, p_1, \dots , etc, are the correction coefficients.

NB. Depth data in the database that were obtained by CTD observations were calculated using corrected pressure.

Attributes	Data Type	Null?	Comment
press_cal_no	longinteger	No	Identification number of pressure sensor calibration.
p_coeff_no	smallint	No	Which coefficient in correction formula; e.g., 0 denotes that the coefficient is the constant term.
press_coeff	decimal(4,3)	No	Value of coefficient.

Creator: wjt

Referential: check_pcal (press_cal_no) INSERT t_press_cals (press_cal_no)

Indices: UNIQUE i_pcoeff ON (press_cal_no, p_coeff_no)

5.8 Table 8: t_temp_cal

Comment: Information on each temperature sensor calibration. Calibrations of probe 45656 up to calibration number 1006 and those of probe 49088 up to calibration number 5 were performed according to International Practical Temperature Scale 68 (IPTS-68). Later calibrations were performed according to International Temperature Scale 90 (ITS-90). To calculate salinity according to the International Salinity Scale (ITSS-78) using temperature measured according to ITS-90, it is necessary to convert these temperatures to IPTS-68 temperatures using the formula:

$$T_{68} = 1.00024 * T_{90}$$

Attributes	Data Type	Null?	Comment
temp_cal_no	longinteger	No	Identification number of temperature sensor calibration.
tcal_date	date(5)	No	Date of temperature sensor calibration.
probe_no	longinteger	No	Serial number of probe to which the calibration relates.
tsensor_no	longinteger	No	Serial number of temperature sensor that was calibrated.
cal_meth	character(3,1)	No	Site or organisation where temperature sensor was calibrated. Codes are: MAN = manufacturer. PEL = former Physics and Engineering Laboratory. (now Industrial Research Ltd, Gracefield). NOI = NZ Oceanographic Institute.
temp_notes	text(75,0,75,1)		Remarks on temperature calibration method, data, or result.

Creator: wjt
Referential: statemp (temp_cal_no) DELETE t_stations (temp_cal_no)
 temp_coeff (temp_cal_no) DELETE t_tem_coeffs (temp_cal_no)
Indices: UNIQUE i_tcal ON (temp_cal_no)\end{tabbing}

5.9 Table 9: t_tem_coeffs

Comment: Temperature corrections used in summarising raw CTD data are found by using a polynomial whose coefficients are listed in this table. The polynomial is of the form:

$$T_c = t_0 + t_1 T_r + t_2 T_r^2 + \dots t_n T_r^n$$

Where:

T_c is corrected temperature

T_r is raw temperature and

t_0, t_1, t_2, \dots are correction coefficients.

NB. Temperature data in the database that were obtained by CTD probes has already had the corrections applied to them.

Attributes	Data Type	Null?	Comment
temp_cal_no	longinteger	No	Identification number of temperature sensor calibration.
temp_coeff_no	smallint	No	Which coefficient in correction equation; e.g., 0 denotes that the coefficient is a constant.
temp_coeff	decimal(6,5)	No	Value of temperature correction coefficient.

Creator: wjt

Referential: check_tcal (temp_cal_no) INSERT t_temp_cals (temp_cal_no)

Indices: UNIQUE i_tcoeff ON (temp_cal_no, t_coeff_no)

5.10 Table 10: t_cond_cals

Comment: Information on each calibration of CTD conductivity against conductivity of rosette or hydrocast samples. These calibrations are made so that the conductivity measured by the CTD conductivity sensor can be corrected. Corrected conductivity is then used to calculate corrected salinity.

Attributes	Data Type	Null?	Comment
cond_cal_no	longinteger	No	Identification number of conductivity calibration.
ccal_date	date(5)	No	Date on which conductivity correction coefficients were determined. NB. This is neither the date of the voyage nor the date that the conductivity of water samples was measured.
probe_no	longinteger	No	Serial number of probe to which the calibration relates.
csensor_no	longinteger	No	Serial number of conductivity sensor to which calibration relates.
cal_meth	character(3,1) = "NOI" = "FRC"		Which salinometer - NOI = NZOI/FRC Guildline Autosal 8400. FRC = FRC Guildline Mark IV
cond_notes	text(75,0,75,1)		Remarks about conductivity calibration method, data or results.

Creator: wjt

Referential: statcond (cond_cal_no) DELETE t_stations (cond_cal_no)
check_ccal (cond_cal_no) DELETE t_con_coeffs cond_cal_no)

Indices: UNIQUE i_condex ON (cond_cal_no)\end{tabbing}

5.11 Table 11: t_con_coefs

Comment: Coefficients used to correct the conductivity as measured by the conductivity sensor are listed in this table. Corrected conductivity is found by using a polynomial of the form:

$$C_c = c_0 + c_1 C_r + c_2 C_r^2 + \dots + c_n C_r^n$$

Where:

C_c is corrected conductivity

C_r is raw conductivity and

c_0, c_1, c_2, \dots , etc, are the correction coefficients listed in the table.

Attributes	Data Type	Null?	Comment
cond_cal_no	longinteger	No	Identification number of conductivity calibration.
c_coeff_no	smallint	No	Which coefficient in correction equation; e.g., 0 denotes that the coefficient is the constant term.
cond_coeff	decimal(6,5)	No	Value of conductivity correction coefficient.

Creator: wjt

Referential: cond_calcheck (cond_cal_no) INSERT t_cond_cals (cond_cal_no)

Indices: UNIQUE i_ccoeff ON (cond_cal_no, c_coeff_no)

6 References

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7 Acknowledgements

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Appendix

A Derivation of Physical Quantities

A.1 Depth Using Cosine of Wire Angle

Depths in this database, which have been ascertained using cosine of wire angle (CWA), are determined by multiplying the length of cable payed out by the cosine of the wire angle, and adding 0.5. If the wire angle is less than 5° the depth can be taken as the length of wire payed out. Where thermometric measurements were made on the same cast the depth can be determined more accurately by finding the ratio of the depth found by reversing thermometers to the depth found by cosine of wire angle, and multiplying by the latter depth. This method has not been used to find depth data for the database.

A.2 Depth and Temperature Using Reversing Thermometers

A.2.1 Temperature

For both protected and unprotected thermometers corrections must be applied to the reading of the main thermometer to allow for index error, which results from any incorrect etchings on the scale and any variations in capillary width.

Corrections are then applied for to allow for thermal expansion of the thermometers after they have been reversed. The corrections for protected thermometers are given by:

$$C_p = \frac{(V_o + T')(T' - t)}{K - (V_o + T') - (T' - t)}$$

and for unprotected thermometers:

$$C_u = \frac{(V_o + T')(T_w - t)}{K - (T_w - t)}$$

where:

V_o	=	volume of mercury (in below 0° C) when thermometer is reversed
K	=	reciprocal of coefficient of thermal expansion of the thermometer glass
T'	=	main thermometer reading after index correction has been applied
t	=	auxiliary thermometer reading after index correction has been applied
T_w	=	corrected protected thermometer reading; i.e. water temperature at depth of reversal (Stanton and Singleton 1980).

A.2.2 Depth

The protected thermometer reads the actual temperature of the water whereas the hydrostatic pressure of the water affects the reading of the unprotected thermometer. Once the corrected protected thermometer reading T_p and the unprotected thermometer reading T_u are known, the depth of reversal (D) can be calculated from:

$$D = \frac{T_u - T_w}{\Gamma_m Q}$$

where:

- Γ_m = mean density of water column above depth of reversal.
 Q = pressure coefficient of individual unprotected thermometer, i.e. the rate of increase in apparent temperature with pressure.

However Γ_m varies with depth and location. Using a constant value for Γ_m at 1000 m of 1.0294 kg.m⁻³ a more accurate value of D can be found using the formula:

$$D = D' + \Delta D$$

where:

$$D' = \frac{T_u - T_p}{1.0294 Q}$$

and ΔD = correction due to change in Γ_m with depth from its value at 1000 m.

According to Stanton and Singleton (1980), ΔD can be approximated by the quadratic expression:

$$\Delta D = 2.6 \left(1 - \frac{D'}{1000}\right) \frac{D'}{1000}$$

A.3 Depth and Temperature Data from Bathythermographs

A mechanical bathythermograph has pressure and temperature sensors that activate a pen that makes a trace on a gold or smoked glass slide. Depth and pressure can be read off the slide with the aid of a scale produced for the specific instrument being used.

The temperatures from an expendable bathythermograph are obtained by reading from a chart or from digital data depending on the system used. Depth is obtained by taking an assumed rate of descent.

A.4 Physical Quantities Derived from the CTD Probe

A.4.1 Initial Processing of Data

Pressure, temperature and conductivity ratio data are sampled by the CTD control unit every 40 milliseconds. Data in a slice of about 1 dbar are averaged. Any data value that deviates from the preceding and succeeding data values by a given amount is not included in the average. The deviations allowed for each quantity are:

pressure	± 0.2 dbar
temperature	± 0.005 °C
conductivity ratio	± 0.004

The formulae below can also be used for calculating salinity and S_t for bottle samples whose conductivity has been measured by a laboratory salinometer where the temperature is usually 15 °C.

A.4.2 Depth

Depth (D) is calculated from pressure (P) and latitude expressed in radians ($radlat$) using Saunders' Method (Saunders 1981):

$$D = ((1.0 - c1) - c2P)P + \frac{dh}{9.8}$$

where:

$$c1 = (5.92 + 5.25(\sin^2(radlat)))1000$$

$$c2 = 2.21E - 6$$

$$dh = \text{dynamic height anomaly (at present set to 0)}.$$

(From source code written by Michael Moore, NZOI, 20 August 1986.)

This method differs from the standard UNESCO formula by less than 1 m over 7000 m.

A.4.3 Salinity

Salinity (S) is calculated from pressure (P), temperature (T) and conductivity (R) using the following method.

$$\text{Let } C = \text{conductivity and } R = \frac{C(S, T, P)}{C(35, 15, 0)} = r_t(T)R_t(S, t)R_p(R, T, P)$$

Now:

$$r_t(T) = \frac{C(35, t, 0)}{c(35, 15, 0)} = \sum_{n=0}^4 C_n T^n$$

where:

$$C_0 = 0.06766097 \quad C_3 = -6.9698E-7$$

$$C_1 = 2.00564E-2 \quad C_4 = 1.0031E-9$$

$$C_5 = 1.104252E-4$$

And:

$$R_p = 1 + \frac{e_1 P + e_2 P^2 + e_3 P^3}{1 + d_1 T + d_2 T^2 + (d_3 + d_4 T)R}$$

where:

$$\begin{aligned} e_1 &= 2.070E-5 & d_1 &= 3.426E-2 \\ e_2 &= -6.370E-10 & d_2 &= 4.464E-4 \\ e &= 3.989E-15 & d_3 &= 4.215E-1 \\ & & d_4 &= -3.107E-3 \end{aligned}$$

so given R , T and P , R_t can now be calculated using:

$$R_t = \frac{R}{R_p r_t}$$

Salinity can then be calculated using the formula:

$$S = \sum_{n=0}^5 \left[a_n + \frac{\Delta T}{1 + k\Delta T} \right] R_t^{n2}$$

(Joint Panel on Oceanographic Tables and Standards 1991).

A.4. Derivation of Specific Gravity Anomaly S_t

The specific gravity anomaly S_t is defined as the difference between the density of the water sample at atmospheric pressure $r_{s,t}$ in g.cm^{-3} multiplied by 1000.

i.e., from McLellan (1968):

$$S_t = [(r_{s,t}) - 1]1000$$

or

$$S_t = \left(\frac{r}{r_m} - 1 \right) 1000$$

where r_m = the maximum density of pure water, which was accepted by 1 g.cm^{-3} . However, the Equation of State of Seawater (EOS-80) defines a density anomaly (g) as:

$$g = r - 1000$$

and the accepted value of density of standard mean ocean water (SMOW) is $r = 999.975 \text{ kg.m}^{-3}$ so:

$$g = 0.999975S_t - 0.025$$

(from Joint Panel on Oceanographic Tables and Standards 1991).

S_t is still an acceptable measure of density anomaly and is calculated using the formula:

$$S_t = r(S, t, 0)$$

where:

$$r = A + BS + CS^{3/2} + DS^2$$

The coefficients A , B , C and D are polynomials in temperature (T) and are listed in Table 1:

	A	B	C	D
T^0	999.8425944	8.24493E-1	-5.72466E-3	+ 4.8314E-4
T^1	6.793952E-2	4.0899E-3	1.0227E-4	
T^2	-9.095290E-3	7.6438E-5	-1.6546E-6	
T^3	1.001685E-4	-8.2467E-7	+5.3875E-9	
T^4	-1.120083E-6			
T^5	6.536332E-9			

Table 2: Temperature Coefficient s for the calculation of S_t

B Data Accuracy

Accuracy of data on the database varies greatly and depends on the measurement methods used. Table 2 shows the accuracy of measurement of depth, temperature and salinity using different gear methods. The gear methods are listed down the side of the table and the physical quantities are listed along the top. Some quantities may be measured using different techniques for the same gear type (e.g. in a messenger bottle cast depth may be measured in three different ways). The body of the table contains accuracy of measurement and any variations in accuracy due to the measurement techniques used.

Note that according to Intergovernmental Oceanographic Commission Standards salinity is defined against a single reference point ($S = 35$), which has the same electrical conductivity as a reference potassium chloride solution with a temperature of $15\text{ }^{\circ}\text{C}$ at atmospheric pressure, and is no longer measured in parts per thousand (from Joint Panel on Oceanographic Tables and Standards 1991).

Method	Physical Quantity		
	Depth	Temperature ($^{\circ}\text{C}$)	Salinity
<i>Bottle Casts</i>	<ul style="list-style-type: none"> • Metre block counter (MBC) $\pm 10\%$ (10m or more at depth^a). • Cosine of wire angle $\pm 5\%$ (10m or more at depth)^b. • Protected and unprotected thermometers (PUT) $\pm 5\text{m}$ down to 1000m, 5% at depths $>1000\text{m}$^c. 	<ul style="list-style-type: none"> • Usually $\pm 0.02^{\circ}\text{C}$, can be as good as $\pm 0.01^{\circ}\text{C}$ 	<ul style="list-style-type: none"> • Autolab salinometer $\pm 0.010^{\text{d}}$ • Guildline Autosol 8400 salinometer $\pm 0.002^{\text{e}}$
<i>CTD Probe</i>	$\pm 0.15\%$ ($<2\text{m}$ at 2000m) ^e	$\pm 0.005^{\circ}\text{C}^{\text{e}}$	± 0.005 after calibration against water samples ^e , ± 0.005 otherwise ^f
<i>MOCNESS CTD</i>	$\pm 5\text{m}^{\text{e}}$	$\pm 0.1^{\text{e}}$	Not yet tested.
<i>MBT</i> ^g	$\pm 1\%$	± 0.5	
<i>XBT</i> ^c			
<i>Mechanical recording</i>	$\pm 2\%$ (a few metres)	± 0.2	
<i>Electronic recording</i>	$\pm 2\%$ (a few metres)	± 0.1	

Table 3: Accuracy of depth, temperature, and salinity data acquired using various methods.

^a Estimate only. If the wire angle is less than 5° the length of wire can be used as a measure of depth.

^b Estimate based on deviation from correct depth at maximum wire angle of 20° , taking no account of variations in subsurface currents.

^c 0.01°C given in Sverdrup *et al* (1942) but thermometer performance may change with time.

^d Anthony Cole, NIWA, *pers. comm.*

^e Manufacturer's Manual

^f This is the largest difference between CTD and rosette salinities that has been found from calibration against bottle samples at Greta Point.

^g From a set of locally-produced instructions on calibrating the MBT.