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Sea Surface Temperatures near Doubtless Bay, New Zealand

by
J. D. Booth

Fisheries Research Division
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Introduction

The coastal areas of Northland are valuable assets in terms of their recreational, transport, and fishery potential. In particular, the present and potential importance of several of Northland's inshore fisheries make it essential that as many data as possible on the coastal marine environment of the region be available. There is little information on the annual range of sea surface temperatures north of the Bay of Islands, and there are no long-term temperature data for any part of Northland. The 6 years of observation on the seasonal variation of inshore sea surface temperatures presented in this publication, and shorter studies by Hefford (1949), Garner (1959, 1961), Booth (1974), Mercer (1979), and Hickman (1979), help to describe the inshore coastal hydrology of the region.

Sea temperature has an important effect on the breeding and behaviour of most marine animals (Orton 1920, Hutchins 1947) and often affects the catch rates of marine fish. The broad distribution of various marine species, which results mainly from the influence of sea temperatures and coastal currents, has led to the recognition of biogeographical provinces in New Zealand (Knox 1963). The Aupourian Province, which is rich in warm water species, extends north from about East Cape on the east coast and Kaipara Harbour on the west coast.

Little is known of the growth, breeding, and behaviour of New Zealand marine species in relation to sea temperatures. However, there have been studies which examined some of these relationships for a few of Northland's commercially important species. For some of the inshore fish and shellfish species there appears to be a link between sea temperature, time of spawning, and possibly spawning success; for example, in marine fish (Paul 1976, 1978a, 1978b, Crossland 1981) and oysters (Dinamani 1974a, 1974b, 1978). In some fish species, movements are influenced by sea temperatures (Eggleston and Paul 1978, Roberts and Paul 1978, Habib, Clement, and Fisher 1980a, 1980b).

Doubtless Bay (34° 56′ S, 173° 23′ E) is a large bay of about 185 km² on Northland's east coast. Mangonui Harbour is a small tidal estuary of about 4 km², with a catchment area of about 250 km², off the south-eastern corner of Doubtless Bay (Fig. 1).

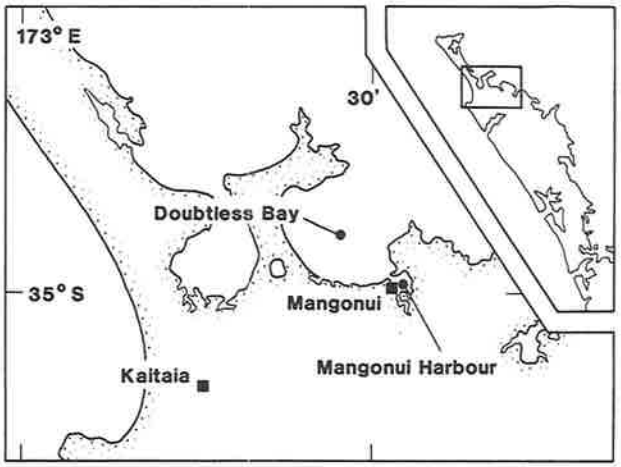

Fig. 1: The study area.

This publication analyses sea surface temperature observations made at Mangonui from April 1974 to March 1980 and relates them to sea surface temperatures in the East Auckland Current (at a point about 50 km offshore from Doubtless Bay) and to air temperatures at Kaitaia Aerodrome (26 km south-west of Mangonui). The predictive value of the air temperatures on Mangonui sea surface temperatures is investigated.

Climate and Hydrology

Northland is in the warm temperate zone of New Zealand, and its climate is characterised by warm, humid summers, mild winters, and plentiful rainfall. Although the air flow over Northland is predominantly from the south-west, in summer and autumn the number of easterly winds may, in many places, equal the number of south-westerlies (de Lisle and Kerr 1964). Mangonui has a high mean annual air temperature (15.0–17.5 °C) (Tomlinson 1976). The mean annual rainfall is 152.5 cm (de Lisle and Kerr 1964). Most rain falls during winter; so the influence of freshwater inflow on sea surface temperatures in Mangonui Harbour is more pronounced at this time.

The east coast of Northland is influenced by the south-east-moving East Auckland Current; a small, western boundary current of subtropical origin (Brodie 1960), which comprises, in part, a series of gyres (Barker and Kibblewhite 1965, Garner 1969, Barker and Denham 1970, 1971).

Surface salinities at the mouth of Mangonui Harbour are generally high (33.0‰–35.5‰), but fall to low values (10.0‰) during high rainfall (my unpublished data).

Methods

Sea surface temperatures were measured daily between 0900 and 1000 h (New Zealand Standard Time) from April 1974 to March 1980 under the Mangonui wharf with a Zeal mercury thermometer; the readings had an accuracy of ± 0.2 °C and were recorded to the nearest 0.5 °C below the reading. The low-water depth under the wharf is 6 m, and the tidal amplitude averages 2.0 m for spring and 1.4 m for neap tides (New Zealand Ministry of Transport 1979).

Weekly radiative sea surface temperatures about 50 km north-east of the mouth of Doubtless Bay were obtained from the Global Operational Sea Surface Temperature Computation (GOSSTCOMP) sea surface temperature maps and generally have a mean accuracy of better than ± 0.5 °C (Brower, Gohrband, Pichel, Signore, and Walton 1976). The main limitations of these maps include there being no differentiation between areas of good and poor satellite coverage, errors due to cloud (particularly thin or uniform layers), and that only the temperature of the extreme surface layer is measured.

The New Zealand Meteorological Service provided air temperature data for the Kaitaia Aerodrome Meteorological Station (Station A53021). Monthly mean values are the average of the mean daily maximum and mean daily minimum temperatures.

Results

Sea surface temperatures at Mangonui from April 1974 to March 1980 (Table 1) are compared with sea surface temperatures offshore from Doubtless Bay and air temperatures at Kaitaia Aerodrome (Table 2) (Figs. 2 and 3). The monthly offshore sea surface temperatures were usually higher than the Mangonui sea surface temperatures, which in turn were higher than the Kaitaia Aerodrome air temperatures; the difference was most marked during autumn and winter. The raw data on Mangonui sea surface temperatures are available from the Fisheries Research Division library.

TABLE 1: Monthly mean sea surface temperatures (°C) at Mangonui, 1974–80

	1974	1975	1976	1977	1978	1979	1980
Jan	-*	20.9	19.8	19.1	20.1	18.8	18.7
Feb	-	20.6	18.7	20.4	22.0	19.5	21.6
Mar	-	20.6	20.0	21.2	21.0	20.8	20.3
Apr	20.0	18.8	19.2	19.1	18.4	18.5	-
May	17.6	17.3	16.3	15.7	15.3	15.3	-
Jun	16.4	14.3	14.3	14.4	14.6	14.6	-
Jul	15.4	13.2	13.7	13.9	12.9	14.4	-
Aug	14.6	14.4	14.2	13.8	13.4	13.6	-
Sep	16.7	14.4	14.4	13.9	14.1	14.1	-
Oct	16.1	16.1	16.0	15.5	15.6	14.8	-
Nov	17.1	17.2	16.5	16.7	17.1	17.3	-
Dec	19.1	18.4	18.6	18.3	18.2	18.2	-

*No data available.

TABLE 2: Annual mean temperatures (°C) for Kaitaia air and Mangonui and offshore sea surface, 1974–80

	Kaitaia	Mangonui	Offshore
1974	16.3	-*	-
1975	15.8	17.2	-
1976	15.0	16.8	18.7
1977	14.7	16.8	18.1
1978	15.4	16.9	17.8
1979	15.8	16.7	18.7
1980	15.4	-	18.3

*No data available.

Occurrence of maximum and minimum monthly mean temperatures

Mangonui sea surface

Maximum: January-March.

Minimum: July-August.

Offshore sea surface

Maximum: February-April (usually coincided with the Mangonui maximum).

Minimum: August-October (on average about 1 month later than Mangonui).

Kaitaia air

Maximum: February-March.

Minimum: July-September. (Both maximum and minimum values usually coincided with those for Mangonui.)

Summary

The months of maximum and minimum mean temperatures usually coincided, except for the offshore sea surface minima, which were on average about 1 month later than the other two sites.

Annual ranges

Mangonui sea surface

Monthly mean temperatures ranged from 12.9 °C in July 1978 to 22.0 °C in February 1978. The average annual range from the coldest to warmest month for 1975–79 was 7.5 °C (6.3–9.1 °C).

Offshore sea surface

Temperatures ranged from 15.0 °C in August and September 1978 to 23.0 °C in April 1975. The average annual range for 1975–80 was 5.8 °C (5.2–6.3 °C).

Kaitaia air

Temperatures ranged from 10.8 °C in September 1977 to 22.9 °C in February 1974. The average annual range for 1974–80 was 9.1 °C (8.5–10.9 °C).

Summary

Kaitaia air temperatures, and then Mangonui sea surface temperatures, had the highest annual range.

Comparisons between years

Mangonui sea surface (April 1974 to March 1980)

Annual mean temperatures for 1975–79 differed by up to 0.5 °C, with 1975 being slightly warmer and 1979 slightly cooler than the other years. Six-monthly means (December-May, June-November) showed a similar trend, except that additional data available for June-November 1974 suggested that 1974 may have been even warmer on average than 1975.

The warmest summers (December-February) occurred during 1974–75 and 1977–78; the coolest during 1975–76 and 1978–79. The warmest autumns (March-May) occurred during 1974 and 1975; the coolest during 1978 and 1979. The warmest winter (June-August) occurred during 1974; the coolest during 1977 and 1978. The warmest springs (September-November) occurred during 1974, 1975, and 1976; the coolest during 1977, 1978, and 1979.

Offshore sea surface (February 1975 to December 1980)

Annual mean temperatures for 1976–80 differed by up to 0.9 °C, with 1976 and 1979 being the warmest years and 1978 the coolest. Six-monthly means showed a similar trend, except that additional data available (June-November 1975) suggested that 1975 may have been even warmer than 1976.

The warmest (and coolest) years for each season were as follows: summer, 1978–79, 1979–80, and probably 1974–75 (1975–76, 1976–77, and 1977–78); autumn, 1975 (1977, 1978, and 1980); winter, 1975 and 1976 (1977 and 1978); spring, 1975 (1978).

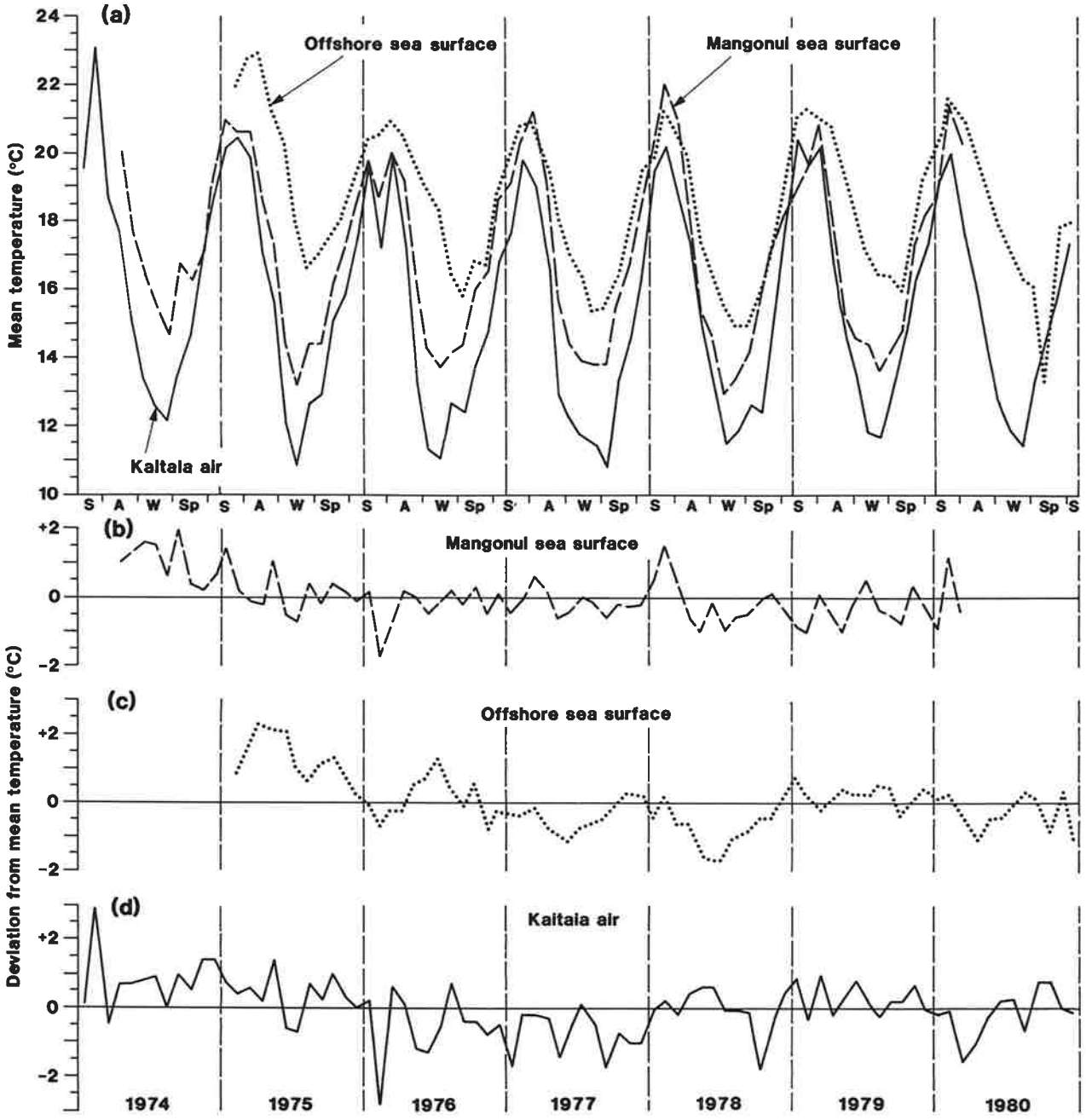

Fig. 2: (a) Monthly mean Mangonui sea surface temperatures, sea surface temperatures offshore from Doubtless Bay, and Kaitaia Aerodrome air temperatures, 1974–80. (b) Deviation of monthly mean Mangonui sea surface temperatures from overall monthly mean, April 1974 to March 1980. (c) Deviation of monthly mean offshore sea surface temperatures from overall monthly mean, February 1975 to December 1980. (d) Deviation of monthly mean Kaitaia Aerodrome air temperatures from overall monthly mean, January 1974 to December 1980.

Kaitaia air (January 1974 to December 1980)

Annual mean temperatures for 1974–80 differed by up to 1.6 °C, with 1974, 1975, and 1979 being the warmest years and 1976 and 1977 the coolest. Six-monthly means showed a similar trend. Since the overall mean for 1974–80 (15.5 °C) is similar to the mean for 1949–80 (15.6 °C), warm and cool years for 1974–80 are also warm and cool years for 1949–80 (Fig. 4).

The warmest (and coolest) years for each season were as follows: summer, 1974–75 and also 1973–74 (1975–76 and 1976–77); autumn, 1974 and 1975 (1977 and 1980); winter, 1974 (1976 and 1977); spring, 1974 and 1975 (1976, 1977, and 1978). Since the monthly mean values for 1974–80 are similar to those for 1949–80, warm and cool seasons for 1974–80 are also warm and cool seasons for 1949–80.

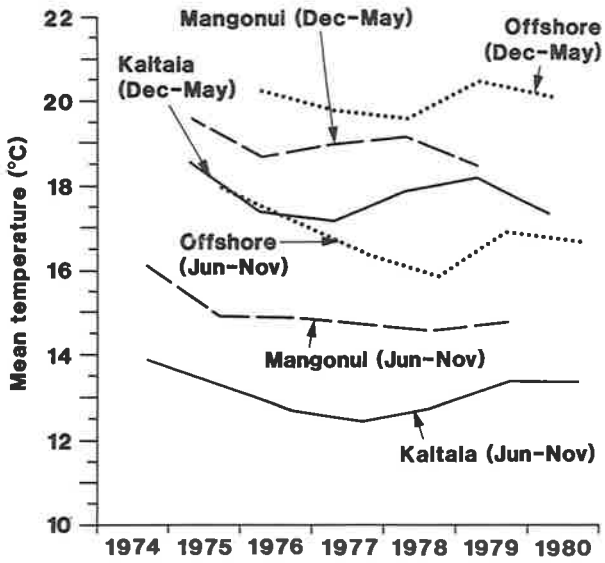

Fig. 3: Six-monthly (December-May, June-November) mean temperatures for Mangonui sea surface, offshore sea surface, and Kaitaia air, 1974–80.

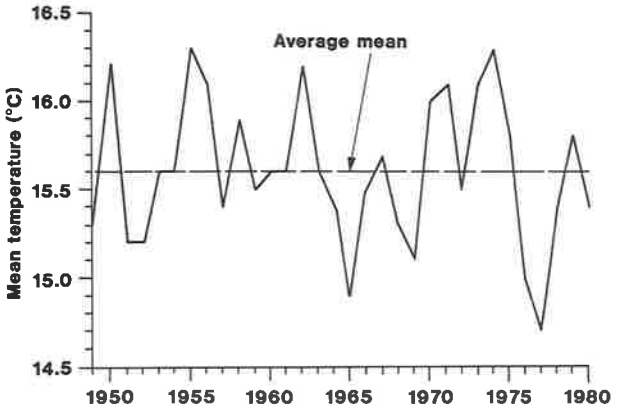

Fig. 4: Annual mean air temperatures for Kaitaia Aerodrome, 1949–80.

Summary

Mean Kaitaia air temperatures (annual and 6-monthly) differed by the greatest margin between years; Mangonui sea surface temperatures differed the least. At all three sites, 1974 and/or 1975 were the warmest years (though no offshore sea surface temperature data were available for January 1974 to January 1975). In addition, offshore sea surface and Kaitaia air temperatures were also high in 1979. The coolest years were different at each site.

The years of highest (and lowest) seasonal temperatures in common for the Mangonui sea surface and Kaitaia air observations were: summer, 1974–75 (1975–76); autumn, 1974 and 1975 (no years); winter, 1974 (1977); spring, 1974 and 1975 (1977 and 1978). The years of highest (and lowest) seasonal temperatures the offshore sea surface observations in 1975–80 had in common with the other two sites were: summer, probably 1974–75 (1975–76); autumn, 1975 (no years); winter, no years (1977); spring, 1975 (1978).

Other comparisons between sites

Three-day means of sea surface temperatures (at 0900 h) at Mangonui correlated closely with 3-day means (of hourly observations) of air temperatures at Kaitaia Aerodrome from 1 November 1975 to 31 March 1976 (Fig. 5). Very high rainfall (300%–400% above normal) occurred over this part of Northland during January 1976. In addition, February was much cooler (2.0–2.5 °C) than normal (New Zealand Meteorological Service 1975–76), and temperatures for December to mid February for New Zealand as a whole averaged 1 °C below normal (Trenberth 1977). The mean air temperature at Kaitaia for February 1976 was 17.2 °C, the lowest since 1949 and almost 3 °C below the mean for 1949–80. Similarly, the mean February 1976 sea surface temperature (18.7 °C) was low, being about 1.2 °C below the January and March 1976 means and an average of 1.8 °C below the February 1975–80 means.

Monthly mean values of sea surface temperatures at Mangonui and air temperatures at Kaitaia Aerodrome during 1974–80 (Figs. 2 and 3) were also closely correlated. These correlations were evident during the seasonal warming and cooling (Pearson correlation coefficient, $r = 0.955$; probability level, $p < 0.001$). When the mean seasonal cycle (for April 1974 to March 1980) was subtracted from each time series the residuals still showed high correlation ($r = 0.508$, $p < 0.001$). However, the temperature difference varied seasonally: Mangonui sea surface temperatures on average exceeded Kaitaia air temperatures by 0.78 °C in summer, 1.69 °C in autumn, 2.14 °C in winter, and 1.73 °C in spring.

The correlation between monthly mean air temperatures at Kaitaia Aerodrome and sea surface temperatures offshore from Doubtless Bay was lower than that between Kaitaia air temperatures and Mangonui sea surface temperatures, but still highly significant ($r = 0.810$, $p < 0.001$). However, variations about the mean seasonal cycle for April 1974 to March 1980 were not significantly correlated at the 5% level.

The maximum monthly mean temperatures offshore on average lagged 0.2 months behind the maximum monthly mean Kaitaia air temperatures; the minimum temperatures lagged by 1.0 months. These results show the slower seasonal heating and cooling of offshore waters than air. Hence the correlation between Kaitaia air temperatures and offshore sea surface temperatures, lagged by 1 month, was higher than when no lag was applied ($r = 0.893$, $p < 0.001$). Similarly, Mangonui sea surface and offshore sea surface temperatures correlated closely when the offshore sea surface temperatures were lagged by 1 month ($r = 0.890$, $p < 0.001$).

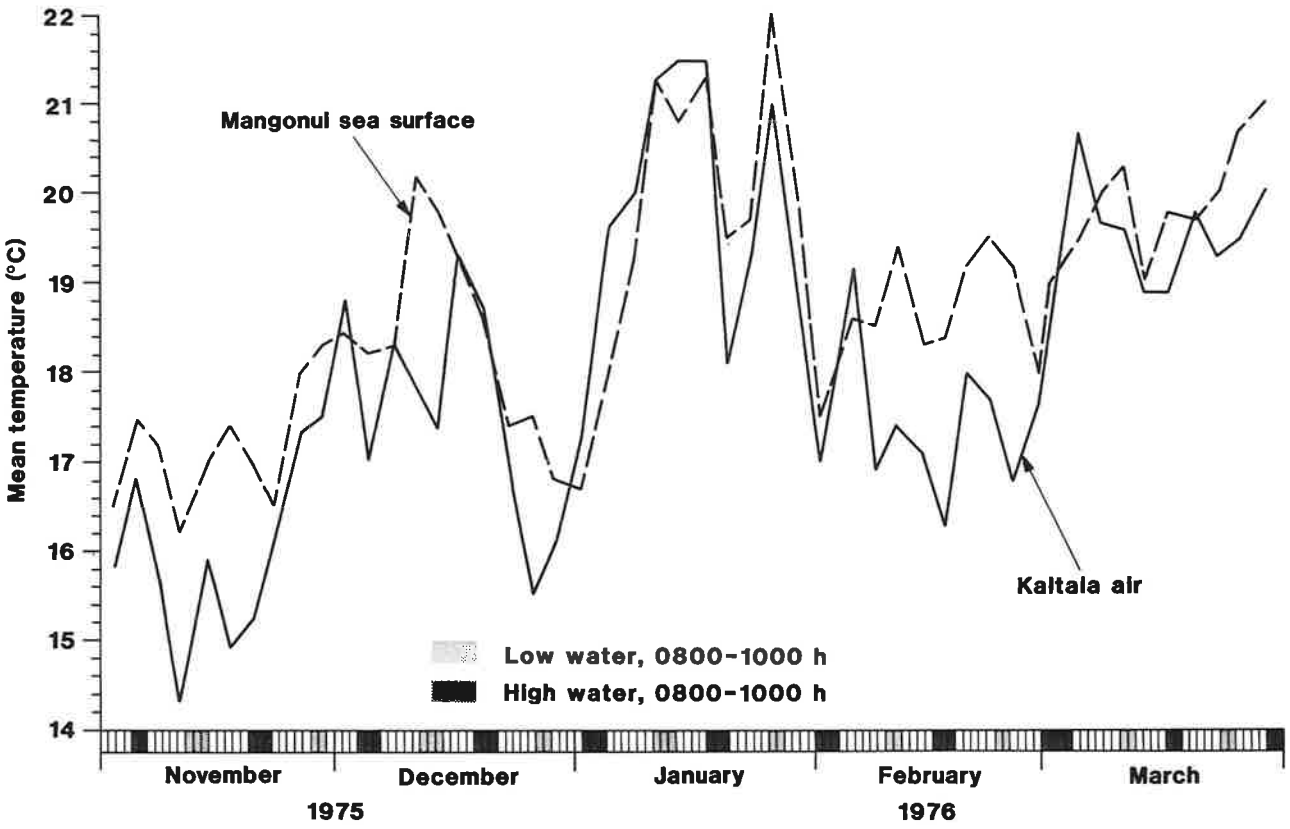

Fig. 5: Three-day means of sea surface temperatures at Mangonui compared with 3-day means of air temperatures at Kaitaia Aerodrome, November 1975 to March 1976.

Discussion

The good correlation between Mangonui sea surface temperatures and Kaitaia air temperatures, when considered on the basis of 3-day means (Fig. 5) and monthly means (Fig. 2), suggests that short-term changes in Mangonui sea surface temperatures can, to a large extent, be derived from air temperature observations. This correlation also extended to 6-monthly and annual means, except for the first half of 1979 (particularly during January, March, May, and June) when Mangonui sea surface temperatures were much cooler than would be expected (Figs. 2 and 3). The reason for this anomaly is unknown. Kaitaia air temperatures were warmer than the long-term average for 1949–80 during 1974, cooler during 1976 and 1977, and about the same during 1975 and 1978–80 (Fig. 3). It is suggested that the mean annual Mangonui sea surface temperatures during 1975–79 departed from the long-term average in a similar manner.

Trends in 6-monthly and annual means in offshore sea surface temperatures were also generally similar to Kaitaia air temperatures, except during 1978, which was the coolest year when 6-monthly and annual mean values are used.

Because annual trends in Kaitaia air temperatures were generally consistent with trends in the Mangonui and offshore sea surface temperatures, it may be reasonable to assume that at least the very warm (1950, 1955, 1956, 1970, 1971, 1973, and 1974) and very cool (1951, 1952, 1965, 1969, 1976, and 1977) years at Kaitaia were reflected in the variation of mean sea surface temperatures at Mangonui and offshore.

Paul (1978a) analysed trends in the sea surface temperatures at Leigh, 55 km north of Auckland, during 1967–77 and compared them with trends in air temperatures at Auckland during the same period. Paul thought sea surface temperatures at Leigh reasonably reflected changes in the outer Hauraki Gulf, an area influenced by oceanic conditions. Both the sea surface temperatures at Leigh and the air temperatures at Auckland were much warmer than average during 1970, 1971, 1973, and 1974, and they were cooler than average during 1968, 1969, 1976, and 1977. For the years in common with this study, the trends in Kaitaia air temperatures were similar and support Paul's conclusion that warm and cold periods measured at Auckland and Leigh usually coincide with similar changes occurring over much larger areas of the Tasman Sea and south-west Pacific Ocean.

Further evidence for this is seen in the GOSSTCOMP sea surface temperatures taken between February 1975 and June 1978 for the whole country. Temperatures in 1975 were warmer than in 1976 and 1977, with the warm water extending further south and persisting for a longer period (Anon. 1978). Trenberth (1973) believes there is a close interdependence between sea surface temperatures over similarly large sea areas around New Zealand and atmospheric weather systems. Analysis of weather systems is therefore likely to provide indications of the sea surface temperature trends in this region.

The nearest site to Mangonui at which sea surface temperatures have been recorded is the Bay of Islands (Booth 1974), where observations were made from June 1970 to December 1971. Although Mangonui is 65 km north-west of the Bay of Islands, and on the same coast, monthly mean sea surface temperatures during 1974–80 were 0.3–2.9 °C (average 1.6 °C) cooler than monthly mean sea surface temperatures at the Bay of Islands during 1971. This may reflect the fact that 1971 had the warmest air temperatures yet recorded over all New Zealand (Salinger and Gunn 1975).

Sea surface temperatures must be used with caution when the effects of temperature on the behaviour of marine animals are analysed. Surface temperatures, as opposed to mid-water or bottom temperatures, are most useful in biological studies of surface habitats and habitats which are hydrologically homogeneous (for example, near the mouth of Mangonui Harbour, where tidal currents prevent severe thermal stratification). However, for mid-water and sea bottom habitats in areas which are not well mixed, sea surface temperatures as indicators of actual conditions lower in the water column are of less value because of hydrological phenomena such as thermal stratification, run-off, and upwelling. Nevertheless, surface temperatures are useful and are widely applied to show the seasonal warming and cooling of nearshore and offshore water masses as well as to define the movement and extent of oceanic currents.

The sea surface temperatures given in this publication help to describe the coastal marine environment of Northland. They may also be useful in explaining or predicting trends in catches of marine species in the area.

Acknowledgments

The Mangonui sea surface temperature data were collected by B. Renner from 1974 to 1977 and J. G. Beamish from 1978 to 1980, and I thank them for the use of these observations. I am grateful to the staff of the New Zealand Meteorological Service for access to their data. Helpful reviews of the manuscript were made by H. J. Cranfield, M. P. Francis, D. J. Gilbert, and L. J. Paul, and D. J. Gilbert gave statistical advice.

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