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The Interaction of Wind, Temperature and Catch Rate of Lobster (*Homarus americanus*) on the Acadian Peninsula

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Abstract

The effects of temperature on catch rate of American lobster (*Homarus americanus*) off the Acadian Peninsula of northern New Brunswick are investigated. Lobster landings and number of trap hauls were available through a volunteer program by fishers and bottom temperatures were measured from moored thermistors. A high positive correlation was found between the mean temperature during the 24 hr prior to trap being hauled and the lobster catch within the Baie des Chaleurs. A similar analysis showed no such correlation outside the Baie along the northern New Brunswick coast adjacent to the Gulf of St. Lawrence. The temperature in the Baie des Chaleurs is wind driven with alongshore winds producing upwelling/downwelling in the classical Ekman response.

Résumé

Les effets de la température sur le taux de capture du homard (*Homarus americanus*) dans la région de la péninsule acadienne située au nord-est du Nouveau-Brunswick ont été étudiés. Les débarquements de homards et le nombre de casiers levés ont été obtenus par un programme volontaire de pêcheurs repères et les températures du fond ont été enregistrées par des thermographes à des stations fixes. Une forte corrélation positive a été trouvée entre la température moyenne de la période de 24 h précédant la levée du casier et les captures de homard dans la baie des Chaleurs. Une analyse similaire a démonté aucune corrélation de ce genre à l'extérieur de la baie dans les régions suivant la côte adjacente au golfe du Saint-Laurent. La température dans la baie des Chaleurs est influencée par le vent avec des vents suivant la côte produisant des montées d'eau/descentes d'eau d'une réponse classique d'Ekman.

Introduction

Wind influences lobster landings off the Acadian Peninsula of northern New Brunswick (Lobster Fishing Area [LFA] 23) according to local fishers. The effect is spatially dependent with decreased landings associated with north or northeasterly winds along the south coast of the Baie des Chaleurs and with southerly winds along the east coast of New Brunswick south of Miscou. Wind-affected catch rates of lobster have also been reported by fishers elsewhere in the Gulf of St. Lawrence (Drinkwater 1994). In St. Georges Bay, Nova Scotia, these effects are believed to through wind-driven temperature variability (Drinkwater 1994) which in turn has been shown to affect lobster catch rates (McLeese and Wilder 1958). Lobster activity, measured by walking rate, increases as temperature rises. This in turn increases the likelihood of a lobster encountering a trap and hence the catchability of lobsters. Few studies have attempted to measure the relationship of catch rate, temperature and winds directly.

During the lobster season in 1994, 1995 and 1996 daily catch rates and temperature information were collected at several sites in LFA 23. In this paper, these data are used to test 2 separate hypotheses. The first is that temperature affects the CPUE (catch per unit effort) and secondly that the temperature variability is principally wind driven.

Data and Methods

The study area is located on the Acadian Peninsula of northeast New Brunswick (Fig. 1). All study sites lay within LFA 23 which extends from Dalhousie near the head of Baie des Chaleurs to Pointe-Sapin on the east coast of New Brunswick in the Gulf of St. Lawrence.

Data on landings and trap hauls at several sites were obtained through a voluntary fisher's log book program (Index-Fisher Program) initiated in 1993 (Lanteigne et al. 1994). From these data, CPUE was calculated as the daily catch (in pounds) per number of traps hauled. As lobster catchability is influenced by soak time (Krouse 1989), only catch and effort data with one soak day were used.

Temperature data were collected using electronic recorders either on stationary moorings or in fisher's traps during the fishing season (mobile stations). In 1994, temperatures were recorded by thermistors (model: Hobo-Temp, Hobo™ Onset Computer Cor., Pocasset, MA, 02559) attached to stationary moorings containing a surface buoy. These moorings were deployed at a nominal depth of 10 m off Stonehaven, Anse-Bleue and Caraquet (Fig. 1). In 1995, fixed temperature sites were established at New Mills, Pointe-Verte, Caraquet and Val Comeau (Fig. 1) under the Coastal Water Temperature Monitoring Program (CWTM) managed by DFO Moncton (Lanteigne et al. 1996). Temperature was recorded using Vemco Minilogs deployed at a depth of 20 m. In addition, a Hobo-Temp was attached to a fisher's lobster trap off Miscou (Fig. 1). In 1996, temperatures were collected at Stonehaven, Caraquet, Petit-Shippagan and Val Comeau (Fig. 1). The mooring system at Caraquet and Val Comeau was similar to that used in 1995 but at the other two sites a complete subsurface design was employed. Details on the design are found in Lanteigne (1997). The 1995 and 1996 temperature data from Anse-Bleue were collected using Vemco Minilogs attached at 20 m to the shipwreck "Louise P". Temperature was recorded every 2 h and linearly interpolated to values on the hour (i.e. 1:00, 2:00, etc.).

Hourly wind data were obtained from the Atmospheric Environment Service for Miscou Island. They were converted to wind stress (the force applied to the sea surface by the wind) using the formulation of Large and Pond (1981).

The daily CPUE and the mean daily temperature (MDT) were used to investigate the relationship of catchability and temperature. To better reflect the average temperature experienced during a fishing period (being the time between the setting and hauling of the traps), the MDT for comparison with the CPUE on day i was calculated by averaging temperatures over a 24-h period beginning at 8:00 am the previous day since most traps are hauled and redeployed during the early morning. To remove seasonal trends, first differences of the CPUE and MDT were taken, i.e.

$$\Delta \text{ CPUE} = \text{CPUE } (t_{i+1}) - \text{CPUE } (t_i)$$
$$\Delta \text{ MDT} = \text{MDT } (t_{i+1}) - \text{MDT } (t_i)$$

where Δ represents the first difference. No serial correlation of the residuals of these transformed data was found (Durbin-Watson test; Ott 1993). The Spearman rank correlation coefficient (Sokal and Rohlf 1981) was then calculated between the transformed CPUE and MDT data.

Spectral analysis techniques (Jenkins and Watts 1968) were used to investigate the relationship between temperature and wind stress components ($\tau_{x,}$ east-west stresses, positive eastward; τ_y north-south stress, positive northward). Due to time constraints only data from 1994 were used in the temperature-wind analysis. Spectra of the temperatures and winds were calculated by dividing the records into 12 blocks of 256 points with 50% overlap. The mean and trend were removed from each block and the data were tapered using a Hanning window (Bloomfield 1976). A multivariate frequency-response analysis (Jenkins and Watts 1968), which is the frequency-domain analogue to time-domain regression for a multiple input-single output model was also undertaken. In this study, temperature was modeled as a function of the wind stress components, τ_x and τ_y. For further details see Drinkwater (1994).

Lobster Catchability

Lobster catchability depends on a series of environmental, physiological and behavioral factors along with mechanical characteristics of the trap (Krouse 1989). Lobsters have a hard exoskeleton and growth is accomplished through molting, i.e. replacing their entire carapace with a larger one. Because of the soft carapace condition following molting, lobsters will seek shelter shortly before molting in order to protect themselves against predators. The molting season in LFA 23 normally starts at the end of June and continues until the end of August.

The lobster fishery in LFA 23 is regulated by a minimal legal size (66.7 mm carapace length), a May and June fishing season, prohibition on landing ovigerous females and a limit of 375 traps per fisher. At the beginning of the fishing season, lobster traps (on strings of 6-10 traps) are concentrated offshore at depths of 20 to 30 m. As the season progresses, fishers gradual move their traps shoreward until the end of the fishing season. Few traps are located at depths greater than 15 m by June. These seasonal changes in the placement of traps corresponds to the inshore movement of lobsters during the spring.

Seasonal trends were observed in both the MDT and CPUE (Fig. 2). Seasonal heating was evident in the Petit-Shippagan temperatures as they rose from approximately 1°C in early May to 13°C in late June, 1996 (Fig. 2). In contrast to the temperature increase, the CPUE declines from a mean of approximately 0.9 lb/trap haul at the beginning of the fishing season to 0.15 lb/trap haul by the end (Fig. 2). This latter trend is believed to correspond to the gradual depletion of the resource by fishing. Our analysis were then restricted to the first four weeks of the fishing season during which no less than 66% of the landings were caught at any one site. This helped to eliminate the possible confounding problem of decreased CPUE due to molting after mid-June and fishing mortality. As the season progressed, the variability in catch declined and hence our signal to noise ratio decreased. Limiting our analysis to the first 4 weeks of the season meant we had a higher signal to noise ratio.

In general, high correlations were observed between MDT and CPUE for the sites located in the Baie des Chaleurs during each year (Figs. 4, 5 and 6; Table 1). In the scattergram of MDT versus CPUE, coordinates of the paired variables located in the upper right (+/+) or the lower left (-/-) quadrant indicate a good correlation (Figs. 4, 5 and 6). Based on the Spearman rank correlation coefficient test, 9 out of 11 possible correlations within the Baie des Chaleur were significant (Table 1). The positive slopes indicate that higher catches were associated with higher temperatures. The only exceptions were at Anse-Bleue in 1994 and Caraquet in 1995. There too the slopes were positive but not statistically significant. In contrast to the results from inside the Baie des Chaleurs, no relationship was found between MDT and CPUE at the 2 sites (Miscou and Val Comeau) outside the bay in the Gulf of St. Lawrence.

Table 1. Spearman rank correlation coefficient test for the mean daily temperature (MDT) and catch per unit of effort (CPUE) for all study sites between 1994 and 1996. Variables (MDT and CPUE) are independent if $p > 0.05$. Study sites identified above and under the doted line are the ones from the Baie des Chaleurs and the Gulf of St. Lawrence, respectively.

SITE	YEAR		
	1994	1995	1996
NEW MILLS		$p = 0.0061$[1]	
POINTE-VERTE		$p = 0.0436$[1]	
STONEHAVEN	$p = 0.0475$[1]		$p = 0.0375$[1]
ANSE-BLEUE	$p = 0.0986$	$p = 0.0247$[1]	$p = 0.0060$[1]
CARAQUET	$p = 0.0005$[1]	$p = 0.2441$	$p = 0.0041$[1]
PETIT-SHIPPAGAN			$p = 0.0134$[1]
MISCOU		$p = 0.7437$	
VAL COMEAU		$p = 0.7942$	$p = 0.4540$

[1] indicate the sites where a good correlation between MDT and CPUE were observed.

Wind/Temperature Variability

Having found temperature-dependent catch rates within the Baie des Chaleurs, we now wish to investigate the relationship between the temperature and local winds. Bonardelli et al. (1993) found evidence for wind-driven temperature variability along the north shore of the Baie des Chaleurs and thus we might expect similar results along the south shore.

Spectra of the Miscou wind stress show peak variance at a period of approximately 4 days for the north-south component, τ_y (Fig. 7). The spectrum plotted as log frequency versus spectral density is simply the variance as a function of frequency and the area under the spectral curve is the total variance. High variance is also observed for periods > 2 d and at approximately 1 d. The latter is most likely due to a land-sea breeze. The variance in the east-west component, τ_x is lower than τ_y but with a broad range of relatively high values at periods > 1 d. Temperature spectra show a general increase towards lower frequencies (longer periods) with the peak near 0.2 cpd (cycles per day), equivalent to a period of 5 days (Fig. 8). No difference in variance is observed between sites at periods of 5-10 d (frequencies below 0.2 cpd). However, Anse-Bleue shows higher variance for frequencies >0.25 cpd (periods less than 4 days) and Stonehaven shows a peak in variance at the M2 tidal frequency (near 2 cpd). The similarities in spectra between the wind stress and water temperatures are at least suggestive that they are related.

The temperature coherency spectrum (frequency dependent correlations) between sites indicate coherence generally increases with frequency with maxima at the tidal frequency, at a period near 2-3 days and another at 5-10 d. Maximum coherence occurred at the latter. This indicates that the temperature variability at the longer periods (lower frequencies) is similar between sites. Coherence was also calculated between temperature and the two wind stress components. They show peak coherence at periods of 5-10 with τ_x (Fig. 10). Phase information indicates that an eastward wind produces warmer water and westward winds colder water. This is consistent with the classical Ekman response. An easterly wind in the Baie des Chaleur therefore results in upwelling, the movement of deeper colder water inshore and into shallower depths. This is opposite response to an easterly wind on the north shore of the Baie des Chaleurs as is expected based on Ekman dynamics. For the other wind stress component, τ_y, the highest coherence occurred at periods below 2 d. Multiple-frequency response analysis allows one to calculate the coherence of both stress components together taking into account the coherence between the wind stress components themselves. Coherence with the both stress components is highest at periods of 2-3 d and remains high at the lowest frequencies (Fig. 11). At the latter, temperature is responding primarily to changes in τ_x (Fig. 10).

Summary

- A high positive correlation was found between the mean daily temperature and the CPUE for sites within the Baie des Chaleurs.
- No correlation was found between the mean daily temperature and the CPUE for sites located outside the Baie des Chaleurs in the Gulf of St. Lawrence.
- The temperature variability along the south coast of the Baie des Chaleurs is largely wind driven at periods of 5-10 d and at periods of 2-3 d. The former is dependent almost solely on the east-west wind stress component and the response is classical Ekman upwelling/downwelling. At periods of 2-3 d both wind stress components are important in generating the response.
- Our analysis supports the observations of fishers in the Baie des Chaleurs that wind effects lobster catch but not those of fishers outside the bay in the Gulf of St. Lawrence. The reason for this difference is presently unknown.

Future work will investigate the temperature response to wind using the 1995 and 1996 data. This includes temperature sites outside the Baie des Chaleurs which were not investigated in the present study. We will also seek to determine the wind direction that produces the maximum response at each site and search for evidence of propagation of temperature events along the coast similar to that found by Bonardelli et al. (1993). Finally, we wish to extend our analysis to investigate wind stress-catch rate relationships directly in order to determine if wind may influence landings through processes other than temperature. This is especially important given the lack of correlation between MDT and CPUE at the sites outside the Baie des Chaleurs.

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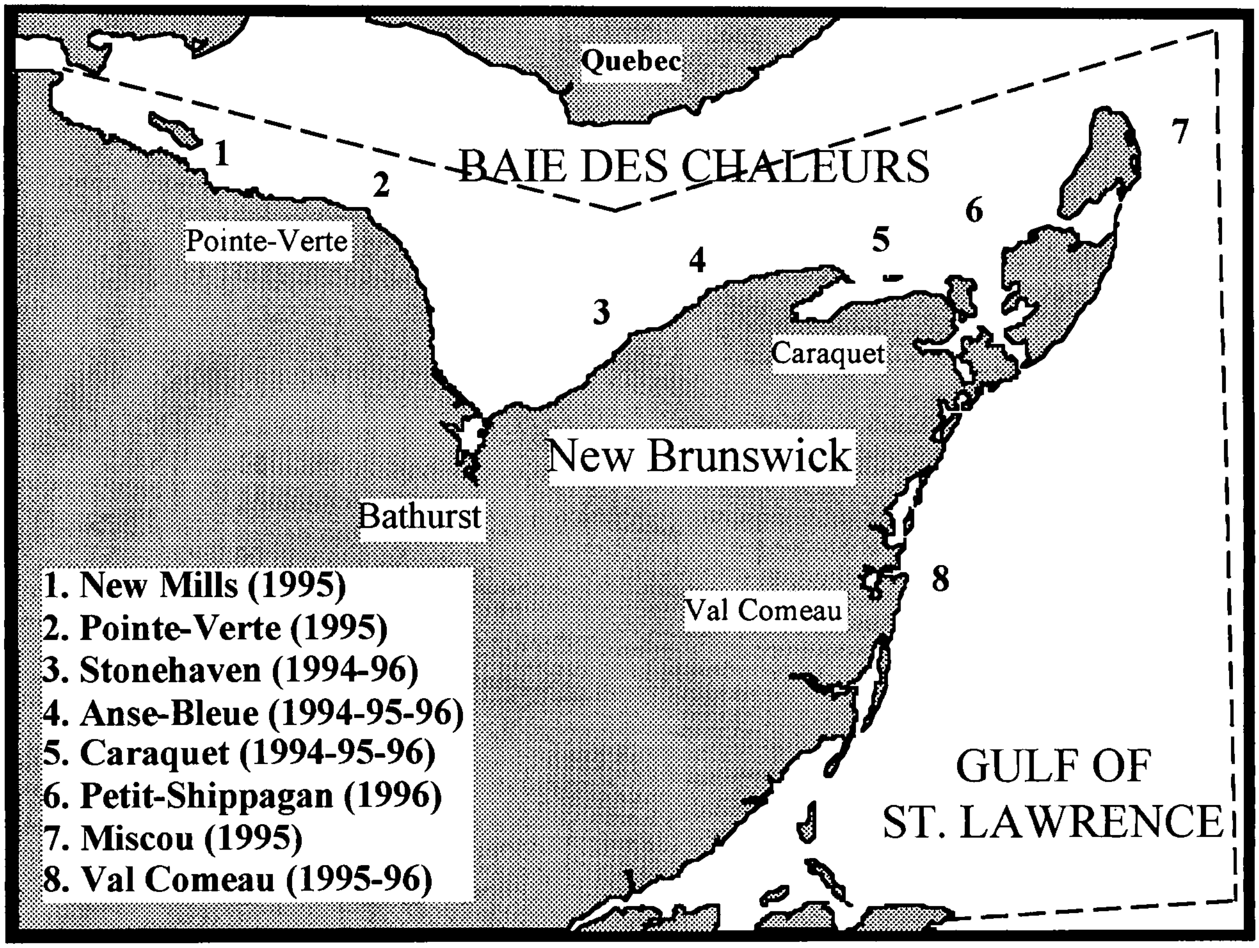

Figure 1. Map of the study area in the lobster fishing area (LFA) 23. The boundary of LFA 23 is represented by the dotted line.

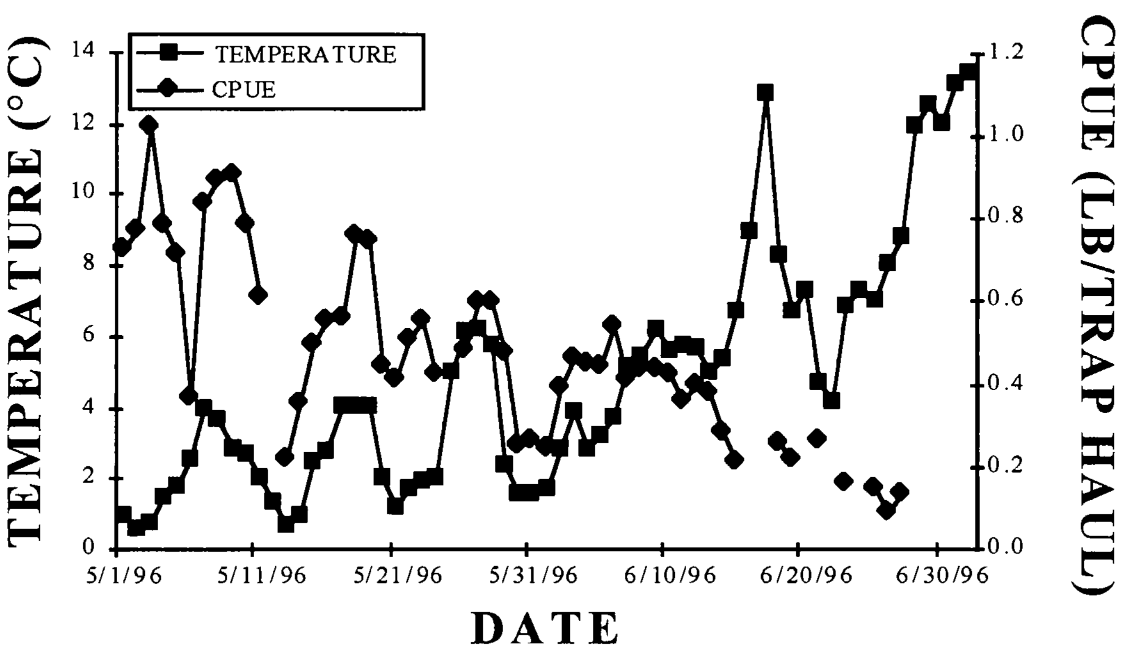

Figure 2. Mean daily temperature and catch per unit of effort trends in Petit-Shippagan.

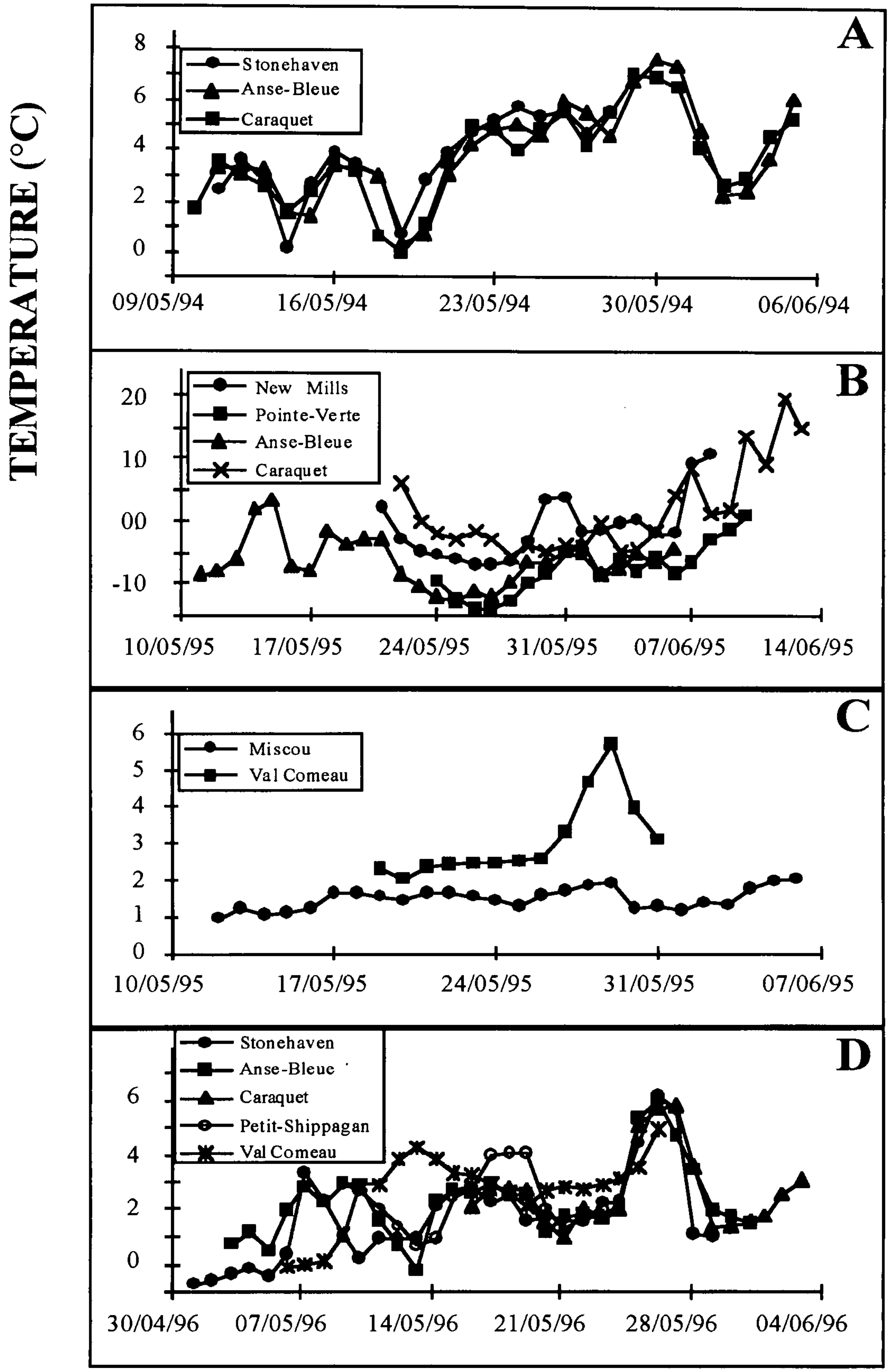

Figure 3. Mean daily temperature observed at all study sites between 1994 and 1996.

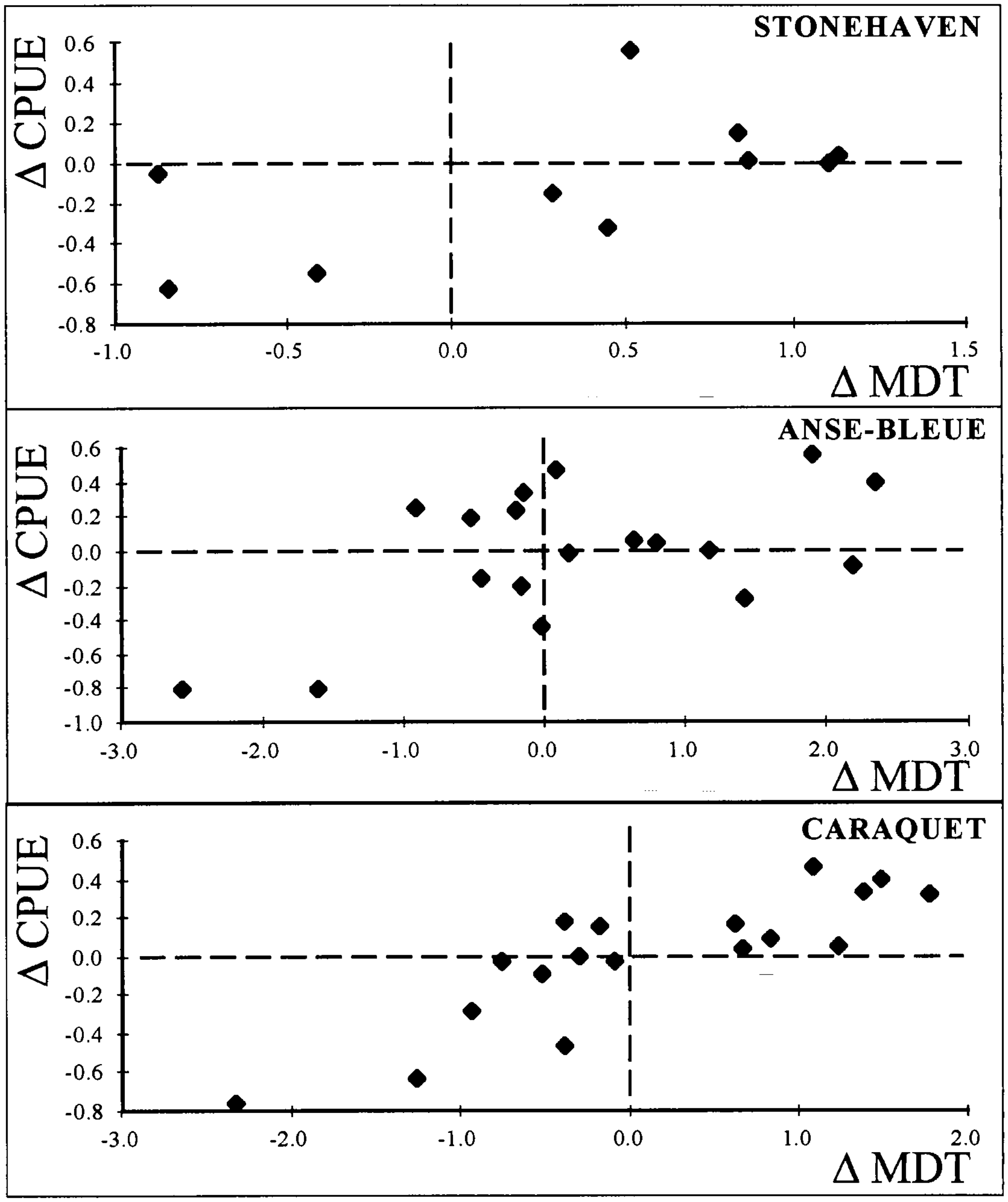

Figure 4. Relationship of the paired transformed data of catch per unit of effort (Δ CPUE) in relation to mean daily temperature (Δ MDT) for Stonehaven (r = 0.58), Anse-Bleue (r = 0.56) and Caraquet (r = 0.85) in 1994.

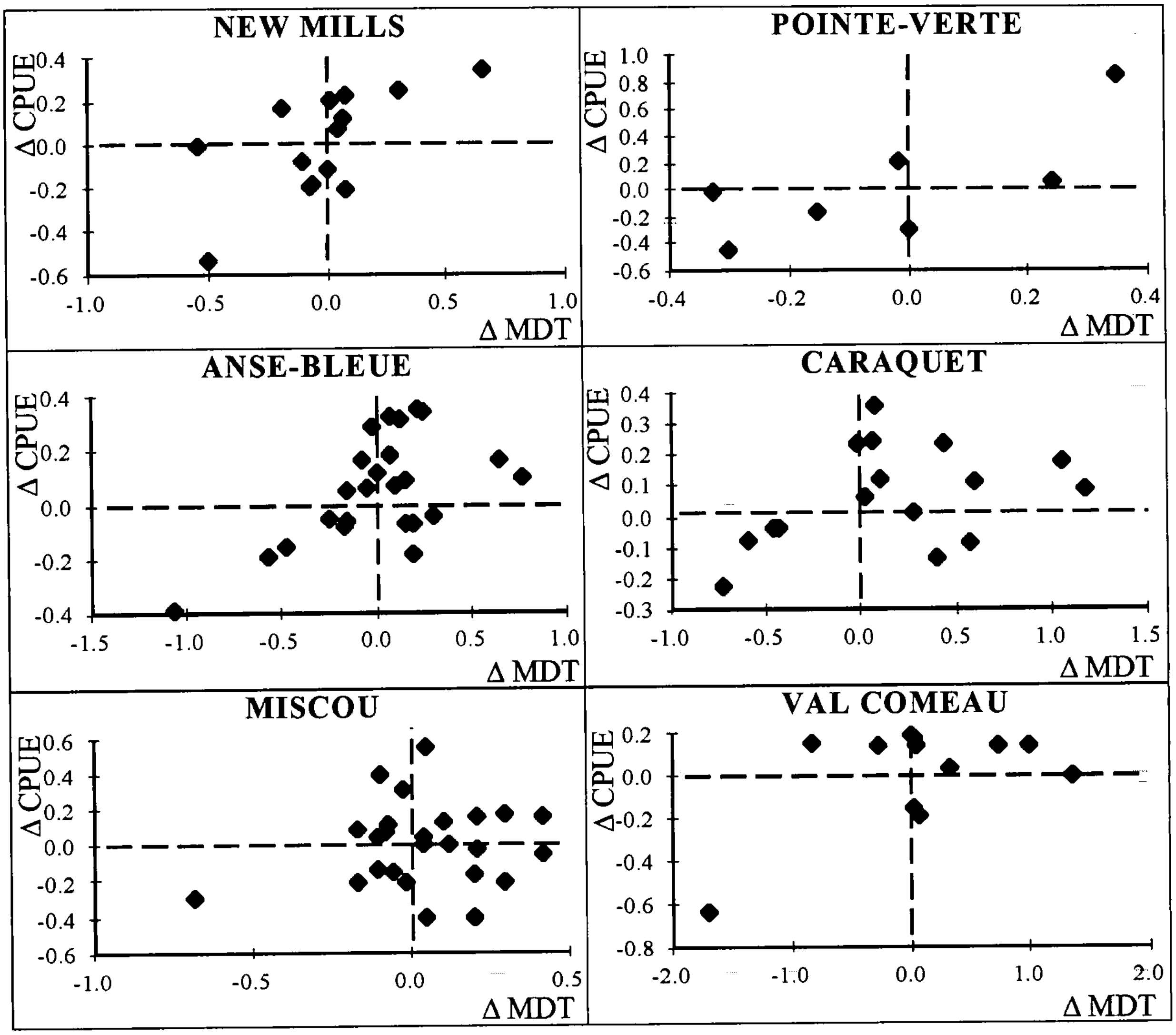

Figure 5. Relationship of the paired transformed data of catch per unit of effort (Δ CPUE) in relation to mean daily temperature (Δ MDT) for New Mills (r = 0.71), Pointe-Verte (r = 0.75), Anse-Bleue (r = 0.57), Caraquet (r = 0.36), Miscou (r = 0.12) and Val Comeau (r = 0.55) in 1995.

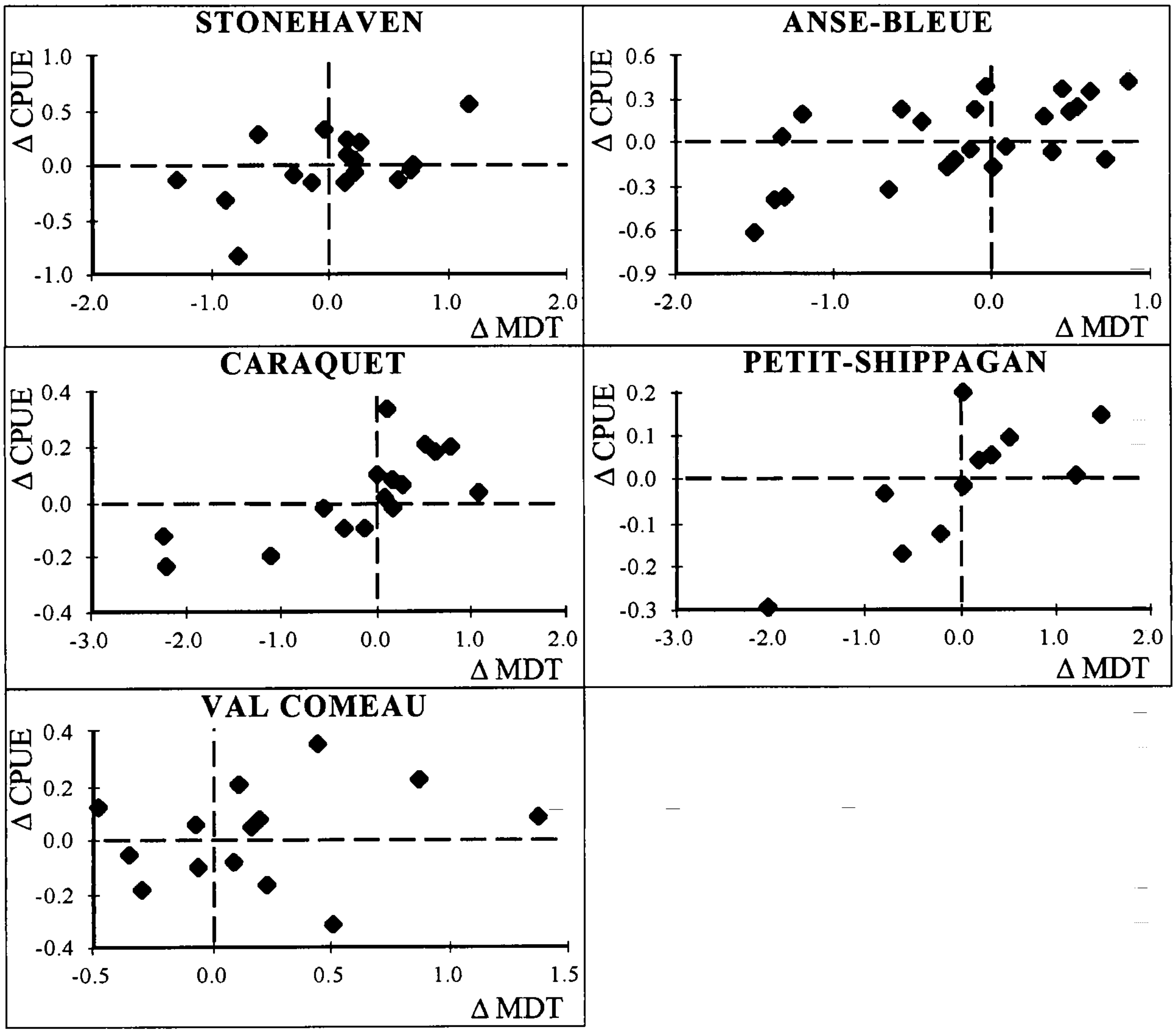

Figure 6. Relationship of the paired transformed data of catch per unit of effort (Δ CPUE) in relation to mean daily temperature (Δ MDT) for Stonehaven (r = 0.52), Anse-Bleue (r = 0.61), Caraquet (r = 0.72), Petit-Shippagan (r = 0.77) and Val Comeau (r = 0.24) in 1996.

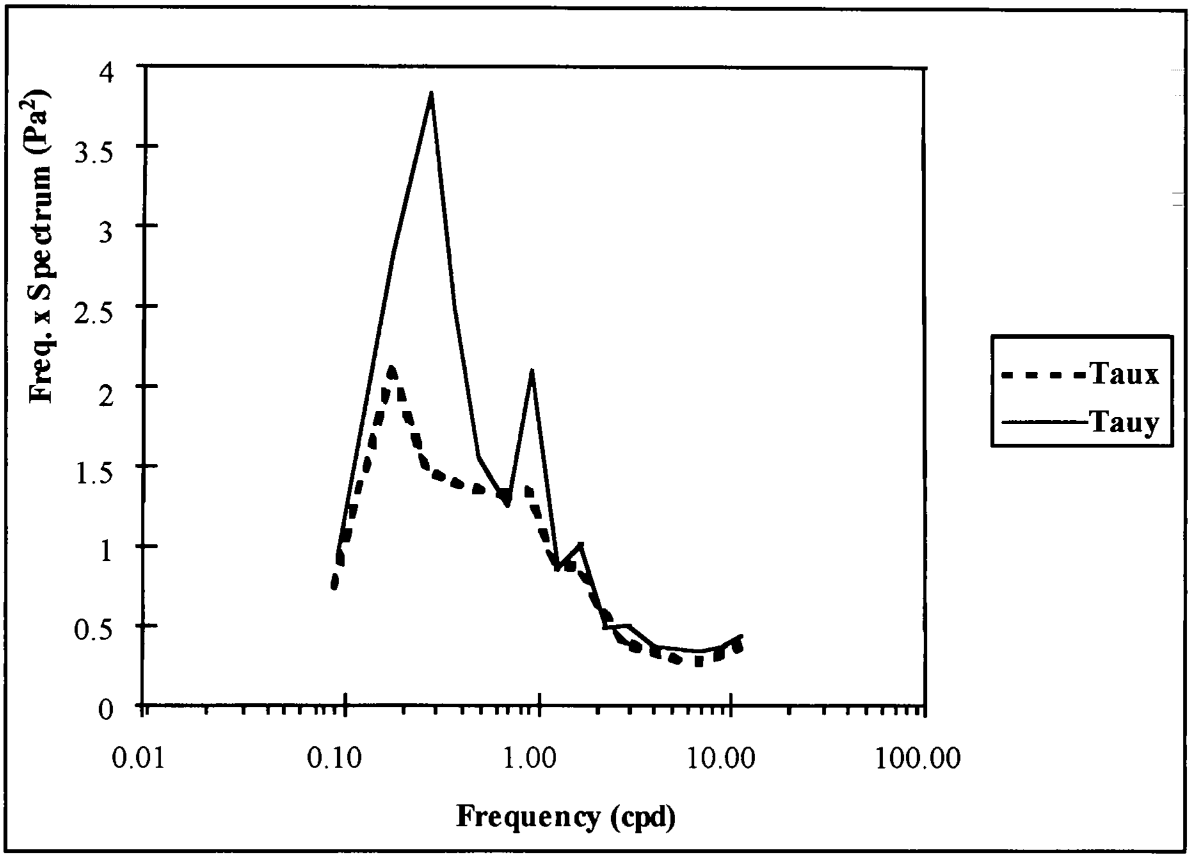

Figure. 7. The spectra of the 1994 Miscou Island wind stress components, Taux (positive eastward) and Tauy (positive northward).

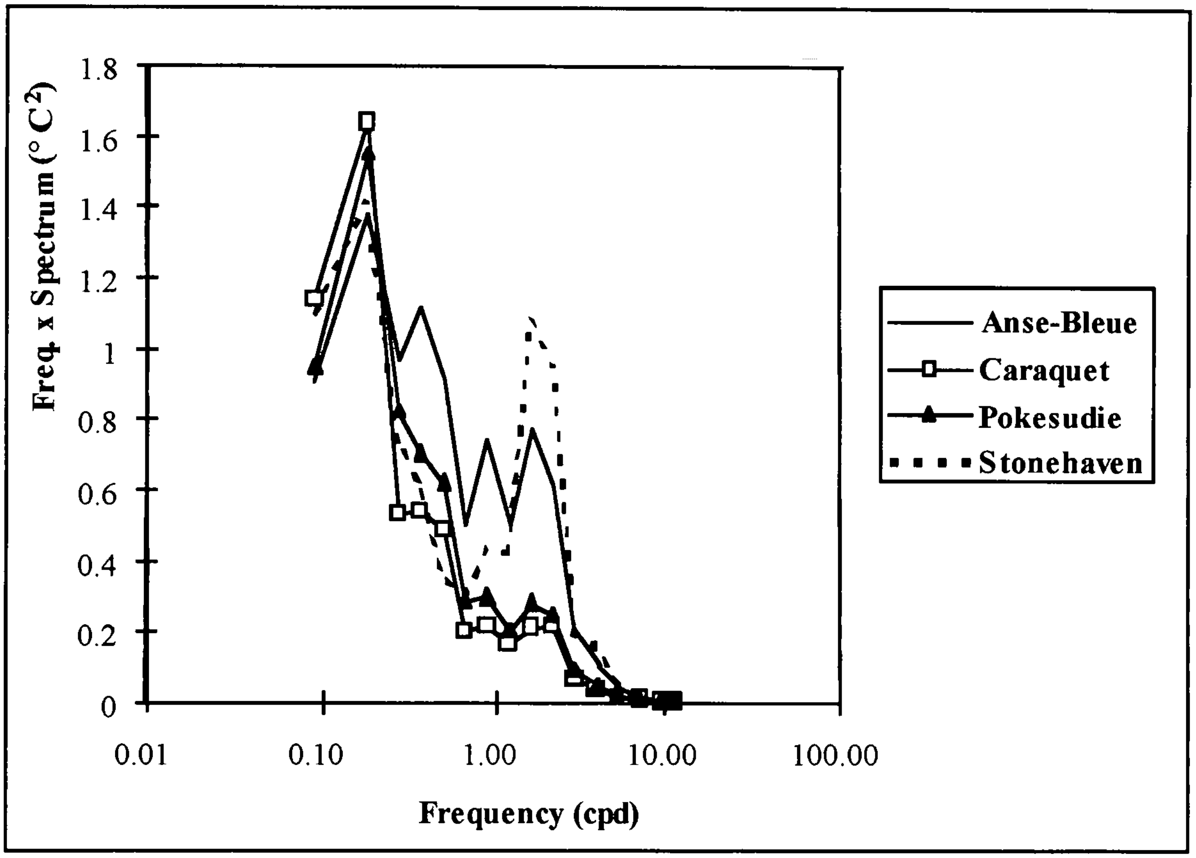

Figure. 8. The 1994 temperature spectra at the four sites along the south shore of the Baie des Chaleurs.

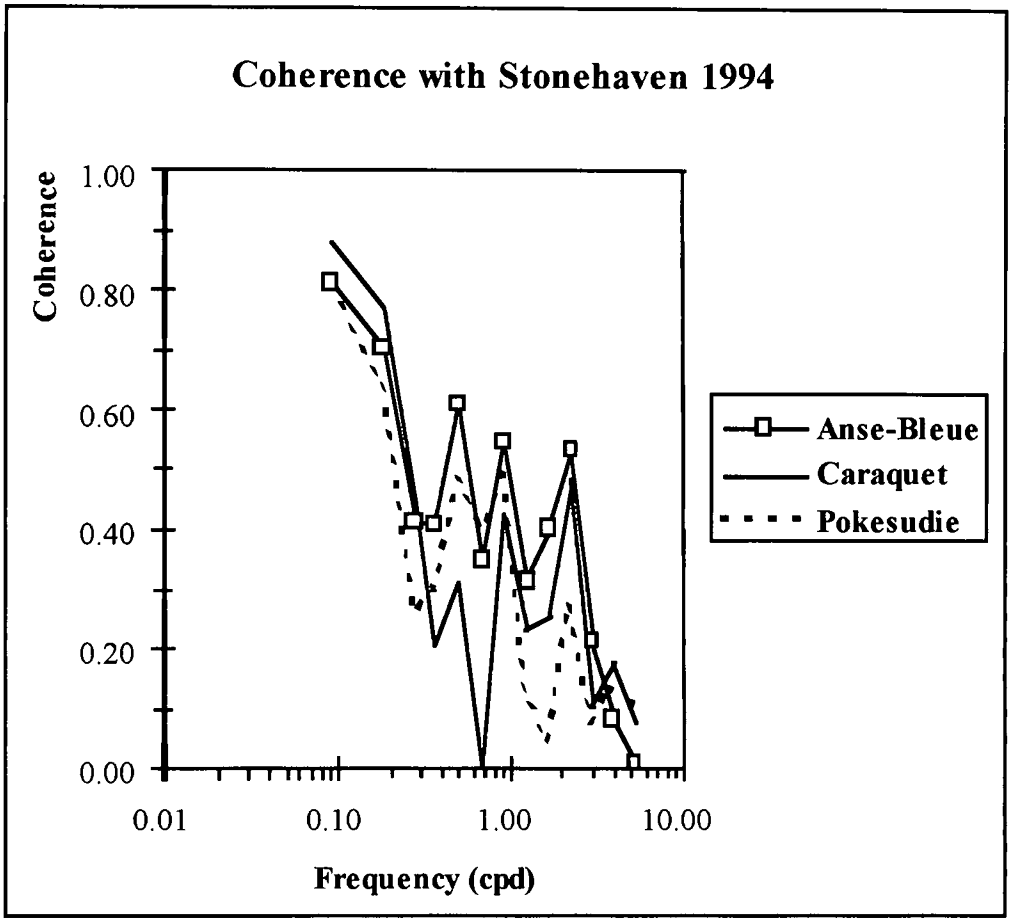

Figure. 9. The coherency spectra of 1994 Stonehaven temperatures with those at Anse-Bleue, Caraquet and Pokesudie.

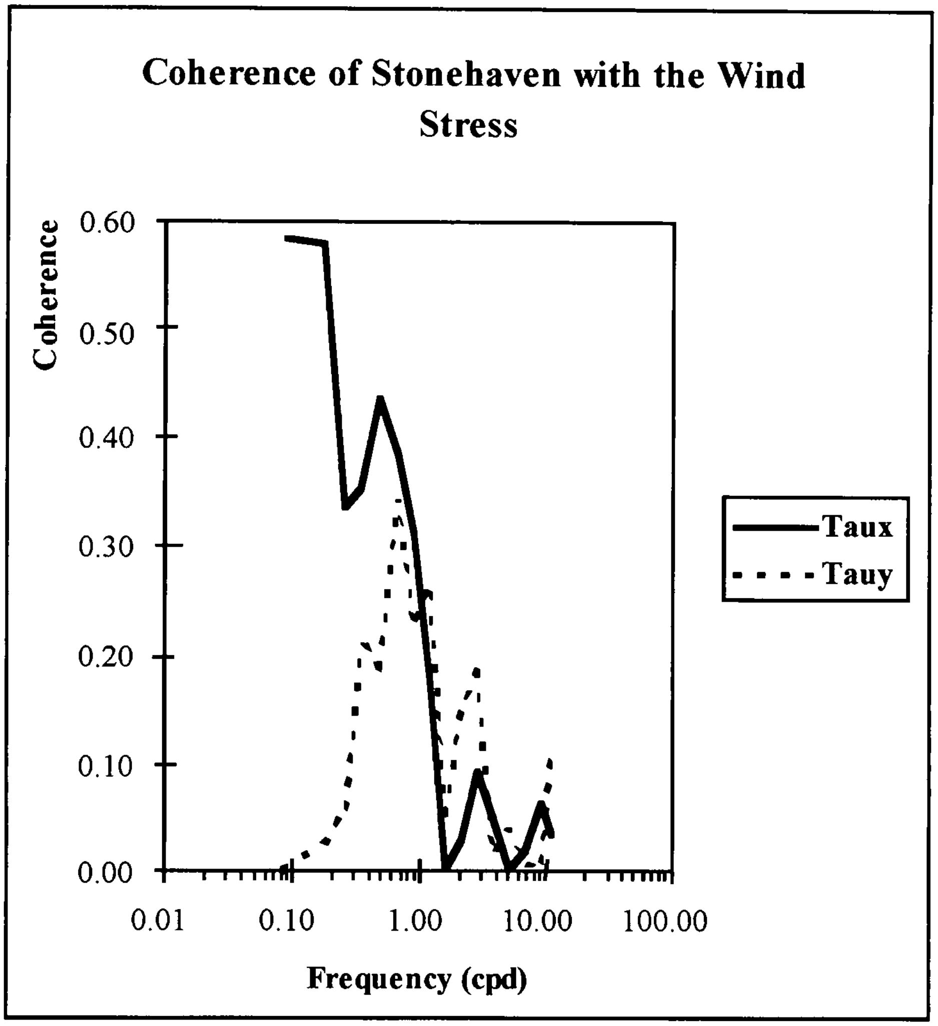

Figure. 10. The coherency spectra of 1994 Stonehaven temperatures with Miscou Island wind stress components. The high coherence at lower frequencies (longer periods) is due almost exclusively to Tauy, the east-west component which is the principal alongshore component.

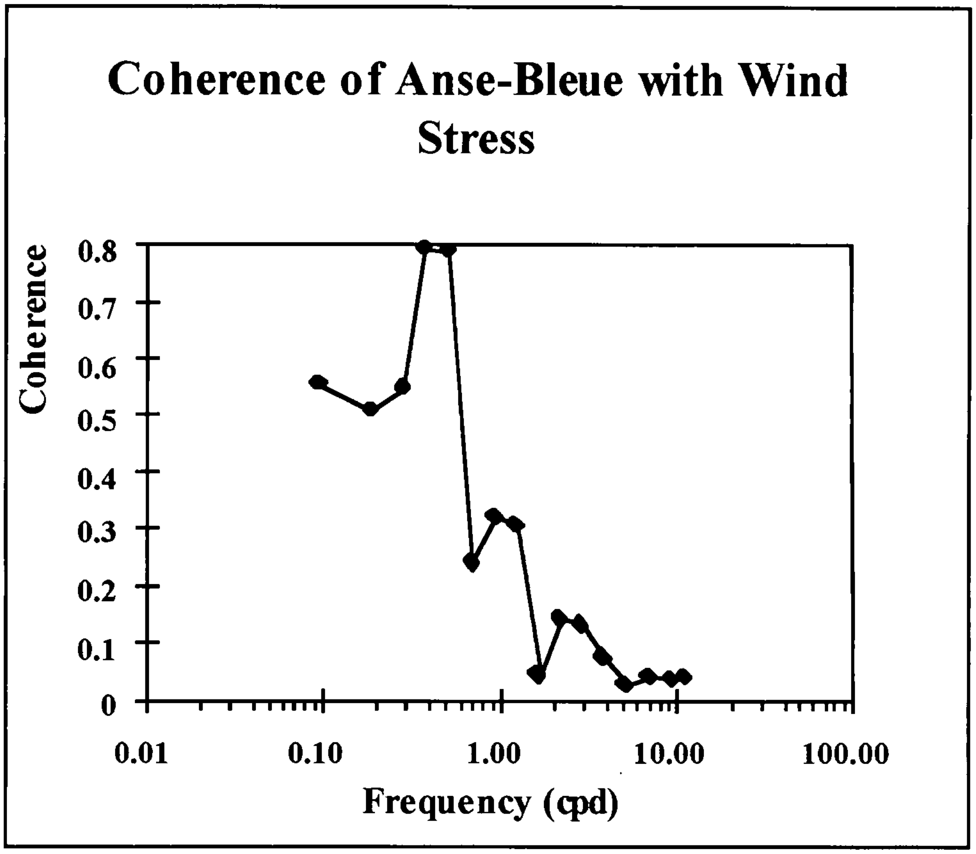

Figure. 11. The coherency spectra of temperatures at Anse-Bleue with the combined wind stress components, Taux and Tauy.