Appendix VI

Further analysis of the potential impacts of nitrogen removal from Bellozanne STW effluent.

To quantify the impact of nitrogen removal from the Bellozanne STW effluent on St. Aubin's Bay, the predictive models proposed by CSTT (1994) (described in Section 5) have been applied to a range of effluent qualities.

The main report considers the impact of nitrogen removal at the Bellozanne plant for an effluent which conforms with the minimum requirements of the Urban Waste Water Treatment Directive (91/271/EEC) (UWWTD): 10mg l^{-1} DAIN and 1 mg l^{-1} DAIP. This Appendix repeats the analysis for DAIN concentrations in the range 1 mg l^{-1} to 15 mg l^{-1} (the impact of DAIP removal is not considered here). The analysis has been completed for February (when zone C DAIN concentrations were high) and June (when zone C DAIN concentrations were low).

Tables VI.1 to VI.3 and Figure VI.1 summarise the results of the analysis.

Table VI.1 summarises the predicted steady-state DAIN concentration (S) in zone B for assuming effluent qualities of between 1 mg l^{-1} and 15 mg l^{-1} DAIN. Table 1 also shows the percentage reduction of S from that predicted using observed DAIN concentrations in the STW effluent during the relevant survey dates. Figure VI.1 illustrates the predicted percentage reduction in S on the two survey dates analysed. Clearly, the percentage reduction in predicted zone B steady-state DAIN concentrations are greater during June when background (i.e. zone C) concentrations are low. However, the absolute reduction in S is greater during February, when, for every 1 mg l^{-1} DAIN reduction in the effluent, zone B DAIN is reduced by 0.05 mmol m^{-3}, as opposed to 0.04 mmol m^{-3} in June. Achieving effluent quality of between 1 mg l^{-1} and 15 mg l^{-1} will result in a reduction of between 40.5% and 18.8%. During February, an effluent with a DAIN concentration of 1 mg l^{-1} will result in a 5.6% reduction in DAIN concentrations in zone B, whilst an effluent with 15 mg l^{-1} DAIN will result in a 1% reduction in zone B.

The predicted range of maximum chlorophyll biomass (X_{max}) in zone B for effluents with DAIN concentrations of between 1 mg l^{-1} and 15 mg l^{-1} are shown in Table VI.2.. Again, both the predicted absolute chlorophyll concentrations and the percentage decrease from that predicted, using observed effluent data, are included in Table VI.2. For STW effluents within the range of 1 mg l^{-1} to 15 mg l^{-1}, the predicted June maximum X_{max} (i.e. the maximum of the predicted range of X_{max}) does not exceed the 10 mg m^{-3} threshold cited by CSTT (1994) as being indicative of eutrophication. It should be noted, however, that during the June survey X_{max} predicted using observed DAIN concentrations in the STW effluent did not exceed this threshold.

Table VI.3 shows the absolute reduction in predicted maximum chlorophyll biomass for effluents of between 1 mg l^{-1} and 15 mg l^{-1} DAIN. The maximum of the range of maximum chlorophyll biomass exceeds the required 1 mg l^{-1} reduction in zone B chlorophyll for all DAIN concentrations in the effluent considered during June, and up to a DAIN concentration of 11 mg l^{-1} during February.

Table VI.1: Predicted steady-state DAIN concentration (S) in zone B (mmol m^{-3}) and percentage decrease from that predicted using observed effluent concentrations following discharge of effluent with specified concentration of DAIN.

	Observed		**DAIN concentration in STW final effluent (mg l^{-1})**														
	Zone B†	S¶	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survey 1 (27/2/97)																	
S (mmol m^{-3})	12.4	15.6	14.7	14.7	14.8	14.8	14.9	14.9	15.0	15.0	15.1	15.1	15.2	15.2	15.3	15.3	15.4
% reduction*			5.6	5.3	4.9	4.6	4.3	3.9	3.6	3.3	3.0	2.6	2.3	2.0	1.6	1.3	1.0
Survey 4 (3/6/97)																	
S (mmol m^{-3})	1.4	2.49	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.8	1.9	1.9	1.9	2.0	2.0
% reduction*			40.5	38.9	37.4	35.8	34.3	32.7	31.2	29.6	28.1	26.6	25.0	23.5	21.9	20.4	18.8

† Zone B geometric mean of observed data during each survey.

¶ Steady-state nutrient concentration predicted using observed DAIN concentration in STW effluent.

* Percentage reduction in steady-state nutrient concentration following treatment of STW effluent to specified DAIN concentration

Table VI.2: **Minimum and maximum values of predicted maximum biomass of phytoplankton (X_{max}) in zone B (mg m^{-3}) and percentage decrease from that predicted using observed effluent concentrations following discharge of effluent with specified concentration of DAIN.**

		Observed	**DAIN concentration in STW final effluent (mg l^{-1})**														
		X_{max}¶	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survey 1 (27/2/97)																	
X_{max} (mg m^{-3})	min	19.3	18.4	18.4	18.5	18.5	18.6	18.7	18.7	18.8	18.8	18.9	18.9	19.0	19.1	19.1	19.2
	max	45.8	43.3	43.5	43.6	43.8	43.9	44.0	44.2	44.3	44.5	44.6	44.8	44.9	45.1	45.2	45.3
% reduction*	min		4.8	4.5	4.2	3.9	3.6	3.3	3.0	2.7	2.5	2.2	1.9	1.6	1.3	1.0	0.7
	max		5.4	5.1	4.8	4.5	4.2	3.8	3.5	3.2	2.9	2.6	2.3	1.9	1.6	1.3	1.0
Survey 4 (3/6/97)																	
X_{max} (mg m^{-3})	min	3.9	2.8	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3	3.4	3.4
	max	8.2	5.3	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.9
% reduction*	min		27.5	26.4	25.4	24.3	23.2	22.1	21.0	19.9	18.9	17.8	16.7	15.6	14.5	13.4	12.3
	max		34.8	33.5	32.2	30.9	29.6	28.2	26.9	25.6	24.3	23.0	21.7	20.4	19.1	17.7	16.4

¶ M maximum chlorophyll biomass predicted using observed DAIN concentration in STW effluent.

* Percentage reduction in m maximum chlorophyll biomass following treatment of STW effluent to specified DAIN concentration

Table VI.3: Predicted range of maximum chlorophyll biomass (X_{max}) removal from zone B following discharge of effluent with specified concentration of DAIN.

		DAIN concentration in STW final effluent (mg l^{-1})														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survey 1 (27/2/97)																
Decrease in X_{max} (mg m^{-3})*	min	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.2	0.2	0.1
	max	2.5	2.3	2.2	2.0	1.9	1.8	1.6	1.5	1.2	1.1	1.0	0.9	0.7	0.6	0.5
Survey 4 (3/6/97)																
Decrease in X_{max} (mg m^{-3})*	min	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5	0.5
	max	2.9	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.3

* Decrease in predicted maximum chlorophyll biomass in zone B from that predicted using observed STW effluent concentrations attained from discharging an effluent with specified DAIN concentration.

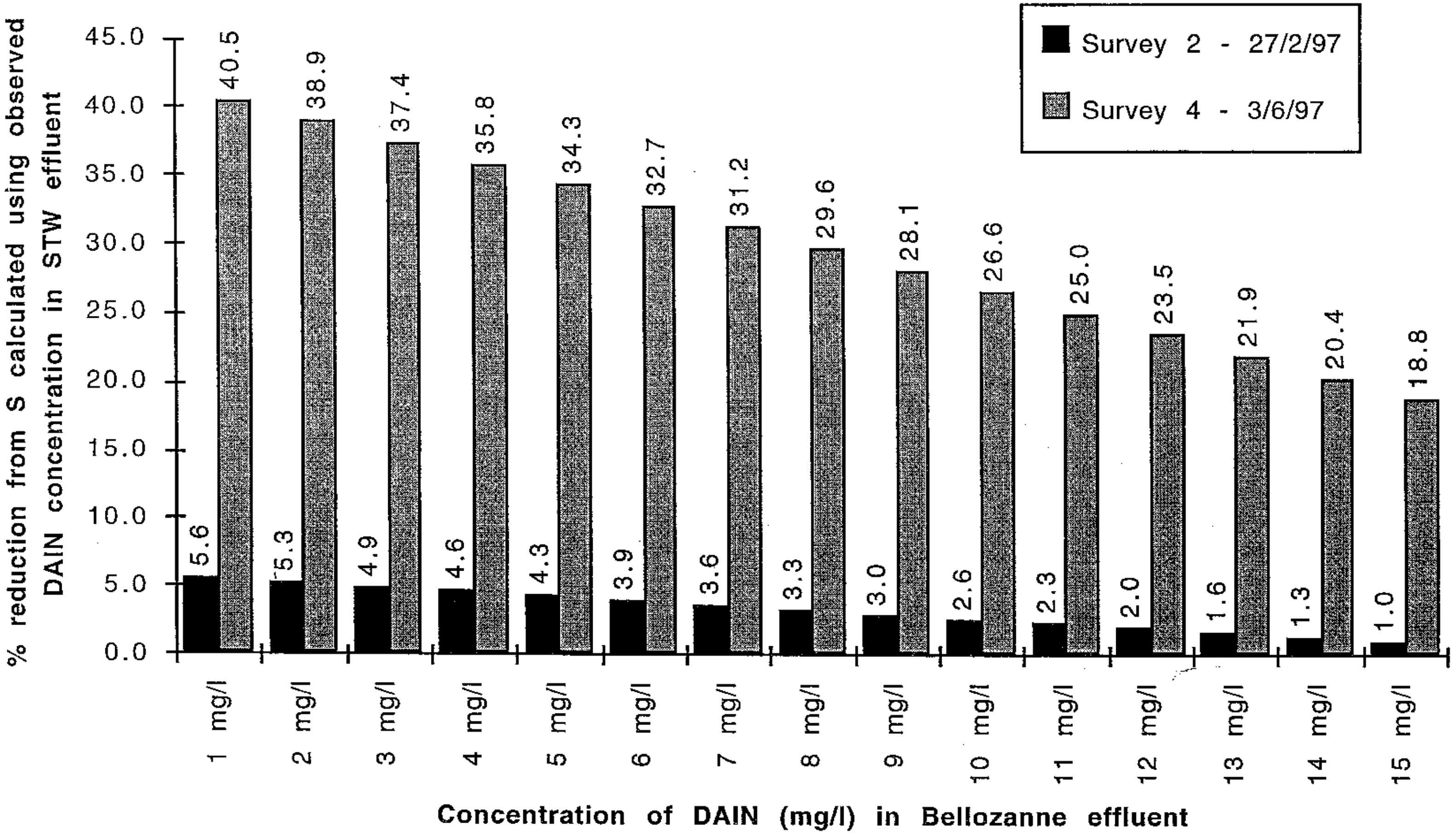

Figure VI.1: Percentage reduction in predicted zone B steady-state DAIN concentration (S) following nitrogen removal at the Bellozanne STW to the specified DAIN concentration.

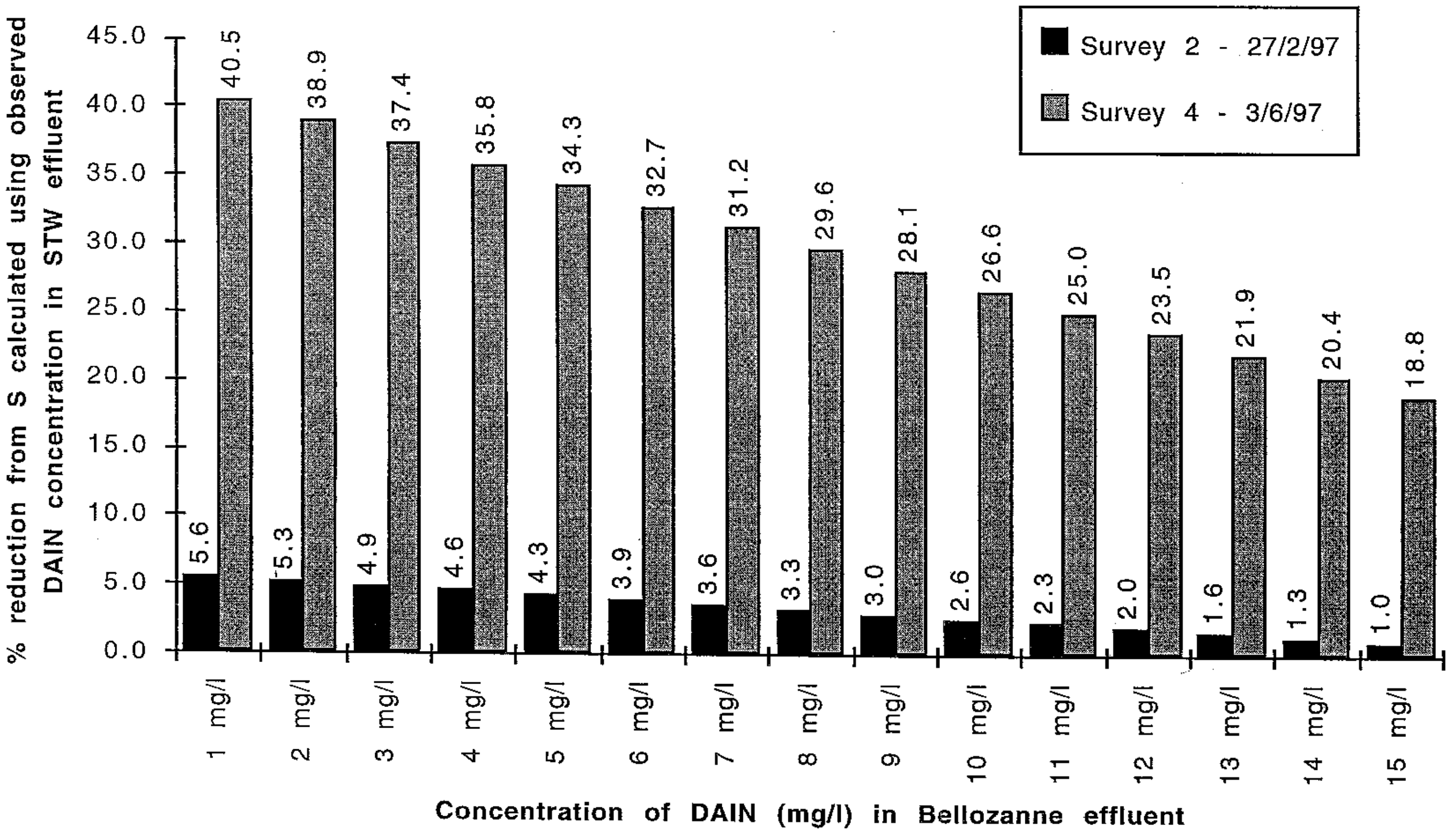

Figure VI.1: Percentage reduction in predicted zone B steady-state DAIN concentration (S) following nitrogen removal at the Bellozanne STW to the specified DAIN concentration.

Appendix V

Analysis of meteorological data.

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This appendix provides an analysis of monthly total sunshine hours and average sea temperatures to allow the meteorological conditions experienced during the survey period to be placed into the context of prevailing meteorological conditions in Jersey. Data for the years 1961 to 1996 and for January to October 1997 has been provided by the States of Jersey Meteorological Department.

To compare the 30 year averages with conditions experienced during the survey period t-tests were carried out between the 1961-1990 (30 year) monthly averages and 1997 monthly data. The results from this analysis are presented in Tables V.1 (monthly sunshine hours) and V.2 (monthly average sea temperature), whilst graphical representations of the data are provided in Figures V.1 (monthly sunshine hours) and V.2 (monthly average sea temperature).

The 1997 monthly total sunshine hours show a significant difference from the 30 year average during all months within the study period, with the exception of March (Table V.1). The months of February, June and August all displayed significantly lower sunshine than the 30 year average, whilst April, May, July, September and October all experienced more sunshine than the 30 year average (Table V.1 and Figure V.1).

Table V.1: T-test results, comparison of sunshine hours data between the 30 year average and 1997 data.

Month	1997	1961-90 average			
	Sunshine hours	Mean (hours)	Std. dev.	t-value	*p*
February	58.10	91.32	20.49	8.88	0.00†
March	141.00	140.66	32.58	-0.06	0.95
April	287.10	192.42	35.84	-14.47	0.00†
May	277.80	240.98	41.87	-4.82	0.00†
June	158.40	249.11	50.16	9.90	0.00†
July	286.50	261.34	41.44	-3.33	0.002†
August	204.60	237.55	35.38	5.10	0.00†
September	251.00	176.72	26.48	-15.36	0.00†
October	155.80	126.08	29.23	-5.57	0.00†

† significant at α=0.05

1997 sea temperatures measured at the end of the oil terminal outer breakwater displayed significant differences to the 30 year monthly averages during the whole study period, with the exception of February and July (Table V.2). Sea temperatures were warmer than the 30 year averages in all cases where there was a significant difference (Figure V.2).

Figure V.3 shows a comparison of Jersey Meteorological Department sea temperature data with the mean sea temperature in zones B and C during each survey. Generally, the sea temperatures recorded during the surveys were similar to either the 1997 monthly averages or the 30 year averages. Sea temperatures during survey 9 (29/10/97) were lower than the monthly averages, whilst during surveys 1, 3 and 6 sea temperatures in zones B and C were warmer. Some differences between the average temperature and those measured during the surveys would be expected due to the surveys representing temperatures for a single day which are compared to monthly mean values. Also, the difference in locations of where the measurements are taken may be a factor in the differences.

Table V.2: T-test results, comparison of sea temperature data between the 30 year average and 1997 data.

Month	1997 Sea Temp (°C)	1961-90 average Mean (°C)	Std. dev.	t-value	*p*
February	7.50	7.54	1.11	0.21	0.83
March	9.40	8.00	1.12	-6.85	0.00†
April	10.60	9.46	0.69	-9.06	0.00†
May	12.50	11.86	0.76	-4.61	0.00†
June	14.70	14.42	0.61	-2.53	0.02†
July	16.40	16.47	0.74	0.49	0.63
August	18.40	17.51	0.70	-6.98	0.00†
September	18.20	17.05	0.77	-8.2	0.00†
October	16.40	15.31	0.56	-10.74	0.00†

† significant at α=0.05

It is unlikely that the intensity and duration of sunlight experienced during February was particularly favourable for phytoplankton growth, especially given the lower than average number of sunlight hours. This is reflected by the high nutrient concentrations during surveys 1 and 2 (late February and early April).

Conditions during April, when over 90 more sunshine hours than the 30 year average were experienced, are likely to favour phytoplankton growth. This is reinforced by the results of the predictive modelling, which indicate suitable conditions during neap tides in March (see Section 5.3). The relatively large difference in the mean zone B sea temperature recorded at the end of April, when compared to the 30 year average (a difference of 3.7°C), may also be related to the increased number of hours sunshine during this month. The warmer than normal sea temperature may also encourage phytoplankton growth. Hence, during April phytoplankton growth was encouraged by the greater tha average sunshine hours and warmer sea temperatures. An increased level of phytoplankton growth during this month (i.e. between surveys 2 and 3) was possibly reflected in the decrease in nutrient concentrations in zones B and C. However, such a drop in nutrient concentrations is expected at this time of year. Therefore, it is difficult to determine whether the above average hours of sunshine, and increased sea temperatures, contributed to an enhanced algal bloom. However, growth of the bloom may have been limited to some extent by the assimilation of nutrients.

June experienced 90 hours less sunshine than the 30 year average, a factor which may have contributed to the cooler than average sea temperature measured during survey 5 (1/7/97). These factors may combine to inhibit algal growth, although there was no evidence to suggest this; chlorophyll *a* concentrations vary little between both the preceding and subsequent surveys. June experienced a total of 158 hours sunshine during 1997, 18 hours more than the average for the month of March. Predictions to determine whether suitable conditions for algal growth exist (see Section 5.3) suggest that suitable conditions occur during neap tides during March. This suggests the reduced hours of sunlight may affect growth to such an extent that it may be similar to that predicted for March. Without *in-situ* measurements throughout the month, however, it is difficult to determine whether this is, in fact, the case.

It should be noted, however, that the 1997 average June sea temperature recorded by the Meteorological Department was warmer than the long-term average, although July showed no variation. Sea temperatures tend to lag air temperatures, and the trend of warmer than average sea temperatures during 1997 may have been interrupted during July by the reduced hours of direct irradiation during June.

The reduced number of sunshine hours during August may also have caused a reduction in phytoplankton growth, although, again, there is no evidence to indicate a reduced chlorophyll *a* concentration during the subsequent survey (survey 7 - 9/9/97). Chlorophyll *a* concentrations in zone B increased slightly between surveys 6 and 7, whilst in the immediate nearshore zone concentrations exceeded the CSTT (1994) threshold of 10 mg chl m^{-3}. Again, it is difficult to ascertain whether an average period of direct sunlight during August 1997 would have further encouraged phytoplankton growth in the immediate nearshore zone.

Despite the significant differences in sunshine hours and average and observed sea temperatures, it is difficult to determine whether the particular conditions experienced affected the data collected for this study. It is, important, however, to note that in terms of sunshine hours and sea temperatures, 1997 appears to be a somewhat anomalous year.

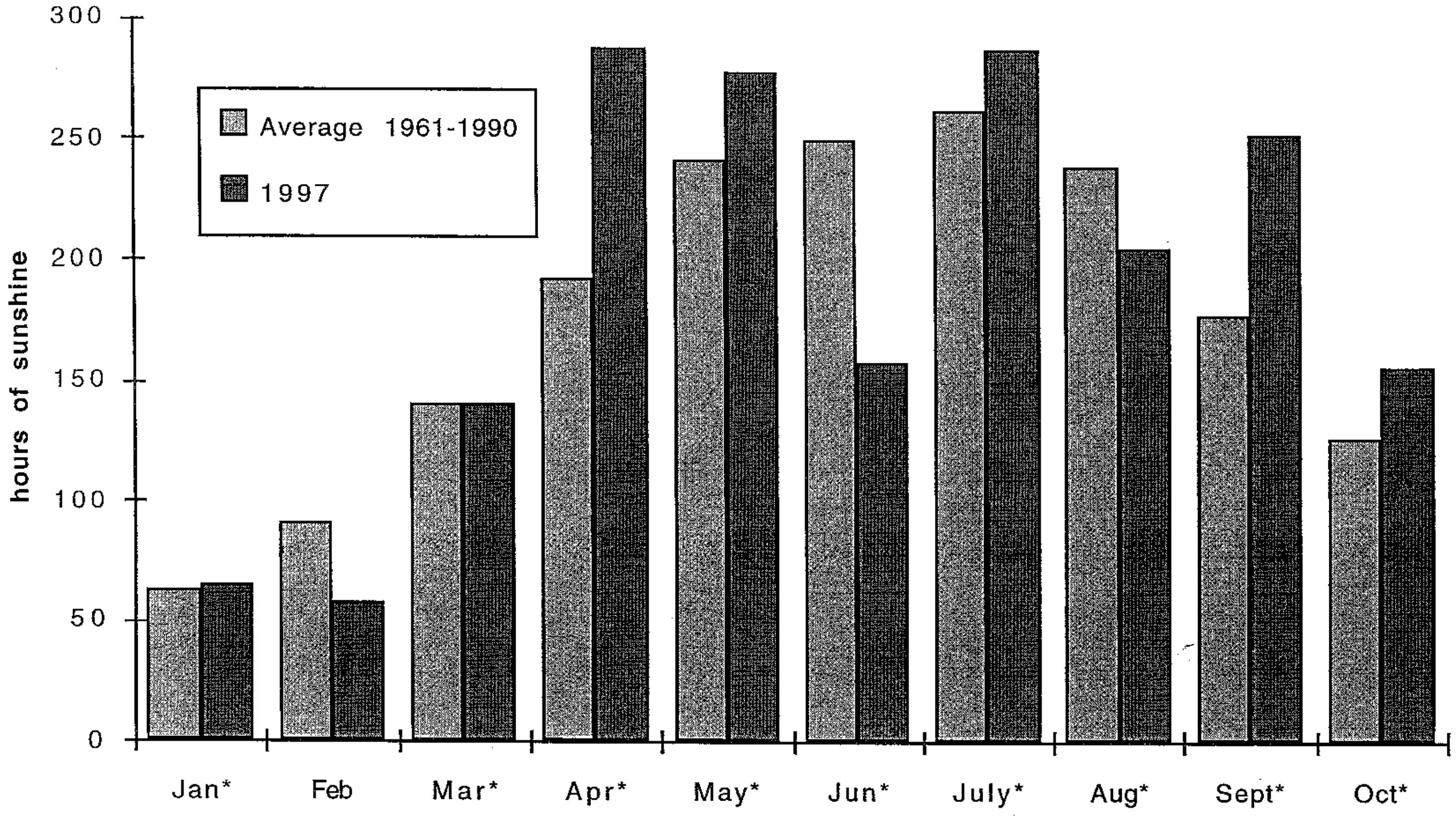

Figure V.1: Sunshine hours recorded at Fort Regent (Data: States of Jersey Meteorological Department).
* denotes months which display a significant difference at $\alpha = 0.05$

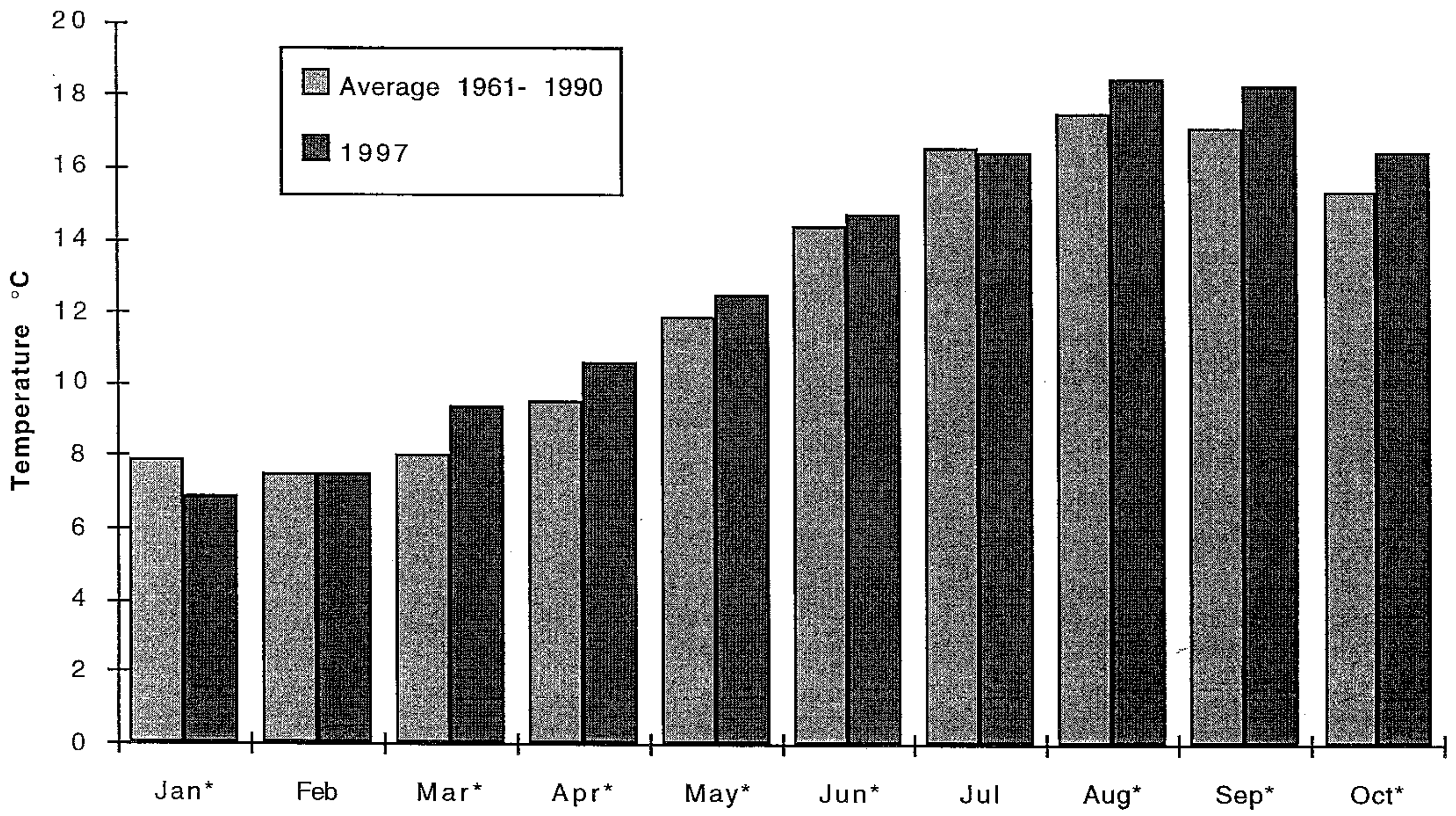

Figure V.2: Sea temperatures recorded at the oil terminal outer breakwater (Data: States of Jersey Meteorological Department). * denotes months which display a significant difference at $\alpha = 0.05$

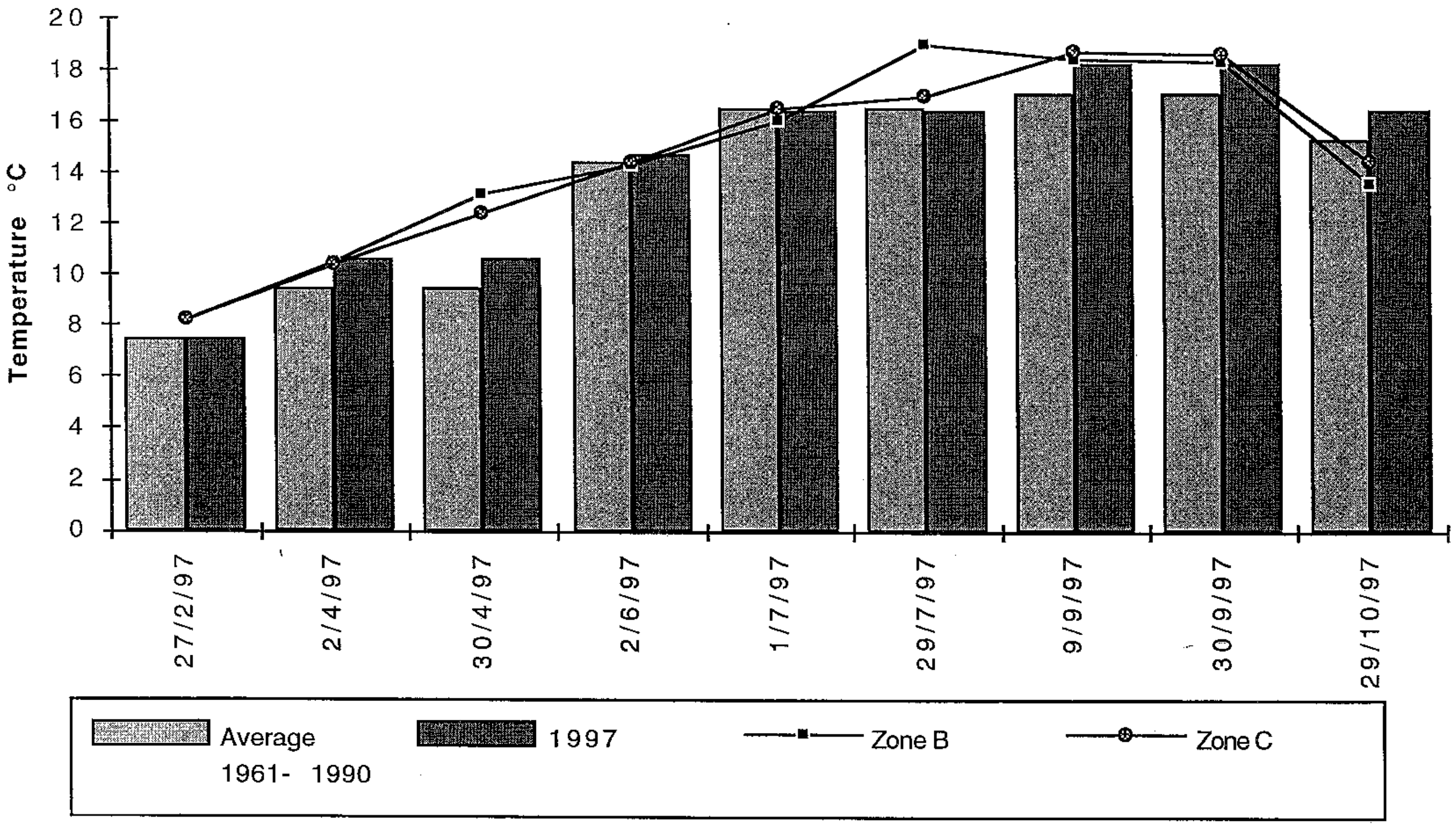

Figure V.3: **Comparison of 1961-1990 average and 1997 sea temperatures with mean zone B and C sea temperatures recorded during the sea surveys.**

Appendix VI

Further analysis of the potential impacts of nitrogen removal from Bellozanne STW effluent.