Shift in Onset of First Inter Monsoon Rain in Coconut Growing Areas in Sri Lanka

K.P. Waidyarathne, T.S.G. Peiris[1] and S. Samita[2]

Coconut Research Institute
Lunuwila, Sri Lanka

ABSTRACT . *Sri Lanka has four rainy seasons namely North East Monsoon (NEM), First Inter Monsoon (FIM), South West Monsoon (SWM) and Second Inter Monsoon (SIM). Studies have shown that the times of rainy spells and rainy periods of each season have changed, but detailed studies have not been conducted. This study was conducted to investigate the change of the onset of FIM rain in coconut growing agro ecological regions (AERs), IL1a, IL3, WL2a, WL2b, WL3, DL3 and DL5 by analyzing weekly rainfall. Daily rainfall data from 1932-2001 were used. During a period of 70 years, FIM rainfall showed significant reduction ($p<0.05$) in IL1a, IL3, WL2a and WL2b. Kendal tau coefficient test showed no systematic pattern of weekly rainfall distribution between years in all AERs. This was further confirmed using ranking procedure applied for weekly rainfall within a year. This analysis found that the time of onset of FIM has been shifted from 11th week (11-17 March) to 13th week (25 March to 1 April) in IL3, WL3 and WL2a. The region IL1 a has been shifted from 11th week to 14th week (1-7 April). In Wl2a onset of FIM has been moved from 9th week (26th February to 3rd March) to 12th week (18-24 March). The above results clearly indicated that the impact of global climate change had different effects on the onset of FIM in different AERS. The statistical methodology developed to detect onset of FIM rain can be applied separately for location so that it would be useful to predict the time of onset of FIM in each location which would be more beneficial to coconut growers.*

INTRODUCTION

Meteorologists have classified the rainfall pattern of Sri Lanka consistent with the seasons defined by Indian Meteorological Department into four seasons namely North East Monsoon (NEM) season from December to February, the First Inter Monsoon (FIM) from March to April, South West Monsoon (SWM) from May to September and the Second Inter Monsoon (SIM) from October to November (Domeros, 1974). Investigating pattern of changes in the climate system is one of the basic necessities of climate research as agriculture is very sensitive to the climate change (Hansen, 2002). The knowledge of the distribution of rainy spells in the temporal domain will be greatly helpful to farmers in particularly for coconut growers in planning and implementation of various agricultural related practices.

Coconut is one of the major plantation crops which is more sensitive to rainfall variability (Abeywardena, 1968; Peiris and Thattil, 1998). Coconut plants can bear up to a

1 Coconut Research Institute, Lunuwila, Sri Lanka.

2 Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

maximum of two to three months drought. Under prolong drought conditions, several disturbances affect the growth of the coconut palm such as water absorption is ceased due to thickening of absorbing region of the roots, growing point of the stem is affected, button nuts and immature nuts fall leading to more than 60% of the reduction of the potential coconut production. Therefore, the predictability of rainfall amount and time has great emphasis to overcome the water shortage of the crop. Unpredictable start of rainy spell has significantly affected various cultural practices in coconut cultivation particularly for fertilizer application (Mahindapala and Pinto, 1991). Fertilizer application of coconut tree should be well planned with time such that soil should be moist when fertilizer application is done. The knowledge of start of rains and withdrawal of rains in each monsoon is extremely useful for coconut growers (Peiris and Mathes, 1997; Peiris *et al.*, 1995; Peiris, 2004) to recommend the most suitable time for various cultural practices. However, studies have not been reported to identify the onset and withdrawal of monsoon rains and inter monsoon rains (Peiris *et al.*, 2000). In this study, the change of weekly rainfall pattern was analyzed separately for coconut growing agro ecological regions in order to understand the behavior of the onset of first inter monsoon rains.

MATERIALS AND METHODS

Database

Daily rainfall data (1932-2001) from seven Agro Ecological Regions (AERs) in the main coconut growing areas were acquired from the climate database from Biometry division, Coconut Research Institute. The seven AERs were IL1a, IL3, WL2a, WL2b, WL3, DL3 and DL5 (NRMC, 2003). The importance of the study of pattern of rainy spells to coconut cultivation in the above seven AERs has been pointed out by Peiris (2004).

Weekly totals

A year was divided in to 52 weeks, ignoring leap years and taking weighted means for the 52nd week.

Let $w_{ij}^{(k)}$ be the rainfall of the jth day (j=1, 2…7) of ith week (i=1, 2…52) of the kth year (k=1932, 1933…. 2001). The total rainfall of the ith week and kth year $w_{i.}^{(k)}$ is given by the following equation.

$$w_{i.}^{(k)} = \begin{cases} \sum_{j=1}^{7} w_{ij}^{(k)} & i=1,2...51 \\ 7/8 \sum_{j=i}^{8} w_{ij}^{(k)} & i=52 \end{cases}$$

Total rainfall in FIM

The total rainfall from March 1st to April 30th was taken as total rainfall of FIM for each year in each AER. The weeks corresponding to FIM is shown in Table 1. Thus, rainfall total of kth year of FIM season is given by;

$$\sum_{i=9}^{18} w_{i.}^{k}$$

Table 1. Week numbers and the corresponding period of weeks for FIM.

Week number	Starting date of the week
9	26 February
10	4 March
11	11 March
12	18 March
13	25 March
14	1 April
15	8 April
16	15 April
17	22 April
18	29 April

Trend analysis

Linear trend analysis (y = a + bt) was carried out to find long term trend of annual rainfall of FIM. Randomness of the de trended series (errors) was checked using Durbin-Watson Statistic.

Change of weekly rainfall pattern

Use of Kendal tau statistics

Kendal tau statistic, T (Gibbons and Chakraborti, 1992) was used to test whether the pattern of weekly rainfall has changed over the years. The test statistic of Kendal tau coefficient (T) is given by, T = 2(C-Q)/n (n-1), where; C = number of concordant pairs and Q = number of discordant pairs and n = total number of points. A comparison was done between adjacent years considering the covariance of two years. Covariance reflects the direction and amount of association between two samples. If the covariance is large and positive, there is a high probability that large (small) values of the first sample are associated with large (small) values of the second sample.

Alternative approach

In addition to Kendal tau statistic, a new statistic was developed by ranking the weekly rainfall amounts within a year, separately for each AER to find the change of pattern. The rank assigned to a given week within a year was analyzed using frequency distribution plots. Let the rank assigned for a given week j (j=1, 2…52), within a year i be r^i_j (j=1, 2…52). Then Pr ($l \le r^i_j \le m$) for arbitrary integers l and m (m = l+5 or m = l+7) was computed separately for each week. A critical value of 0.75 for P ($l \le r^i_j \le m$) was decided subjectively a given week followed a considerably pattern. If the pattern of rainfall is consistent throughout the years, rank assigned to a given week should be concentrated around a fix value.

Anomalies of FIM rainfall

In order to examine the variability of FIM rainfall pattern, the time series plots of the rainfall anomaly was obtained for the period of 1932-2001. Rainfall anomaly is the difference between rainfall of a particular year and the mean rainfall of the period 1961-1990 (IPCC, 2001).

Ninety five percent confidence interval (CI) of the reference mean ($mean \pm t_{0.05} \times SE$) was used to identify the deviations of the seasonal rainfall total. If the rainfall is within the 95% CI, it indicates the stability of rainfall over time. If significant amount of anomalies lies above the upper confidence limit that period is taken as a high rainfall period and if it lies below the lower confidence limit that is taken as low rainfall period. This was used to identify different scenarios during the period of 1932-2001.

Rainy week

The average water requirement of adult coconut palm is 50 liters per day (Mahindapala and Pinto, 1991). Considering that the radius of the root system is approximately 2.1 m and the depth is 1 m, the height of requirement of water was calculated as 5 mm, excluding a circle of 0.30 m radius for the area of root ball. Thus, it can be assumed that 35 mm rainfall per week is sufficient for the coconut palm. Thus a 'rainy week' with respect to coconut cultivation is defined as a week in which rainfall exceeds more than 35 mm.

Onset of FIM

Defining onset of rain is subjective. Different authors have used various criteria (Peiris *et al.*, 2002). In this study the onset of FIM was defined as the first rainy week during the period of 26th February to 05th May (Table 1).

Shift of onset of FIM rain

Third order polynomials ($y = a + bx + cx^2 + dx^3$) were fitted to FIM rainfall for each disjoint scenario identified using rainfall anomaly. This was repeated for each AER. Based on the fitted model, time of onset of rain was computed using 'rainy week' criteria.

RESULTS AND DISCUSSION

Long-term trend of FIM rains

The estimated slope of the linear trend lines for each region is shown in Table 2.

Table 2. Rate of increasing of annual FIM rainfall (b) and its' statistical significance by AER.

AER	b	Significance level (p)
IL1a	-1.59	0.017
IL3	-1.80	0.005
WL2a	-2.11	0.035
WL3	-0.99	0.297
WL2b	-1.85	0.015
DL3	0.34	0.664
DL5	-0.91	0.264

Results indicate the statistically significant ($p<0.05$) decrease of FIM rainfall over the years in IL1a, IL3, WL2a, and WL2b. Decreasing trend in rainfall could be due to reduction of number of rainfall events, rainfall intensity or the length of rainfall events. No significant decline was found in WL3, DL3 and DL5.

Change of rainfall pattern

Results of the significance of statistic are shown in Appendix 1. Analysis found that most of the coefficients were not significant (Appendix 1) indicating that the pattern of weekly rainfall was not consistent throughout the period for all AERs. The inconsistency was highest in DL5 and the lowest in DL3. Further, clear differences among AERs can also be seen in Appendix 1. Similarities could be seen in changing pattern of rainfall between IL1a and IL3. These results confirmed that the weekly rainfall pattern has changed significantly among years in a given AER.

Results of the alternative approach

The results of the ranking analysis found that the allocation of ranks for a given week is not consistent for the entire period. This was true for all AERs. It indicates that it is not possible to specify that a particular week always gives highest rainfall, irrespective of AERs. Further, probability of a given week i (i=1, 2… 52) getting the same rank was always less than 50% to all AERs.

Identification of different periods

The plots of FIM rainfall along with the 95% CI for the reference mean of FIM rainfall (that is, mean rainfall during March to April from 1961-1990) for IL1a is shown in Figure 1.

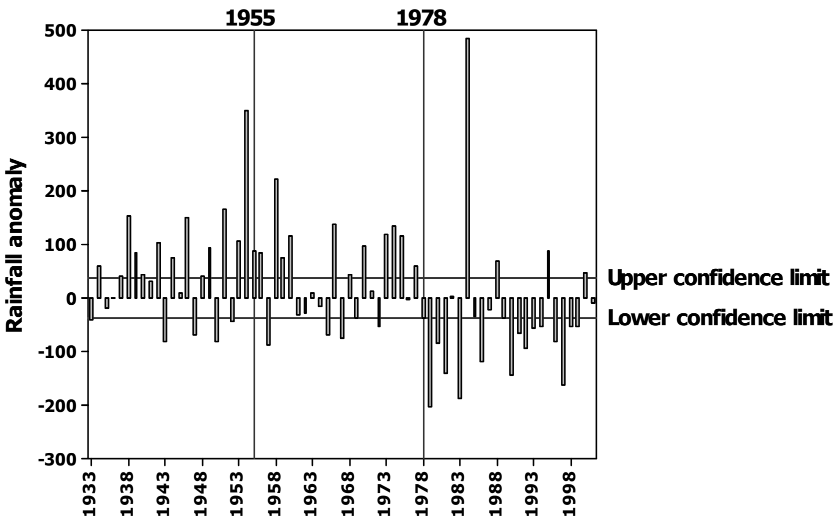
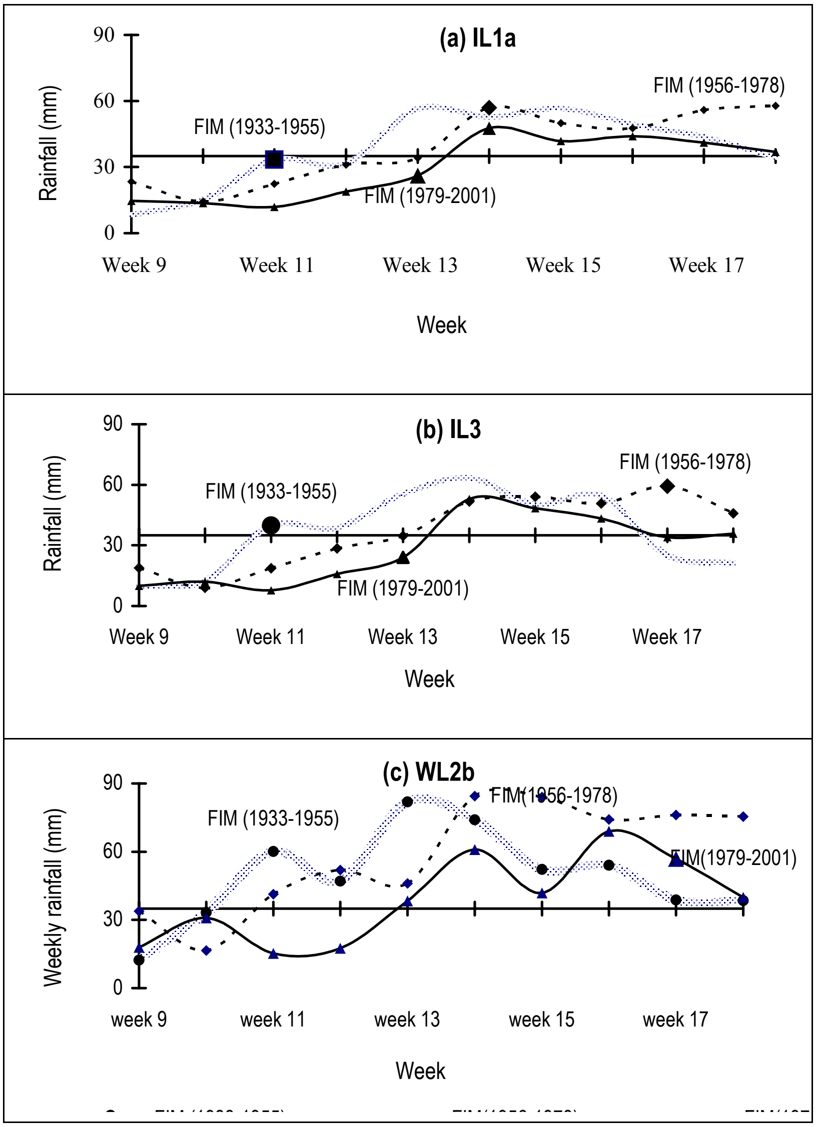


Fig. 1. Distribution of rainfall anomaly for IL1a.

Figure 1 clearly indicates that FIM rainfall in almost all years after 1978 are below lower the limit of 95% CI for the reference mean. The period from 1933 to 2001 can be separated into two different groups; 1933-1977 and 1978-2001 for IL1a. This was further confirmed by comparing means of FIM rainfall prior to 1978 and after 1978. The ‘t’ test showed significance at $p < 0.05$.

However, only for IL1a the FIM rainfall prior to 1955 was above 95% for the reference mean (Fig. 1). This indicates that the entire 69 year period (1933-2001) can easily be divided into three disjoint scenarios, namely, 1933-1955, 1956-1978 and 1979-2001 based on FIM rainfall in IL1a. This grouping was used to identify the time of onset of rainfall for all the regions. Weekly rainfall plots for above three periods are shown in Figure 2.



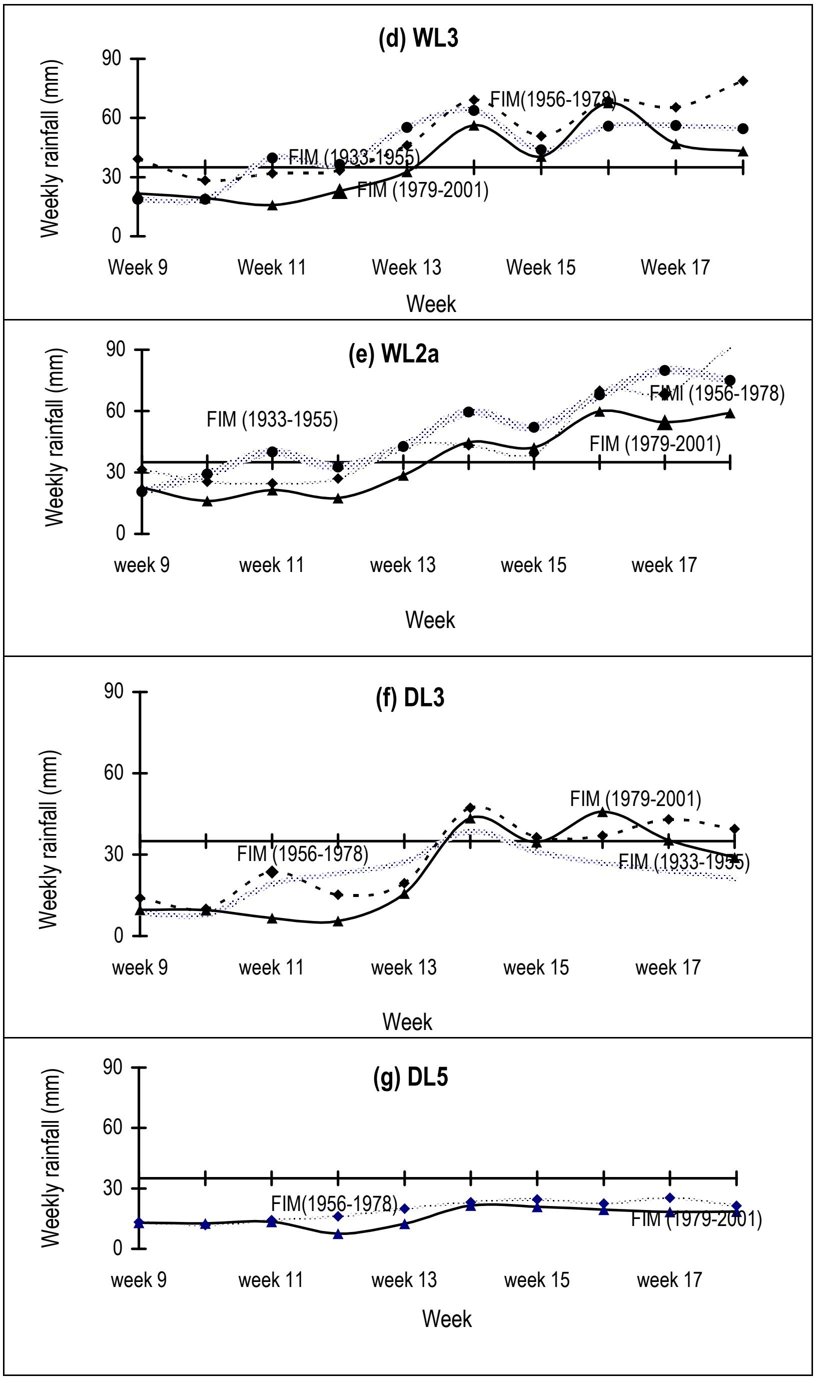


Fig. 2. **Weekly rainfall during FIM for three periods (1933-1955, 1956-1978, and 1979-2001) for different Agro Ecological Regions. (a) IL1a, (b) IL3, (c) WL2b, (d) WL3, (e) WL2a, (f) DL3, (g) DL5 .**

Figures 2a, b, c, d, and e clearly show a shift in the onset of rainfall season over the period towards April during the period from 1979-2001. For the period of 1933-1955, the onset of period can be seen during the 11th week (Table 3). Only for DL3 and DL5 a clear onset of rain with respect to the above criteria, cannot be seen (Figs. 2f and g). This was further confirmed in a study conducted in DL5 region (Kularathne *et al.*, 2004).

In order to identify the exact week of onset, 3rd order polynomials were fitted to each period separately. Different order of polynomials were fitted and it was found that the 3rd order polynomials gave the best fit models to data. The results of these polynomials are shown in Table 3. The validity of the model was confirmed by significance of R^2 ($p<0.05$) and significance of three parameters ($p<0.05$). All the fitted models explained more than 80% of variability.

Using the models the week of which rainfall exceed 35 mm was computed for all three periods and for all AER (except DL5). The point at which rainfall reaches 35 mm was taken as the time of onset of FIM. The corresponding results are shown in Table 3.

Table 3. Coefficients of fitted polynomials of rainfall, their significance and computed onset of FIM.

AER	Period	Coefficients			R^2	Probability for significance	Starting week of FIM
		linear	quadratic	cubic			
IL1a	1	- 16.41*	3.16*	- 0.12	0.93	0.0009	11
	2	- 80.97*	6.74	- 0.17	0.88	0.0037	13
	3	-143.99*	11.71	- 0.30*	0.91	0.0014	14
IL3	1	- 6.73	2.96*	-0.13	0.87	0.0043	11
	2	-155.30*	12.76*	-0.33	0.95	0.0003	12
	3	-102.53*	7.88	-0.19	0.83	0.0095	13
WL2b	1	-203.41*	16.25	-0.41*	0.82	0.0117	9
	2	-165.82*	13.68	-0.36*	0.83	0.0102	10
	3	181.32	-11.34*	0.23	0.80	0.0152	12
WL3	1	-147.44*	12.54	0.33	0.85	0.0076	11
	2	-223.41*	17.89	-0.45	0.76	0.0278	11
	3	35.29*	-1.47*	0.0154*	0.81	0.0131	13
WL2a	1	- 17.76*	1.75	-0.041	0.92	0.0009	11
	2	-28.26*	1.52*	-0.011	0.93	0.0008	13
	3	-137.83*	10.58	-0.254*	0.95	0.0003	13
DL3	1	-11.05	1.89*	-0.068	0.87	0.0050	-
	2	-78.96*	6.51	-0.166	0.77	0.0251	13
	3	-210.00*	16.64	-0.419*	0.87	0.0050	13

Note: * - statistically significant at 0.05 probability.

FIM of the first period begins at the 11th week in IL1a, Il3, WL2a and WL3. WL2b shows comparatively early start of FIM but shift is significant. IL3, WL2a, WL2b, Wl3 and DL3 show the start of FIM at 13th week during third period. That indicates clearly the shift of FIM towards April from March.

The rainfall curve for the first period in DL3 lies under the reference level but the start of the spell of second and the third periods is around mid 13th week. Shift of DL5 is not discussed as it received very low amount of rainfall which is below the critical level. According to above findings it is clear that the start of FIM shows a considerable shift throughout the total period from 1932 to 2001. Therefore, special consideration should be given to study the fluctuation of start of FIM season as well as the distribution of peaks, spells and length of the seasons.

CONCLUSIONS

FIM rainfall in the AERs of IL1a, IL3, WL2a and WL2b has significantly reduced over the years. No significant decreasing trend in FIM rainfall was found in WL3, DL3 and DL5. There is no consistency in the pattern of weekly rainfall over the years in all seven AERs. Onset of FIM rainfall is highly unpredictable in DL5. The onset of FIM has shifted towards end of March and early April in the regions of IL1a, IL3, WL2a, WL2b, WL3 and DL3. The methodology suggested to prove the shift of onset of rains by fitting 3rd order polynomials, can be extend to yearly data separately so that more details on year to year change can be obtained. Further, the statistics approach developed in this paper can easily be extended to study the onset and withdrawal of other seasons as well.

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APPENDICES

Appendix 1. Results of Kendal tau coefficient test for individual years.

Year group	DL3	DL5	IL3	IL1a	WL2b	WL3	WL2a
32-33	*	-	*	*	*	*	*
33-34	ns	-	Ns	ns	ns	*	*
34-35	*	-	*	*	ns	*	*
35-36	ns	-	*	*	ns	*	*
36-37	*	-	Ns	ns	ns	*	ns
37-38	ns	-	Ns	ns	ns	ns	ns
38-39	ns	-	Ns	ns	ns	ns	ns
39-40	*	-	*	*	*	*	*
40-41	*	-	*	*	*	*	*
41-42	ns	-	Ns	ns	ns	ns	ns
42-43	ns	-	Ns	ns	ns	ns	ns
43-44	*	-	*	*	*	*	*
44-45	*	-	*	*	*	ns	*
45-46	*	-	*	*	*	*	ns
46-47	ns	-	Ns	ns	ns	ns	ns
47-48	*	-	*	ns	ns	ns	ns
48-49	ns	-	Ns	ns	ns	ns	ns
49-50	ns	-	*	*	ns	ns	ns
50-51	*	-	*	ns	ns	ns	ns
51-52	*	-	*	*	ns	ns	*
52-53	ns	*	Ns	ns	ns	ns	ns
53-54	*	ns	*	ns	ns	ns	ns
54-55	*	*	Ns	ns	ns	ns	ns
55-56	ns	ns	Ns	ns	ns	ns	ns
56-57	*	ns	*	*	ns	*	ns
57-58	*	ns	*	*	*	ns	ns
58-59	*	ns	Ns	*	*	ns	ns
59-60	*	ns	*	*	*	*	*
60-61	*	ns	Ns	ns	ns	*	ns
61-62	ns	ns	Ns	ns	ns	ns	ns
62-63	*	ns	*	ns	ns	ns	ns
63-64	*	ns	Ns	ns	ns	ns	*
64-65	*	ns	*	ns	ns	ns	ns
65-66	*	ns	*	*	*	*	ns
66-67	*	ns	*	*	ns	ns	ns
67-68	*	ns	*	*	*	ns	*
68-69	*	ns	*	ns	ns	ns	ns
69-70	*	ns	Ns	ns	ns	ns	ns
70-71	ns	ns	Ns	ns	ns	ns	ns
71-72	*	ns	*	*	*	*	ns
72-73	*	ns	*	*	*	*	*
73-74	ns	ns	Ns	ns	ns	ns	ns

Appendix 1 conti…

Year group	DL3	DL5	IL3	IL1a	WL2b	WL3	WL2a
74-75	ns	ns	*	*	ns	ns	*
75-76	ns	ns	Ns	*	*	ns	ns
76-77	*	ns	*	*	*	*	*
77-78	*	*	*	*	*	*	*
78-79	*	*	*	*	ns	*	ns
79-80	*	*	*	*	ns	ns	*
80-81	*	*	*	*	*	*	ns
81-82	*	ns	*	*	ns	*	ns
82-83	*	ns	Ns	*	*	*	ns
83-84	ns	ns	Ns	ns	ns	ns	ns
84-85	*	ns	*	ns	ns	ns	ns
85-86	ns	ns	Ns	ns	ns	ns	ns
86-87	*	ns	Ns	*	ns	*	*
87-88	ns	ns	*	ns	ns	*	ns
88-89	ns	ns	*	ns	*	*	*
89-90	*	ns	*	*	ns	*	*
90-91	*	ns	*	*	*	*	ns
91-92	*	ns	*	*	*	*	*
92-93	*	ns	*	*	*	*	*
93-94	ns	*	Ns	*	*	ns	ns
94-95	ns	ns	Ns	ns	ns	ns	ns
95-96	ns	ns	Ns	ns	ns	ns	ns
96-97	*	ns	Ns	ns	ns	*	ns
97-98	*	ns	*	*	*	ns	*
98-99	ns	*	Ns	ns	ns	ns	ns
99-00	*	ns	Ns	ns	ns	ns	ns
00-01	*	*	Ns	ns	ns	ns	ns

Note: *: significant at 0.05 probability, ns: non significant, -: data not available.