factors: radioactive decay during downward mixing and upward mixing of ^{32}P-poor waters through the thermocline.

The $^{33}P/^{32}P$ activity ratios in the DIP (Table 1) are higher than at production, 0.99, considering both the atmospheric flux and *in situ* production. The ~1.3 times increased ratio in the mixed layer corresponds to a mean residence time of 20 days for DIP in the mixed layer, not inconsistent with the observed deficiency in the ^{32}P inventory.

The results for zooplankton show large variations for the September collections (Table 2). During night collections, the

Table 2 ^{32}P activities in zooplankton examples collected at SCBS 205

Sample code	Collection Date	Time	Observed activity* (c.p.m.)	^{32}P d.p.m. g P^{-1}
ZN1.SC1	21 July 1987	22-03	0.11	8.0 ± 1.6
ZN2.SC1	21 July 1987	22-03	0.11	8.9 ± 1.6
MXN.SC2	27 Sept. 1987	03-06	0.37	45.1 ± 5.0
ZON.SC2	27 Sept. 1987	03-06	0.58	39.1 ± 4.0
MD1.SC2	27 Sept. 1987	07-09	0.07	11.0 ± 2.0
MD2.SC2	27 Sept. 1987	07-09	0.31	100 ± 10

ZN1.SC1 and ZN2.SC1 samples are primarily euphausiids and calanoid copepods; the remaining samples were mostly calanoid copepods. Samples with codes starting with Z are primarily zooplankton; others are mixed with some phytoplankton.

* Net observed activity at first counting.

catch was higher as a result of zooplankton migrating up from depths. (One purpose of the investigations was to see if ^{32}P and ^{33}P activities differred significantly in the day and night catches.) The night samples collected during 21 July have a very low ^{32}P, <10 d.p.m. ^{32}P per g P. These values translate to a value of 0.08 d.p.m. ^{32}P per m^3 sea water, taking the measured DIP concentrations for the mixed layer. This conversion is useful as it allows comparison of ^{32}P activity with that found in surface waters where primary production occurs and with regions of different phosphorus concentrations. The highest value observed (MD2.SC2; Table 2) yields a value of 0.96 d.p.m. per m^3 sea water. Four zooplankton samples, one from the Celtic Sea and three from the Bedford basin, gave values of 0.3, 0.35, 0.30 and 1.00 d.p.m. per m^3 sea water respectively. These values are of the same order as those found in our collections on 27 September. The observed variability would probably also be expected. The much lower activity for the collection of 21 July probably reflects the dominating contributions from euphausiids that feed on deeper 'older' food.

Samples of phytoplankton from the Bedford basin[10] show ^{32}P specific activities ~3 times higher than zooplankton collected on the same day. The results are in accord with a relatively short turnover time of phosphorus in the phytoplankton (<2 weeks) and a highly variable and much larger turnover time for the zooplankton samples (>30-40 days).

Two samples of DOP were collected using the activated charcoal method[17]. The charcoal was eluted with 1:1 HCl before use. The results for 3 m and 12 m depth are ≥0.01 and ≥0.26 d.p.m. $^{32}P\ m^{-3}$ sea water; these values are lower limits because of uncertainties in the intrinsic phosphorus content of the activated charcoal. (We can rule out the possibility of any appreciable contamination from POP on the basis of the total amount of POP trapped in the particulate filter used. The filter was very efficient, the particulates being confined to within 5 mm of the outer layer of the filter cartridge.) The significant ^{32}P concentration of the 12 m DOP sample indicates a fairly rapid exchange in the upper ocean, apparently a result of the activity of the microbial food web[18].

We thank H. Craig, LeRoy Dorman, J. D. Macdougall, M. M. Mullin and G. Shor for their encouragement, S. P. Wallace of Monsanto Fibres and Intermediates Co. for acrilan fibres, F. Azam, R. W. Eppley, G. A. Jackson, R. A. Jahnke, B. L. K. Somayajulu for advice. We also thank R. Adams, H. Bissell III, G. Hargreaves and B. Ip for help with experiments. Critical ideas for improving the efficiency of pumping water through the acrilan fibre columns were contributed by O. Rodriguez.

Research was supported by ONR, and in part by the SIO Department. T. Lee acknowledges the support of Korean government scholarship.

Received 16 February; accepted 10 May 1988.

1. Karl, D. M. & Bossard, P. *Appl. envir. Microbiol.* **50,** 706-709 (1985).
2. Harrison, W. G. in *Nitrogen in the Marine Environment* (eds Carpenter, E. & Capone, D.) 763-807 (Academic, New York, 1983).
3. Dugdale, R. C. & Goering, J. J. *Limnol. Oceanogr.* **12,** 196-206 (1967).
4. Eppley, R. W. & Peterson, B. J. *Nature* **282,** 677-680 (1979).
5. Eppley, R. W., Renger, E. H. & Harrison, W. G. *Limnol. Oceanogr.* **24,** 483-494 (1979).
6. Altabet, M. A. & Deuser, W. G. *Nature* **315,** 218-219 (1985).
7. Vezina, A. & Platt, T. *Can. J. Fish. aquatic Sci.* **44,** 198-205, 1987.
8. Platt, T. & Harrison, W. G. *Nature* **318,** 55-58 (1985).
9. Lal, D. & Peters, B. in *Encyclopedia of Physics* (ed. Flugge, S.) Vol. 46/2, 551-612 (Springer, Berlin, 1967).
10. Lal, D., Chung, Y., Platt, T. & Lee, T. *Limnol. Oceanogr.*, submitted.
11. Lal, D., Rama, & Zutshi, P. K. Jr *Geophys. Res.* **65,** 669-674 (1960).
12. Somayajulu, B. L. K., Rengarajan, R., Lal, D., Weiss, F. & Craig, H. *Earth planet. Sci. Lett.* **85,** 329-342 (1987).
13. Strickland, J. D. H. & Parsons, T. R. *Bull. Fish. Res. Bd. Can.* **167,** 310 pp. (1972).
14. Cembella, A. D. *et al. CRC Crit. Rev. Microbiol.* **10,** 317-391 (1984).
15. Lynn, R. J., Bliss, K. A. & Eber, L. E. *CALCOFI Atlas No. 30* (Scripps Inst. of Oceanography, La Jolla, 1982).
16. Eppley, R. W. *Plankton Dynamics of the Southern California Bight*, cf Ch. 2 (Springer, Berlin, 1986).
17. Azam, F. & Hodson, R. E. *Nature* **267,** 696-698 (1977).
18. Azam, F. in *Plankton Dynamics of the Southern California Bight* (ed. Eppley, R. W.) Ch. 7, 274-288 (Springer, Berlin, 1986).

Interannual variability in climate and fisheries in Tasmania

G. P. Harris*, P. Davies†, M. Nunez‡ & G. Meyers§

* Division of Fisheries, CSIRO Marine Laboratories, GPO Box 1538, Hobart, Tasmania 7001, Australia
† Inland Fisheries Commission, Hobart, Tasmania, Australia
‡ Department of Geography, The University of Tasmania, Tasmania, Australia
§ Division of Oceanography, CSIRO Marine Laboratories, Hobart, Tasmania, Australia

Whereas the interannual variability of the climate and fisheries of the Northern Hemisphere has been extensively documented[1], very little is known about the interannual variability in the fisheries of the Southern Pacific Region. Recent work in the Northern Hemisphere has demonstrated the close relations between interannual variability in climate, the timing of events in the water column, the structure of food chains and recruitment to both marine and freshwater fisheries[2,3]. Forty years (1945–85) of observations at a coastal station (Maria Island, 42°36′ S, 148°16′ E) in Tasmania showed strong interannual variability in sea-surface temperatures. Maria Island is close to the region of convergence of the surface currents, on the equatorial side of the Subtropical Convergence (STC) water mass boundary[4]. The spring bloom was often extended by as much as three months in some years. Previous work[4] has not offered any explanation for the observed interannual variability and does not show any links with commercial fisheries. Here we explain the reason for the interannual climatic and oceanic variability in Tasmania and show the links between climate and the fisheries.

The westerly wind belt of the Southern Hemisphere has a dominant influence on the climate of Tasmania. The position of the main westerly wind belt over Tasmania is determined by the position of the continental high-pressure area over Australia and hence by El Niño-Southern Oscillation (ENSO) events[5]. There was a clear cyclical pattern in these zonal westerly winds (ZWW) with a mean periodicity of 11 yr (Fig. 1, Table 2). Interannual changes in ZWW were correlated with annual mean atmospheric pressures at Hobart and Macquarie Island (Table 1). Throughout the 40-yr record, the annual mean atmospheric pressure in Hobart was low the year before peaks in pressure at Darwin[6]; the year before ENSO events. Decreases in annual mean pressure at Hobart and Macquarie Island were associated with increases in ZWW over Tasmania, increases in rainfall from the zonal westerlies, increases in the level of Great Lake (in the Central Highlands of Tasmania) and reductions in the annual maximum summer air temperatures near the lake at Shannon (Table 1, Fig. 2). The zonal westerlies bring gales and cold, wet weather to Tasmania. The maximum summer air temperature at Shannon has, however, risen by 2 °C during the period 1945-85 without a long-term decrease in westerlies (Figs 1 and 2).

Changes in the level of Great Lake (elevation 1,030 m) were significantly correlated with ZWW and rainfall at Shannon over the period 1945-1985 (Table 1, Fig. 2). The lake-level data indicated that the cyclical pattern of fluctuation in the incidence of ZWW has been consistent since at least 1916 when records began. Changes in rainfall and lake level controlled variations in both the numbers and mean weight of trout caught in the lake. The census data obtained from returns of anglers' questionnaires showed a negative correlation between total angling effort (and therefore total harvest of trout) and ZWW at Great Lake ($n = 13$, $r = -0.71$). Angling effort was lower during cold, windy, wet weather (high ZWW), which resulted in changes in angling mortality from year to year. Mean weight of trout in the anglers' catch was negatively correlated with the minimum lake level of the same year. When lake levels decreased, larger fish resident on the deep water *Chara* beds were more frequently caught from shore and by shallow trolling (P.D. and R. Sloane, in preparation).

The numbers of fish of first spawning age (3 yr) at Liawenee Canal, Great Lake, were significantly correlated with mean maximum air temperture at Shannon over the period 1945-85 (Table 1). A high correlation was found between the lake temperatures and maximum air temperature at Shannon ($r = 0.76$, $n = 61$). The gradual rise in temperature at Shannon, and hence the rise in lake temperatures over the period 1945-85, led to a rise in the proportion of 3-yr-old trout in the spawning populations. This indicate that the interannual variability of ZWW, the ambient temperature and the age structure of the trout in spawning migrations at Great Lake were directly related (Fig. 2). The relation was particularly strong for female brown trout.

Strong westerly winds also drive colder, nutrient-rich subantarctic waters up the east coast of Tasmania in summer[4]. Increased westerly winds disrupt the pycnocline throughout the summer months, replenishing the nitrate in surface waters by

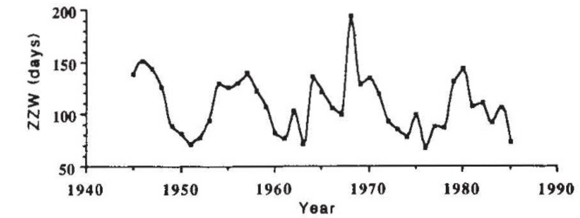

Fig. 1 The interannual variability in the total number of days of zonal westerly winds over Tasmania. Westerly wind data for Tasmania was obtained by classification of the 09:00 surface synoptic pressure chart for the southern Australian region. Daily charts from 1945 to 1985 were classified into eight types: (1) anticyclone over the Bight; (2) anticyclone over the Tasman Sea; (3) anticyclone over Tasmania; (4) zonal westerlies; (5) cyclone to the north of Tasmania; (6) cyclone to the east of Tasmania; (7) cyclone to the west of Tasmania; (8) cyclone over Tasmania. The classification assumed that each weather system dominated the entire Island for the day. Thus it was possible to derive a time series of yearly totals of each weather type. In classifying a weather type as being 'zonal westerlies' the following critieria were used. (1) The presence of a marked N-S pressure gradient, with isobars mostly aligned E-W. Cases with an orientation of NW-SE and SW-NE were also included. (2) The presence of more than one cold front embedded in the westerly stream. Cold fronts follow one another in rapid succession in the westerly stream. Cold fronts follow one another in rapid succession in the westerly streams over Tasmania. (3) Total duration of the weather system of more than one day. Typical duration is a few days.

Table 1 Statistically significant correlations between climatological, limnological, oceanographic and fisheries data assuming no time lags

	DAR	HOB	MAC	ZWW	MAX	RAI	GLL	DEL	TRO	SPR	MAR	TAS	NSW	NZ	TUN	SEA
DAR	—	0.41‡	−0.69							0.40		0.32‡				
HOB		—		−0.65†	0.73†			−0.33				0.72†	−0.57†			
MAC			—	−0.67			0.47			−0.40	0.43	−0.36‡			−0.47	−0.33
ZWW				—	−0.28	0.30		0.43		0.50		−0.35†	0.62†	0.30		
MAX					—				0.53*			0.66†				
RAI						—		0.46								
GLL							—	0.31	0.40	−0.50	0.31					
DEL								—								
TRO									—		0.40	0.59*				
SPR										—	−0.70†					
MAR											—			0.41	−0.43†	0.37
TAS												—	−0.32†			
NSW													—			
NZ														—		
TUN															—	
SEA																—

* Data showing long-term trend.
† Data analysed from 1950 to 1980.
‡ Two lowest MAC years deleted as outliers from trends DAR, HOB, MAC.
Statistical analyses were performed by GENSTAT and SYSTAT. Series were rendered stationary by differencing. Methods as in refs 20 and 21. DAR, HOB, MAC, atmospheric pressure at Darwin, Hobart and Macquarie Island. ZWW, annual total of zonal westerly winds over Tasmania. MAX, maximum temperature at Shannon. RAI, annual rainfall at Shannon. GLL, Great Lake level. DEL, change in Great Lake level. TRO, percentage of 3-yr-old female brown trout. SPR, timing of spring bloom on Maria Island. MAR, maximum summer sea-surface temperature at Maria Island. TAS, NSW, NZ, total lobster catch (weight), Tasmania, New South Wales, New Zealand (Otago). TUN, New South Wales tuna catch (weight). SEA, abundance of leopard seals Macquarie Island.

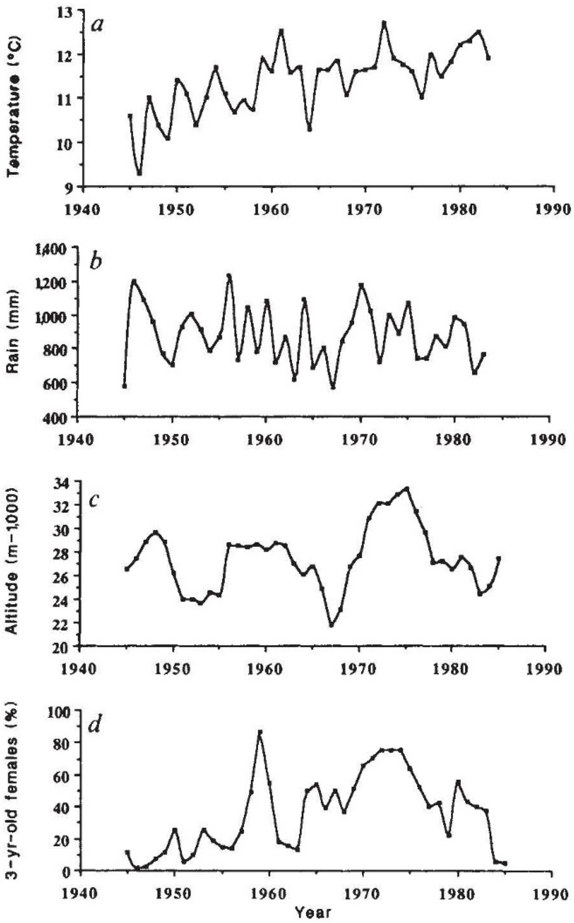

Fig. 2 Climatological and limnological data for the Tasmanian Central Highlands, 1945–85. Time series of *a*, mean maximum annual air temperatures at Shannon weather station; *b*, annual rainfall at Shannon; *c*, mean annual level of Great Lake as altitude above sea level (data from records of the Bureau of Meteorology, Hobart and the Hydro-Electric Commission, Hobart); *d*, percentage of 3-yr-old female brown trout in the spawning migrations at Liawenee Canal, Great Lake. All fish were trapped in a fixed diversion trap and aged by scale reading[19].

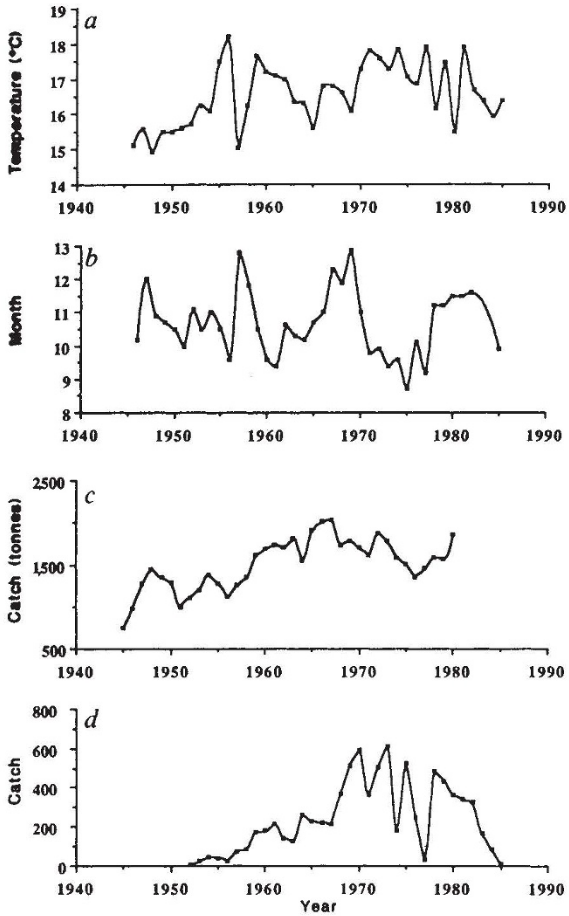

Fig. 3 Time series of oceanographic and fisheries data from Tasmania and New South Wales. *a*, Maximum summer sea surface temperatures at Maria Island, Tasmania; *b*, timing of the spring bloom at Maria Island as determined by methods in ref. 4 (8, August; 12, December; 13, January); *c*, total Tasmanian spiny lobster catch (tonnes); *d*, New South Wales southern bluefin tuna catch (total numbers). Oceanographic data was obtained from CSIRO records and was collected by methods detailed in ref. 4. Fisheries data were obtained from records kept by Australian Commonwealth agencies and State Department of Fisheries.

vertical mixing. The annual totals of zonal westerly winds were correlated with the timing and duration of the spring bloom in Tasmanian coastal waters at Maria Island and with reductions in maximum summer water temperatures (Fig. 3, Table 1). The seasonal cycle of phytoplankton was therefore controlled in precisely the way described by Sverdrup[7], with frequent windy periods leading to frequent restarting of the spring bloom and sustained productivity throughout the summer.

The local wind field determines the position of the convergence in the surface currents on the northern edge of the water mass boundary between Australia and New Zealand as Wyrtki suggested[8]. In ENSO years the surface convergence appears to move north so that the southern Tasman Sea is cooler by 3 °C across 3° of latitude[9]. Crosscorrelations between climatological and oceanographic parameters and fisheries catches in Tasmania, New South Wales and New Zealand (Tables 1 and 2) revealed a widespread effect that was correlated with changes in the Darwin–Macquarie Island pressure gradient and the incidence of ZWW over Tasmania. Both the Tasmanian and New Zealand populations of spiny (rock) lobsters are caught on the southern side of the surface convergence and show positive correlations with increased temperatures at Maria Island (Tables 1 and 2). The Tasmanian and New Zealand (Otago) populations of the lobsters (*Jasus novaehollandiae* and *J. edwardsii*) are now thought to be conspecific[10] and are caught at ~7 and 3 years old, respectively. The significant crosscorrelations between the catches of lobsters on both sides of the Tasman Sea and the biologically realistic time lags indicate a widespread effect of climate and ocean circulation and the possibility of long-range larval transport. A different species of *Jasus* (*J. verreauxi*) is caught on the northern side of the STC in New South Wales and on the northern tip of the North Island of New Zealand[13] and shows a correlation of opposite sign to those species on the southern side of the STC convergence. *J. verreauxi* also occurs on the tip of the north island of New Zealand; also north of the STC[11].

Two effects are evident in the fisheries data: an immediate effect of effort and a lagged effect of recruitment. Fishing effort increased in periods of high atmospheric pressure and calm seas. This explains the high correlations (Table 1) between the Tasmanian spiny lobster (*Jasus novaehollandiae*) catch and air temperatures and pressures in Tasmania in the same year. The significant time lags of 3–7 yr (Table 2) between oceanographic events and the lobster catch data are consistent with the known life histories of the organisms and the mean ages of animals caught.

As the West Wind Drift is driven by the zonal westerlies, it is not surprising to find a correlation between ZWW and the recruitment of stocks of lobsters over a wide area. Circumpolar larval transport in the '*lalandii*' group of *Jasus* species is a possibility[12]. The phyllosomata larvae spend ≤2 yr at sea, so circumpolar transport in the West Wind Drift is possibily via the tips of the continents and seamounts on the northern edge of the Southern Ocean. It has been suggested that recruitment of *J. tristani* at Vema Seamount results from transport from Tristan da Cunha[13]. Pearce and Phillips[14] showed that ENSO events and the recruitment of the western rock lobster in Western Australia were correlated.

Other stocks in Tasmanian waters also show large interannual variability. Harrison's[15] data on scallop catches in Tasmania from the 1940s to the 1960s indicate the possibility of similar climatological control by ZWW. For scallops, years of high incidence of ZWW appear to favour good recruitment perhaps by a link between high productivity in high ZWW years, and increase in spawning and high larval survivorship. Data on the New South Wales catch of southern bluefin tuna (*Thunnus maccoyii*) from 1950 to 1984 indicates that sea-surface temperature affects the distribution of the fish (Fig. 3, Table 1)[16]. Southern bluefin tuna migrate across the southern coast of Australia as far north as the 20 °C isotherm. In years of low pressure at Macquarie Island (increased ZWW) and low sea surface temperature at Maria Island bring more fish into the area of the fishery. Leopard seals (*Hydrurga leptonyx*) are residents of the Antarctic pack ice but juveniles disperse northwards in winter as far as subtropical waters[17]. The abundance of leopard seals recorded at Macquarie Island[17] from 1949 to 1979 is also a function of atmospheric pressure on the island (Table 1) as well as sea surface temperatures at Maria Island in Tasmania. This also indicates an interaction between ENSO, ZWW, the strength of the West Wind Drift in the Southern Ocean and the migration of some species of marine mammals in the subantarctic.

The air and sea surface temperature data both show consistent rises in temperature in Tasmania during the period 1945–85 (Figs 2 and 3). This was noted a decade ago in southeast Australia and the same effect has been noted in Auckland, New Zealand[16,18]. It appears that southeastern Australia is located so as to be very sensitive to changes in the atmospheric and oceanic circulation associated with ENSO events[6]. Increased pressure at Darwin was correlated with late spring blooms in Tasmania which therefore tended to be more pronounced in ENSO years (Figs 1 and 3). These changes, together with longer-term changes in the air and sea temperatures in the southern Tasman Sea area, have had, and are likely to continue to have, significant effects on the fisheries in this area.

Table 2 Statistically significant crosscorrelations between climatological, oceanographic and fisheries data

	r	lag (yr)	n
Autocorrelations			
Number of days ZWW	0.40	11	29
Crosscorrelations			
Hobart atmospheric pressure against Darwin atmospheric pressure	−0.46	1	40
Annual rainfall at Shannon against Great Lake level	0.37	1	40
Maximum temperature (°C) Maria Island against:			
total weight, Tasmanian Lobsters	0.37	7	30
total weight, New Zealand lobsters	0.38	3	30
total weight NSW lobsters	−0.35	5	30
Total weight, Tasmanian lobsters against			
total weight, New Zealand lobsters	0.49	4	30

Time series-methods are as described in refs 20 and 21. Series were rendered stationary by differencing.

Received 18 December 1987; accepted 25 April 1988.

1. Cushing, D. H. *Climate and Fisheries* (Academic Press, London, 1982).
2. George, D. G. & Harris, G. P. *Nature* **316**, 536–539 (1985).
3. Harris, G. P. *Phytoplankton ecology* (Chapman and Hall, London, 1986).
4. Harris, G. P., Nilsson, C., Clementson, L. A. & Thomas, D. P. *Aust. J. mar. Freshwat. Res.* **38**, 569–590 (1987).
5. Williams, M. BMRC Res. Rep. 6. (Bureau Met. Res. Centre, Melbourne, 1987).
6. van Loon, H. & Shea, D. J. *Mon. Weath. Rev.* **113**, 2063–2074 (1985).
7. Sverdrup, H. U. *J. Cons. perm. int. Explos. Mer.* **18**, 287–295 (1953).
8. Wyrtki, K. CSIRO Div. Fish. Oceanogr. Tech. paper **8**, Hobart (1960).
9. Edwards, R. J. CSIRO Div. Fish. Oceanogr. Rep. 88, Cronulla (1979).
10. Smith, P. J., McKoy, J. L. & Machin, P. J. *N.Z. J. mar. Freshwat. Res.* **14**, 55–63 (1980).
11. Booth, J. D. *Can. J. Fish. Aq. Sci.* **43**, 2212–2220 (1986).
12. Phillips, B. F. & McWilliam, P. S. *Can. J. Fish. aq. Sci.* **43**, 2153–2163 (1986).
13. Lutjeharms, J. R. E. & Heydorn, A. E. F. *Deep Sea Res.* **28**, 631–636 (81).
14. Pearce, A. F. & Phillips, B. F. *J. Cons. perm. int. Explor. Mer.* **45(1)** (in the press).
15. Harrison, A. J. *Aust. Fish. News lett.* 9–13, June 1965.
16. Rochford, D. J. CSIRO Div. Fish. Oceanogr. Rep. 114, Hobart, (1981).
17. Rounsevell, D. & Eberhard, I. *Aust. J. Wildl. Res.* **7**, 403–415 (1980).
18. Paul, L. J. *Proc. Pelagic. Fish. Conf. N.Z. MAFF Fish. Res. Div. Occ. Publ.* **15**, 70–74 (1978).
19. Davies, P. E. & Sloane, R. D. *J. Fish. Biol.* **31**, 353–373 (1987).
20. Box, G. E. P. & Jenkins, G. M. *Time Series Analysis* (Holden-Day, San Francisco, 1976).
21. Harris, G. P. & Trimbee, A. M. *J. Plank. Res.* **8**, 1011–1025 (1986).

Mid-Holocene rainfall in the Negev Desert from ^{13}C of land snail shell organic matter

Glenn A. Goodfriend

Isotope Department, Weizmann Institute of Science, 76100 Rehovot, Israel

Analysis of the $^{13}C/^{12}C$ ratio of organic matter in fossil bones has been used in a number of studies for reconstruction of palaeodiets, especially the presence or absence of plants having a C_4 photosynthetic pathway (enriched in ^{13}C relative to C_3 plants)[1,2]. This isotope method has also been used to detect organic matter derived from C_4 plants in materials such as sediments[3–5] and desert rock varnishes[6]. In the present study, the $^{13}C/^{12}C$ ratio of the organic matrix of fossil land snail shells from the Northern Negev Desert in southern Israel was used to map out the distribution of C_4 shrubs in the past. Because in this region C_4 shrubs are generally restricted to the arid zone (≤ 280 mm mean annual rainfall), shifts in rainfall patterns could be inferred from the changes in plant distributions. Analysis of land snail shells dated to the period ~2,800–4,000 yr BP showed that during this time the northern limit of C_4 shrubs was shifted 20–30 km south of its present position, implying substantially wetter conditions in the Northern Negev than occur there at present.

The Northern Negev is a region of strong rainfall gradients, representing the transition zone from the hyperarid Saharan-Arabian desert belt in the south to the more humid Mediterranean climate of the north (Fig. 1). Within this desert boundary region (100–400 mm mean annual rainfall), a survey was carried out to document the distribution of C_4 shrubs and forbs (herbs that are not grasses). Results (Table 1) indicate that in areas receiving ≥290 mm mean annual rainfall, nearly all (94%) of the plant communities consist entirely of C_3 plants. In areas receiving ≤230 mm, most (90%) of the plant communities contain C_4 species (nearly all are shrubs in the Chenopodiaceae), whereas within the narrow transition zone of 240–280 mm, a mixture of pure C_3 and mixed C_3+C_4 plant communities occurs. The few pure C_3 communities that occur at ≤230 mm are generally dominated by *Zygophyllum dumosum* Boiss. or *Artemesia herba-alba* Asso, and are found in the more southerly area (100–125 mm) on hill slopes where the soil cover is thin[7]. This relation of the distribution of C_4 Chenopodiaceae to moisture conditions has also been documented on a worldwide scale[8].