STATISTICAL RELATIONSHIPS BETWEEN PELAGIC FISH CATCHES AND LONG-TERM SERIES OF ENVIRONMENTAL CONDITIONS IN THE SOUTHERN BENGUELA REGION

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by

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TO JILL AND MY PARENTS

THE IMPORTANT THING IS NOT TO STOP QUESTIONING,
CURIOSITY HAS ITS OWN REASON FOR EXISTING.

A. EINSTEIN

Table of contents

ABSTRACT

Three different techniques are used to established statistical relationships between annual pelagic fish species catches *viz.* pilchard, horse mackerel and chub mackerel, and monthly environmental indices. The three techniques are Spearman's Rank correlation, multiple regression and cross-correlations of the Box-Jenkins time series approach. The first method yielded interesting results but only in terms of the nature of the relationship not in terms of the response effect. In the same way the multiple regression analysis showed inherent problems in the interpretation of the results due to serial correlation in all fish catches and environmental data series. The Time-Series analysis yielded more coherent results, presumably due to the fact that the data series were pre-whitened to remove serial correlation.

Monthly means of sea surface temperature, north-south wind component, west-east wind component and sea level were used as environmental indices.

Over the period 1950 to 1985, annual pilchard catches are found to be negatively correlated to sea surface temperature in the Namaqualand and Agulhas Bank areas, but are positively related to sea surface temperature in the south western Cape area. With regard to wind components, northerly and westerly winds in the Namaqualand and south western Cape areas are found to be significantly correlated to annual pilchard catch, whereas in the Agulhas Bank southeasterly and southwesterly wind are found to be predominant.

Warmer waters improved horse mackerel catches in all areas, immediately in the Agulhas Bank area but affecting catch the following year in the other two areas. In the Namaqualand area predominantly northwesterly winds are found to favour horse mackerel catch immediately and this response is probably due to availability. The same wind orientation is found in the south western Cape area

but with one-year-lag. In the Agulhas Bank area the favourable wind orientation is southerly with a zero lag and westerly with one-year-lag.

Cooler waters influence chub mackerel catches favourably in all areas and in all seasons. In the Namaqualand area the effect of the sea surface temperature is immediate in all but the winter season. Northwesterly winds are most important in this area having an immediate effect from winter to summer. Cooler temperatures in the south western Cape area the previous year improve the annual chub mackerel catch. Northerly and easterly winds favour catch immediately during summer while northwesterly winds are most important during spring. In the south coast area, southwesterly winds improve catches immediately during spring and summer but south-westerly winds during autumn are related to improved catches the following year.

These results are not easy to interpret because of problems in the quality of the catch data. These problems may be identified as constraints due to the effect of the different age-classes to the catch and the variability in the effort exerted by the fishery onto the resource. Furthermore, age-length distributions have changed recently for all three species, so that it is difficult to establish relationships which link up to specific effects of the environment on specific age-classes. It is assumed, however, that a zero-lag in the relationships between fish catches and environmental variables represents availability rather than environmental effects on spawning, recruitment or stock abundance.

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CHAPTER 1

GENERAL INTRODUCTION

1 GENERAL INTRODUCTION

1.1 Environment and fisheries

Fisheries oceanography deals with the environment of fish resources and their response to this environment (Seatersdal 1978, Lasker 1978a). The term environment should be taken to include physical and chemical properties of the sea. From the above definition, fisheries oceanography includes the study of oceanic processes affecting the abundance and availability of commercial fish stocks (Tont and Delistraty 1980). The working hypothesis of the fisheries oceanographer is that fluctuations in the apparent abundance of fish stocks are primarily due to changes in the environment (Elizarov 1983, Shannon *et al.* 1985). These changes must be described and understood before the role of man (fisherman) can be properly evaluated (Wooster 1961).

Opinions differ as to the relative importance of anthropogenic impacts on pelagic fish stocks, as opposed to natural environmental factors (Seatersdal 1978, Summers *et al.* 1985, Kerr and Ryder 1988). The fact that large fluctuations occur in the abundance of commercial pelagic fishes cannot be denied, and although the reason for these fluctuations is not known, it is likely that the environment plays an important role (Buys 1959, Bernal 1981, Stetsjuk 1983). Fish populations in nature repeatedly increase and decrease in size (Southward *et al.* 1975) under some unknown and complex natural environmental conditions. Most stock collapses are explained by a series of failing recruitments, but this serves only as an explanation of the mechanism behind a stock collapse, and not as a reason for the collapse.

Based on the record of sediments of biological origin, Soutar and Isaacs (1969, 1974) and Shackleton (1987) have shown that natural fluctuations in pelagic fish stocks appear to be the rule rather than the exception. Apart from anthropogenic causes (overfishing, water pollution etc...) fluctuations of fish populations may be due to variation of reproductive potential (Prosch *et al.* 1988) or survival in relation to variations in environmental conditions.

To investigate the importance of environmental factors for the abundance and availability of a fish stock, long-term data series are needed, which describe and characterise trends in commercial harvesting, along with environmental factors. Ideally, it would be preferable to have data which describe abundance of an unexploited stock, as well as the environmental conditions during that period. The elucidation of connections between biological variability and physical forcing at the climate time scale (longer than the seasonal period) requires that we have access to climate and biological data series extending over many years (Gillooly and Walker 1984). This condition, especially with regard to the biological variables, has been difficult to comply with, and only recently have data series of sufficient length become available. The compilation of coherent environmental variables has been made even more difficult by the relatively weak and transitory nature of the physical structure of the pelagic environment (Mackas and Boyd 1979).

In spite of considerable research, growth and maintenance of valuable resource populations cannot be assured, but at best can be assumed to depend more on the pattern of suitable climate and oceanic/ecological conditions than on other processes. Fish populations are neither self-determining, nor "equilibrium seeking" entities, but rather populations operating in response to short-term consequences of a series of climate-driven, oceanographic and ecological processes (Doubleday 1976). Pelagic fishes such as anchovy *Engraulis japonicus capensis* and pilchard *Sardinops ocellatus*, the dominant species in South Africa's purse-seine fishery (Crawford 1979), have several requirements with regard to their habitat in order to build up large populations. These requirements include high plankton productivity and standing stocks for feeding purposes (such as those found on shallow continental shelves and in upwelling regions), warm (16°-19°C, King *et al.* 1977), stable waters for sustaining serial spawning, and a transport of larvae to suitable feeding grounds (Hutchings and Nelson 1985).

The environmental conditions that affect fishes in the South-east Atlantic Ocean are largely influenced by the existence and intensity of upwelling zones (Strogalev 1983), and the fisheries in the area are directly dependent upon the production processes occurring in such zones. From a fisheries standpoint, the role of upwelling in the cycle of organic production in the sea is important. During upwelling, cold nutrient-rich water is transported from depth into the illuminated surface layers, where nutrients are available for primary production (Cushing 1975). The importance of upwelling regions is evidenced by Ryther's (1969) suggestion that coastal upwelling areas, comprising about one-tenth of the ocean surface, may produce one-half of the world's harvestable fish supply. There is little doubt, then, that some indication of the magnitude and frequency of fluctuations in the upwelling regime is extremely important for understanding fluctuations in marine fish populations (Baird 1975, Bakun 1985).

Areas of upwelling are notably variable, but the southern Benguela region is, perhaps, more variable than most (Shannon 1985). Not only does it experience the normal cycles of upwelling and downwelling, but it is unusual in being positioned at the tip of a continent. Consequently, periodic incursions of warm water take place from the Agulhas Current, a totally different, and much warmer, water-mass on the east coast of southern Africa (Shannon 1985, Branch *et al.* 1987). Upwelling has beneficial and detrimental effects on marine fish populations, for example nutrient enrichment versus excessive mixing, and marine animals are probably adapted to some mean or optimal conditions but can tolerate a range of variability (Hutchings *et al.* 1987). Fisheries biology in the southern Benguela region has been directed mainly towards determining the level of the Total Allowable Catch (TAC), using a number of mathematical models (e.g. Sette 1961, Bergh 1983, Butterworth 1983). Some modelling has assumed that the environmental capacity is constant or random and that the observed or computed changes in recruitment and mortality, and hence annual yield, are functions of population size (or density) alone. However, environmental randomness can have important effects on the dynamics of animal populations (De Villiers 1985).

The influence of large-scale, low frequency climatic variability on fish populations has been considered by a number of authors (Bernal 1981, Shelton *et al.* 1985). Kawasaki (1983) described " The Kawasaki sardine cycle", in which he hypothesized that cycles in Japanese sardine population abundances lag at least 3-4 years behind any effect on year-class survival, because it takes that period for these fish to recruit to the fishery. Marr (1960) found a positive correlation between year class strength of California sardine *Sardinops carulea* and cumulative temperatures; if low temperatures delayed spawning, recruitment was adversely affected. The year classes of the North sea haddock were correlated with southerly winds (Carruthers 1938) and westerly winds (Rae 1957). Herman & Hansen (1965, cited by Cushing 1975) established a positive correlation between recruitment to the West Greenland cod stock and temperatures between 0^{o} and 4 ^{o}C. Cyclic fluctuations of approximately five years have been reported by Mysak *et al.* (1982, cited by Huato-Soberanis and Lluch-Belda 1987) for mean sea level (MSL), sea surface temperature (SST) and salinity and were related to catches of herring and salmon in the northeast Pacific Ocean. Mysak (1986) proposed a mechanism which explained the connection of such a cycle to El Niño-Southern Oscillation (ENSO) events through the propagation of Kelvin and Rossby waves across the Pacific Ocean and along the west coast of North America.

Off tropical West Africa, the seasonal upwelling between Cape Three-Points and Cape Palmas is associated with a sardine fishery which fails in years in which the upwelling does not occur. During such years the fish do not follow their usual migration routes and physical changes in the environment may lead to reproductive failure (Longhurst 1984). In the case of the Moroccan sardine fishery, Belveze and Erzini (1983) suggested an empirical relationship between rainfall and catches of sardines, reduced rainfall favouring larger catches. Also, they established relationships between the abundance of sardines and winds and upwelling indices.

In the southern Benguela region, some attempts have been made to relate fluctuations in fish stocks to environmental conditions (Boyd 1979, Crawford *et. al.* in press). According to Buys (1959) the catches of pilchard *Sardinops ocellatus* and horse mackerel *Trachurus trachurus* increased as temperature increased during the period 1950 to 1957 (pilchard $r=0.95$, horse mackerel $r=0.92$). Du Plessis (1959) found a significant relationship between sea surface temperature of the previous year and pilchard availability for the period 1943 to 1958. More recently, Shannon *et al.* (1988) analysed perturbations in the Benguela environment and their effects on demersal and pelagic fish year-class strength. They suggested that the pilchard and anchovy stocks appeared to have been favoured by warmer conditions in the southern Benguela region, whereas the opposite would apply to hakes.

Fluctuations in fisheries for some important pelagic species appear to occur on a world-wide scale (Crawford 1987), which may correspond with global climatic change. The four major eastern boundary current systems - California, Peru, Canary and Benguela - are characterised by equatorward surface flow, persistent coastal upwelling of cold, nutrient-rich waters, high biological productivity, and similar marine populations (Parrish *et al.* 1983, McLain *et al.* 1985). An inverse relationship has been observed between sardine and anchovy stock size in the four systems (Skud 1982). These observations suggest some law of balance or of alternate dominance in the seas (Uda 1961). Reasons for the alternation of massive populations of planktivorous fish in eastern boundary current regions remains one of the major gaps in marine ecology (Smith and Eppley 1982). Nevertheless, serious attempts to correct this have been made by Silvert and Crawford (1988), who developed a model involving two levels of interaction, competition and lagged effort. This model therefore incorporated factors which according to the authors, explain the phenomenon of fish alternations.

Environmental changes are likely to affect fish populations in a variety of ways (Shepherd *et al.* 1984). These include:
a) Direct physiological effects
b) Diseases
c) Feeding
d) Predation
In addition, there may be interaction effects between two or more of the above factors and other responses, confounding the final understanding. Approaches to analysing relationships between environment and fish stocks fall between two extremes (Shepherd *et al.* 1984):
1) those which are essentially empirical in nature and;
2) those which are founded upon certain hypotheses about the mechanisms involved. Both approaches have advantages and disadvantages. The former makes few assumptions about the relationships, allowing the data to "speak for themselves", thus enforcing objectivity, and may generate interesting and important results, as well as stimulating thought regarding positive causative

mechanisms. The latter corresponds more closely to the scientific method, but once a hypothesis is established, biased estimations may mislead the investigator. Results obtained may not necessarily prove or disprove any hypothesis, but could be explained by the interaction of a third variable not included in the analysis. In this study, the first approach was used.

1.2 History of the Benguela pelagic fishery

Fishing in South Africa has been an important industry since the beginning of the present century (Crawford 1979). Six species contribute to the Republic of South Africa's purse-seine landings: pilchard *Sardinops ocellatus*, anchovy *Engraulis japonicus capensis*, horse mackerel *Trachurus trachurus*, chub mackerel *Scomber japonicus*, round-herring *Etrumeus teres* and a lantern fish *Lampanyctodes hectoris* (Crawford 1981a).

Climatic perturbations in the southern Benguela may have an important effect on the fisheries. Previous warm events in the southern Benguela have had both a positive and negative effect on the stock size of pelagic fishes (Shannon *et al.* 1985) and the establishment of " crash programmes" of research into declining stocks has indicated the extent of scientific concern (Grindley 1975).

A commercial purse-seine fishery for pilchard was initiated in 1943 in the St Helena Bay area (Figure 1.1) under the stimulus of a war-time demand for canned fish (Butterworth 1983). No accurate records were kept at the start of the fishery. Over the next few years the industry expanded rapidly, and by 1949 the quantity landed was recorded to be approximately 68000 tons (Du Plessis 1959).

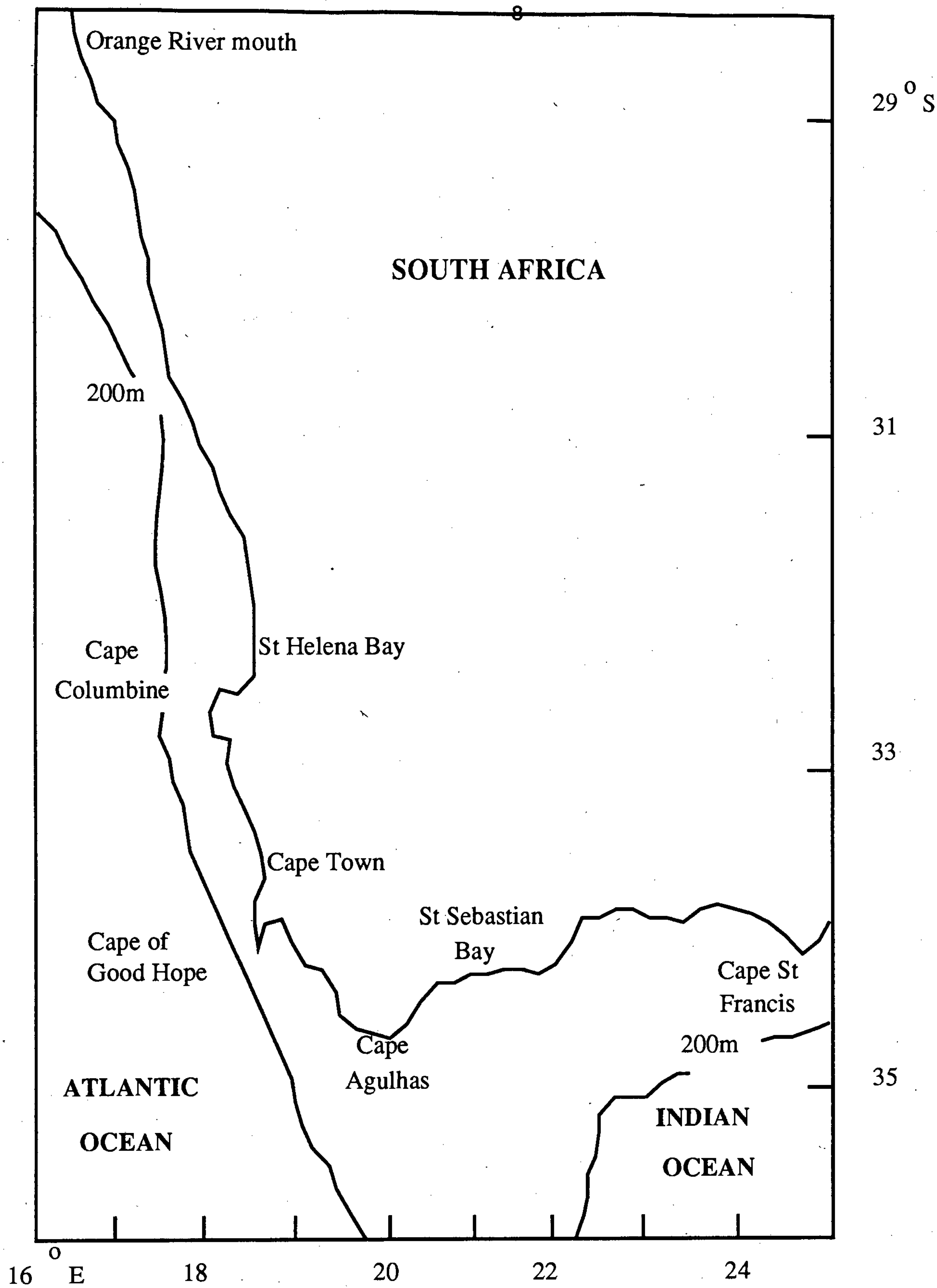


Figure 1.1 Map of the Republic of South Africa's west and south coasts.

The expansion of this fishing effort prompted the introduction of certain control measures, which have since come to include restrictions on the number and capacity of processing plants and vessels, limitations of the maximum allowable catch and duration of the fishing season, and enforcement of a minimum mesh size (Stander and Le Roux 1968, Gertenbach 1973, Newman and Crawford 1980).

The purse-seine fisheries off South Africa and South West Africa (Namibia) have been based largely on pilchard, anchovy and Cape horse mackerel. Off South Africa, chub mackerel, round herring and lantern fish have also made an important contribution to the landings (Crawford *et al.* 1987).

Considerable changes in fishing power and catch composition have occurred since 1950 (Newman *et al.* 1979). The introduction of 12.7 mm stretched mesh net during 1964/1965 to replace the 32 mm and 38 mm nets previously used, led to the appearance in the catch of increased numbers of small individuals of large species, and an increase in the numbers of small species such as anchovy and lantern fish.

During the early years of commercial exploitation of pelagic species off the south western Cape, substantial quantities of large pilchards were regularly caught off St. Helena Bay (Du Plessis 1959). On the basis of length information these fish are believed to have been aged five years or older (Crawford *et al.* 1978).

Following the decline of the pilchard stock in the early 1960s (Table 1.1) and the introduction of small-meshed nets in 1964, adult pilchards ceased to occur in significant numbers west of Cape Point.

Table 1.1 Recorded annual catches (Thousands of metric tons) from the South African purse-seine fishery of pilchard *Sardinops ocellatus*, Cape horse mackerel *Trachurus trachurus* and chub mackerel *Scomber japonicus*, 1950-1985 (from Crawford *et al.* 1987).

YEAR	PILCHARD	HORSE MACKEREL	CHUB MACKEREL
1950	85.3	49.9	-
1951	101.9	98.5	-
1952	170.0	102.6	-
1953	132.5	85.2	-
1954	88.3	118.1	4.0
1955	121.9	78.8	20.2
1956	76.6	45.8	32.6
1957	109.5	84.6	7.4
1958	194.4	56.4	21.6
1959	260.2	17.7	33.1
1960	318.0	62.9	31.0
1961	402.2	38.9	49.7
1962	410.2	66.7	20.4
1963	390.1	23.2	13.2
1964	256.1	24.4	50.0
1965	204.5	55.0	41.4
1966	118.0	26.3	53.4
1967	69.7	8.8	128.2
1968	107.8	1.4	91.0
1969	56.1	26.8	91.7
1970	61.8	7.9	77.9
1971	87.6	2.2	54.2
1972	104.2	1.3	56.7
1973	69.0	1.6	58.8
1974	16.0	2.5	30.7
1975	89.2	1.6	69.3
1976	176.4	0.4	0.5
1977	57.8	1.9	21.3
1978	97.0	3.6	2.4
1979	52.9	4.3	2.7
1980	50.4	0.4	0.2
1981	46.2	6.1	0.3
1982	33.5	1.1	2.7
1983	60.5	1.4	3.8
1984	27.2	2.5	0.7
1985	30.7	0.8	0.1

The bulk of the adult population currently inhabits the waters east of Cape Point (Crawford 1981d), and comprises fish aged two to four (Crawford *et al.* 1983). It is apparent from annual landing figures (Table 1.1) that the performance of the pilchard stock was dominated by the exceptionally large catches which were recorded during the late fifties and early sixties. These have been attributed to strong recruitment experienced between 1956 and 1959 (Newman and Crawford 1980).

The increased abundance of pilchard in the years 1956 to 1959 led to a considerable increase in fishing effort, of which much was later diverted to anchovy and other resources through the introduction of the small meshed (12,7 mm) net. After 1966, anchovy displaced pilchard as the main contributor to the commercial landings, but pilchard remains an important component of the multispecies fishery, as evidenced both by the large catch of 176 000 tons recorded in 1976 and the considerable influence exerted by pilchard availability on overall catch rate (Crawford 1981a, Crawford 1981d).

There has been an obvious reduction, from the late fifties to the present (Table 1.2), in the maximum age of capture, as well as the age of the dominant group present in the catches of all three species . Furthermore, corresponding to the decline of the pilchard population, there has been a substantial change in the length at first maturity of pilchard. During the 1950s and early 1960s, 50 % of mature pilchard attained an average caudal length of 18.5 cm, corresponding to an age of four years (Crawford *et al.* 1980). After the decline, the average length at 50 % maturity was reduced to 15.5 cm or two years of age (Crawford *et al.* 1980).

From Table 1.2, it can be seen that there has also been a decline in the maximum age of capture of horse mackerel since the late 1960s. After "anchovy nets" (12.7 mm) were introduced in 1963/64, 0-year-old horse mackerel were the mainstay of the fishery.

Table 1.2 Estimated maximum (MAX) and average (AVG) age of pilchard *Sardinops ocellatus*, horse mackerel *Trachurus trachurus* and chub mackerel *Scomber japonicus* in the purse-seine commercial catches. 1950-1976 (from Shelton and Armstrong 1983).

	PILCHARD		HORSE MACKEREL		CHUB MACKEREL	
YEAR	MAX	AVG	MAX	AVG	MAX	AVG
1950	8	5	11	3	--	--
1951	8	4	11	3	--	--
1952	8	4	11	5	--	--
1953	8	5	11	5	--	--
1954	8	5	11	6	5	2
1955	8	5	12	7	5	2
1956	8	5	12	10	8	2
1957	8	4	12	8	8	4
1958	8	4	12	8	8	4
1959	7	3	12	5	4	2
1960	7	3	12	5	5	2
1961	7	4	12	6	5	2
1962	7	4	--	--	7	2
1963	7	4	8	3	3	0
1964	7	4	10	4	3	1
1965	7	3	10	0	7	2
1966	7	3	4	2	6	0
1967	6	0	10	0	7	2
1968	6	0	10	0	7	2
1969	6	0	2	0	7	2
1970	5	0	5	0	7	4
1971	6	0	5	3	7	0
1972	6	0	7	0	7	1
1973	6	0	2	0	5	2
1974	6	0	--	--	4	0
1975	6	0	--	--	6	1
1976	6	2	--	--	3	1

Chub mackerel, *Scomber japonicus*, appeared for the first time in commercial catches during 1954 (Table 1.1) and has since been a regular component of the annual pelagic landings (Baird 1975). Since 1954, catches of chub mackerel have been made all along the western Cape coast. The largest proportion of the annual chub mackerel catch is made in the area between Lambert's Bay and Cape Town (Crawford and De Villiers 1984).

The age composition estimates of all chub mackerel catches, as seen in Table 1.2, show that they consisted of fish ranging in age from 0+ to 8+ year old fish, with 1+ and 2+ predominant. Chub mackerel maximum age at capture and average fish age in catches have declined since the early sixties, similar to the pattern for pilchard and horse mackerel, although the decline has not been as dramatic as in the other two species.

1.3 Biology of the pelagic resources

1.3.1 Species considered

Three species of pelagic fish are considered in this study, the choice of species being determined by the length of the data series available. The three species are pilchard, horse mackerel and chub mackerel. Thus, the study is not comprehensive; a complete range of species should include anchovy *Engraulis japonicus capensis*, which in the 1970s dominated overall catches by the southern Benguela purse-seine fishery. Unfortunately, catches of anchovy off South Africa were only initiated in the mid 1960s, and insufficient data are available for long-term time series analysis.

Pilchard have a wide distribution off southern Africa, extending from Baia dos Tigres in Angola, south to the Cape of Good Hope and north-east to Durban (Natal) on the east coast of South Africa (Davies 1956). Although there are no major genetic differences between pilchard off South Africa and the Namibian pilchard stocks (Grant 1985), tagging has shown that fish in the two areas belong to relatively discrete stocks (Newman 1970). Only the South African stock was considered in this study. It has been argued that one of the reasons for the decline of the South African pilchard stock in the 1960s was a reduced age structure of the stock, leading to a greatly reduced distribution (Crawford 1979). Analysis of 2374 fishes sampled during the 1975/76 spawning season indicated that fish were maturing at a much earlier age than at the start of the fishery in the late 1940s (Armstrong 1984). This change may have been caused by the population responding to decreased abundance and a reduced size structure brought about by a lowering of the minimum mesh size of purse-seine nets from 32 to 12.7 mm over the period 1963-1965 (Crawford *et al.* 1978). There has also been a decrease in age at first maturity, from two years in the early 1950s, to one year in the 1980s (Prosch *et al.* 1988). Reduced abundance of pilchard off South Africa since the 1950s is reflected in a decreased contribution of pilchard to the diet of seabirds in the vicinity (Berruti and Colclough 1987, Berruti 1988).

The presence of two different stocks of horse mackerel in South Africa is recognised, resulting from analysis of effort trends of the purse-seine pelagic fishery (De Villiers 1977), and also by biological studies (Draganik 1977). In recent studies, however, these two populations have been recognised as a single stock (Hecht 1989; Naish 1990). For simplicity, both stocks are lumped together for this analysis. The age at first maturity has been determined for horse mackerel (Naish 1990) to be two years, which is somehow less than the age at first maturity of the Namibian stock, which matures at three or four years of age (Crawford 1981b). In contrast to pilchard, horse mackerel feed selectively (Hecht 1976) on zooplankton (Bergh *et al.* 1985).

The genus *Scomber* contains three species, viz *Scomber japonicus, S. scombrus and S. australasicus* (Baird 1975). The South Africa chub mackerel is a cosmopolitan species (Parrish and MacCall 1978). In the South East Atlantic it occurs along the west coast of Africa, extending from Angola in the north to Cape Agulhas in the south (Crawford *et al.* 1987). It also occurs along the eastern Cape coast, and may even penetrate as far east as Natal but is of little commercial importance in these eastern areas (Baird 1978b). Chub mackerel matures from its second year onwards (Baird 1977) and adults are piscivorous. Baird (1978b) found lantern fish to be the main prey item in the west coast, while Nepgen (1982) found anchovy to be more important in the False Bay area.

1.3.2 Temperature preferences

Monofactorial experiments, in which eggs or larvae are exposed to temperature ranges, can establish tolerance limits as well as temperature optima , but in real life conditions are usually not so simple (King 1977b). Nevertheless, these experiments provide some insight into the environmental preferences of species.

It is well known that, within limits, eggs of pelagic fishes, such as pilchard (King *et al.* 1977, King 1977a), or herring (Skud 1982) experience an increase in growth rate with an increase in temperature. It is also interesting to note that pilchard larvae hatched from eggs incubated at low temperatures, were considerably larger than those hatched at high temperatures (King *et al.* 1977). This may indicate that pilchard eggs subjected to low temperatures need a large yolk sac to maintain them, presumably due to slower development rates, than do those incubated at high temperatures. Alternatively, at low temperatures, embryos respire more slowly, therefore more energy is available for growth. In another experiment, (King 1977b) observed that the highest percentage (90 %) of pilchard eggs to hatch occurred at temperatures between 16° and $20.5^{\circ}C$. At the other end of the spectrum, King (1977b), found that pilchard larvae failed to develop eye pigmentation and a functional jaw at temperatures cooler than $13^{\circ}C$. He therefore assumed that $13^{\circ}C$ was the lower temperature limit for pilchard development.

For horse mackerel, King *et al.* (1977) found that eggs developed more rapidly in warm water than cold water, and that the lower lethal temperature limit was approximately 12.6°C.

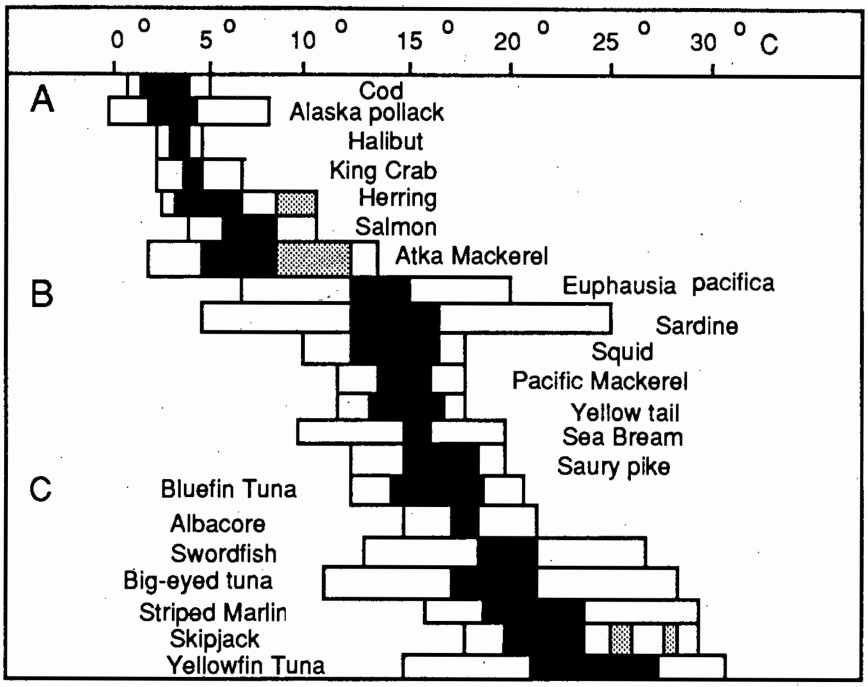


Figure 1.2 Optimal water temperature spectra of important Japanese fishes (After Uda 1961).

Uda (1961) prepared a diagram of optimal temperature spectra for some important commercial Japanese fish species (Figure 1.2). It can be seen from this diagram that the range of temperatures for pelagic fishes like chub mackerel and pilchard (B group in the diagram), and especially the optimal temperatures, are very close to those in the literature about the South African species. However, temperatures also occur outside or close to the extremes of the tolerance ranges of different species and it is important to assess the effect of these temperatures on the population as a whole, especially if the extreme temperatures are maintained for an extended period of time. The problem becomes more acute when one considers that marine fishes may be sensitive to temperature changes of 0.003^{o}C (Bull 1952). Murphy (1961) concluded that a 3^{o}C change in temperature results in a tenfold variation in survival of the Pacific sardine population.

Young adult pilchard migrate south from the fishing grounds on the west coast of South Africa to spawn on the Agulhas Bank. Older fish often spawn on the west coast. Generally, the onset of spawning by the pilchard in western and southern waters occurs in late winter during conditions of reduced temperatures and increased salinity (Anders 1974). The main spawning of pilchard occurs within a temperature range of 13.8^{o}C - 16^{o}C off South Africa (Davies 1956). A mean temperature of 15^{o}C indicated conditions favourable for intense spawning, while 13^{o}C was found to be the threshold temperature for major spawning activity (Davies 1956, Baird 1970b). For chub mackerel a temperature range of between 14^{o}C and 15.2^{o}C was established as suitable for spawning (Baird 1975).

Spawning

Iteroparity, or repeated spawning, was noted as a potential bet-hedging trait in clupeoid fish populations (Stearns 1976). Bet-hedging involves the spreading of risk over both time and space in order to maximize survival, growth and reproduction. It is generally accepted that the variable year-class strength associated with many neritic fish species, particularly clupeoids, is associated with variable mortality early in the life history, with natural mortality assumed to be comparatively constant for recruited fish (Shelton 1987).

Temperate fish species usually spawn during fixed seasons in the same geographical areas from year to year. Larval drift is of great biological importance as a means of dispersal for the stock and during this period much of the natural regulation takes place (Cushing 1978). The onset of spawning of the pilchard in western and southern African waters occurs during periods when temperatures are reduced, and lie towards the cool end of the tolerance range (Anders 1974). Previously, heavy spawning of pilchard was also recorded in the St. Helena Bay and Saldanha Bay grounds (Crawford 1979). In these areas the pilchard eggs were generally located offshore in warm waters of oceanic origin. As the initial rate of development of pelagic fish eggs increases exponentially with temperature (King 1977b), spawning in warm waters is likely to enhance survival of the early ichthyoplankton stages by reducing the age at which complete retinal pigmentation is attained and so decreasing mortality caused by predation (Lasker 1978b). Thus, the advantages of spawning on the west coast, as occurred prior to the decline of the pilchard stocks in 1962-63 are obvious; eggs are spawned offshore in warm waters where egg development is enhanced (King 1977a), and at the same time the larvae are close to the recruitment grounds, decreasing the risk of high mortalities due to advection offshore. Spawning in the northern grounds (St Helena Bay) by five and six year-old pilchard (Crawford *et al.* 1978) has in recent years been greatly reduced or has ceased, probably due to reduction of the population size.

Pilchard have a protracted spawning season (Armstrong 1986). Results obtained between 1951 and 1967 by Crawford (1981d), and other reports (Davies *et al.* 1981, Shelton *et al.* 1985), demonstrated that in South African waters most of the spawning of pilchard takes place between September and February. In the Cape, Davies (1956, 1957) and Crawford (1981b, d) showed that egg production by pelagic fish was maximal in September and late summer, reaching a minimum during May-June. Results from the Cape egg and larval programme (CELP), conducted during August 1977 to August 1978 suggested a maximum egg abundance on the Agulhas Bank during October (Davies *et al.* 1981).

Horse mackerel are believed to spawn from July to February in the central zone of the Agulhas Bank (Naish 1990). However, previous egg and larval surveys indicated that horse mackerel also spawn during spring and summer along the west coast outside the oceanic front (Davies *et al.* 1981, Shelton *et al.* 1985). Chub mackerel spawn off Cape Columbine in winter and early spring (June-September) (Baird 1975, 1977, Shannon and Pillar 1986) when onshore currents, set in motion by north-westerly winds, transport relatively warm (14-15 ^{o}C) water inshore (Shannon 1976, Crawford *et al.* 1983). The chub mackerel population, thought in the late 1970s to consist of two distinct geographical groups (Baird 1975, Baird 1978a), is now considered to be a single stock (Crawford and De Villiers 1984). The reasons for this are that chub mackerel undertake extensive migrations, and are found to be mainly absent from one ground when abundant on another along the coast. Furthermore, it has been found that some specific age-classes, which have contributed notably to the catches, were so in both Namibia and South Africa (Crawford and De Villiers 1984). Shoals of offshore chub mackerel are brought inshore towards the west coast by easterly intrusions of South Atlantic Surface Water (Baird 1978a). Eggs may be distributed over a large area (Baird 1975) but the highest concentrations have been found during the winter months in a patch of water west of Saldanha Bay approximately 10 nautical miles wide (Baird 1978a). Although the frequency of spawning could not accurately be determined, it was nevertheless concluded that several batches of ova are released within a spawning season (Baird 1974). Chub mackerel display asynchronous gonad development.

In all three pelagic species described above, the cool upwelled water of the west coast is avoided when spawning. In addition, sites of strong offshore transport are avoided, even though productivity may be highest in these areas (Shelton *et al.* 1985). Thus, environmental conditions during the spawning season favour rapid egg development and maintain eggs and larvae near the inshore environment.

Recruitment

Most natural environments are not entirely uniform, random or predictable. Usually, some non-random temporal and spatial patterning is apparent. During the last decade, increased attention has been focused on the stock and recruitment problem of commercially important fishes (Shelton 1987).
The eggs and larvae of pelagic fishes are planktonic, and surface currents, set in motion by the prevailing south-easterly winds of spring and summer, could possibly transport large quantities westwards around Cape Point (Duncan and Nell 1969, Shannon *et al.* 1985). In addition, Bang and Andrews (1974) have demonstrated the presence of a strong shelf-edge frontal jet, which transports large volumes of water at rapid speeds (100 cm s^{-1} at the core) in a northerly direction along the west coast. Shelton and Hutchings (1979) are of the opinion that this jet may be important in the dispersal of anchovy larvae and probably also pilchard larvae. In winter the highest plankton concentration is found in a narrow strip inshore along the west coast, with maximum standing stocks being found in the north (Crawford *et al.* 1980). It is there that the catch rates of nought-year-old pilchard, which feed predominantly on zooplankton (King and Mcleod 1976), are greatest (Crawford 1981d). Although recruitment in May and June takes place along the entire coast, there is a tendency for these juvenile fish to initially appear in their greatest numbers in the northern fishing grounds (Armstrong 1984), thereby allowing catch rates for this component of the

population to be greater north of Cape Columbine (Crawford 1981d). Seasonal patterns of availability are therefore apparent, with adult pilchard usually being caught in summer and early autumn (Newman *et al.* 1979). Juvenile pilchard catches are small in winter, increase in spring, reach a maximum in summer, and then decrease in autumn in the west coast (Figure 1.1). There is a distinct movement of young pilchard towards the south in August and September, though some remain off the west coast throughout the year. A close similarity between the pattern of 0-year-old catches in the spring and summer months and the egg abundance indices for the previous September-January suggests that young pilchard recruit to the fishery approximately eight months after being spawned (Crawford 1981d).

Recruitment of horse mackerel takes place along the west coast from mid-autumn onwards, and similar to pilchard 0-year-olds are found initially in the northern area. At the onset of spring, there is a definite tendency for the young fish to move south into newly initiated regions of upwelling, and mature fish continue to the spawning grounds east of Cape Point, in very much the same way as pilchard. At the close of the spawning season they frequently migrate eastwards, well beyond Cape Agulhas (Crawford 1981b).

Chub mackerel are reproductively active from June to Mid-August, i.e. winter (Baird 1977). Adult chub mackerel apparently occur in a specific offshore environment which is not part of the inshore ecosystem. On the other hand, the remainder of the chub mackerel population, being smaller fish, are associated with the cool inshore waters of the Benguela current (Baird 1974). Adult chub mackerel tend to be more abundant during late autumn and winter (Newman *et al.* 1979). Chub mackerel 0-year-olds are recruited at the beginning of each year (Crawford *et al.* 1983), and occur inshore along the west coast in much the same region as round herring, where they form mixed shoals (Geldenhuys 1978). They then assume a progressively more offshore existence, the adults generally only being encountered by purse-seiners on their spawning migration off Cape Columbine (Baird 1978a). Adults then being caught by deep-sea trawlers.

1.4 The Benguela environment

The Benguela current flows parallel to the west coast of southern Africa in a north to north-westerly direction. The main body of the current is approximately 200 Km wide (Shannon 1985), and forms the eastern boundary of the South Atlantic (Figure 1.3). The Benguela current has no documented core, though various authors have quoted volume fluxes ranging between 7x10 cm^3 and 16x10 cm^3 per second (Bang and Andrews 1974). Environmental variability in the southern Benguela appears to result from variability in mesoscale processes like upwelling, as well as from low-frequency variability caused by alternating periods of strong and weak advection of warm tropical or subtropical water from the north (Shelton *et al.* 1985). Remote sensing by satellites (Jury 1985a, Taunton-Clark 1985, Lutjeharms and Stockton 1987) has greatly increased awareness of the large-scale features and variability of the system.

Episodic, longshore equatorward winds are the primary driving force of the southern Benguela system. In an upwelling area, the wind blows parallel to, or at a slight angle to, the coast and by Coriolis's force, the deflecting force of the earth's rotation, it drives the water offshore. The deflection is at right angles and to the left of the current in the southern hemisphere. Where the surface water is pushed offshore, cool water upwells at the coast, often not very far from the shoreline. This cool water is nutrient-rich so that primary production is high and, as a consequence, it is one of the world's great fisheries which are often found in upwelling areas (Andrews & Hutchings 1980, Nelson & Hutchings 1983, Schumann *et al.* 1982).

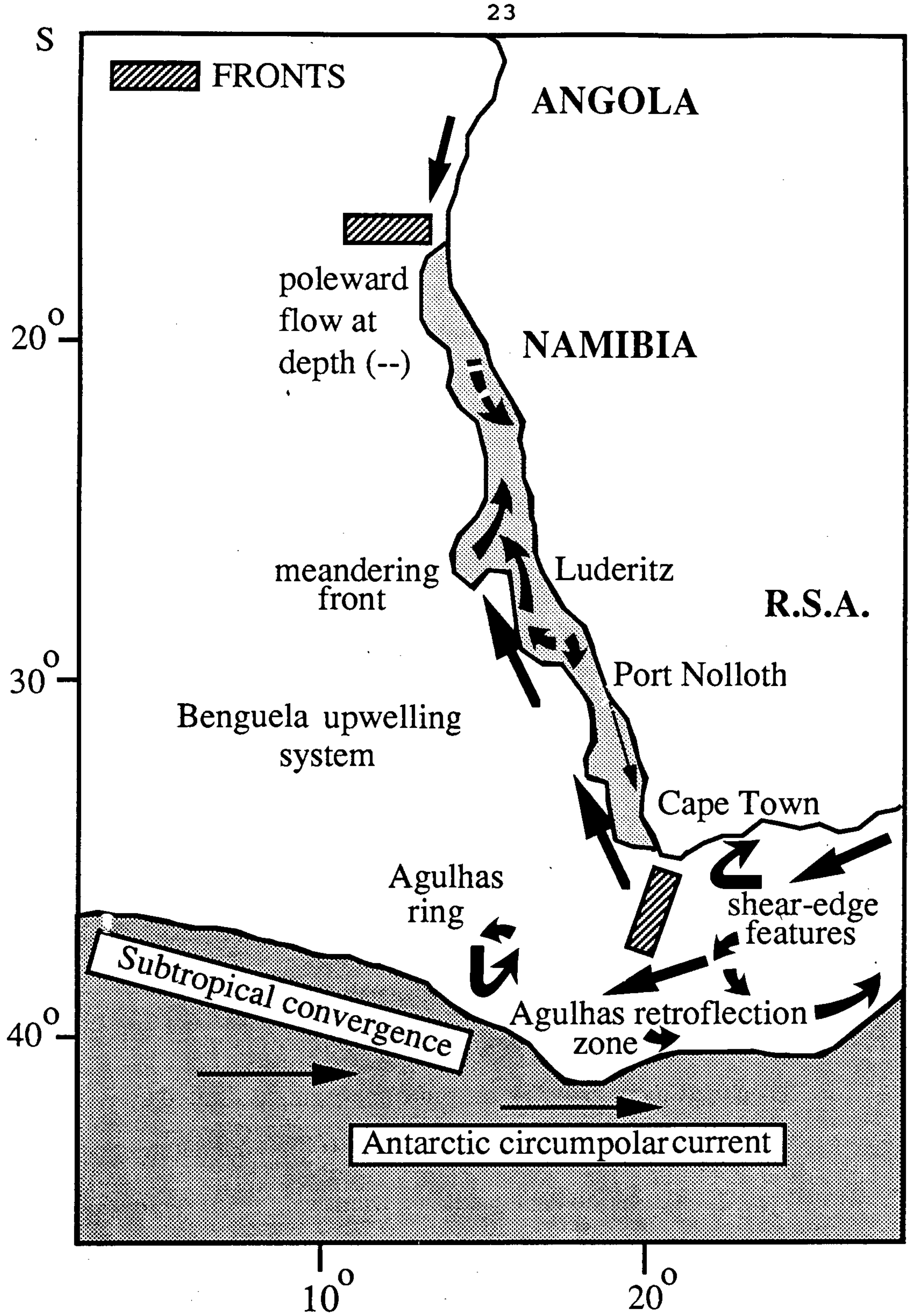


Figure 1.3 Main ocean currents around South Africa (After Shannon 1989).

In the southern Benguela, the upwelling process is influenced by topographic irregularities in the form of capes and canyons, which modify the local wind patterns (Nelson and Hutchings 1987). Winds over the Benguela upwelling region are governed by three macroscale meteorological features: the South

Atlantic high pressure cell, eastward moving cyclones across the southern part of the Atlantic (produced by perturbation on the subtropical jet stream) and the pressure field over the African subcontinent.

The upwelling season in the southern Benguela region is initiated in spring, is strong during summer, moderate or absent in autumn and reaches a minimum in winter (Shannon 1966). Upwelling plumes are separated from oceanic waters by fronts with sharp gradients of temperature and salinity (Crawford *et al.* 1983).

Model results have demonstrated the importance of the wind field south of Africa in determining the penetration of the Agulhas current into the Atlantic Ocean (Shannon 1985, Shannon *et al.* 1988), and the contribution of Agulhas water to the flow over the west coast shelf appears to be large but sporadic (Lutjeharms and Walters 1985). Agulhas Bank water is premixed from Atlantic and Indian ocean water types and does not differ markedly from South Atlantic Central Water (Lutjeharms and Valentine 1987). No direct measurements of water rounding Cape Point from the shallow Agulhas Bank exist, but temperature and salinity analyses of CTD casts off the Cape peninsula show that this process occurs (Shannon 1985). East of Cape Agulhas limited upwelling takes place off prominent capes, especially during summer and autumn (Crawford *et al.* 1983). On the Agulhas Bank, winds vary between south and southwest during upwelling events. This upwelling is therefore of a different nature from the west coast upwelling process (Lutjeharms and Meeuwis 1987).

Whereas the links between ocean and atmosphere are easily recognised at a local and regional scale, there may also be identifiable interactions at a larger scale. So called "teleconnections" (Wyrtki 1973, cited by Kawasaki 1983) which show significant relations in variation between very distant areas of the ocean and atmosphere, have been the subject of considerable study. Warm events have been linked to major changes in the Californian fisheries during the late 1940s (MacCall 1980), the performance of the pilchard *Sardinops ocellatus* off Namibia in 1963 (Stander and De Decker 1969) and the collapse of the Peruvian anchoveta *Engraulis ringens* fishery in 1971-73 (Shannon *et al.* 1984). The collapse of the Peruvian anchoveta fishery highlighted the fact that the effects of major perturbations, together with heavy exploitation, can be catastrophic. During recent years, there has been a renewed interest in analyzing the periodic fluctuations of certain natural phenomena, particularly those occurring on a large geographic scale. El Niño events and their seeming relation to the Southern oscillation have been analysed by various authors (Huato-Soberanis and Lluch-Belda 1987, Kerr 1988, Lindesay 1988). One may anticipate that climatological fluctuations on a time scale of several years may have a parallel in the Benguela system to El Niño. In principle the nature of El Niño is one of anomaly; anomalous values of temperature, salinity and other properties of the waters. However, anomalies can be defined only in terms of some norm, which can be defined in terms of many different criteria. A simple example of such a criterion proposes the calculation of the arithmetic mean of all values of a particular variable recorded at a particular point at a particular time of the year. However, this criterion suggests regularities which natural systems might not be able to maintain (Valdivia 1978). Kerr (1988) posed the question: Why pay so much attention to El Niño events ? Are not the relevant scales of importance perhaps those with longer term impacts, such as those described by Kawasaki (1983) for Pacific sardines, or by Lindquist (1983) for the Baltic sprat/herring ? El Niño events may only reflect relatively high frequency noise, perturbations such as those described by Kawasaki (1983) and Sharp (1981, 1987), superimposed upon long-term processes. In fact, episodic events such as El Niño appear to be uncommon in the southern Benguela system, with warm events being linked to variations in the wind field and the intrusion of warm Agulhas rings from the south east rather than to advection of warm water from the north (Shannon 1985).

1.5 Aims of the thesis

The objectives of this work are to assess the historic role of environmental variation in relation to fluctuations in catches of pilchard, horse mackerel and chub mackerel made by the South African purse-seine fishery. The study is approached using statistical analyses of historic data as are available, and may serve as a pre-cursor to future possible modelling of the hypothesis that may emerge.

CHAPTER 2

RESEARCH AREA

(Figure 2.1), and is a region of high chlorophyll concentrations and fast rates of primary production (Andrews and Hutchings 1980).

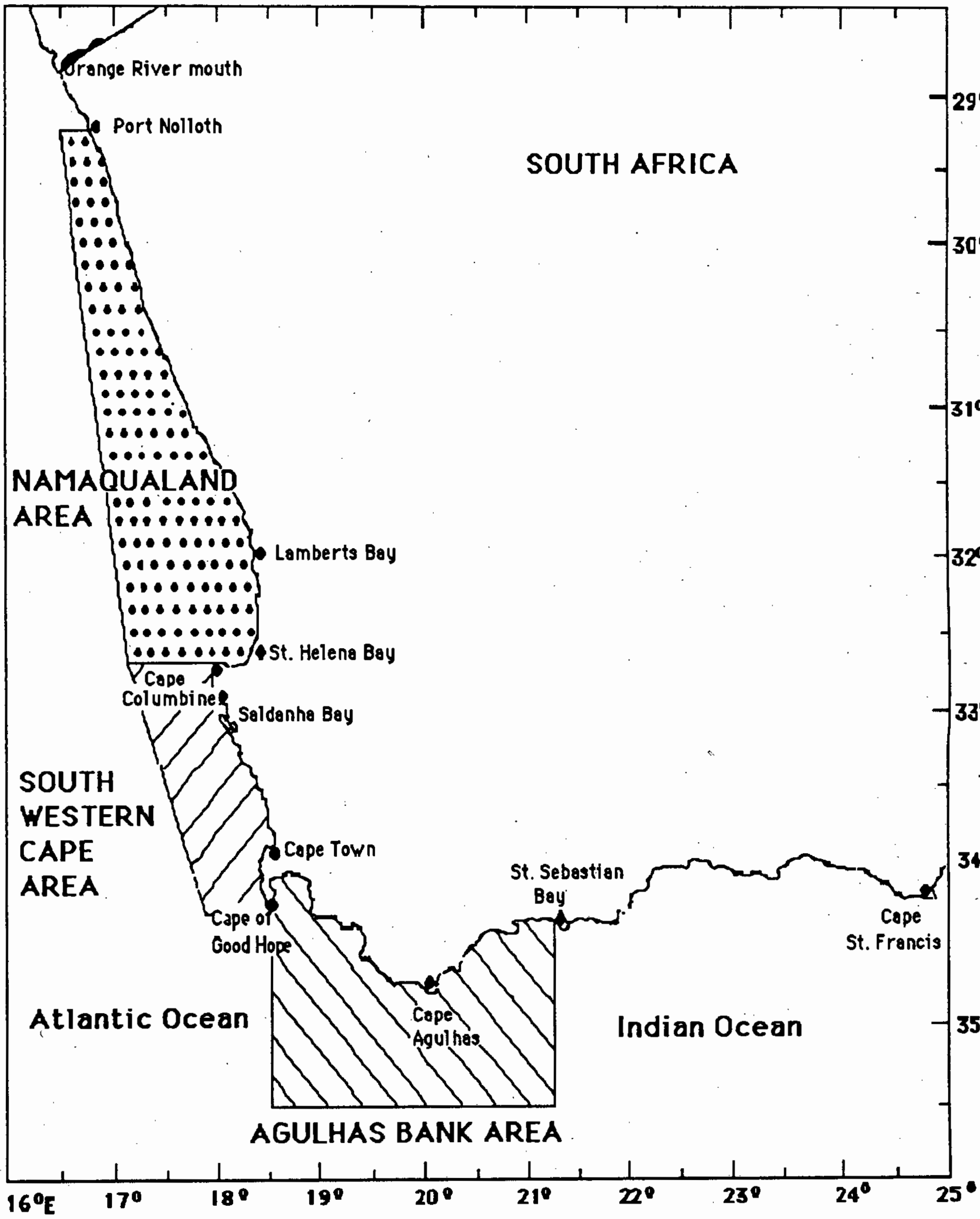


Figure 2.1: Map of the three areas of the South African coast used in the analysis.

For the analysis, the southern Benguela region is divided into three specific areas, chosen as a consequence of the behavioural patterns exhibited by pelagic fish species. From north to south these areas are (Figure 2.1):

Namaqualand area.- (Port Nolloth to Cape Columbine) 29^{o} to 32^{o} 40' S of longitude, 16^{o} 30' to 18^{o} 30'E of latitude. This area represents the pilchard, anchovy, horse mackerel and chub mackerel nursery grounds, where new recruits join the main fishery, as well as being the main area of commercial fishing activity for all the species. Commercial fishing for pilchard has been recorded as far north as the Orange River mouth (Crawford 1981d). This area is also one of the main areas of chub mackerel spawning (Baird 1977).

South western Cape.- (Cape Columbine to Cape of Good Hope) 32^{o} 40'to 34^{o} 15' S of longitude, 17^{o} 10' to 18^{o} 30' E of latitude. This area represents the region through which the fish recruits travel from the spawning grounds in the south to the fishing grounds in West coast. The south western cape area is also a residence area for pilchard and chub mackerel adults. Chub mackerel spawns offshore in this area (Baird 1977).

Agulhas Bank area.- (Cape of Good Hope to St. Sebastian Bay) 34^{o} to 35^{o} 30' S of longitude, 18^{o} to 21^{o} 15' E of latitude. Since the mid 1960s this has been the main spawning area for most pelagic species. Large concentrations of eggs have been recorded near St Sebastian Bay (Crawford 1981d); consequently it was decided to set St Sebastian Bay as the eastern boundary of the Agulhas Bank area. The existence of a large spawning ground on the Agulhas Bank has been documented by Crawford (1980), Davies *et al.* (1981), Crawford *et al.* (1983) and Shelton and Armstrong (1983), and there is some evidence to suggest that spawning on the Agulhas Bank has increased following the altered size composition of the Cape pilchard stock, coinciding with a reduced size at maturity (Crawford 1981d, Shannon and Pillar 1986). The overall extent of this spawning area is about 30 000 km^2 (Shannon and Field 1984) and encompasses a region of water of optimal temperature (14-18°C) for egg survival (King *et al.* 1977). Good purse-seine catches of horse mackerel have also been achieved in this area (Crawford 1981b).

The offshore boundaries of the three areas loosely follow the 200 m depth contour, although, 84 % of the chub mackerel catch and over 95 % of the other pelagic species catches are caught inside the 100 m depth contour (Newman *et al.* 1979). This pattern of catches close to the shore may reflect both the nearshore location of the fish shoals, as well as the preference of fishermen to remain close to the coast.

The pattern of most pelagic fish migrations in the southern Benguela region indicates that mature fish migrate south to spawn (see section 1.3 for full details). The spawning grounds are centered on the Agulhas Bank, where egg abundances derived from monthly surface tows and obliquely hauled nets from 100 m to the surface, show peak spring-summer spawning activity for pilchard and horse mackerel (Crawford *et al.* 1980). Once spawning has taken place, eggs and larvae are transported to the northwest. Shelton & Hutchings (1982) have shown that a coastal jet between Cape Agulhas and Cape Columbine aids transport of larvae from the spawning grounds to the inshore nursery grounds represented as west coast.

The Namaqualand and the south western Cape areas correspond roughly to area 1.6 of the International Commission for the south-east Atlantic Fishery (ICSEAF) (Crawford *et al.* 1987), whereas the Agulhas Bank area corresponds to division 2.1 of ICSEAF (De Villiers 1985).

3. DATA EXTRACTION AND TREATMENT

3.1 Introduction

The reliability of any scientific conclusion is limited by the quantity and quality of the data upon which it is based. Most studies of climatic change and its effect are hampered by limited data availability. It is worth noting that statistical rigour is a desirable attribute of a tool and not an end in itself (Kelly 1983).

Based on studies in the literature, it appears that climatic variations have ecological effects on commercial fisheries and fishing resources (Summers *et al.* 1985). Pinpointing relationships, whether causal or simply correlative, depends on the availability of straightforward, complete data sets for fisheries and environmental factors (Summers *et al.* 1985). Data availability constrains the development and implementation of analytical techniques that might be used to represent stock dynamics.

The data available on the abundance of fish stocks are of three main types:
a) Data on catch weights, which are usually the only information available for several years and spanning many decades (Clark et al. 1975). There are many advantages in having a long term data series, but the data often are of variable quality, and do not provide an unambiguous index of stock size, because they depend also on the level of fishing effort, which is often not known (Armstrong 1984). To assess whether commercial landings are a measure of stock abundance, one needs to elucidate the degree to which effort affects landings, as well as the size and availability of the fish stocks (Newman *et al.* 1979), where "availability" refers to the quantity of catchable fish in the fishing area (Buys 1959). In this study, it is assumed that the fishing effort has remained fairly constant over the

past, so that long-term trends in landings represent major fluctuations in abundance (Skud 1982).

b) Data on year class strength, which are rarely available for more than a few decades. The most recent data are often obtained from Virtual Population Analysis (VPA), providing the most realistic estimates, with the older data based on Catch per unit effort (CPUE). Estimates of biomass and production are needed, these parameters being obtained first as relative indices from VPA, CPUE, predator studies, and by acoustic and egg-and-larval surveys. These procedures require accurate parameter estimates to provide absolute values of abundance. The application of VPA techniques to the South African pilchard and anchovy stocks was first attempted by Centurier-Harris (1977). The results quoted in most of the papers of this nature are seen as poorly founded, mainly due to the fact that critical VPA parameters (terminal fishing mortality, etc ...) are not determined in an objective fashion or because the objective techniques used are inadequate (Bergh 1987).

c) Data from research vessels of eggs, larvae or pre-recruit young fish, which rarely extend for more than a few years.

Various new methods have been used in recent work on stock assessment. A calibrated high-frequency echo-sounder has been used to measure the density of pelagic fish shoals (Hampton 1987). Various aircraft-borne remote sensors have also been employed to good effect. These sensors have included airborne radiation thermometers and low-light-level television cameras (Cram 1974). Unfortunately, for the period of time in which we are interested, i.e. from the early start of the fishery, the only reliable estimates of fish stock abundances are found in the relationship with catches.

The reduction of the data to monthly means within large areas of ocean, masked the environmental signals and disguised the dynamics which occur on small temporal and spatial scales (Radach 1984). McLain *et al.* (1985) found sea surface temperature anomalies within the Benguela system to be more persistent in time, than with distance along the coast. In the California current ecosystem there is a well defined seasonal response (Bernal and McGowan 1981); consequently an evaluation of the importance of a seasonal response must be made in the southern Benguela region.

Wind components are used in the analysis because coastal upwelling is the result of longshore, equatorward winds driving surface water away from the coast (Jury 1985b, Taggart and Leggett 1987). Also, winds are indirectly important in transportation of larvae into favourable or unfavourable conditions (Ahlstrom 1961). The depth of mixing depends also upon the wind's direction , particularly if it shifts with respect to a coastline near which the fish are spawning. Calculation of averaged resultant wind stress, made by Lutjeharms and Meeuwis (1987), during the seven days preceding upwelling events showed that there is a substantial correlation between wind direction and both upwelling frequency and offshore penetration of upwelled water.

Sea level mean values taken over time periods of months and years are of interest as integrated measures of the variability in the marine environment at the coast. The sea level data were included as a potentially important variable because of the relationship between geostrophic flow and coastal sea level (Parrish and MacCall 1978).

3.2 Time scale

It is recognized that close interactions between ocean and atmosphere can produce variability in climate on interannual and decadal time scales (Brundrit *et al.* 1984). This variability has a profound effect on the marine environment and on the ability of that environment to sustain consistent levels of biological productivity and hence fish stocks, particularly in the most productive fisheries of the world (Sharp and Csirke 1983). The abundance of fish stocks and their geographical ranges vary considerably with time (Christensen 1980), and there is evidence to suggest that certain stocks have displayed major variations for several centuries or more, long before fishing by man could have been a major contributing factor (Wooster 1961). Physical variability in the ocean occurs over a number of spatial and temporal scales (Smith 1978), and processes operating at the different scales are continuously interacting (Horne and Platt 1984). For example, seasonal and year-to-year changes in the intensity and location of upwelling zones exerts a considerable influence on the spawning condition, distribution patterns, and catches of pelagic fishes (Strogalev 1983). Similarly, biological processes in the sea may operate on various scales of periodicity, ranging from centuries to decades to annual cycles (Garrod and Colebrook 1978, Cushing 1978).

Analysis of long time series of environmental variables may provide some insight into the variability observed at the ecosystem level in the inter-annual and inter-decadal time scales (Bernal 1981), which have been shown to be important for the fluctuations of some fish stocks (Cushing 1975, Parrish & MacCall 1978). The choice of environmental variables to be included in the analysis and the time scale to be used were largely dependent upon available long-term data.

3.3 Methods of data extraction

Firstly, all environmental variables were averaged over calendar months so that monthly means for all variables were obtained. The monthly means discussed above may not be realistic because "Gregorian months" may not reflect realistic time periods for life cycles, which could span longer periods. To assess the association between long term environmental conditions and catches of pelagic fishes, several month-groupings were made. These month-groupings were chosen to represent conditions in the environment when fishes are actively spawning, recruiting or migrating.

Fish catches

Commercial fishing for pelagic fish in South African waters commenced in 1943 (Geldenhuys 1973). However, catch records are only reliable from 1950 onwards (Centurier-Harris 1977), providing time series of commercial catches of pilchard (*Sardinops ocellatus*) and horse mackerel (*Trachurus trachurus*) for 35 years, and chub mackerel (*Scomber japonicus*) for 31 years. All catch figures were obtained from published information found in Crawford (1981a), Armstrong (1986), as well as records kept at the Sea Fisheries Research Institute. The total pilchard , horse mackerel and chub mackerel catches has varied considerably from year to year and from season to season, as is evident from catch statistics (Table 1.1). Only annual catches have been used in this thesis.

All annual catches were logged to reduce the homogeneity of the variance in the data sets. A three-year running mean was also calculated to smooth the catch data sets and be able to see trends more clearly. These smoothed data sets were used in the Spearman rank correlation and the multiple regression analysis.

Environmental variables

The sea surface water temperature (SST) data were used as an indirect measure of the spatial variability of the upwelling zones (Strogalev 1983), and therefore as an index of environmental change. The choice of SST was influenced by the existence of a long-term series with high data density for the south east Atlantic .

Voluntary Observing Ships' (VOS) data containing records of sea surface temperature (SST), wind speed and wind direction were obtained for the period January 1940 - September 1985 from the South African Data Centre for Oceanography (SADCO) Marine Climatology database. This database contains data from the British Meteorological office in Bracknell and the South African Weather Bureau in Pretoria (Phillips 1986). Record selection was carried out only if at least 5 observations were available in each area for any month, although normally there was at least one observation per day. This was found to be an adequate selection procedure for the period 1950-1985.

The environmental data used in this study were available primarily as daily observations. Values were then averaged over a month. Annual environmental factors thus consisted of 12 individual variables. These variables are not completely independent. For example, SST from adjacent months are obviously highly correlated, so that a three-year-running mean was warranted for the Spearman Rank correlation and the Multiple Regression analysis. In fact, seasonal patterns occurred in most of the environmental factors. Unlike the Pacific Ocean, the interannual signal in the Atlantic is small compared with the seasonal signal (Walker 1987, 1990).

For the purpose of establishing an interannual signal, the long-term (1940-1985) monthly sea surface temperature mean was calculated. The long-term monthly mean was then subtracted from the individual monthly means giving sea surface temperature anomalies.

The mean wind is normally computed by components. The components of the mean wind along any orthogonal directions are equal to the simple means of the individual wind components along the same direction (Panofsky and Brier 1968). The direction along which the components are taken is most commonly chosen as the north-south and west-east directions. Daily wind speed and direction data for the three areas were therefore decoded into north-south wind and west-east wind components. The monthly average was then calculated. Average procedures and filtering were developed as in the sea surface temperature data.

Sea level is routinely measured on tide gauges in many coastal harbours, where it is important in providing an accurate prediction of tides (Brundrit *et al.* 1984). Through an alternative analysis of the tide-gauge data, it is possible to isolate the extra-tidal sea-level signal. Air pressure will provide a partial contribution to this sea level signal (Brundrit *et al.* 1987), but this contribution can be separated off through an air pressure correction based on the inverse barometer equivalence.

According to Brundrit *et al.* (1984), visual correlations enabled good agreement to be attained between the interannual component in the sea level variability at each site and interannual variability in shore temperatures. Unfortunately, a contribution to the correlation arises at the highest frequency (6cpy) signal, which is noticeably present in the time series. In order to isolate the interannual contribution, it is necessary to smooth this high frequency signal. This was achieved by filtering with a double 2-month running mean to form time-series of smoothed anomalies in monthly sea level. Chelton and Davis (1982) also reinforced the low interannual frequencies (< 1 cpy) by filtering the anomalies with a double-running mean filter to form a low frequency time series anomaly.

The data set for each port was filtered using the Doodson tide-killer which effectively removes the main solar and lunar semi-diurnal and diurnal tidal components (De Cuevas 1986).

Studies of anomalies in monthly mean sea level along the eastern boundary current of the north and south Pacific oceans, have revealed the nature of interannual variability in sea level. The short time series for monthly sea level from most of the sites, and the clear presence of anomalies, together with a strong seasonal signal which will tend to obscure the variability on longer time scales, made it unwise to attempt to establish a seasonal signal from the overall means of the monthly data (Brundrit 1987). Therefore, a seasonal signal formed a constituent part of the total signal, and some caution had to be exercised when drawing apparently statistically significant conclusions. Further details of the analytical methods used to proceed from the raw data on sea level and atmospheric pressure, to the time series of pressure corrected monthly mean sea level can be found in Brundrit (1984).

The present study uses time-series between 1959 and 1985 of pressure-corrected monthly mean sea levels from three sites, each site lying within one of the study areas, along the coast of the eastern south Atlantic Ocean (Figure 2.1). The sites, their location and the length of the records available for use are shown in Table 3.1.

Table 3.1 Harbours where data were collected with their geographical coordinates (After De Cuevas 1986).

Harbour	latitude			longitude		
Port Nolloth	29^{O}	15'	South	16^{O}	52'	East
Granger Bay	33^{O}	54'		18^{O}	25'	
Simons Bay	34^{O}	12'		18^{O}	25'	

3.4 Results of data treatment

Environmental variables

Three data areas were chosen as being representative of those areas where the major commercial pelagic fishing operations take place. The first two areas, *viz* Namaqualand and south western Cape areas, are placed along the west coast of South Africa, the third one being situated along the south coast. The data are expected to have some degree of coherence within each area with regard to data collection, since systematic errors in data collection are only considered to be significant (Taunton-Clark and Shannon 1988) before the Second World War, and these errors may not even be significantly important in the Southern Benguela context (Shannon pers. comm.).

In Table 3.2 the monthly means and standard deviations of the sea surface temperature are presented for all three areas and for all months.

From Table 3.2 it can be seen that the greatest variability is found during late spring and summer due to the effect of upwelling. Within areas, the western Cape area was found to have the highest variability, suggesting that the pulsed nature of upwelling in this area.

Table 3.2 Monthly mean SSTs (AVG), standard deviations (SD) and number of observations (n x 1000) (over the period 1950 to 1985) for the three areas used in the analysis. Values are in degrees Celsius.

	Namaqualand area			**South Western Cape area**			**Agulhas Bank area**		
	AVG	SD	n	AVG	SD	n	AVG	SD	n
January	16.87	2.50	1.4	17.85	2.96	2.6	20.26	1.77	3.5
February	16.54	2.41	1.4	17.33	3.13	2.3	19.84	2.41	3.2
March	16.15	2.29	1.5	16.54	3.07	2.6	19.19	2.42	3.4
April	15.50	1.98	1.3	15.99	2.65	2.3	17.83	2.19	3.1
May	15.37	1.78	1.3	15.91	1.94	2.2	16.88	1.51	3.1
June	14.92	1.68	1.2	15.52	1.57	2.0	15.89	1.36	3.1
July	14.49	1.63	1.4	14.93	1.48	2.2	15.28	1.38	3.3
August	14.21	1.19	1.4	14.59	1.29	2.2	14.88	1.28	3.3
September	14.49	1.27	1.3	14.74	1.32	2.1	15.14	1.29	3.3
October	15.06	1.52	1.3	15.29	1.63	2.2	16.11	1.28	3.3
November	15.43	1.92	1.3	15.91	2.12	2.3	17.42	1.52	3.4
December	16.35	2.09	1.2	16.62	2.50	2.4	18.94	1.67	3.3

Seasonal cycle

The mean monthly SST in the three areas is illustrated in Figure 3.1. A clear seasonal signal is evident in all areas with an amplitude of 3 °C in the Namaqualand and the south western Cape areas and 5 °C in the Agulhas Bank area. These results agree with those found by Taunton-Clark and Shannon (1988) in SST data from similar areas. As seen in Figure 3.1 the coherence in all three areas is good. A clear increase in average sea surface temperature from the Namaqualand area to the Agulhas Bank area is apparent, this was expected due to the influence of the upwelling on the first two areas and the Agulhas current on the south coast.

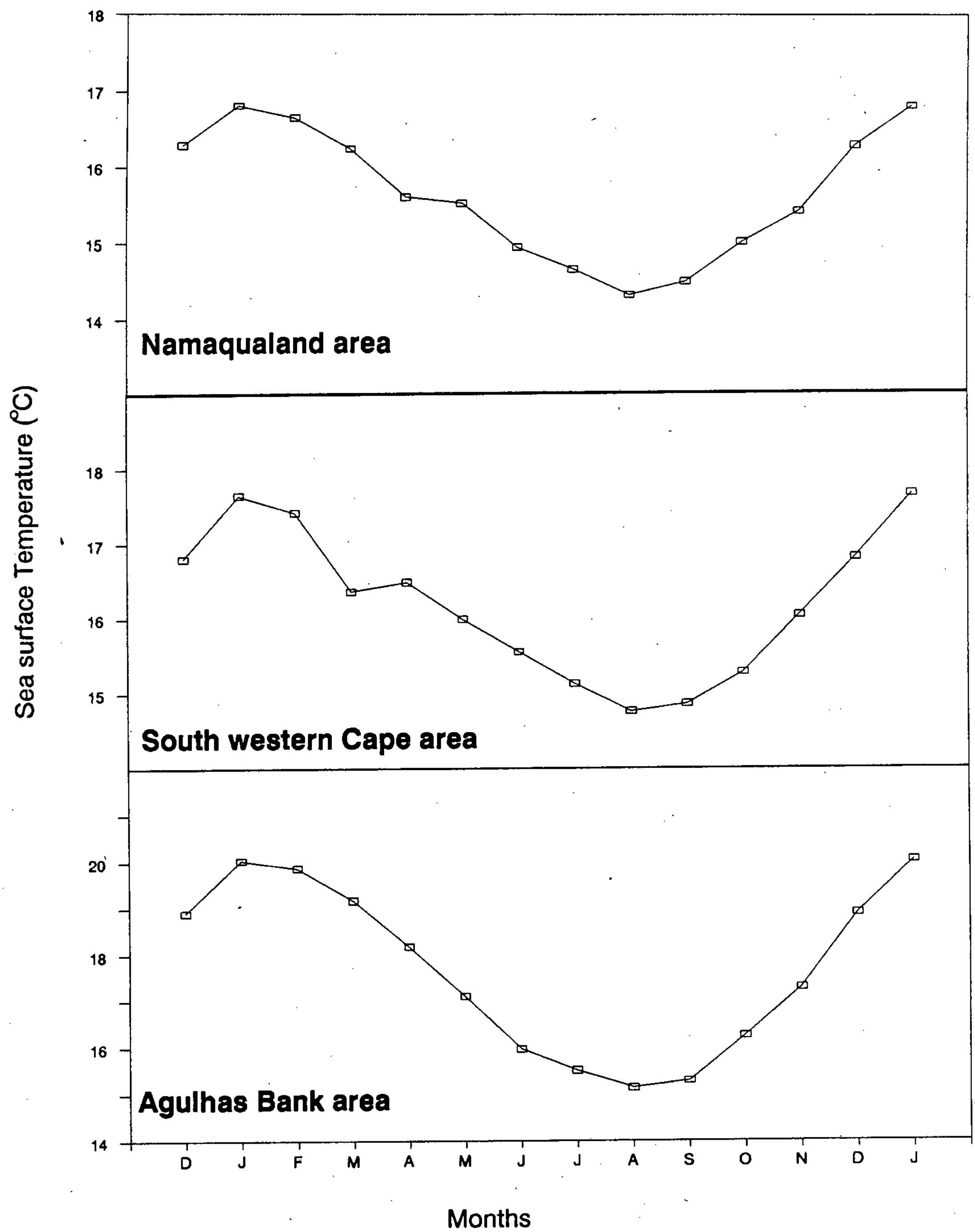


Figure 3.1. Mean monthly sea surface temperature records for the three areas, 1950-1985.

Taunton-Clark and Shannon (1988) mention that the seasonal signal found in the Namaqualand area is surprising, because the upwelling season in this area (September through to March) coincides with the period of maximum insolation, which could warm up the surface waters, and a flatter response of the seasonal cycle might be expected. The action of a thermal front which sometimes intersects this area, was quoted as a possible reason for this unexpected result. In all three areas the warmest month was found to be January, with August being the coolest (Figure 3.1).

Equatorial wind stress variation seems to decrease from the Namaqualand to the Agulhas Bank area, indicating, perhaps, the more zonal nature of the winds towards the Agulhas Bank (Taunton-Clark and Shannon 1988). Also, there seems to be a tendency in all three areas towards strong southerly winds throughout the year, with northerly winds only being important during the pre-winter and winter months (May to August).

With respect to the westward wind stress, it is highest in the south western Cape area followed by the Agulhas Bank area, the Namaqualand area having the lowest westward wind stress (Figure 3.2). In the Namaqualand area, westerly winds dominate during most all the year, with the exception of March. The westward wind components were found, especially in the Namaqualand and south western Cape areas, to correlate visually with the equatorward wind vectors (Figure 3.2). On the Agulhas Bank, zonality of the winds during all seasons was expected (Lutjeharms and Meeuwis 1987), with changes in the equatorward wind stress mirroring those in the eastward component. In fact the situation in the Agulhas Bank area followed very closely those of the other areas, suggesting that the Agulhas Bank area as defined here is similar to the Namaqualand area because of the arbitrary boundary between the two.

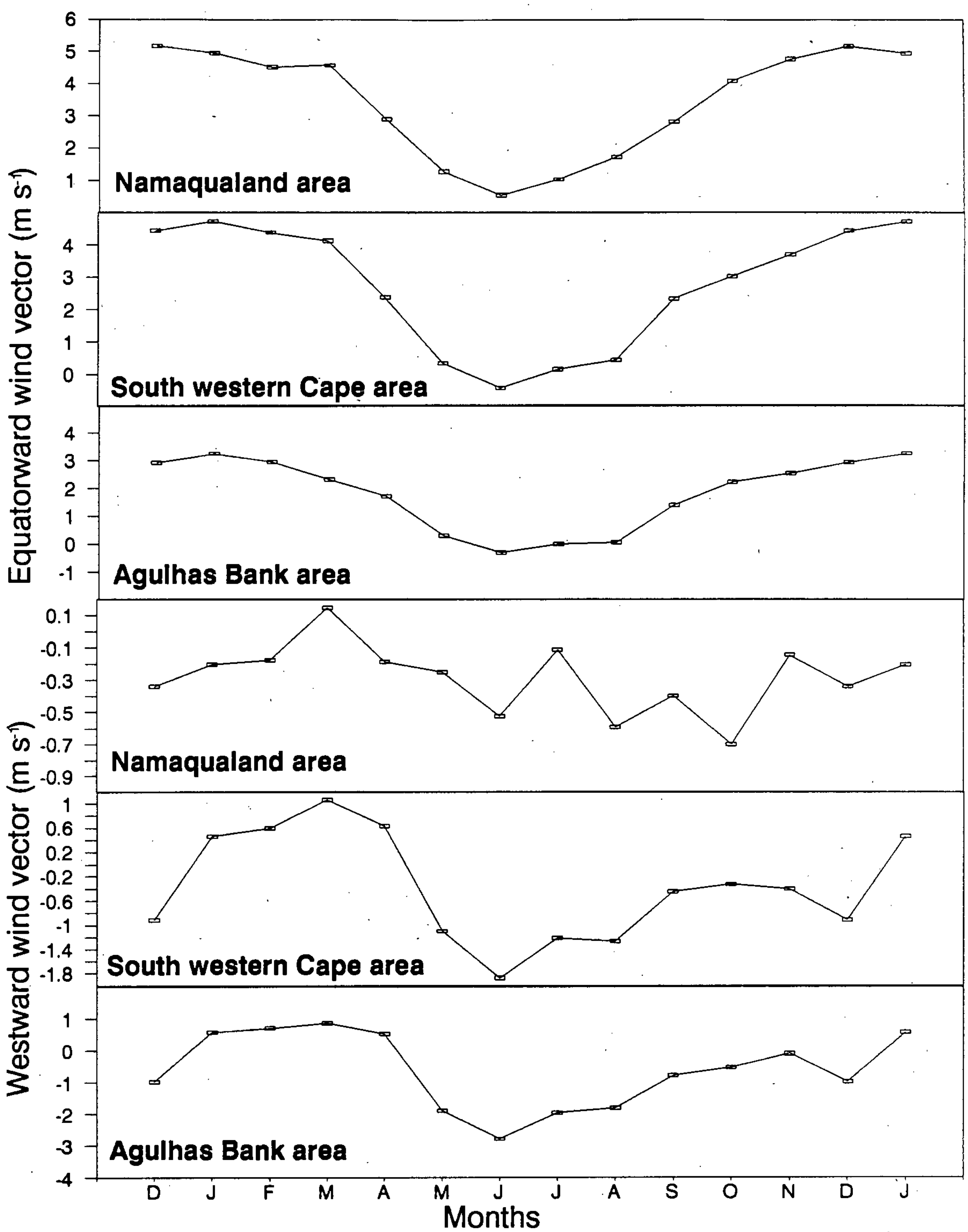


Figure 3.2 Mean monthly Equatorward and Westward wind stress for the three areas, 1940-1985.

Overall, there seems to be some suggestion of a broad summer maximum in all areas and for all vectors, indicating south-easterly winds as being predominant during this season. In winter there are minima in all areas, indicating north westerly wind as being more prevalent.

Interannual variability

Although an overall warming trend in sea surface temperature was established by Taunton-Clark and Shannon (1988) for the South East Atlantic, they found that this trend is only apparent in the open ocean and not in coastal areas. Therefore, as expected, the trend was not apparent in any of the three areas (Figure 3.3).

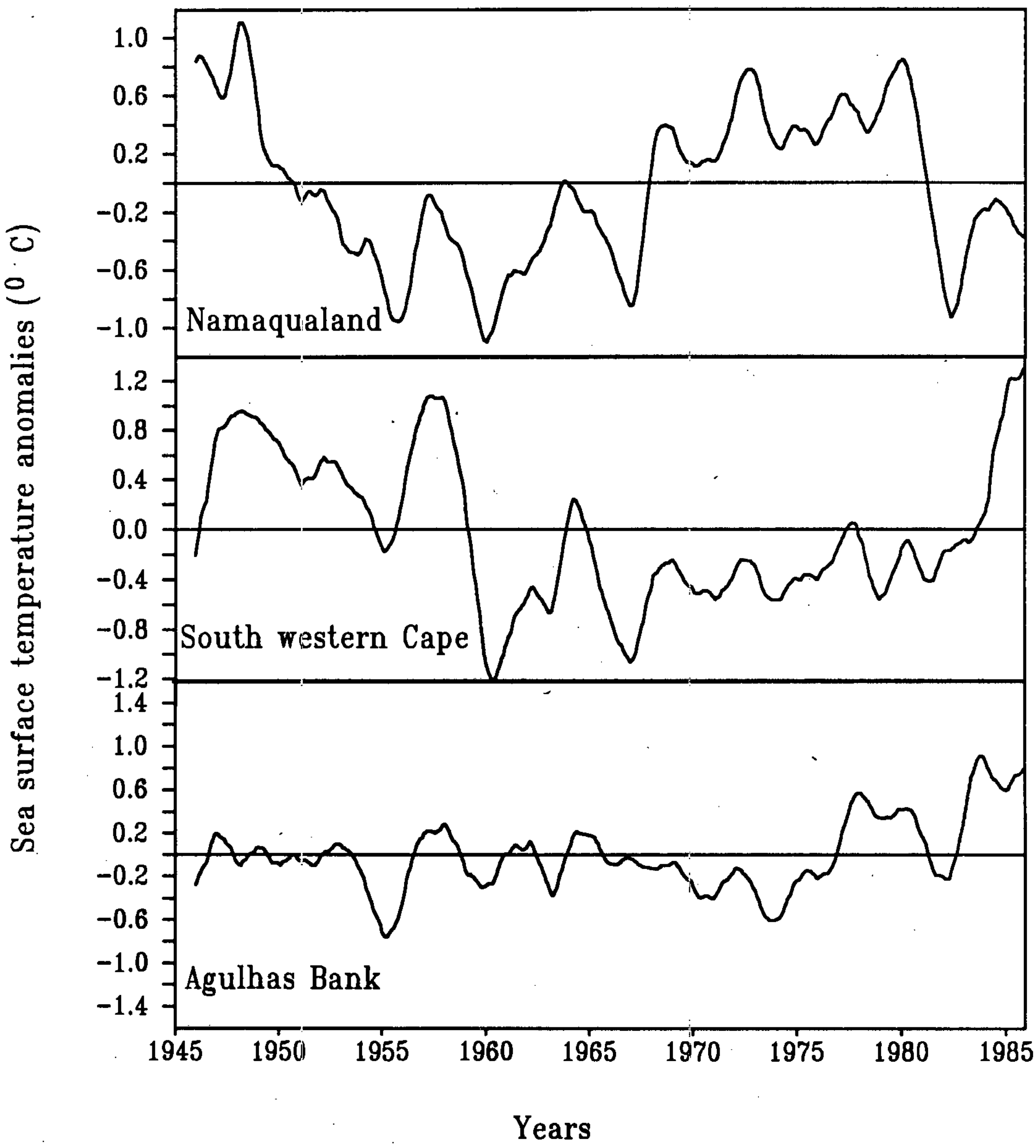


Figure 3.3. 13-point smoothed monthly sea surface temperature (SST) anomalies in all areas.

According to Taunton-Clark and Shannon (1988), there may be "climatic jumps" in sea surface temperature records, which may be hemispheric or global in nature. Unfortunately, due to the primary aim of relating fish catches to climate and due to the short series of catch statistics, the time series of data analyzed here is too short to pinpoint such jumps.

There is no visual correlation between the three data sea surface temperature series (Figure 3.3) and "Benguela Niños" episodic events as shown by Shannon *et al.* (1986) and Taunton-Clark and Shannon (1988). This again suggests that sea conditions, as evidenced by the sea surface temperature record, are confounded nearshore due to a variety of factors. The three data series are in agreement with cold events in evidence during 1955, as well as in 1960, 1967 and 1982. Another point of interest is the fact that the sea surface temperature record for the Agulhas Bank area shows a very flat response, with an increase after 1974 (Figure 3.3).

The 13-point smoothed north-south wind component anomalies record shows an increase trend in both Namaqualand and south western Cape areas, whereas in the Agulhas Bank area the plot describes a more flattened response especially after 1960 (Figure 3.4).

Although there are difficulties in determining the exact nature of the change, it can be seen that the point at which a transition or change of winds takes place, is between 1960 and 1965. Here the winds change from a more northerly to a more southerly direction in the first two areas, while in the Agulhas Bank area the opposite appears to be true. It is interesting to note that this period of change is the one at which the pilchard resource collapsed off South Africa. Hopefully, this relationship will come out in the statistical analysis between the climatic and the pilchard catch variables.

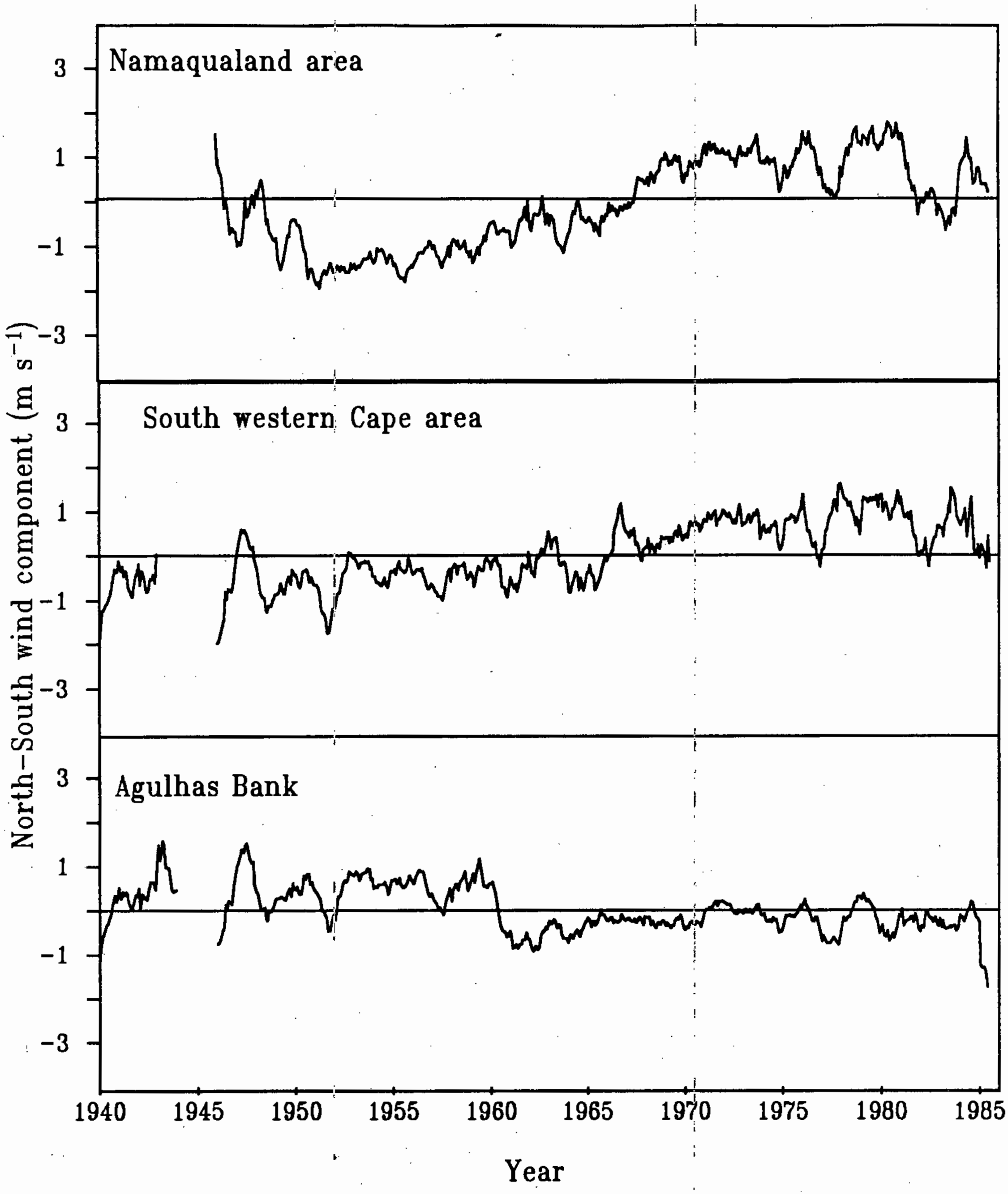


Figure 3.4 13-point smoothed monthly north-south wind component in all areas.

When the smoothed west-east wind component anomalies (Figure 3.5) are investigated, there is no apparent trend in any of the three areas and it is easy to see that the three areas show a great coherence. Furthermore, the west-east wind component appears to follow the north-south component rather closely, not in magnitude but in structure. In all three areas the magnitude of the west-east component is mostly constant throughout the record, indicating that not much variation has taken place during the period of analysis. Nevertheless, it is interesting to note the relatively "westerly years" of 1957, 1962, 1977 and 1983 and the "easterly years" of 1955, 1961, 1974, 1976 and 1985.

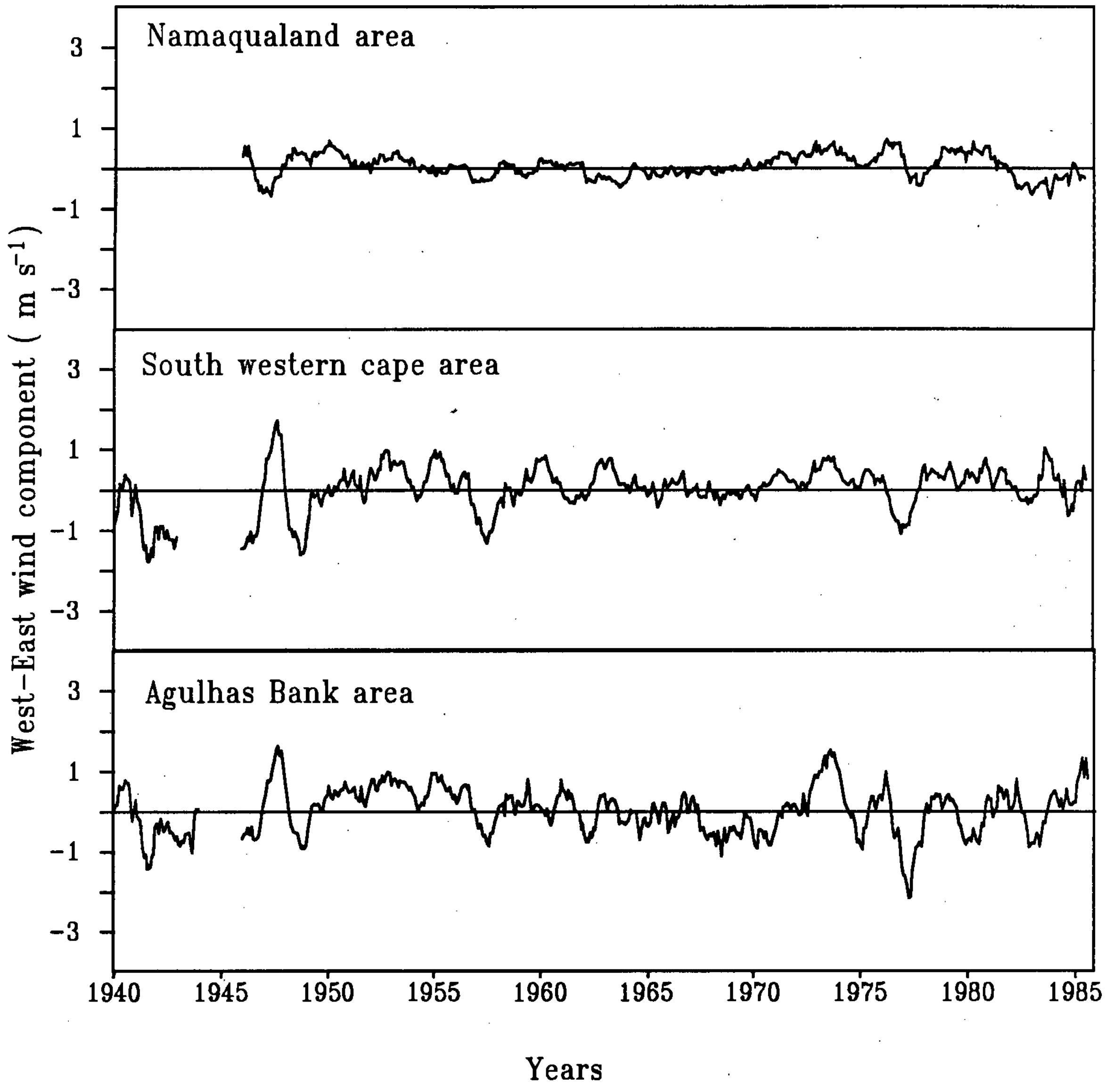


Figure 3.5 13-point smoothed monthly west-east wind component anomalies in all areas.

Fish catch data

Pelagic fish catches are depicted in Figure 3.6. The history of the fishery reflected by the catches has been discussed in section 1.2.

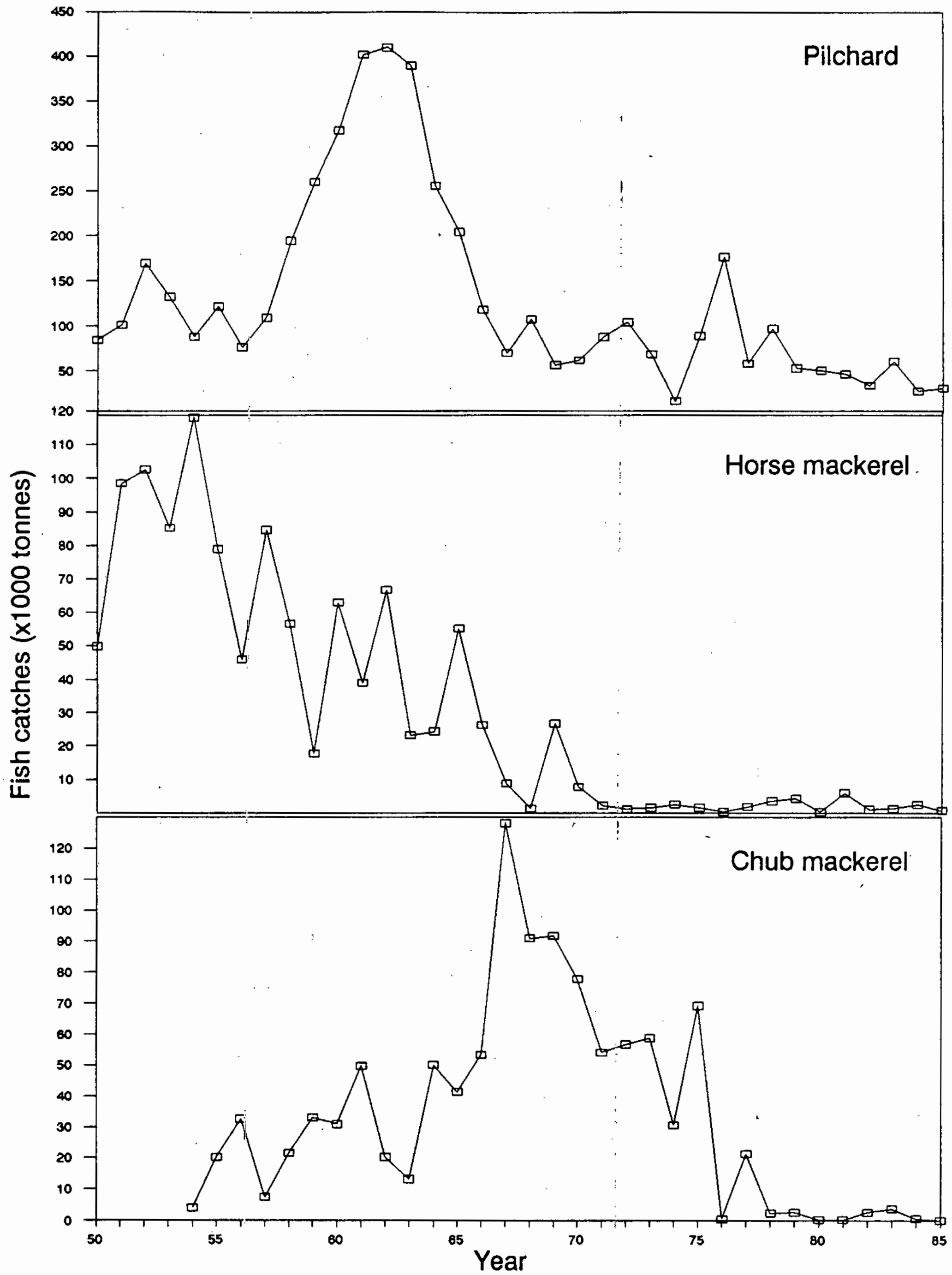


Figure 3.6 Pelagic fish catches (1950-1985) of the three species by the South African fishing industry.

3.5 Autoregressive models

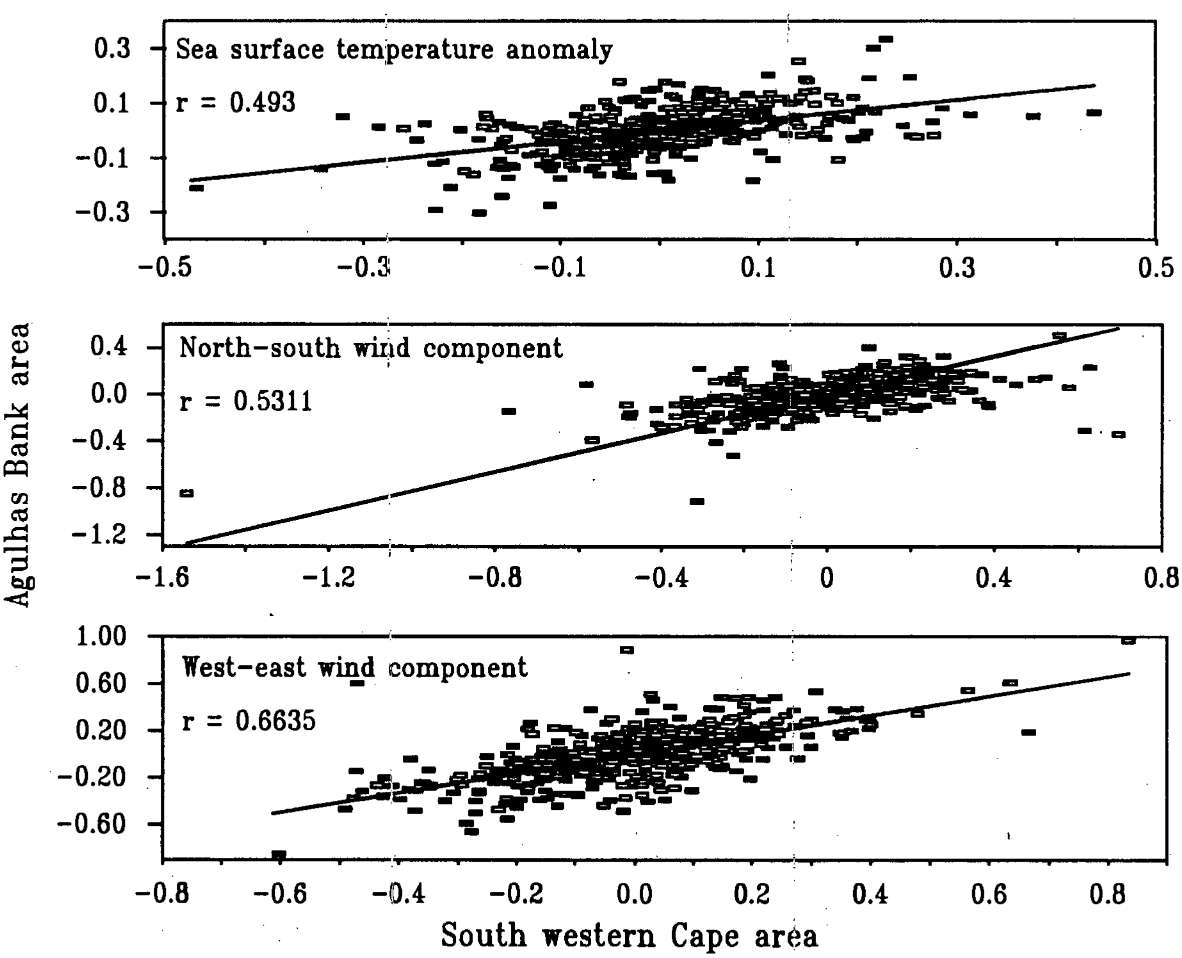
All environmental data series were analyzed, using MicroTsp statistical package on an MS-DOS PC (MicroTSP 1984), for obvious trends and after applying autoregressive models, white noise residuals were obtained. These models are normally of order one or two to account for the correlation relationship between each data series and itself over the one or two previous years, and hence AR(1) and AR(2) models. A constant (C) was also used in the models. The models for the sea surface temperature (SST), north-south wind component (NSW) and west-east wind component (WEW) data series, length of data and the structure removed by the model can be seen in Table 3.3. The models used on the annual fish catches is shown in Appendix 9.3.

Table 3.3 Details of the Auto-regressive (AR) structure and residuals applied to the data series; 1940-1985.

Series	Order of AR model fitted	Coefficients			Structure (%)	Residuals (%)
		Ar(1)	Ar(2)	C		
SST						
Namaqualand	2	1.22	-0.24	-0.11	97	3
SW Cape	2	1.28	-0.29	0.10	97	3
Agulhas Bank	2	1.28	-0.31	0.06	95	5
NSW						
Namaqualand	1	0.99	----	0.05	97	3
SW Cape	1	0.96	----	0.11	92	8
Agulhas Bank	2	1.18	-0.17	0.49	95	5
WEW						
Namaqualand	2	0.87	0.06	0.07	85	15
SW Cape	2	1.05	-0.13	0.12	87	13
Agulhas Bank	2	1.09	-0.17	0.14	86	14

In all cases there seems to be a better agreement between the environmental variables of the south western Cape and Agulhas Bank areas, than any with the Namaqualand area.

The cross-correlations between all variables of the south western Cape and the Agulhas Bank area are shown in Figure 3.7. All three cross-correlations are significant at the 99 % level, indicating a very good coherence between environmental variables in these two areas. This effect is immediate, since the highest and only significant cross-correlation has a no lag value.



<u>Figure 3.7</u> Relationships between the south western Cape and Agulhas Bank areas for monthly (1940-1985) sea surface temperature (SST), north-south wind and west-east wind component; n = 478 observations.

The relationships amongst environmental variables were found to be immediate in that the highest cross-correlation was at the no lag value. The values of the cross-correlations can be seen in Table 3.4.

<u>Table 3.4</u> Cross-correlations coefficients between monthly environmental variables. T (sea surface temperature), N (North-South wind component), W (West-East wind component), P is the probability with 476 degrees of freedom. Suffixes 1,2 and 3 refer to the different areas.

Data series	r	P
T1 vs N1	-0.0446	n.s.
T1 vs W1	-0.0217	n.s.
T2 vs N2	-0.0217	n.s.
T2 vs W2	-0.1956	P< 0.001
T3 vs N3	0.0862	n.s.
T3 vs W3	-0.1014	P< 0.050
N1 vs W1	0.5277	P< 0.001
N2 vs W2	0.4686	P< 0.001
N3 vs W3	0.3508	P< 0.001
T1 vs T2	0.3607	P< 0.001
T1 vs T3	0.2703	P< 0.001
T2 vs T3	0.4930	P< 0.001
N1 vs N2	0.1452	P< 0.002
N1 vs N3	0.2330	P< 0.001
N2 vs N3	0.5311	P< 0.001
W1 vs W2	0.2290	P< 0.001
W1 vs W3	0.3676	P< 0.001
W2 vs W3	0.6635	P< 0.001

From Table 3.4, it is easy to see that there is a greater degree of coherence between the south western Cape and Agulhas Bank areas than either of these areas with the Namaqualand area. It is also important to note that the correlation between sea surface temperatures and any of the wind components are mostly non-significant, but very significant between the two wind components (Table 3.4).

The relationships between North-South and West-East wind components for all areas are illustrated in Figure 3.8.

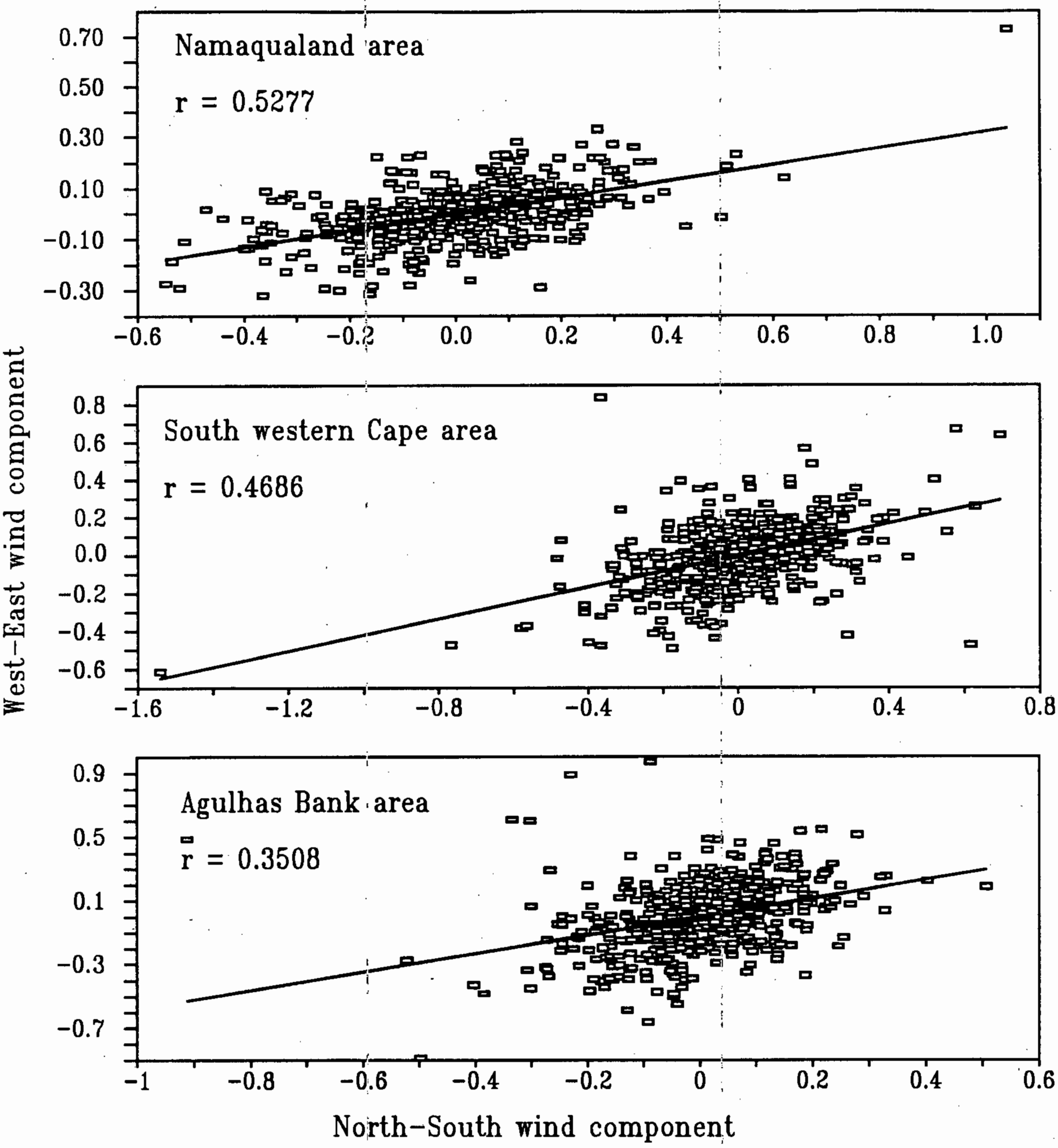


Figure 3.8 Relationship between monthly (1940-1985) north-south and west-east wind components for all areas; n = 478 observations.

All three areas show a positive relationship between North-South and West-East wind component, indicating immediate (0 lag) and simultaneous changes in both vectors in the same direction.

Environmental versus fish catches

Table 3.5 depicts the cross-correlation coefficients at the appropriate lags between sea surface temperature anomalies and pelagic fish catches white noise residuals, i.e. after the autoregressive models were applied. There are no significant relationships between pilchard and sea surface temperature in any of the three areas. A significant relationship between sea surface temperature and horse mackerel is evident in the Namaqualand area. The relationship is an immediate one, and it indicates that an increase in horse mackerel catches is experienced with a decrease in sea surface temperature.

Table 3.5. Cross-correlations between annual sea surface temperature anomalies residuals (t) in all three areas(1-3) and annual pelagic fish catch residuals, for the first three lags (0-2).

	Lag	t1	t2	t3
Pilchard	0	0.0539	-0.1944	0.0139
	1	-0.1131	0.2072	0.0524
	2	-0.2777	-0.1759	-0.2730
Horse mackerel	0	-0.3448*	-0.2515	-0.1046
	1	0.1470	0.1379	0.2429
	2	0.0821	0.2360	-0.0796
Chub mackerel	0	-0.1690	-0.0643	0.1199
	1	-0.4100**	-0.2764	-0.4277**
	2	-0.0783	-0.0424	-0.2565

** $P<0.025$
* $P<0.050$

With regard to chub mackerel, significant relationships at the 2.5 % level, were found between catches and sea surface temperatures in the Namaqualand and Agulhas Bank areas. Both relationships are negative and show one year lag, indicating a favouring of chub mackerel catches with decreased temperatures the previous year. In fact, the majority of relationships significant or not, are negative, suggesting that chub mackerel catches are better with a below than average sea surface temperature.

Regarding the north-south wind component, there is only one significant relationship between pilchard catches and north-south wind components (Table 3.6) in the Agulhas Bank area. Nevertheless, the cross-correlation coefficients between pilchard catches and the wind component in the south western Cape and Agulhas Bank areas, with one year lag is almost significant (P< 0.1), and most importantly negative. This may suggest improved pilchard catches with northerly winds the previous year.

Table 3.6 Cross-correlations between annual north-south wind component residuals (n) in all three areas (1-3) and annual pelagic fish catch residuals for the first three lags (0-2).

	Lag	n1	n2	n3
Pilchard	0	0.0353	0.1491	0.0609
	1	-0.2449	-0.3377	-0.3621*
	2	0.0740	0.1690	-0.1052
Horse mackerel	0	-0.1426	-0.2085	0.0310
	1	-0.0615	-0.0784	-0.2140
	2	-0.0806	0.0906	-0.2138
Chub mackerel	0	-0.3726*	-0.5354***	0.0994
	1	-0.3132	-0.0611	-0.2576
	2	0.0479	0.0488	-0.1331

*** P<0.002
* P<0.050

Horse mackerel catches are non-significantly correlated with north-south wind components, but there again the signs of the cross-correlations are overwhelmingly negative, indicating a similar result to that of pilchard. Chub mackerel catches, however, are very significantly correlated with the north-south wind component in the Namaqualand and south western Cape areas, the second one being very significant at the 0.2 % level. This relationship and the first one are both negative, suggesting above average chub mackerel catches with northerly winds in these areas. Chub mackerel catches came primarily from the south western Cape area, but also in a lesser amount from the Namaqualand area, and this result may indicate that wind conditions do in fact affect either the distribution of chub mackerel, perhaps making them more available to the fishery by migrating onshore, or a beneficial effect by the influence of northerly winds on abundance.

Table 3.7 Cross-correlations between annual west-east wind component residuals (w) in all three areas (1-3) and annual pelagic fish catch residuals for the first three lags (0-2).

	Lag	w1	w2	w3
Pilchard	0	0.0896	0.1680	0.0922
	1	-0.3155	-0.1310	-0.2492
	2	0.0566	0.0709	0.2988
Horse mackerel	0	-0.0237	0.1543	0.0645
	1	-0.0649	-0.1322	-0.0566
	2	0.0397	0.0933	0.0937
Chub mackerel	0	0.0025	0.2847	-0.1849
	1	-0.1647	-0.0214	0.0306
	2	-0.0225	0.0474	0.0209

The relationships between west-east wind component and fish catches are presented in Table 3.7. None of the three species was significantly correlated with the west-east wind component. However, there is a negative, but non-significant at the 5 % level, correlation between pilchard catches and Namaqualand west-east wind component. Indicating favouring of pilchard catches with westerly winds. Since pilchard are most abundant in that area towards autumn and winter, this effect may simply reflect the fact of the most common winter direction of those winds i.e. westerly and northerly (Table 3.6). With regard to chub mackerel the highest cross-correlation is found in the south western Cape area, with no lag.

CHAPTER 4

SIMPLE SPEARMAN RANK CORRELATION ANALYSES

correlations, even quite "significant" ones, but it is necessary to be cautious in deducing causal relationships from them. It is well known, for example, that correlations between "time series" are particularly likely to be accidental (involve no causal relationship) when both quantities have a unidirectional trend over a period of years. A correlation is more likely to have meaning when the two quantities vary the direction of their trend in parallel fashion. However, even these cases sometimes prove to be related (if at all) by way of some third factor, whose mode of operation may be unknown and whose very existence is at first unsuspected.

4.2 Methods

Each species catch and environmental data series was smoothed using a three-year running mean (Wooster 1988). The method of smoothing and filtering of the environmental data series has been described in section 3.3. The fish catches were first correlated with all months in all areas. Then the species catches were correlated with combination of months, for reasons already explained. It was realized that the pooled months analyses did not normally resulted in any new relationships, but merely confirmed the individual months results. Therefore, only the individual months analyses are presented here. The pooled months analysis results are presented in Appendix 9.1.

4.3 Results and Discussion

Although all correlations with respect to fish species, areas and months were calculated (Appendix 9.1), only the largest correlation coefficient for each month is displayed in this section. Emphasis will be placed on those areas and months where the fish stock is thought to occur. For example for pilchard, in the south coast analysis, the emphasis will be in those months which relate to the spawning season, when the fish are present in this area.

4.3.1 Pilchard and environmental variables

Namaqualand area and pilchard catches

The largest correlation coefficients with regard to pilchard catch and sea surface temperature have negative signs in the analysis by individual month for the Namaqualand area (Figure 4.1). Thus, a decrease in temperature appears to relate to an increase in pilchard catches. This response has a predominant 4-5 year lag from January to May, a 2 year lag in June, and a 6 year lag from September to December (Table 4.1).

It is important to note that during July and August the largest correlation occurs at the no lag correlation (Table 4.1), indicating an immediate effect of the sea surface temperature on the catch of pilchard, precisely at the time when pilchard is supposed to be present in this area (Crawford 1981d). It is, therefore, an immediate response of the pilchard catch to temperature immediately after the recruitment months, in the recruitment area.

The fact that up to the collapse of the pilchard population in the early 1960s, main catches were made up of 4 and 5 year-old fish (Table 1.2) could account for the prevalence of the 4 and 5 year lag in the results from the month of January to May.

Of interest is the fact that Shannon *et al.* (1988) also found a negative relationship for the Namibian pilchard in the same time period. They reasoned that this effect, to them unexpected, could be explained due to the persistent appearance of Benguela Niños which are evident in the record of the Namibian coastal zone (Taunton-Clark and Shannon 1988). Although the Benguela Niños are not so evident in the South African coastal sea surface temperature record (Shannon *et al.* 1988), it is possible that their effects may still be felt in the Namaqualand area, therefore accounting for the negative sign of the correlation.

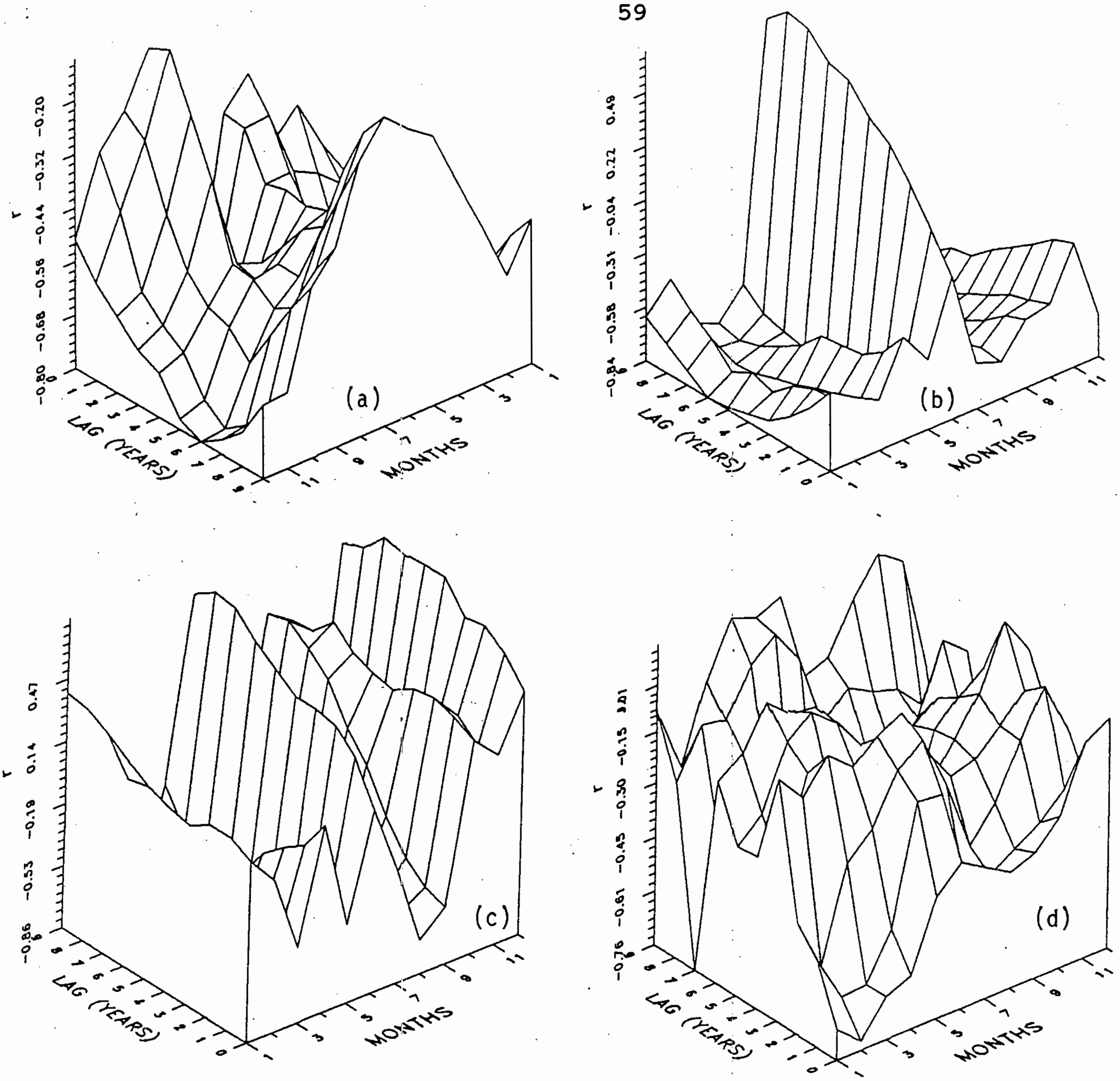


Figure 4.1 Three dimensional representation of Spearman rank correlation coefficients (r_s) of annual pilchard catches in the Namaqualand area, versus monthly (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

Table 4.1 Spearman Rank correlation coefficient (r_s), significance (P)(to two decimal places) and lag of the largest correlations between annual pilchard catches and monthly environmental variables in the Namaqualand area .

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.76	0.00	4	-0.84	0.00	6	0.39	0.04	9	-0.67	0.00	0
February	-0.75	0.00	5	-0.77	0.00	6	0.18	n.s.	9	-0.73	0.00	0
March	-0.75	0.00	5	-0.84	0.00	7	-0.54	0.00	3	-0.64	0.00	1
April	-0.71	0.00	4	-0.86	0.00	8	-0.86	0.00	9	-0.61	0.00	0
May	-0.56	0.00	4	-0.81	0.00	6	-0.75	0.00	6	-0.41	0.05	0
June	-0.48	0.01	2	0.70	0.00	8	0.73	0.00	8	-0.50	0.05	7
July	-0.73	0.00	0	-0.83	0.00	7	-0.26	n.s.	8	-0.47	0.03	1
August	-0.64	0.00	0	-0.82	0.00	8	-0.68	0.00	0	-0.47	0.03	1
September	-0.57	0.00	6	-0.78	0.00	9	-0.55	0.00	0	-0.43	0.05	1
October	-0.67	0.00	6	-0.83	0.00	9	0.43	0.02	7	-0.38	n.s.	1
November	-0.79	0.00	6	-0.77	0.00	9	-0.53	0.01	9	-0.32	n.s.	1
December	-0.80	0.00	6	-0.83	0.00	8	0.77	0.00	4	-0.66	0.02	8

The north-south wind component correlation coefficients are all negative , with the exception of the month of June (Figure 4.1b). Overall, therefore, the negative correlation indicate northerly winds as being important in this area throughout the year. For the west-east wind component (Figure 4.1c), June together with October, December, January and February are positive while the rest of the months highest correlation coefficients are negative. During the recruitment and post-recruitment months (May to September, with the exception of June) northerly and westerly wind directions tend to favour larger catches. With regard to lags, the highest correlation coefficients are based around long lags (6-9) for the equatorward wind component (north-south), but for the west-east wind component, the lags vary widely. However, it is important to note that there is a no lag value for the west-east wind component found during the months of August and September, the latter months being very significant , i.e. an immediate response. Furthermore, although the pattern does not hold with regard to the N/S wind-component which highest correlation coefficient is found in December with a six year lag, cognizance has to be taken of the fact that during the months of June to August, the 0 lag correlation coefficient is at first higher, decreasing in magnitude, and increasing again to the high values found at longer lags (Appendix 9.1). According to Crawford (1981d), this is not unreasonable, as juvenile pilchard migrate, from the Namaqualand to the south western Cape area during late winter and spring. Furthermore, there seems to be a portion of the 0-year-old cohort which remains in this northern area.

Overall, therefore, it would appear that although the evidence cannot be substantiated, there is a tendency for the relationship with winds in the recruitment area in the post-recruitment months to be centered around the no-lag relation with north-westerly wind being generally favourable.

With regard to sea level the correlation is also highly significant and negative (Figure 4.1d), having the highest correlations in the months of December to April (Table 4.1). These negative correlations indicate that larger catches of pilchard are obtained when a lowering of the sea level takes place, i.e. during upwelling. Thus catches of pilchard should increase in years in which there has been an increase in upwelling (from December to April). During late winter and early spring months (July to September) the correlation coefficients are significantly negative with a lag of one year. This pattern continues through the months of October and November, but the relationship is not significant.

South western Cape area and pilchard catches

The relationship between pilchard catches and sea surface temperature shows a highly significant negative value for the recruitment months (May-August) as shown in Figure 4.2a, but overall the positive sign prevails (see Appendix 9.1).

Table 4.2 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual pilchard catches and monthly environmental variables in the south western Cape area.

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	0.64	0.00	9	-0.84	0.00	7	0.75	0.00	2	0.66	0.02	3
February	0.75	0.00	9	-0.81	0.00	1	0.58	0.00	8	0.66	0.02	3
March	0.76	0.00	9	-0.87	0.00	9	0.45	0.02	8	-0.68	0.04	7
April	0.76	0.00	9	-0.80	0.00	8	-0.44	0.02	9	-0.50	n.s.	7
May	0.66	0.00	9	-0.55	0.00	3	-0.69	0.00	5	0.48	n.s.	3
June	0.57	0.01	9	0.54	0.01	9	-0.47	0.02	9	0.43	n.s.	3
July	0.63	0.00	7	0.43	0.01	1	0.47	0.01	1	0.57	0.03	3
August	0.68	0.00	8	-0.74	0.00	6	-0.39	0.03	3	-0.47	n.s.	8
September	0.74	0.00	8	-0.75	0.00	5	-0.43	0.01	2	-0.46	n.s.	8
October	0.71	0.00	9	-0.69	0.00	1	0.45	0.02	8	0.57	0.03	3
November	0.68	0.00	9	-0.77	0.00	9	-0.42	0.01	1	0.66	0.01	4
December	0.65	0.00	8	-0.90	0.00	8	0.68	0.00	0	0.61	0.03	4

In the north-south wind component correlations, the relationship is highly negative, except for the months of May and June, in which a reversal of the largest significant correlation occurs (Figure 4.2b). About half the west-east wind component correlations are negative and the other half positive (Figure 4.2c).

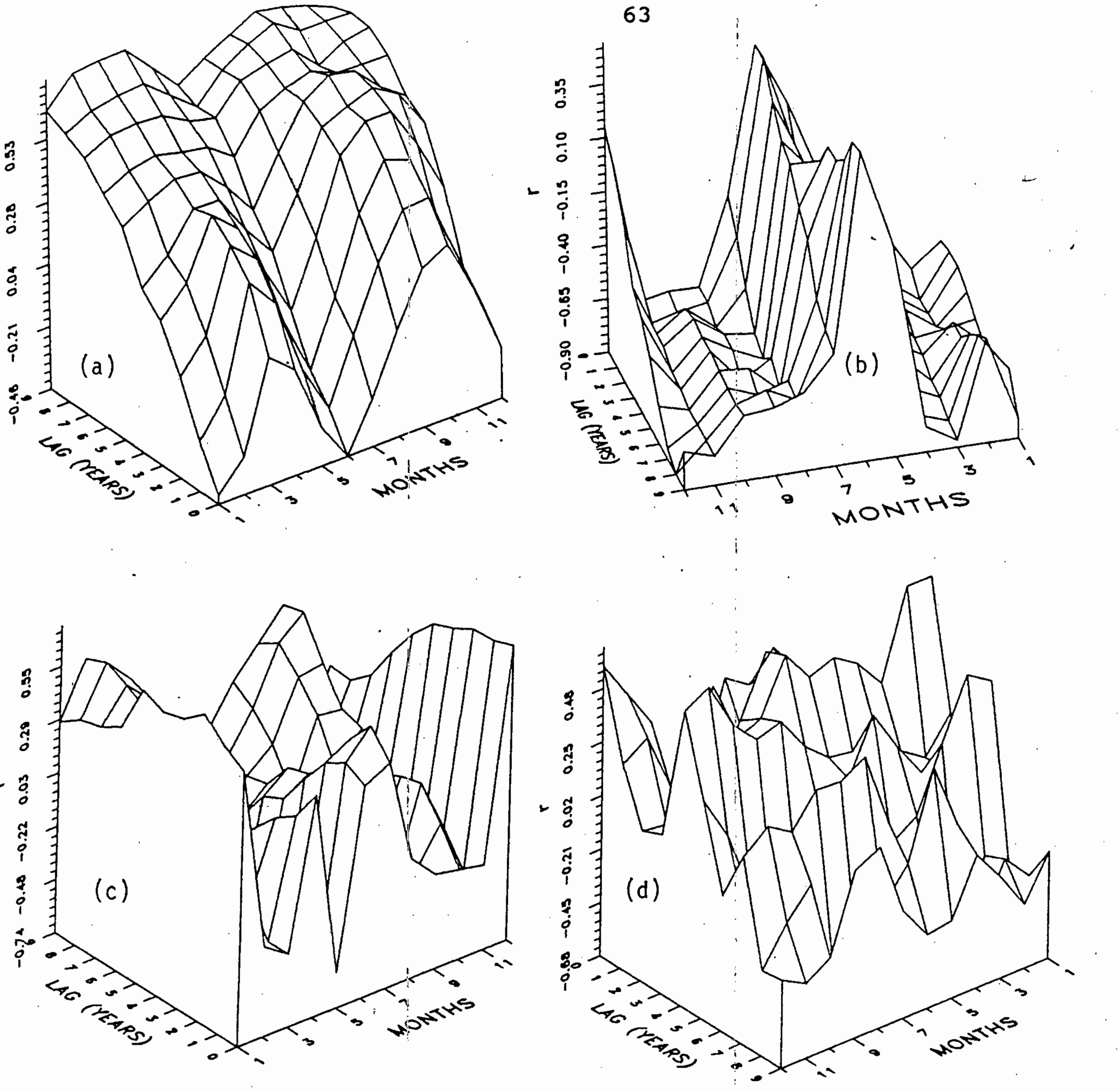


Figure 4.2 Three dimensional representation of Spearman rank correlation coefficients (r_s) of annual pilchard catches in the south western Cape area, versus monthly (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

There is a positive sign from December to March and the months of July and October, while the rest are negative (Table 4.2). Correlations between sea level and pilchard catches are positive except in March-April and August-September (Figure 4.2d; Table 4.2).

These results indicate that in the winter months, when the main fish shoals are present in this area, catches are favoured by higher sea surface temperatures, higher sea level and south westerly winds. The lags do not show any coherence, having a wide range of values, and do not give a clear picture.

The way the lags are distributed, however, shows that in the recruitment months (May-July) the correlations are high and significant at the 0-lag or one year lag, decreasing as the lag period increases but increasing yet again at longer lags (Appendix 9.1).

Agulhas Bank area and pilchard catches

Sea surface temperature correlations with pilchard catches show a negative response in the summer months and a positive one in the winter months (Figure 4.3a). It suggests, therefore, increased catches with lower temperatures in the summer months, when fish are present in this area. There is also a negative response of pilchard catches with regard to sea level (Figure 4.3d), showing larger pilchard catches with a lowering of sea level. The lags in this analysis are long and explanation is difficult (Table 4.3).

Wind component correlations with pilchard catches in this area show a positive north-south wind component correlation sign (Figure 4.3b) as well as a negative west-east wind component correlation for the months of November to April, with the exception of December (Figure 4.3c). This indicates a south-westerly wind combination as more important.

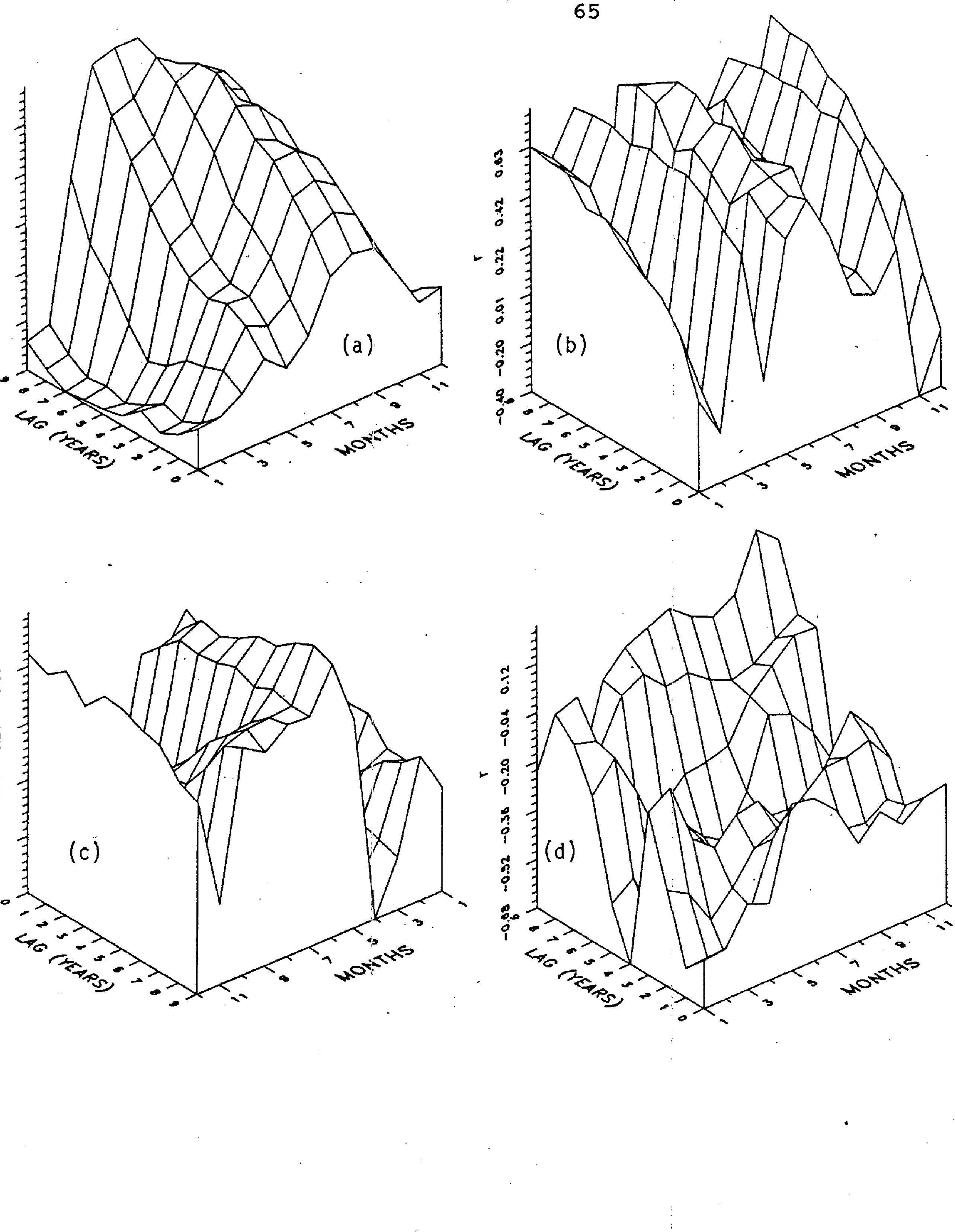


Figure 4.3 Three dimensional representation of Spearman rank correlation coefficients (r_s) of annual pilchard catches in the Agulhas Bank area, versus monthly (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

Table 4.3 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual pilchard catches and monthly environmental variables in the Agulhas Bank area.

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.80	0.00	7	0.6331	0.00	9	-0.1511	n.s.	0	-0.6784	0.00	4
February	-0.79	0.00	5	0.5440	0.01	9	-0.5238	0.00	0	-0.5785	0.01	1
March	-0.63	0.00	5	0.73	0.00	5	-0.37	n.s.	9	-0.63	0.00	1
April	0.62	0.00	9	-0.24	n.s.	9	-0.66	0.00	9	-0.64	0.00	4
May	0.65	0.00	9	0.77	0.00	8	0.53	0.00	0	-0.53	0.01	4
June	0.65	0.00	9	0.79	0.00	7	0.89	0.00	8	-0.53	0.01	5
July	0.59	0.00	6	0.63	0.00	2	0.64	0.00	7	-0.66	0.00	5
August	0.44	0.03	5	-0.38	0.04	6	0.62	0.00	9	-0.55	0.01	4
September	0.39	0.04	8	0.55	0.00	8	0.58	0.00	8	-0.42	0.03	1
October	-0.27	n.s.	4	0.69	0.00	5	0.60	0.00	9	-0.46	0.03	1
November	-0.79	0.00	8	0.42	0.03	7	-0.26	n.s.	1	-0.52	0.01	5
December	-0.76	0.00	7	0.74	0.00	9	0.68	0.00	2	-0.60	0.00	5

4.3.2 Horse Mackerel and environmental variables

Namaqualand area and horse mackerel catches

The correlations of annual horse mackerel catches with monthly environmental variables are negative for most months and all variables, indicating a rise in catches with cooler conditions as a result of the relationship with sea surface temperature and sea level (Figures 4.4a, d).

Table 4.4 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual horse mackerel catches and monthly environmental variables in the Namaqualand area .

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.76	0.00	3	-0.86	0.00	3	0.51	0.00	9	-0.72	0.01	5
February	-0.81	0.00	4	-0.69	0.00	4	0.31	n.s.	0	-0.65	0.00	0
March	-0.77	0.00	3	-0.93	0.00	3	-0.52	0.00	3	-0.43	0.05	3
April	-0.68	0.00	3	-0.95	0.00	8	-0.94	0.00	7	-0.36	n.s.	0
May	-0.57	0.00	4	-0.85	0.00	6	-0.60	0.00	4	-0.28	n.s.	3
June	-0.40	0.03	4	0.60	0.00	5	0.65	0.00	1	-0.30	n.s.	3
July	-0.57	0.00	0	-0.89	0.00	0	-0.55	0.00	0	-0.45	0.04	0
August	-0.56	0.00	0	-0.95	0.00	0	-0.75	0.00	0	-0.46	0.04	0
September	-0.44	0.02	5	-0.96	0.00	7	0.21	n.s.	9	-0.41	0.05	0
October	-0.53	0.00	5	-0.96	0.00	9	0.59	0.00	0	-0.27	n.s.	3
November	-0.80	0.00	4	-0.94	0.00	9	-0.69	0.00	9	-0.16	n.s.	4
December	-0.84	0.00	6	-0.98	0.00	2	0.86	0.00	1	-0.46	n.s.	6

It also shows a preference for larger catches with north-westerly winds (Figures 4.4b, c).

It is important to note that in late winter, i.e. July and August, the relationship between horse mackerel catches and environmental variables shows an immediate and negative response of the catches to all environmental variables (Table 4.4). This may reveal an important effect of the environment on the fish just before spawning takes place. Also, it is important to note that in that area, the catches of 3-7-year-old horse mackerel are very important in the late summer to mid winter months (Crawford 1981b). According to Macer (1974), horse mackerel do not spawn until they are three or four years old.

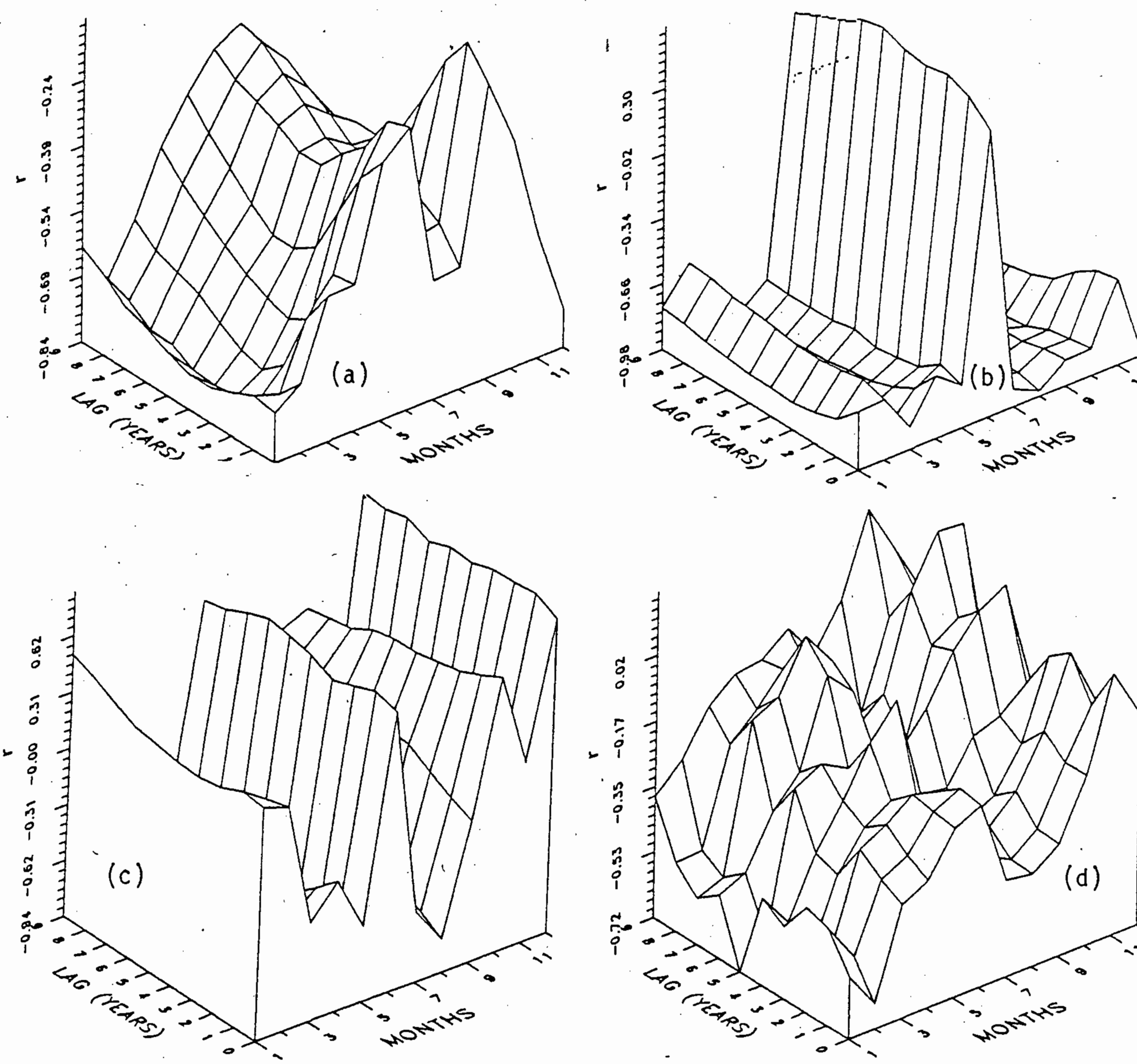


Figure 4.4 Three dimensional representation of Spearman rank correlation coefficients (r_s) of annual horse mackerel catches in the Namaqualand area, versus monthly (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

If one looks at the correlation coefficients, there is an agreement in a three year lag in March for all environmental variables (Table 4.4). This may indicate that conditions in the ocean, represented by these environmental variables, influence the 0-year-old class. The effect on the catch, however, is only apparent three years later.

South western Cape area and horse mackerel catches

The correlation coefficient signs for the relationship between horse mackerel catches and sea surface temperature are positive (Figure 4.5a), indicating a preferential increase in catches with higher temperatures within the temperature range. The increase in catch also appears to be positively related to the sea level correlations, except for the first three months, when the relationship is negative (Table 4.5). The lags in the sea surface temperature relationship show maximal correlations at eight and nine year lags (Table 4.5).

North-south wind component correlations with horse mackerel catches are negative with the exception of the late autumn and early winter months (Figure 4.5b). The opposite is true for the west-east association, which is positive in the summer months and negative in the autumn and early winter months (Figure 4.5c).

Although Geldenhuys (1973) indicated the spawning season to be in the winter months, according to the availability of large fish, plankton surveys indicate (Crawford 1981b), that spawning of horse mackerel also occurs in this area from spring to early summer.

In the horse mackerel catches and north-easterly wind and west-east wind correlations from the south western Cape area, very high correlations are based around the 0-lag association. This is important since according to Crawford (1981b), 0-year-old fish are most abundant in that area in the summer months with a peak in January.

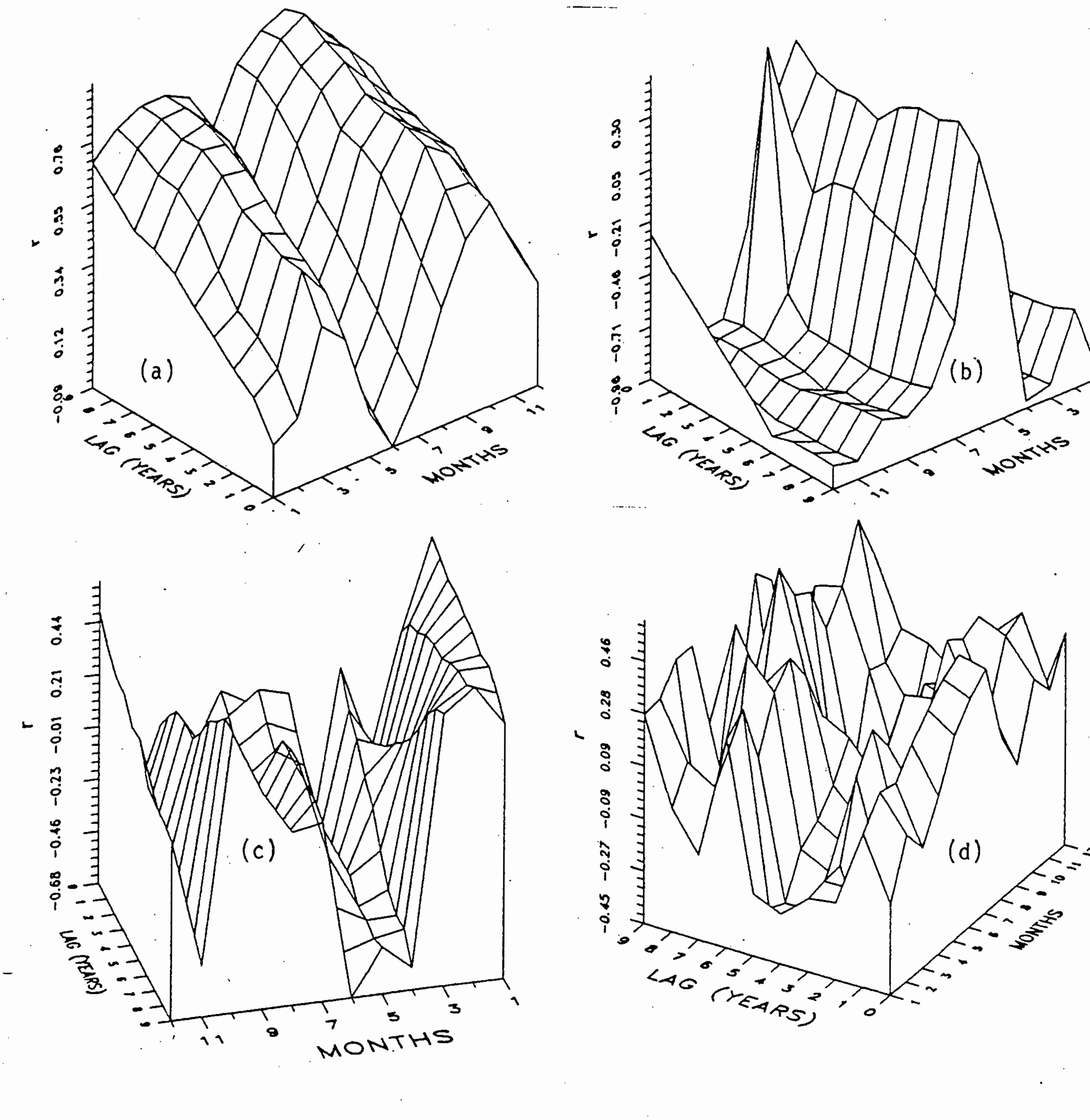


Figure 4.5 Three dimensional representation of Spearman rank correlation coefficients (r_s) of annual horse mackerel catches in the south western Cape area, versus monthly (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

Table 4.5 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual horse mackerel catches and monthly environmental variables in the south western Cape area .

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	0.69	0.00	9	-0.96	0.00	0	0.61	0.00	0	-0.28	n.s.	4
February	0.77	0.00	9	-0.83	0.00	0	0.58	0.00	9	-0.34	n.s.	4
March	0.81	0.00	9	-0.96	0.00	1	0.48	0.01	9	-0.45	n.s.	2
April	0.81	0.00	8	-0.93	0.00	8	-0.58	0.00	9	0.39	n.s.	7
May	0.77	0.00	9	-0.20	n.s.	6	-0.62	0.00	0	0.30	n.s.	1
June	0.63	0.00	9	0.45	0.02	8	-0.68	0.00	9	0.60	n.s.	7
July	0.82	0.00	9	-0.41	0.04	9	0.14	n.s.	6	0.42	n.s.	1
August	0.91	0.00	8	-0.75	0.00	6	-0.11	n.s.	4	0.39	n.s.	2
September	0.96	0.00	8	-0.87	0.00	5	0.24	n.s.	9	0.35	n.s.	2
October	0.85	0.00	9	-0.84	0.00	0	0.51	0.01	8	0.38	n.s.	2
November	0.77	0.00	9	-0.96	0.00	0	-0.40	0.02	0	0.53	n.s.	7
December	0.65	0.00	9	-0.89	0.00	6	0.48	0.05	0	0.37	n.s.	7

Agulhas Bank area and horse mackerel catches

The relationship between horse mackerel catches and sea surface temperature is highly significant and negative in the summer months (November to February) and positive for the rest of the year (Figure 4.6a).

The correlations between north-south and west-east wind components are positive with the exception of the summer months in the west-east relationship, which are negative

(Figures 4.6 b, c). Sea level correlates negatively with horse mackerel catches (Figure 4.6d).

Table 4.6 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual horse mackerel catches and monthly environmental variables in the Agulhas Bank area .

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.88	0.00	1	0.76	0.00	9	-0.40	0.01	0	-0.54	0.01	0
February	-0.88	0.00	2	0.49	0.01	7	-0.26	n.s.	0	-0.51	0.01	0
March	-0.55	0.00	0	0.87	0.00	0	-0.59	0.00	7	-0.62	0.01	7
April	0.60	0.00	9	-0.46	0.02	8	-0.73	0.00	7	-0.57	0.00	0
May	0.60	0.00	9	0.89	0.00	0	0.71	0.00	0	-0.42	0.04	3
June	0.76	0.00	8	0.88	0.00	0	0.91	0.00	5	-0.44	0.04	4
July	0.76	0.00	8	0.64	0.00	4	0.81	0.00	8	-0.54	0.01	4
August	0.72	0.00	8	-0.24	n.s.	6	0.71	0.00	9	-0.51	0.01	0
September	0.70	0.00	8	0.54	0.00	0	0.54	0.01	9	-0.45	0.02	0
October	-0.38	0.03	0	0.72	0.00	3	0.55	0.00	6	-0.42	0.03	0
November	-0.87	0.00	0	0.39	0.04	9	-0.31	n.s.	0	-0.32	n.s.	0
December	-0.85	0.00	1	0.80	0.00	9	0.71	0.00	0	-0.42	0.03	0

The results, therefore, suggest an increment in horse mackerel catches with increased temperatures, with north-westerly winds and with a decrease in sea level (Table 4.6).

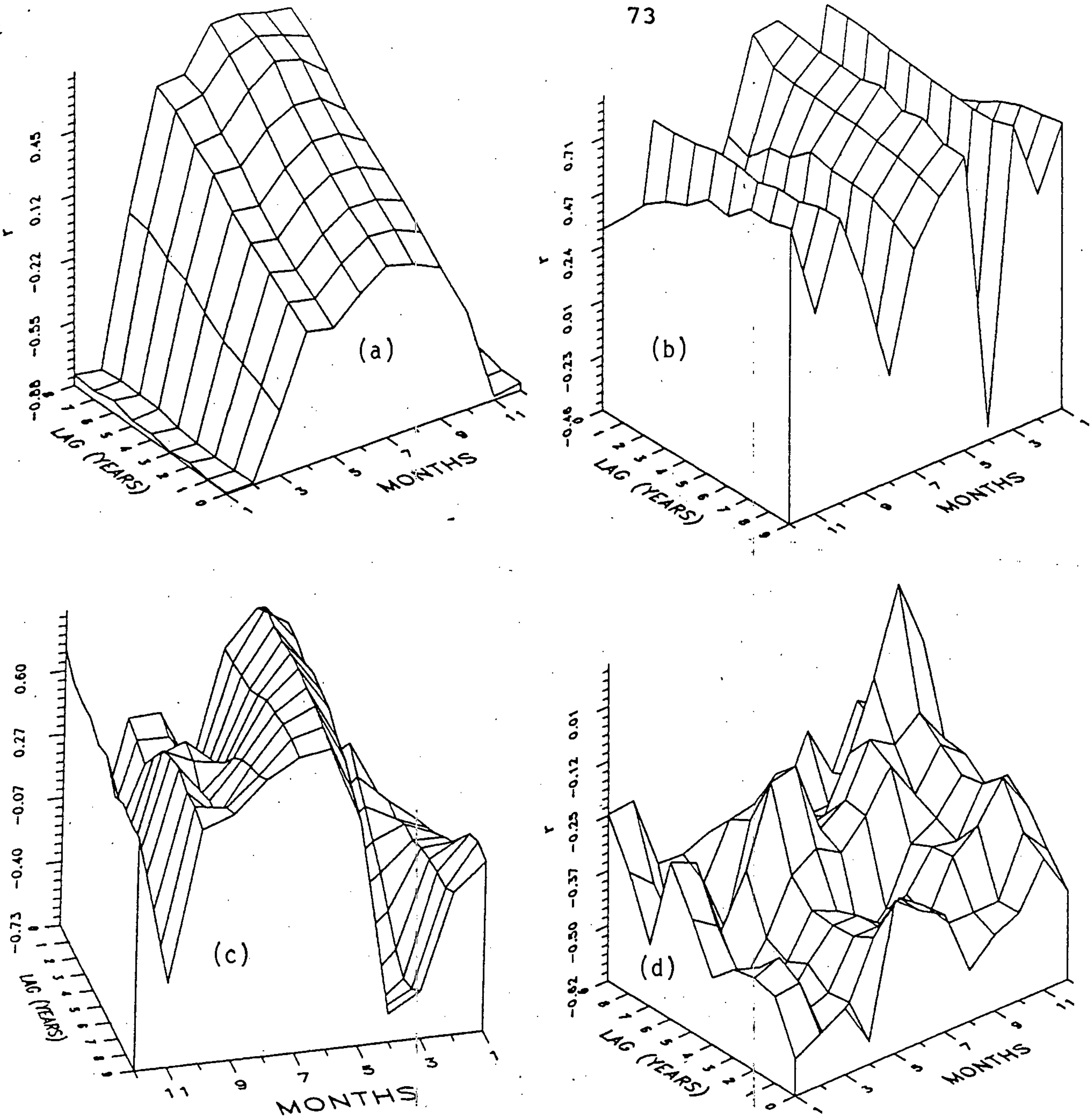


Figure 4.6 Three dimensional representation of Spearman rank correlation coefficients (r_s) of horse mackerel catches in The Agulhas Bank area, versus (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

In the summer months and while spawning is taking place, however, the situation is different. The relationship with sea surface temperature, sea level and west-east wind component in these months is negative, and positive with the north-south wind component.

4.3.3 Chub mackerel and environmental variables

Namaqualand area and chub mackerel catches

The relationship between chub mackerel catches and all environmental variables is negative for all environmental variables (Figures 4.7 a, b, c, d).

One and two year-old chub mackerel are most abundant in this area during the summer months (Crawford 1981c). During the spring months, the correlations generally are high at the 0-lag value for the sea level and west-east correlations (Table 4.7). The correlation coefficients for the same period and for sea surface temperature are also high at the 0-lag value, then decrease, but then increase again giving the largest values at longer lags (Appendix 9.1). The results as they stand suggest favouring of chub mackerel catches in this area with a decrease in sea surface temperature and sea level and with north-westerly winds.

Chub mackerel spawn from June to September and recruits join the main stock almost immediately (Crawford 1981c). Catches of chub mackerel are highest in summer. In the period between spawning and the main fishing months (i.e. October to December) the correlations with SST and wind components are significant at the 0-lag value (Appendix 9.1). Here again, the Spearman rank correlation analysis seems to be biased in favour of the longest lags.

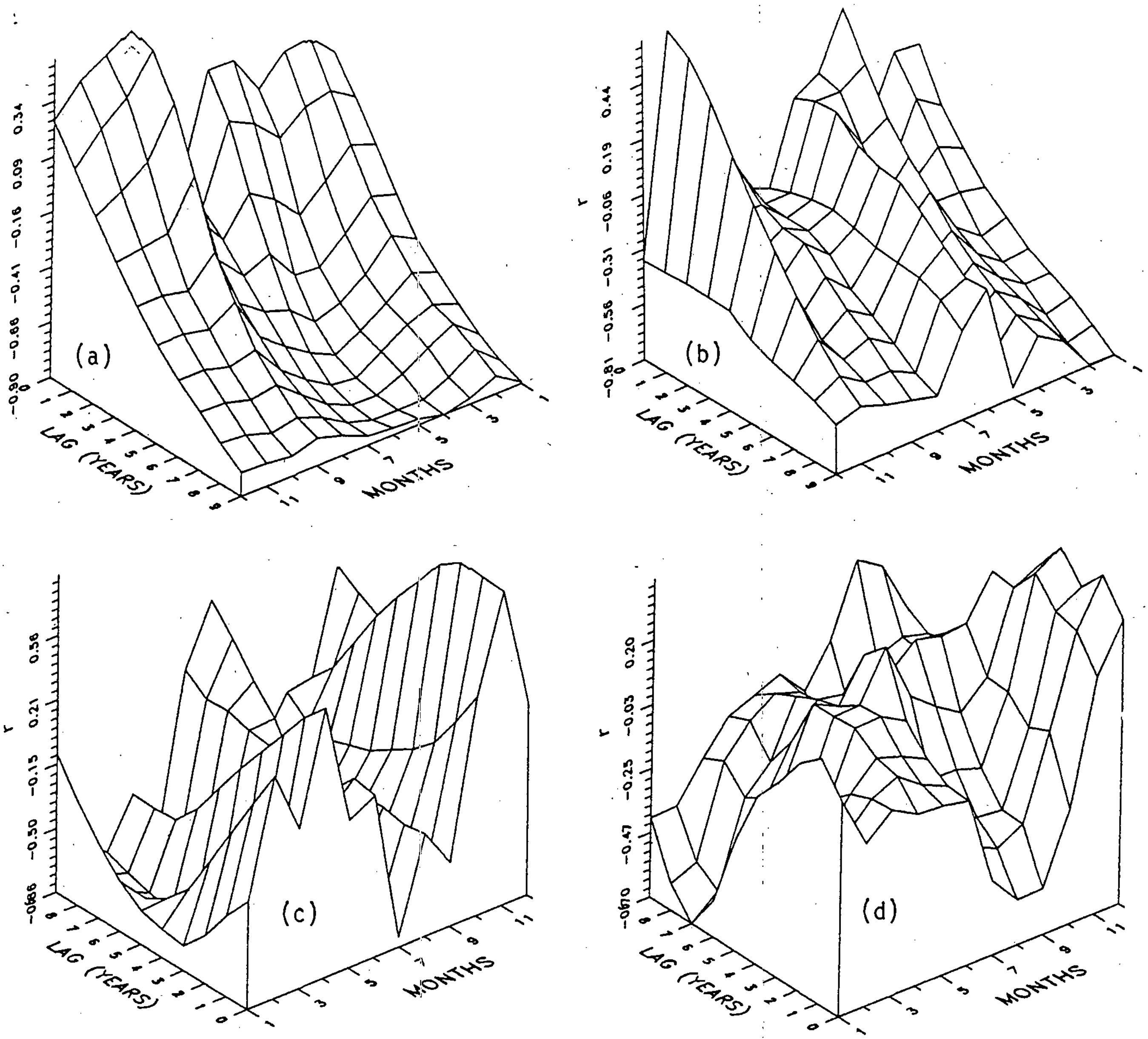


Figure 4.7 Three dimensional representation of Spearman rank correlation coefficients (r_s) of chub mackerel catches in the Namaqualand area, versus (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

Table 4.7 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual chub mackerel catches and monthly environmental variables in the Namaqualand area.

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.90	0.00	9	-0.81	0.00	9	-0.72	0.00	3	-0.70	0.01	7
February	-0.82	0.00	9	-0.81	0.00	9	-0.77	0.00	7	-0.62	0.01	7
March	-0.88	0.00	9	-0.66	0.00	9	-0.86	0.00	5	-0.33	n.s.	7
April	-0.90	0.00	9	-0.58	0.00	9	0.63	0.00	0	-0.24	n.s.	7
May	-0.89	0.00	8	-0.77	0.00	9	-0.74	0.00	8	-0.11	n.s.	0
June	-0.89	0.00	8	-0.28	0.15	8	-0.18	n.s.	3	0.22	n.s.	4
July	-0.86	0.00	9	-0.41	0.04	9	-0.81	0.00	0	-0.44	0.04	0
August	-0.81	0.00	9	-0.66	0.00	9	-0.67	0.00	8	-0.54	0.01	0
September	-0.78	0.00	9	-0.63	0.00	9	-0.57	0.00	6	-0.54	0.01	0
October	-0.81	0.00	9	-0.60	0.00	9	0.39	0.05	7	-0.30	n.s.	0
November	-0.80	0.00	9	0.63	0.00	0	0.90	0.00	2	0.38	n.s.	3
December	-0.80	0.00	9	-0.59	0.00	9	0.31	n.s.	9	0.40	n.s.	1

<u>South western Cape area and chub mackerel catches</u>

Sea surface temperature and north-south wind component correlations with chub mackerel catches in the south western Cape area are negative (Figures 4.8 a, b), signalling larger catches with cool conditions and northerly winds. The relationships with sea level and west-east wind component are not clear cut, and alternate between positive and negative signs (Figures 4.8 c, d).

According to Crawford (1981c), chub mackerel are most available in this area. The relationship between chub mackerel catches and sea surface temperature shows that the highest significant correlations are in the winter months and with a zero lag, except for the month of June which has a one year lag (Table 4.8). The immediate response shown by the zero lag in most months with respect to temperature suggests a favouring of the fish catch with a decrease in sea surface temperature.

Table 4.8 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual chub mackerel catches and monthly environmental variables in the south western Cape area.

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.73	0.00	0	-0.61	0.00	9	0.57	0.00	9	-0.54	n.s.	7
February	-0.74	0.00	0	-0.90	0.00	9	-0.52	0.00	5	-0.41	n.s.	8
March	-0.64	0.00	0	-0.59	0.00	9	-0.82	0.00	0	-0.75	0.02	7
April	-0.75	0.00	0	-0.57	0.00	9	0.84	0.00	1	-0.40	n.s.	7
May	-0.85	0.00	0	-0.75	0.00	9	-0.61	0.00	8	0.31	n.s.	0
June	-0.80	0.00	1	-0.41	0.02	3	0.83	0.00	1	0.40	n.s.	1
July	-0.81	0.00	0	0.79	0.00	4	0.65	0.00	8	0.43	n.s.	0
August	-0.70	0.00	0	-0.84	0.00	9	-0.84	0.00	6	-0.35	n.s.	8
September	-0.55	0.00	0	-0.81	0.00	9	-0.76	0.00	1	-0.43	n.s.	8
October	-0.31	0.08	0	-0.75	0.00	8	-0.81	0.00	1	0.33	n.s.	3
November	-0.54	0.00	0	-0.63	0.00	8	0.47	0.01	3	0.38	n.s.	1
December	-0.55	0.00	0	-0.49	0.01	0	0.71	0.00	8	0.33	n.s.	0

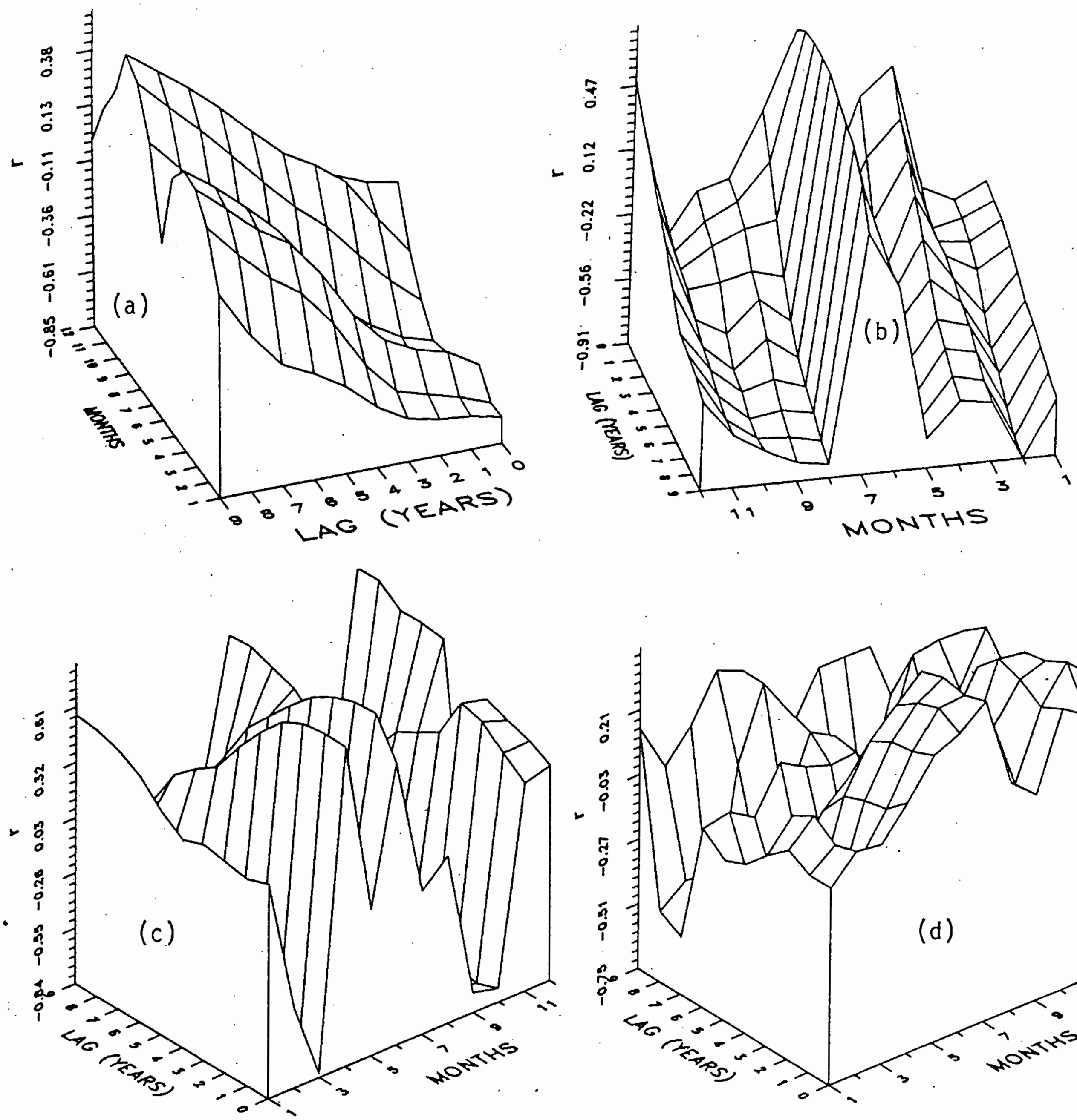


Figure 4.8 Three dimensional representation of Spearman rank correlation coefficients (r_s) of chub mackerel catches in the south western Cape area, versus (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

According to various authors (Baird 1977, Crawford 1981c), adult chub mackerel spawn from June to September in both the Namaqualand area and in this area. Later chub mackerel often move within this area in a southerly direction. The fish, therefore, will remain available to the fishery after the winter months. The relationship between chub mackerel and sea level also shows a zero year lag in the month of July (Table 4.8).

In summary, on the one hand, chub mackerel catches are enhanced by cooler conditions, as indicated by sea surface temperature correlations, and in the other by the absence of upwelling, found in those months, as evidenced by the wind correlations indicated by the north westerly preference and sea level.

Agulhas Bank area and chub mackerel catches

Similarly to the previous area, chub mackerel catch correlations with environmental variables are mostly negative (Figures 4.9 a, b, c, d). It is interesting to note, however, the positive peaks for the correlations with sea surface temperature in the winter months, although they are not as significant as the negative ones with short lags.

In this area, the results appear to have coherent values for all variables. With the exception of the west-east wind component, all other variables show significant correlations around the 0-lag relationship in the late spring and early summer months (Table 4.9). Crawford and De Villiers (1984) explain that in this area the highest catches of chub mackerel are made in the spring months.

The signs of the correlation in these months indicate an increase in the catch with cooler temperatures and lower sea level (upwelling index in the spring and summer months) and north easterly winds. The sign of the correlation with the west-east wind component in the month of January, reverses its sign to negative, indicating westerly winds.

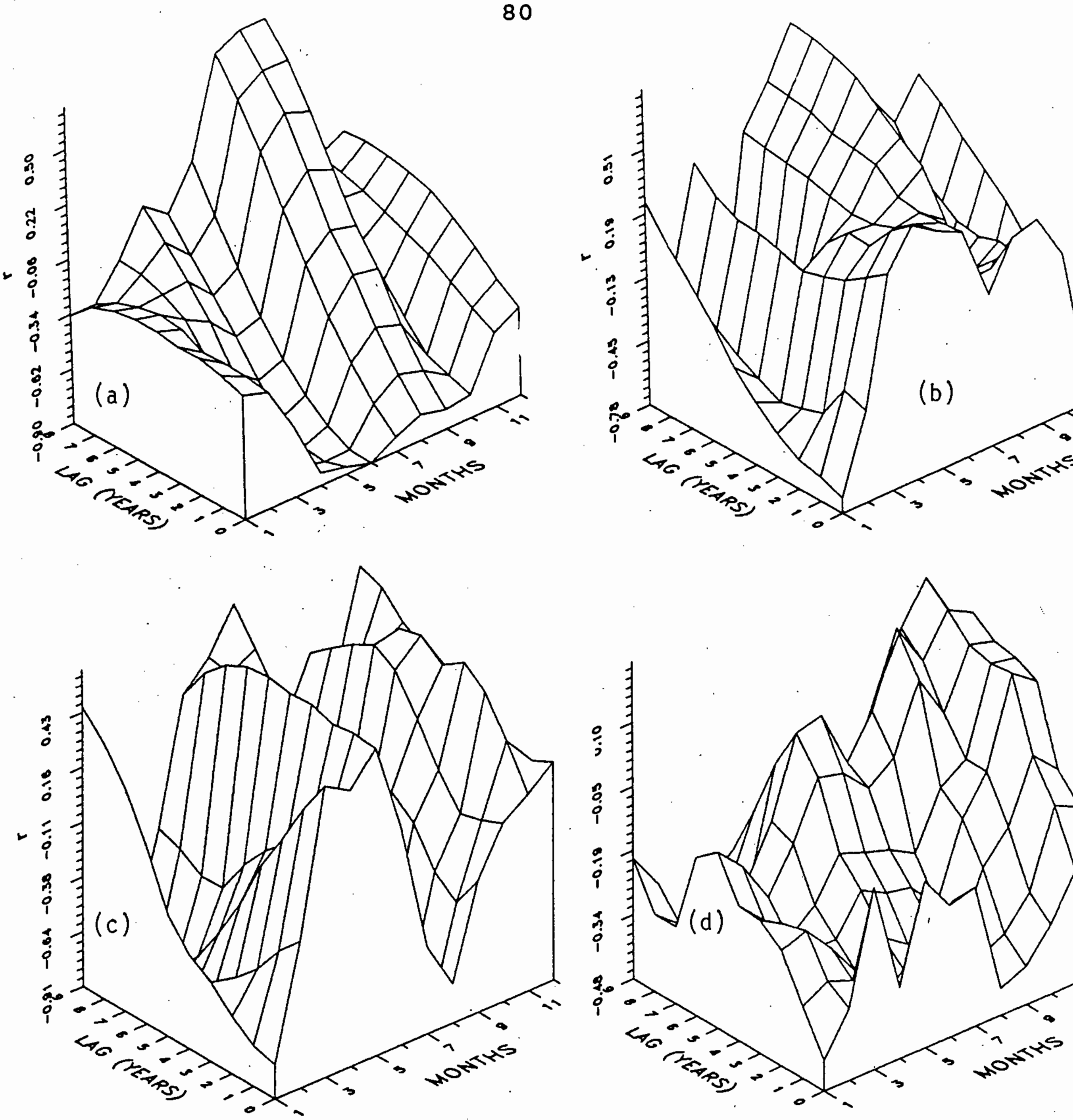


Figure 4.9 Three dimensional representation of Spearman rank correlation coefficients (r_s) of chub mackerel catches in The Agulhas Bank area, versus (a) sea surface temperature, (b) north-south wind component, (c) west-east wind component and (d) sea level for different months and lags.

Table 4.9 Spearman Rank correlation coefficient (r_s), lag and probability (P) of the highest correlations between annual chub mackerel catches and monthly environmental variables in the Agulhas Bank area.

Months	SST			N/S wind			W/E wind			Sea Level		
	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag	r_s	P<	lag
January	-0.42	0.03	9	-0.70	0.00	0	-0.74	0.00	0	-0.41	0.04	0
February	-0.46	0.01	9	-0.52	0.00	4	-0.78	0.00	7	-0.32	n.s.	0
March	-0.56	0.00	2	0.32	n.s.	0	-0.84	0.00	8	-0.48	0.04	8
April	-0.87	0.00	1	0.51	0.00	0	0.44	0.02	0	-0.38	n.s.	1
May	-0.90	0.00	1	0.42	0.02	0	0.63	0.00	5	-0.33	n.s.	1
June	-0.90	0.00	0	0.57	0.00	9	0.43	0.03	9	-0.33	n.s.	2
July	-0.83	0.00	0	0.82	0.00	9	0.63	0.00	9	-0.32	n.s.	2
August	-0.77	0.00	0	-0.78	0.00	6	-0.92	0.00	0	-0.42	0.03	0
September	-0.81	0.00	0	-0.52	0.01	6	-0.44	0.02	1	-0.39	0.04	0
October	-0.79	0.00	0	0.27	n.s.	9	0.46	0.01	6	-0.32	n.s.	0
November	-0.53	0.00	0	-0.77	0.00	0	0.51	0.00	5	-0.23	n.s.	0
December	-0.45	0.01	0	-0.65	0.00	0	0.55	0.00	9	-0.22	n.s.	0

4.4 Summary and conclusions

The original motivation behind these analyses was the establishment of hypotheses which could be later confirmed by the more powerful statistical analyses which follow. The lags in the analyses are long and lack biological explanation. The trends, however, give more coherent results which can be tested in the other analyses.

Annual pilchard catches appear to be favoured by cooler temperatures in all but the south western Cape area. With regard to winds, north-westerly winds appear to favour catches in the Namaqualand and south western Cape areas, whereas south-easterly winds favour total annual catch in the Agulhas Bank area.

A very similar response was found for annual horse mackerel catch with the exception of the Agulhas Bank area in which catches appear to be favoured by cooler temperatures in spring and summer but warmer temperatures the rest of the year. North-westerly winds favour annual horse mackerel catch in the Namaqualand and south western Cape areas. In the Agulhas Bank area, south-easterly winds favour catches during spring and summer, but south-westerly winds are favourable during the rest of the year.

Total annual chub mackerel catches are favoured by cooler sea surface temperatures and north-westerly winds in the Namaqualand and south western Cape areas. In the Agulhas bank area, cooler sea surface temperatures benefit catches, but wind directions have a variable correlation with catch throughout the year.

CHAPTER 5

MULTIPLE REGRESSION ANALYSES

5 MULTIPLE REGRESSION ANALYSIS.

5.1 INTRODUCTION.

A match/mismatch type of mechanism may operate at several critical stages of life history, and several environmental factors are likely to be potentially important in determining a relationship. This suggests that some form of multivariate analysis technique should be used.

If measurements of all environmental variables examined are all available for the same period of years, the best method of analysis would be that of multiple regression. For a multiple regression analysis, it is not necessary that the separate factors examined be independent. For example, the joint effects of sea temperature, salinity and wind velocity upon survival of pelagic eggs of a fish might be examined in a situation where these three are all somewhat correlated among themselves. The "standard regression coefficients" provide estimates of the relative value of each factor for predicting survival. The proportion (or percentage) of the total variation in Y that is explained or accounted for by the fitted regression is termed coefficient of determination R^2. In cases where more than one independent variable is used, R^2 is known as the coefficient of multiple determination (Green 1978, Polgar *et al.* 1985). Causal relationships may be inferred only with some insight into the natural phenomenon being investigated, and may not be declared by statistical testing alone. R^2 is actually a biased estimator of the population parameter ρ^2, the proportion of the variance in Y in the population accounted for by the multiple regression equation (Zar 1984).

Determination of the "best" model requires a systematic method of model building, the approximate specification of a candidate set of explanatory variables and reasonable lags based on known or hypothetical ecological information. When deciding which relationships to choose for presentation in this kind of analysis, large numbers of parameters have to be considered. The first parameter is that of the relative contribution of each environmental variable towards the whole regression. Secondly, regression theory rests on the assumption of zero serial correlation. A good measure of such serial correlation is the Durbin-Watson statistic (Kendall 1976). If there is no problem of association between adjacent residuals, the statistic will be around 2. When the Durbin-Watson statistic falls below 2, it is an indication of a positive serial correlation, whereas if above 2, it indicates negative serial correlation. Finally, the coefficient of multiple determination will ascertain the goodness of fit of the regression as a whole or the proportion of the total variability found in the fish catches that can be explained by the variability in the environmental variables (Zar 1984).

In spite of dangers, it would be foolish to accept the defeatism of those who argue that because a regression or correlation is based on "the theory of errors ", any information it provides is bound to contain errors and hence will be of little value. Soundly-considered regression analysis does exactly the opposite; from an originally large variability ("error") which has unknown causes, regression analysis quantitatively separates the components ascribable to each of a number of factors, so that the unidentified variability or residual error is substantially reduced.

The effect of a unit change in an environmental factor may be to change the number of recruits by some constant quantity, or by some constant multiple or fraction of the initial value, or it may act in some more complex manner. In practice, we should expect the effect of the physical environment to be multiplicative rather than additive; if conditions are favourable, all fry have a chance of benefiting; if unfavourable, a certain fraction (not a fixed number) will be lost. To make multiplicative affects amenable to linear regression analysis, the logarithm of the observed effect is used rather than its actual value. The logarithmic transformation has an additional advantage; it commonly makes the variability of the number of recruits (y values), nearly uniform over the observed range of environmental effects (x values). These advantages, however, are obtained only at a price and the price is that "expected" or "most frequent" value of Y, calculated from the logarithmic relationship for some particular X, is not the arithmetic mean of actual observed Y values at that X. Instead, one uses geometric mean (GM), which is less than the corresponding arithmetic mean (AM).

5.2 METHODS

All logged fish catches as dependent variables were regressed against four independent variables. The four independent variables were sea surface temperature, north-south wind component, west-east wind component and sea level.

The method of smoothing and filtering of the biological and environmental data series has been described already in section 3.3. The fish catches were first correlated with all months in all areas. Then the species catches were correlated with a combination of months.

5.3 RESULTS

All R^2 values referred to in the text refer to the coefficient of multiple determination adjusted for degrees of freedom. Tables present the multiple regression results of fish species vs sea surface temperature (SST), north-south wind vector (N/S), west-east wind vector (W/E) and sea level at different lags (years) and months in all areas.

Those Durbin-Watson statistics which give a significant result, i.e. the residuals of the analysis are uncorrelated, are italized in the tables.

Similarly to the Spearman Rank correlation results only the individual monthly analyses are being presented in this chapter. The pooled months analyses are, however, presented in Appendix 9.2.

5.3.1 Pilchard and environmental variables

Namaqualand area and pilchard catches

The problem of serial correlation is not serious in this set of variables, since with the exception of the month of September, all Durbin-Watson statistic values are not significantly different from 2 (Table B.1, page 193, Kendall 1976). In the multiple regression analysis, the relationship between pilchard and environmental variables shows an immediate significant response to the late winter months ($R^2 = 0.558$ $p < 0.001$, $R^2 = 0.653$, $p < 0.0001$, for July and August, respectively). Indeed, as stated in section 4.3.1, pilchards recruit in the Namaqualand area from the month of May onwards, hence, these results do not appear to be surprising. According to Crawford (1981d), there is a marked increase in 0-year-old catches at the southern range of this area during winter and spring, which may account for this immediate response of the pilchard catches during these months. In the multiple regression analysis for the month of July, temperature is the only variable contributing significantly to the overall regression, and it has a negative sign. With regard to the month of August, the wind components are the variables which explain most of the variability in fish catches, the rest being non-significant. The direction of these components as indicated by the signs of the regression contributions, is both northerly and easterly.

Overall, the lags are centered around the 0 and 1 year values (Table 5.1), except for the months of February and May. Interestingly, the sign for the sea surface temperature contribution in these months is positive, whilst being negative for the rest. With regard to the north-south wind vector, all the individual significant contributions are negative. Thus, it would appear that northerly winds are an important factor contributing to the pilchard catch variability.

Table 5.1 Highest multiple regression results of annual pilchard (*Sardinops ocellatus)* catch versus monthly environmental variables at different lags (years) in the Namaqualand area. P< represents the significance of the overall regression. Plus and minus signs are shown in those months where the individual environmental variables contribute significantly positively or negatively to the regression.

					WIND				
Month	Lag	R^2	Adj. R^2	SST	N/S	W/E	Sea Level	P<	Durbin-Watson
January	1	0.821	0.767	-		+		0.000	*1.989*
February	3	0.850	0.810	+	-		+	0.000	*1.843*
March	0	0.744	0.690		-	+	-	0.000	*2.295*
April	0	0.768	0.719		-	+	-	0.000	*1.925*
May	3	0.646	0.557	+	-	-		0.001	*1.787*
June	1	0.432	0.281	-		-		n.s.	*1.580*
July	0	0.642	0.558	-				0.001	*1.768*
August	0	0.719	0.653		-	+		0.000	*1.911*
September	1	0.761	0.708			-	-	0.000	*2.076*
October	1	0.783	0.735	-		+		0.000	*2.374*
November	1	0.436	0.310	-			-	0.028	*1.445*
December	0	0.793	0.729		-			0.000	*2.032*

Significant west-east wind component signs are positive from October to April and in August, but negative in May, June and September. Hence, it would seem that the negative sign, indicating westerly winds, prevails around the recruitment months (May and June), whereas an easterly direction is indicated in the rest of the months, with the exception of September.

With the exception of the month of February, the sea level contribution signs are negative in all months but it is interesting to note that the sea level contribution is not significant in any of the winter months. This is not surprising, since upwelling is rare, in the three areas, during this period of the year (Hutchings *et al.* 1984). This links with the fact that the west-east wind component, primarily responsible for the onset of upwelling, is mostly negative, hence a westerly wind is prevalent during these months (Armstrong *et al.* 1987a).

During the months of March and April, there are immediate and highly significant relationships with pilchard catches. In both months upwelling indications are found, as indicated by an easterly wind component and lower sea levels. The north-south component contribution is also significant and negative in both months (Table 5.1).

The multiple regression results established a one year lag as being very important from September to January, excluding December. Furthermore, from October to January, the signs of the environmental variables which contribute significantly to each regression, are all the same. These signs establish cool conditions (negative signs for SST), northerly and easterly winds and lower sea levels as the conditions benefiting pilchard catches the following year.

South western Cape area and pilchard catches

There seems to be a tendency for the summer months and April to have a 3 year lag period in the multiple regression between pilchard catches and environmental conditions in the south western Cape area, February being an exception. The highest coefficient of multiple determination of all months is found in January ($R^2=0.624$, $P< 0.001$; Table 5.2).

According to Crawford (1981d), in the south western Cape pilchard recruits and adults start to appear in the late spring and winter months. Also, the three year lag could be due to the important contribution to the catch of 3-year-olds during the early part of the record.

In the months of May and June, the regressions have the largest coefficient at a one year lag with June not being significant (Table 5.2). However, the regression coefficients are small compared with those found in the summer months. The signs of the individual contributions also differ so that an overall effect cannot be found.

All Durbin-Watson statistics in the relationships between pilchard catches and environmental variables in the south western Cape area show negative serial correlations in the residuals, except for the month of February.

If the month of April, which shows a very high Durbin-Watson statistic and hence serial correlation, is excluded, all late spring and summer months are in excellent agreement with respect to their individual environmental contributions to the regressions. These contributions indicate cooler temperatures, southerly and easterly winds and higher sea level in the south western Cape area favouring total annual pilchard catch.

Table 5.2 Highest Multiple regression results of annual pilchard (*Sardinops ocellatus)* catch versus monthly environmental variables at different lags (years) in the south western Cape area. Symbols as in Table 5.1.

Month	Lag	R^2	Adj. R^2	SST	WIND N/S	WIND W/E	Sea Level	P<	Durbin-Watson
January	3	0.739	0.624				+	0.001	*2.319*
February	0	0.661	0.537	-	+	-		0.012	*1.724*
March	3	0.587	0.403				+	n.s.	*2.491*
April	3	0.727	0.591	+		+	+	0.021	3.008
May	1	0.645	0.503					0.023	*2.390*
June	1	0.532	0.363					n.s.	*2.136*
July	0	0.318	0.108	-				n.s.	*2.152*
August	5	0.745	0.617		+	-		0.016	*2.358*
September	0	0.489	0.319	-		+		n.s.	*2.245*
October	4	0.598	0.419					n.s.	*2.237*
November	2	0.518	0.325	-				0.034	*2.229*
December	4	0.631	0.447				+	n.s.	*2.192*

Agulhas Bank area and pilchard catches

The largest coefficient of multiple determination between pilchard catches and environmental variables in the Agulhas Bank area is evident during the summer months (December to March)(Table 5.3). When looking at the Durbin-Watson statistics, most of the values during that period are in the permissible range, exceptions being the months of June, September and October. The lags for December to March are established at one and two years. The sign of the sea surface temperature contribution to the overall regression is negative in these months, suggesting that cooler temperatures in this area favour total pilchard catches one and two years later. The north-south wind vector does not contribute notably to any of these regressions, except for March in which a positive contribution is present, indicating favourable southerly winds.

The west-east wind component during the period is positive in December, a sign of easterly winds, and negative in the months of February and March, indicating westerly winds.

<u>Table 5.3</u> Highest multiple regression results of annual pilchard (*Sardinops ocellatus)* catch versus monthly environmental variables at different lags (years) in the Agulhas Bank area. Symbols as in Table 5.1.

Month	Lag	R^2	Adj. R^2	SST	WIND N/S	WIND W/E	Sea Level	P<	Durbin-Watson
January	1	0.659	0.591	-				0.000	*1.534*
February	1	0.755	0.707	-		-		0.000	*1.804*
March	2	0.769	0.721		+	-	-	0.000	*2.353*
April	5	0.591	0.495	-			-	0.003	*1.959*
May	5	0.492	0.372				-	0.016	*1.823*
June	0	0.739	0.687		-	-		0.000	1.130
July	0	0.566	0.479	-	+	+		0.001	*1.812*
August	1	0.680	0.619	-	-	+		0.000	*1.805*
September	3	0.422	0.301	+	+	-		0.027	1.241
October	1	0.348	0.234	-				0.036	0.863
November	5	0.625	0.541				-	0.001	*1.554*
December	2	0.781	0.738			+		0.000	*1.730*

Pilchard catches over the last twenty years have consisted mainly of 0-year-old fish. Thus, the one year lag does not seem unreasonable, mainly because juvenile fish recruit further up along the Namaqualand area and are only available in this area on their return to the southern grounds the following year.

As a result of the reduction of the minimum mesh size of nets over the period 1963-1965, it has been postulated (Crawford 1981d) that there was a considerable reduction in the age structure of the pilchard population. This was evident during the mid 70s when 50% of the two-year-olds were reproductively active. Crawford (1981a) stated that during the early fifties, no fish had matured before the age of four years. Thus, it is reasonable to assume that a two-year lag during the summer months may be linked to the response of the eggs and larvae to environmental conditions. This response will be noticed in the number of fish which reach the age at first maturity. The pattern emerging, therefore, assigns importance to the effect of the environmental conditions on spawning and has consequences for two different parts of the population. On the one hand, they benefit catches of the new recruits being fished eight months after being recruited, i.e. the following year. On the other hand, they benefit those fish which begin to form an important part of the spawning stock.

It is of consequence to note that the regression results for the winter months are also highly significant. August has a one year lag, whereas June and July have no lag (Table 5.3). Unfortunately, the contribution signs of the environmental variables do not show much coherence during this period, and no generalization could be found.

5.3.2 Horse mackerel and environmental variables

Namaqualand area and horse mackerel catches

In this analysis, the Durbin-Watson statistic shows sure signs of serial correlation between the environmental variables in most regressions (Table

5.4). The exceptions are mostly based around the summer months. According to Crawford (1981b), the largest horse mackerel catches in this area are fished in late summer to mid winter. During winter, there is a no-lag relationship between horse mackerel catches and environmental conditions, indicating an immediate response of the catches during this period. This could link to Crawford's (1981b) observation and relate the effect of the environmental conditions to the highest catches. Unfortunately, the signs of the contributions by the environmental variables alternate.

<u>Table 5.4</u> Highest multiple regression results of annual horse mackerel (*Trachurus trachurus*) catch versus monthly environmental variables at different lags (years) in the Namaqualand area. Symbols as in Table 5.1.

					WIND				
Month	Lag	R^2	Adj. R^2	SST	N/S	W/E	Sea Level	P<	Durbin-Watson
January	5	0.988	0.983		-	-		0.000	*1.665*
February	3	0.975	0.968	-	-	+	-	0.000	*1.787*
March	0	0.869	0.841	-	-	+		0.000	0.728
April	1	0.962	0.954	-	-	+		0.000	*1.836*
May	6	0.961	0.949	+	-			0.000	*2.172*
June	0	0.570	0.463	-	-	+		0.000	0.237
July	0	0.929	0.912	-	+	-		0.000	0.908
August	0	0.920	0.901	+	-	+		0.000	*1.481*
September	1	0.895	0.871		-	-		0.000	1.328
October	1	0.969	0.963	-	-	+		0.000	*1.423*
November	0	0.689	0.620	-	+			0.000	1.079
December	0	0.984	0.979	-	-			0.000	*2.272*

It is important to note that in June-July the Durbin-Watson statistic indicates problems in serial correlation between all variables and therefore, caution should be used in establishing a general response for all the winter months. There is better agreement, and better Durbin-Watson values for the months of September and October (Table 5.4). In these months the lag is one year, indicating improved horse mackerel catches with environmental conditions of the previous year. The SST relationship is negative for the month of October, whereas in the month of September its contribution is not significant. With regard to the north-south wind component, it is significant in both months with a negative sign, hinting at northerly winds as being important in the overall regression. The signs for the west-east wind component contributions are negative in September and positive in October.

During November, December and March, the lag of the best regression is zero. This suggests an immediate response in the horse mackerel catches during these months. The SST contribution sign is negative in all three, the north-south contribution indicates northerly winds during December and March, and southerlies during November. The west-east contribution during November, December and March is only significant during the month of March, with a positive value indicating easterly winds, whereas sea level is not significant in any of those months.

The best coupled Durbin-Watson statistic and coefficient of multiple determination are found in the month of April. Here the lag is one year, and the environmental contribution signs indicate lower temperatures, northerly and easterly wind directions as benefitting catches.

<u>South western Cape area and horse mackerel catches</u>

The lag for the late winter to spring months is zero, with the exception of September which has a one year lag, suggesting an immediate relationship between horse mackerel catch and environmental conditions in this area (Table 5.5) According to Crawford (1981b), horse mackerel spawn during spring and early summer in this area.

<u>Table 5.5</u> Highest multiple regression results of annual horse mackerel (*Trachurus trachurus*) catch versus monthly environmental variables at different lags (years) in the south western Cape area. Symbols as in Table 5.1.

Month	Lag	R^2	Adj. R^2	SST	WIND N/S	WIND W/E	Sea Level	P<	Durbin-Watson
January	4	0.863	0.802		-	+		0.000	*2.515*
February	4	0.843	0.773	-	-			0.001	*2.329*
March	6	0.939	0.899	+	-	+		0.000	2.771
April	2	0.787	0.681			+		0.003	*1.839*
May	5	0.856	0.760	-				0.010	*1.955*
June	5	0.875	0.803	-				0.002	*2.518*
July	0	0.885	0.849	-	+	-		0.000	1.369
August	0	0.918	0.893	-				0.000	*2.013*
September	1	0.760	0.673	-	-			0.002	*1.839*
October	0	0.656	0.542			-		0.008	*1.526*
November	0	0.871	0.828		-	+		0.000	1.220
December	5	0.919	0.878		-	+	+	0.000	*2.063*

The sign of the individual environmental variable contributions to all the monthly regressions, shows a certain degree of coherence. Significant SST contributions are negative in all months with the exception of March. The wind components, seem to indicate a reversal of the contribution signs.

In the winter months, horse mackerel catch appears to be influenced by the onset of immediate cooler conditions and southerly and westerly winds. However, caution should be applied, since the north-south wind component contribution is only significant in the month of July during winter, and the Durbin-Watson statistic is low for this month (Table 5.5). This effect may be accounted for by the prevailing sea conditions of cool waters and westerly winds encountered during this period (Armstrong *et al.* 1987a). Although the response in the catches might be a physiological one, linked to the environmental conditions, it might also be a response due to the increased availability of fish to the fishery, induced by wind forcing warm water shorewards. According to Crawford (1981b), the presence of adult horse mackerel inshore can be associated with feeding, the abundance of food items in turn is associated with the environmental conditions.

During the remaining months, the SST contribution sign is still negative but the wind component signs are reversed. In the month of December, there is a significant positive contribution to the regression made by sea level. All the signs together, therefore, establish cool conditions, northerly and easterly winds and higher sea level as those conditions improving horse mackerel catch in this area.

<u>Agulhas Bank area and horse mackerel catches</u>

Availability of one- and older, year-old horse mackerel in this area is greatest from January to June (Crawford 1981b), nought-year-olds being caught in January and May-June.

The Durbin-Watson statistic values are low for all months with the exception of June and July (Table 5.6). Although the coefficient of multiple determination is very high in both months, the lags are different. During the months of March and April, there is a two year lag, but the low Durbin-Watson values and the discrepancy in the north-south wind component contribution makes any generalization difficult. The lags for the rest of the months vary quite considerably.

Table 5.6 Highest multiple regression results of annual horse mackerel (*Trachurus trachurus*) catch versus monthly environmental variables at different lags (years) and months in the Agulhas Bank area. Symbols as in Table 5.1.

					WIND				
Month	Lag	R^2	Adj. R^2	SST	N/S	W/E	Sea Level	P<	Durbin-Watson
January	8	0.835	0.788	-	-	+		0.000	1.132
February	1	0.943	0.931	-	+	-		0.000	*1.688*
March	2	0.947	0.935	-	+	-	-	0.000	*1.525*
April	2	0.965	0.631	-	-			0.000	1.037
May	0	0.736	0.685			+	-	0.000	1.130
June	6	0.910	0.887	+	+			0.000	*2.061*
July	1	0.873	0.847	-	+	+		0.000	*1.718*
August	4	0.875	0.847	+	+	-	-	0.000	0.941
September	6	0.768	0.709	+				0.000	0.632
October	1	0.537	0.453	-	+	+		0.001	0.553
November	0	0.549	0.471		-	+	-	0.000	0.380
December	4	0.739	0.680			-		0.000	1.041

5.3.3 Chub mackerel and environmental variables

Namaqualand area and chub mackerel catches

There is very good agreement between chub mackerel catches and environmental conditions during the winter months (Table 5.7). The lag is set at five years and in this area three to five year old mackerel show a peak in catches during the month of July (Crawford 1981c). The signs of the individual environmental variable contributions derived from the regressions indicate an enhancement of chub mackerel catch, during May to July, with cooler temperatures and prevailing south-westerly winds. During September to December the lag is centered around one year, with the exception of a two year lag in November. The Durbin-Watson values are, however, low, except for the months of November-January. The signs of the individual environmental contributions differ for different months.

Since it is thought that mackerel migratory behaviour is similar to that of pilchard (Crawford 1981c), the 1-year lag in the spring months may suggest the effect of the environmental conditions on the juveniles. This effect will only be reflected in the catches the following year, when those juveniles are fully recruited.

The lag between chub mackerel catch and environmental conditions in January is seven years. The coefficient of multiple determination ($R^2 = 0.955$) and the Durbin-Watson statistic (Db = 1.712) are very significant. The environmental contribution signs in that month establish cooler temperatures, southerly and westerly wind directions and lower sea levels as significant. The lag, however, is difficult to explain. It is possible, though, that the environmental conditions in this month have an effect which is reflected on the maximum age of chub mackerel in the catches from the mid 50s, which is around seven years.

<u>Table 5.7</u> Highest multiple regression results of annual chub mackerel (*Scomber Japonicus*) versus monthly environmental variables at different lags (years) and months in the Namaqualand area. Symbols as in Table 5.1.

Month	Lag	R^2	Adj. R^2	SST	WIND N/S	WIND W/E	Sea Level	P<	Durbin-Watson
January	7	0.976	0.965	-	+	-	-	0.000	*1.712*
February	3	0.718	0.643	-		+		0.000	1.144
March	1	0.769	0.717	+	-			0.000	0.653
April	4	0.872	0.837	-	+			0.000	*1.848*
May	5	0.825	0.775	-	+	-		0.000	1.460
June	5	0.944	0.923	-	+	-		0.000	*1.971*
July	5	0.872	0.830	-		-		0.000	1.413
August	6	0.782	0.709		-	+		0.000	0.345
September	1	0.752	0.696	+		-		0.000	0.680
October	1	0.926	0.909	+	-	+		0.000	1.339
November	2	0.851	0.816	-	+			0.000	*1.611*
December	1	0.879	0.841	+	-			0.000	*1.975*

<u>South western Cape area and chub mackerel catches</u>

Chub mackerel spawn from June to September (Crawford 1981c), and juvenile chub mackerel are fully recruited by the start of the following year.

The lag found in the first two months of the spawning season is one year. This indicates that ocean conditions during the spawning months increase catches the following year. These conditions are cooler temperatures and easterly winds (Table 5.8), as reflected by the signs of the significant environmental contributions.

Table 5.8 Highest multiple regression results of annual chub mackerel (*Scomber Japonicus*) catch versus monthly environmental variables at different lags (years) in the south western Cape area. Symbols as in Table 5.1.

Month	Lag	R^2	Adj. R^2	SST	WIND N/S	WIND W/E	Sea Level	P<	Durbin-Watson
January	8	0.952	0.914	-	-	+	+	0.001	1.152
February	8	0.913	0.844	-	-			0.007	*2.079*
March	1	0.959	0.942		-	+		0.000	*1.668*
April	5	0.953	0.922		-	+		0.000	2.367
May	1	0.940	0.916	-		+		0.000	*1.800*
June	1	0.936	0.912	-		+		0.000	*1.610*
July	5	0.954	0.931	-	+	-	-	0.000	1.433
August	4	0.902	0.858	-	+	-		0.000	*2.087*
September	1	0.846	0.790			-		0.000	*1.471*
October	0	0.806	0.741		+	-		0.000	1.148
November	2	0.853	0.794	-		+		0.000	1.176
December	0	0.727	0.628		-	+	+	0.004	0.993

During October and December the lag of the multiple regression is zero (Table 5.8). In this area where chub mackerel catch is largest, adults tend to move in a southerly direction, after spawning in the Namaqualand area. These trends were confirmed by Crawford (1981c), who showed the positions of shoals sighted from the air in the spring months. Caution should be used when drawing conclusions from these results, since the Durbin-Watson statistic indicates positive serial correlation in these months (Table 5.8).

Overall, when looking at the signs of the environmental variable, there seems to be two main month groupings in this area. One is determined by cooler temperatures, southerly and westerly winds and lower sea levels during the months of July to October. The other is determined by cool conditions (negative SST), northerly and easterly wind components and higher sea levels.

The coefficients of multiple determination for the regression between chub mackerel catch and the environmental conditions in January and February are very significant. The Durbin-Watson statistic associated with February is significant (Table 5.8). The signs derived from the contribution by the environmental variables to the regression shows cool conditions, i.e. negative SST, northerly and easterly winds and higher sea levels. The Lag, however, is long at eight years. It is interesting to note that this long lag in January and February corresponds closely to the lag found in January in the Namaqualand area. As explained for that result, it may relate to the maximum age of chub mackerel in the catches (Table 1.2).

Agulhas Bank area and chub mackerel catches

With the exception of the months of March and April, the Durbin-Watson statistics are all significantly low, disclosing a positive serial correlation between the environmental variables in most monthly analyses (Table 5.9).

During March and April there is homogeneity in the signs of contributions of the environmental variables, revealing cooler temperatures, northerly and westerly wind components and higher sea levels in this area as having a significant effect on chub mackerel catches. The lags, however, do not agree, March having a four year and April a two year lag.

From September to February, the best lags are one and five years. In these regressions, the SST and the north-south wind component contribution signs are negative whilst west-east and sea level contribution signs are positive. These suggest cooler temperatures, northerly and easterly winds and higher sea levels as being responsible for the higher chub mackerel catches during the period of analysis.

Table 5.9 Highest multiple regression results of annual chub mackerel (*Scomber Japonicus*) catch versus monthly environmental variables at different lags (years) in the Agulhas Bank area. Symbols as in Table 5.1.

					WIND				
Month	Lag	R^2	Adj. R^2	SST	N/S	W/E	Sea Level	P<	Durbin-Watson
January	1	0.886	0.863	-		-	+	0.000	1.236
February	1	0.500	0.400	-				0.005	0.642
March	4	0.874	0.846	-		-	+	0.000	*1.758*
April	2	0.884	0.859	-	-	-	+	0.000	*1.961*
May	2	0.827	0.790	-		+		0.000	1.251
June	5	0.854	0.819	-	+			0.000	1.373
July	1	0.900	0.881	-	-	-		0.000	1.089
August	0	0.901	0.883	-	-	-		0.000	0.924
September	1	0.724	0.671	-				0.000	0.222
October	5	0.645	0.566	-		+		0.000	0.695
November	1	0.904	0.887	-	-	+		0.000	1.093
December	5	0.608	0.516	-	-	+		0.000	0.581

During the late winter months (July and August) the regressions are very significant, but as explained previously, there is positive serial correlation problem. The environmental variables of significance in these regressions show favouring of catches with cooler temperatures and north-westerly winds.

It, therefore appears, that there is in fact an immediate response by the chub mackerel catches in this area to the environmental conditions. This response indicates a favouring of catches with cooler conditions, as well as with lower sea level and northwesterly winds.

CHAPTER 6

TIME SERIES ANALYSES

6. TIME SERIES ANALYSIS

6.1 Introduction

Ecologists face problems when attempting to decipher trends and identify important controlling variables from data consisting of multivariate time series. The large degree of uncertainty and the multiple lag structure commonly found in fisheries data, and in other ecological situations, make intuitive interpretation difficult. Colinearity among variables creates problems when interpreting the effects of individual explanatory variables on the response variable (Chatterjee and Price 1977). This problem is common to all regression analyses in which two or more of the explanatory variables are correlated (Rose *et al.* 1986). One or more of the assumptions of least squares estimations may be violated by the inclusion of the response variable as an explanatory variable or by the presence of autocorrelated errors. Such violation assumptions may result in biased and/or inconsistent estimates of the regression coefficients. Also, the regression diagnostics used to detect such problems as autocorrelations among the residuals (e.g. Durban-Watson statistic) can produce misleading results (Fuller 1976).

It is clear that if fish stocks are approximately adapted to particular environmental conditions, any change is likely to be detrimental. The response to environmental factors is therefore unlikely to be monotonic (let alone linear), except for species at the extremes of their range. Ordinarily, when a time series is related to another independent time series, the analysis includes adjustments in the form of transformations to remove generally correlated errors.

Time series of annual data have to be available for at least a decade to permit an evaluation of events on these scales with sufficient resolution (Bergh 1983). Short-term experiments and longer but discontinuous data collection can be used to formulate and test hypotheses, but only long-term, continuous and carefully planned monitoring can lead to forecasting capabilities beyond the present stage of educated guesses (Sharp 1987). When lagged correlations or correlations that are valid only on certain time scales are likely, methods of analysis are required which take account of the sequential nature of the data (unlike ordinary correlation). The commonly used approaches for analysing time series data with lagged response variables as explanatory variables, are Box-Jenkins models and time series linear regressions (Shepherd *et al.* 1984). Although in theory Box-Jenkins models can be specified *a priori*, rather than on information empirically deduced from the data, this is typically not done in practice.

6.2 Methods

In time series analysis, correlations are computed over all possible lags in the data (Panofsky and Brier 1968). Consequently, this type of correlation can pick up correspondence in variation that would not normally appear by computing an ordinary correlation coefficient (Shaffer and Cahoon 1987). If the data exhibit any important trend or trends extending over periods of years comparable to the total length of the series, it is usually necessary to remove this trend before examining year-to-year effects of environmental factors.

Cross correlations between time series often give a correct picture of a more permanent relationship than ordinary regression analysis, particularly when the coefficients are large and are based on a known physical mechanism which may, theoretically, be responsible for the observed effect on the dependent variable.

It was demonstrated in chapter 5 that serial correlation between data variables was evident in the data series. In order to remove that serial correlation, low order auto-regressive and moving average models were fitted to each of the data series (see Appendix 9.3 for models used; Box and Jenkins 1970). This removes effects which are due purely to persistence from the past. After removing the structure, the residuals are characteristic of uncorrelated white noise.

After white noise residuals were obtained from all variables, standard cross-correlations were performed for all annual catches and all monthly environmental variables. These correlations were performed for all individual months as well as for different combinations of months, very much in the same way as in the previous sections.

6.3 Results and Discussion

Only the first three lags are presented in this analysis, with the largest cross-correlations being normally found here (see Appendix 9.4).

6.3.1 Pilchard and environmental variables

Namaqualand area and pilchard catches

The cross-correlation between annual pilchard catches and sea surface temperature in the month of March has a significant negative value ($r = -0.3805$, $P < 0.05$) with a lag of one year (Table 6.1). This result suggests that the annual pilchard catch is favoured when cool conditions have prevailed in this area in March the previous year. The cross-correlation of annual pilchard catches with the SST in April is almost significant with the same sign and lag. Crawford (1979) explained that availability of one-year-old pilchard is at a peak in April. This suggests that the result obtained here may be accounted for by pilchard availability. The environmental conditions might directly influence 0-year-old fish. Since 0-year-olds recruit in this area from May onwards, it is possible that conditions created during the two previous months could benefit these recruits. The effect of this mechanism would be manifest the following year, primarily in the catch of one-year-olds. In this regard, Crawford (1981d) showed that in this area and from the period 1964-1976, one-year-old pilchards contributed greatly to the total catch.

Table 6.1 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = $P < 0.05$).

	Lags 0	Lags 1	Lags 2
January	-0.1843	-0.2491	-0.1968
February	-0.1259	-0.2317	-0.1992
March	-0.2056	-0.3805*	-0.1297
April	-0.1970	-0.3050	-0.1575
May	-0.0086	-0.0363	-0.1616
June	0.0723	0.1040	-0.0613
July	0.1156	0.1181	-0.0670
August	0.1846	0.1278	-0.0854
September	0.1927	-0.1485	-0.1277
October	-0.0394	-0.2508	-0.1588
November	-0.2534	-0.1626	-0.1556
December	-0.3031	-0.0920	-0.2958

It is also interesting to note that the relationship in the same year, i.e. lag zero, is highest in the months of November and December, also with a negative sign, but these relationships are not significant.

Another point to take into consideration is the fact that at least some of the adult pilchard have tended to spawn in this area until 1966 (Buys 1957) during the summer months (Figure 6.1), so that the results may reflect an immediate response of the catches, either directly as a response to environmental conditions or indirectly through availability to the fishery during November and December.

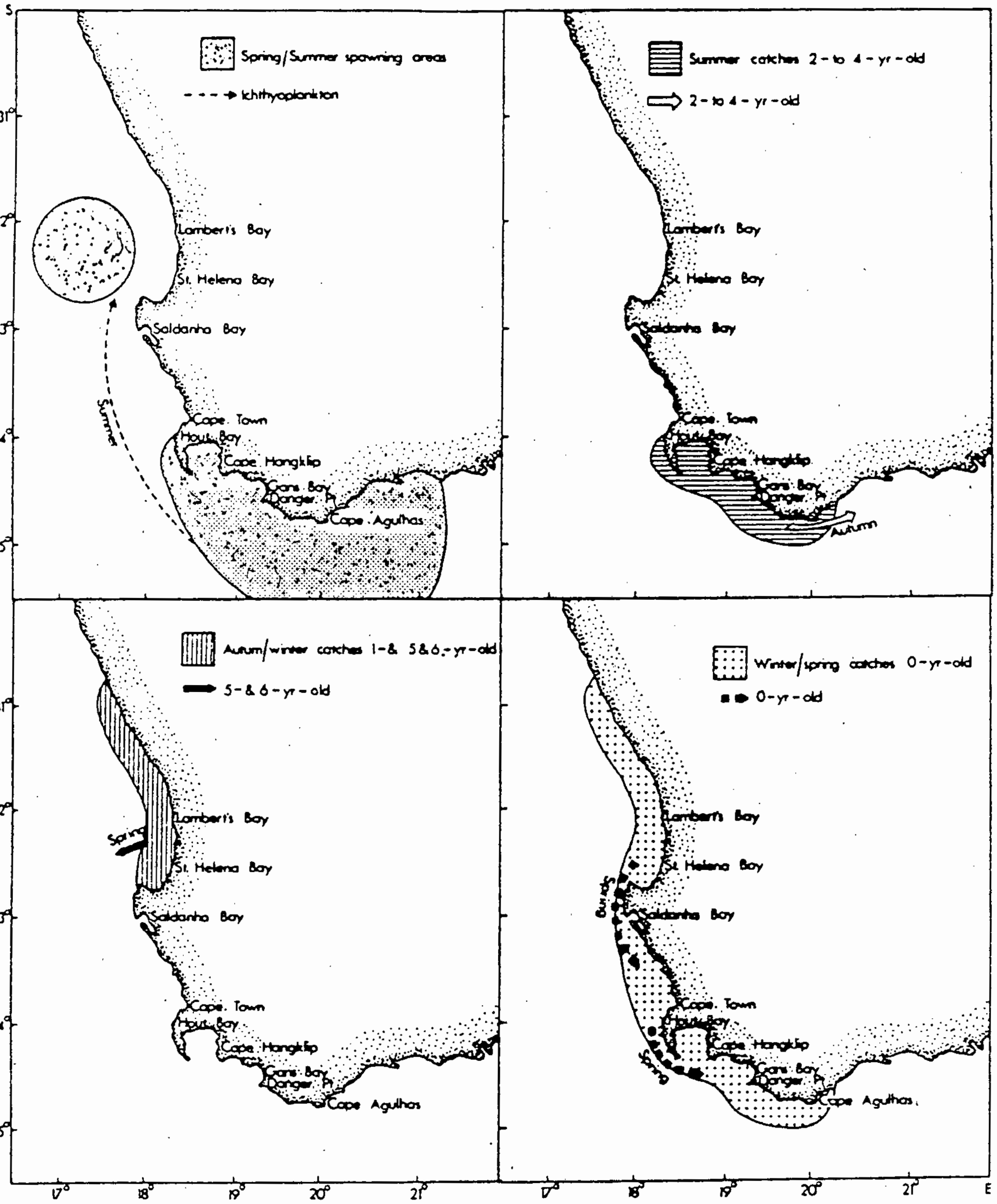


Figure 6.1 The main spawning area and catch locations for different age components of the South African *Sardinops ocellatus* population (After Crawford *et al* 1983).

The relationship between annual pilchard catch and pooled months in this area shows a very similar response to that of the analysis of individual month, the greatest cross-correlation occurring in the period March-April with a one year lag (Table 6.2). This provides greater confidence in the results of pilchard catch relationships with sea surface temperature in the individual months. Overall, therefore, there is a suggestion that in the Namaqualand area, pilchard catches are enhanced by lower temperatures in the months of March and April of the previous year.

<u>**Table 6.2**</u> Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985. (* = P< 0.05).

	Lags		
	0	1	2
May-July	0.0463	0.0816	-0.0942
December-February	-0.2361	-0.2425	-0.1994
March-April	-0.2050	-0.3567*	-0.1476
August-November	-0.1042	-0.3081	-0.1940
October-April	-0.0076	-0.1364	-0.1164

The relationship between pilchard catches and the north-south wind component can be seen in Table 6.3 The largest significant cross-correlation coefficient (r= -0.3560, P< 0.05) occurs in the month of May with a one year lag. There is, thus, a suggested increase in pilchard catches with northerly winds in the month of May the previous year.

During May northerly winds were found to be prevalent (see also Figure 3.2). Therefore, it seems that this result indicates a response of the catches in this area to the prevailing wind direction found in May. An explanation for this is that northerly winds, due to Coriolis force, pushes the surface water masses towards the inshore area, where the majority of the catches occur, and where plankton abundance is highest (Pillar 1986). In confirmation of this hypothesis, Davies (1956) found that an increased occurrence of northerly winds in this area from autumn onwards coincided with increasing pilchard availability.

Table 6.3 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = $P<0.05$).

Months	Lags 0	1	2
January	-0.0708	-0.3175	-0.2894
February	-0.1023	-0.2406	-0.2065
March	-0.1498	0.0231	-0.1870
April	-0.0803	-0.2520	0.1983
May	-0.1796	-0.3560*	-0.0480
June	-0.1286	0.0493	0.2114
July	-0.0382	0.0233	-0.1320
August	0.0598	-0.0417	0.1719
September	-0.1470	0.1316	-0.2355
October	0.0717	-0.1079	-0.0275
November	-0.2016	-0.0991	0.0195
December	-0.0306	0.1297	-0.1721

Although the period May-July does not show any significant relationship with catches as one would have expected following from the individual month analysis, it is interesting to note that in the individual month analysis, the relationship of pilchard catches with north-south wind component in the months of January and February the previous year is high but not significant (Table 6.3).

The relationship between annual pilchard catches and the north-south wind component is significant in December to February (Table 6.4). This period also shows a one year lag and a negative sign for the regression, indicating a favouring of pilchard catches when cool conditions were experienced over the previous summer months (December-February).

Table 6.4 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985. (* = $P<0.05$).

	Lags		
Months	0	1	2
May-July	-0.2205	-0.1223	-0.1858
December-February	0.1731	-0.3453*	-0.0592
March-April	-0.1896	0.0001	0.0606
August-November	0.0810	-0.2235	0.0281
October-April	-0.0783	0.0010	0.0298

In the cross-correlations between pilchard catches and the west-east wind component, there are several significant relationships. In much the same way as the relationship of the north-south wind, the west-east wind component versus pilchard catch analysis shows a very highly significant correlation coefficient in the month of May, with a one year lag ($r = -0.4593$, $P< 0.005$; Table 6.5). This result reinforces the hypothesis that an increase in pilchard catches is coupled with stronger north-westerly winds, mainly due to the prevailing winds in this area during the recruitment months.

These results may perhaps be explained in terms of these wind orientations, which push the fish via the current shorewards where the fish will become available to the fishery. Also, whilst in this area, it is possible for the fish to take advantage of the increased availability of plankton in the nearshore zone (Shannon and Pillar 1986). The first explanation seems unlikely since one would expect, in this scenario, to have an immediate response of the catch and not a one year lag.

Table 6.5 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05, *** = P<0.01).

Months	Lags 0	Lags 1	Lags 2
January	0.3320*	-0.0292	0.0575
February	-0.0770	0.0580	-0.0283
March	-0.1050	0.0646	-0.1226
April	0.0175	-0.0200	0.1767
May	-0.1767	-0.4593***	-0.1449
June	0.0410	0.2190	0.0718
July	-0.0140	0.0238	0.0211
August	0.1189	-0.1187	0.3586*
September	0.1268	0.0235	-0.0501
October	0.1106	-0.1309	0.1803
November	-0.0620	-0.0360	-0.0878
December	0.2126	0.2003	0.1626

Buys (1959), although lacking long-term data, established that pilchard catch, up to 1959, correlated well with sea surface temperatures of the previous year. The one year lag in the present results agrees with Buys' finding and may be related to the effect that environmental conditions have on pilchard catch the following year. North-westerly winds, in this scenario, will favour nought-year-olds by keeping them closer inshore where there is a greater plankton productivity and retain them in the Benguela region. This effect will be reflected in catches of one-year-old fish, peaking during April (Crawford 1981d), the following year. Two other cross-correlations yielded significant results (Table 6.5). The first one shows a positive relationship between annual pilchard catch and an easterly wind component in the month of January. This correlation implies an immediate response of the catch to easterly winds in January in this area. Since nought-year-olds have been encountered in moderately large numbers during this month (Crawford 1981d), the relationship may indicate that upwelling conditions created by an easterly wind component (Taunton-Clark 1985) would favour this age class and pilchard catch in general. The second correlation is based in the month of August with a two year lag and is also positive (Table 6.5).

The pooled-months analysis does not yield any significant results (Table 6.6). However, the cross-correlation between annual pilchard catch and the west-east wind component in the months of May-July the previous year is high. Furthermore, the sign of the correlation, being negative, is comparable to the result of the individual monthly analysis.

Table 6.6 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985.

Months	Lags 0	1	2
May-July	-0.1198	-0.2413	-0.1122
December-February	0.2236	0.0535	0.0697
March-April	-0.0510	0.0240	0.0659
August-November	-0.0118	-0.0095	0.2914
October-April	0.2226	-0.1988	0.1654

South western Cape area and pilchard catch

The cross-correlation between annual pilchard catches and sea surface temperature is highly significant in the month of September (Table 6.7).

Pilchard juveniles join the fishery in the Namaqualand area from May onwards, and then slowly make their way south through the South western Cape area to the spawning grounds of the South Coast (Crawford 1981d). It is, therefore, not unexpected to find a significant correlation in the month of September. This relationship does not have a lag effect, indicating that the response, as reflected in the catches, is immediate. Furthermore, the sign of the correlation is positive, suggesting that pilchard catches appear to be favoured by warm conditions. This result agrees with the current knowledge of pilchard responses to environmental conditions (Shannon *et al.* 1988). However, it does not agree with the previous preliminary results of Spearman Rank correlation analysis and multiple regression analysis.

Table 6.7 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the south western Cape area, 1951-1985. (** = P<0.025).

Months	Lags 0	1	2
January	-0.1622	0.0200	0.1415
February	-0.1490	-0.0570	0.1218
March	-0.0721	-0.0553	0.1391
April	-0.0497	-0.0128	-0.0958
May	-0.1246	0.1636	-0.1706
June	-0.1805	0.2607	0.0136
July	-0.1721	0.1972	0.1175
August	0.1695	0.1951	0.1317
September	0.3984**	0.2379	0.1226
October	0.1108	0.2394	-0.0104
November	-0.1835	0.1539	0.0271
December	-0.1736	-0.0680	0.0496

Table 6.8 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985.

Months	Lags 0	1	2
May-July	-0.1565	0.2566	-0.0237
December-February	-0.1421	-0.0121	0.0132
March-April	-0.0542	-0.0699	-0.0062
August-November	0.0706	0.2592	0.0244
October-April	-0.0557	-0.0266	0.0185

In the pooled months analysis, there are no significant cross-correlations (Table 6.8). Nevertheless, there are high non-significant values in the winter and spring months with a one year lag. Here the signs are again positive, indicating increased pilchard catches with warm conditions. The response of the annual catch is immediate to September's SST in the individual month analysis.

The cross-correlation between annual pilchard catches and the north-south wind component for the month of June is highly significant ($r = -0.4109$, $P < 0.025$), with a one year lag (Table 6.9). The sign of this relationship is negative, indicating that a northerly wind is favourable. Northerly winds prevail in this area during the winter months.

<u>**Table 6.9**</u> Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the south western Cape area, 1951-1985. (** = P<0.025).

Months	Lags 0	1	2
January	-0.0106	-0.0934	-0.0223
February	-0.1053	-0.0851	-0.0735
March	-0.1654	-0.1364	-0.0617
April	-0.3091	-0.0348	0.0764
May	-0.1232	-0.2751	0.2506
June	0.1049	-0.4109**	0.0492
July	0.0962	-0.0859	-0.0935
August	-0.0313	-0.0022	-0.0118
September	-0.1450	0.1868	-0.3011
October	-0.1784	-0.1836	0.1221
November	-0.2904	-0.0105	-0.0117
December	-0.0163	0.0001	-0.1351

Pilchard recruits join the fishery primarily in the Namaqualand area and then move south; thus a cross-correlation between pilchard catch and northerly winds in the month of June may prove to be a reflection that northerly winds favour the southerly migration. This effect of the northerly winds may again be reflected in the catches the following year, when the recruits have attained the age of one year.

The cross-correlation between annual pilchard catches and the north-south wind component of the previous May-July period is highly significant ($r = -0.3806$, $P < 0.05$; Table 6.10). The sign of this relationship is negative, so that northerly winds are also, as with the individual month analysis, indicated as being favourable. The highest cross-correlation between pilchard catch and the May-July north-south wind component is found at a one year lag. The cross-correlation at zero lag is also very significant. The signs of these cross-correlations differ, the zero lag cross-correlation has a positive sign, the one year lag cross-correlation has a negative sign. To explain this phenomenon one should look at the behaviour of the different age classes in this area. According to James (1988) and King and MacLeod (1976) there is a specific dietary difference between juveniles and adults. King and MacLeod postulate that this difference comes as a result of a switch in the diet as the gill rakers develop, whereas James indicated that this effect was rather due to an increased amount of phytoplankton ingested as the rakers develop. Whatever the mechanism, the effect may be to reduce competition intraspecifically. Looking at the results, it is possible that the northerly wind forcing water inshore could benefit juveniles by the greater concentration of zooplankton inshore during winter (Hutchings 1981). This effect will be reflected in the catches the next year. Chlorophyll is assumed to represent the biomass of phytoplankton (Andrews and Hutchings 1980) and according to Hutchings *et al.* (1984) chlorophyll concentrations, although small, were greater offshore in August 1977 in this area. Whether or not this pattern will hold in the long-term is open to debate, but the zero lag relationship found in the results may suggest that adults, being better adapted for the ingestion of phytoplankton (James 1988), could be found in a more offshore position. Also, the sign in this relationship indicates easterly wind as being favourable to the catch, suggesting this upwelling favourable wind could enhance primary productivity and hence survivorship and availability of the adult pilchards in the same year.

Finally, there is another significant cross-correlation between pilchard catch and north-south wind component during the period December to February. This relationship has a one year lag and a negative sign, indicating northerly winds as being favourable (Table 6.10). This result may be related to the fact that previous to 1965, mature pilchards used to spawn in this area during that period. Furthermore, the wind direction (northerly) could perhaps indicate pilchard catch as being favoured the following year, when reduction of upwelling, and hence warmer temperatures are found. This effect would hasten development of the eggs and larvae after spawning (Baird 1970a, Shelton 1987).

__Table 6.10__ Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985. (* = P<0.05).

Months	Lags 0	1	2
May-July	0.3327*	-0.3806*	0.1437
December-February	0.1185	-0.3370*	-0.0540
March-April	-0.2491	-0.0406	0.0139
August-November	-0.2725	0.0701	-0.0965
October-April	-0.0746	0.0237	0.0047

With a one year lag, the cross-correlation between annual pilchard catches and west-east wind component for the month of May is very significant ($r = -0.4325$, $P < 0.01$; Table 6.11). This result indicates a favouring of pilchard catches with winds having a westerly component (negative sign). Westerly winds, in association with northerly winds, bring warm water close inshore, which presumably makes the fish more available to the fishery. This relationship is stronger in the month of May, when juveniles are most abundant. The lag might suggest that these conditions favour juveniles in their migration towards the south coast for spawning and the effect on the catch will be made apparent the following year.

Table 6.11 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component residuals for all months and for the first three lags in the south western Cape area, 1951-1985. (*** = P<0.01).

	Lags		
Months	0	1	2
January	0.1538	-0.1035	0.1418
February	0.1003	0.0898	0.0293
March	-0.0371	-0.0074	0.0887
April	-0.0321	-0.1181	-0.0039
May	-0.0582	-0.4325***	0.0397
June	0.1208	-0.2335	-0.0789
July	0.2489	-0.0785	-0.0085
August	-0.0661	0.0180	-0.0728
September	0.0353	0.1481	-0.1825
October	-0.0403	0.0354	-0.1695
November	-0.2571	-0.2591	-0.1287
December	0.0823	0.2408	0.1348

In the pooled months analysis, the previous cross-correlation is confirmed, indicating a westerly wind as being important in this area, and reflected in the catches the following year. The largest cross-correlation coefficient is found in the one year lag period of May-July ($r = -0.3837$, $P < 0.05$; Table 6.12).

As an example, the September sea surface temperature residuals, June north-south wind component and May west-east component residuals, the latter two being lagged one year, cross correlations with pilchard catch residuals are displayed in Figures 6.2 and 6.3.

Table 6.12 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985. (* = P<0.05).

Months	Lags 0	1	2
May-July	0.1477	-0.3837*	-0.0243
December-February	0.2809	0.0298	0.1428
March-April	-0.0587	-0.0704	0.0777
August-November	-0.1022	-0.0855	-0.1676
October-April	0.0291	-0.0396	0.1556

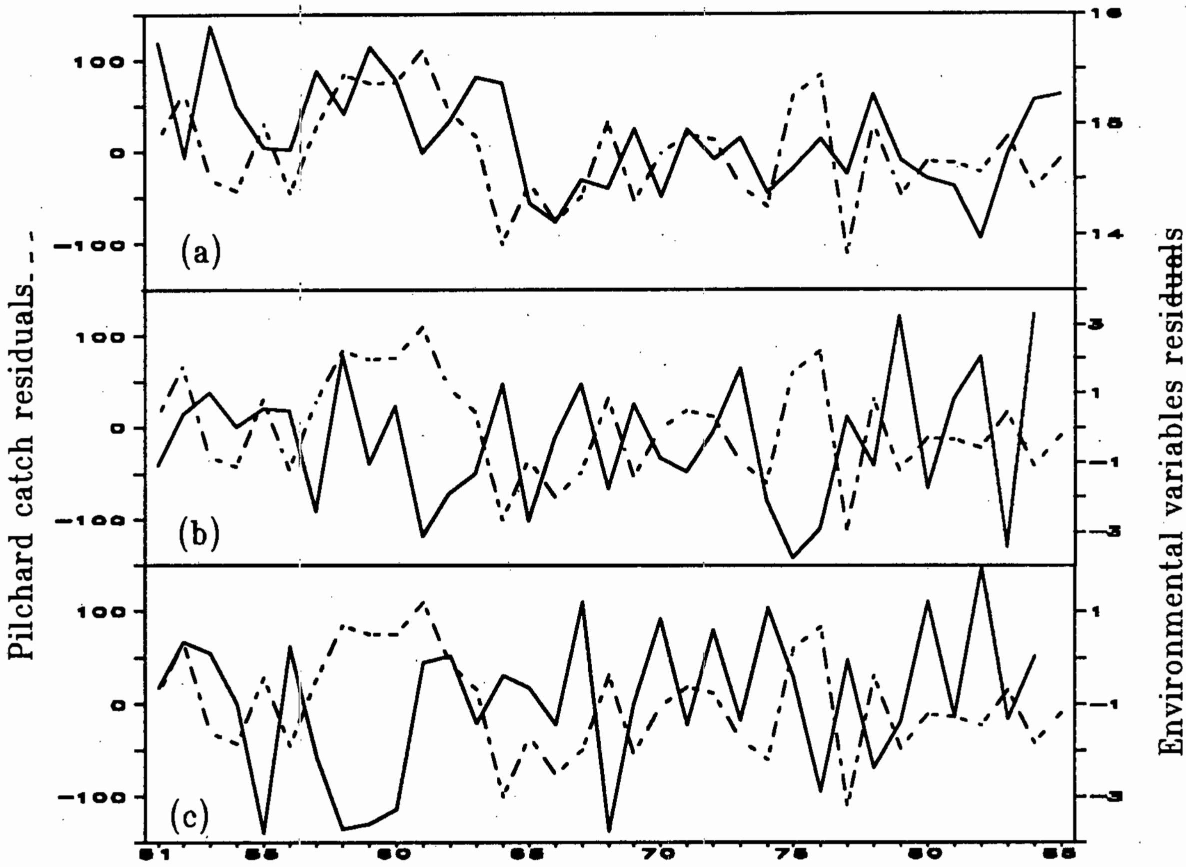


Figure 6.2 Annual pilchard catch residuals and monthly (a) September sea surface temperature residuals, (b) June north-south wind component and (c) May west-east wind component residuals, the latter two being lagged one year, in the south western Cape area.

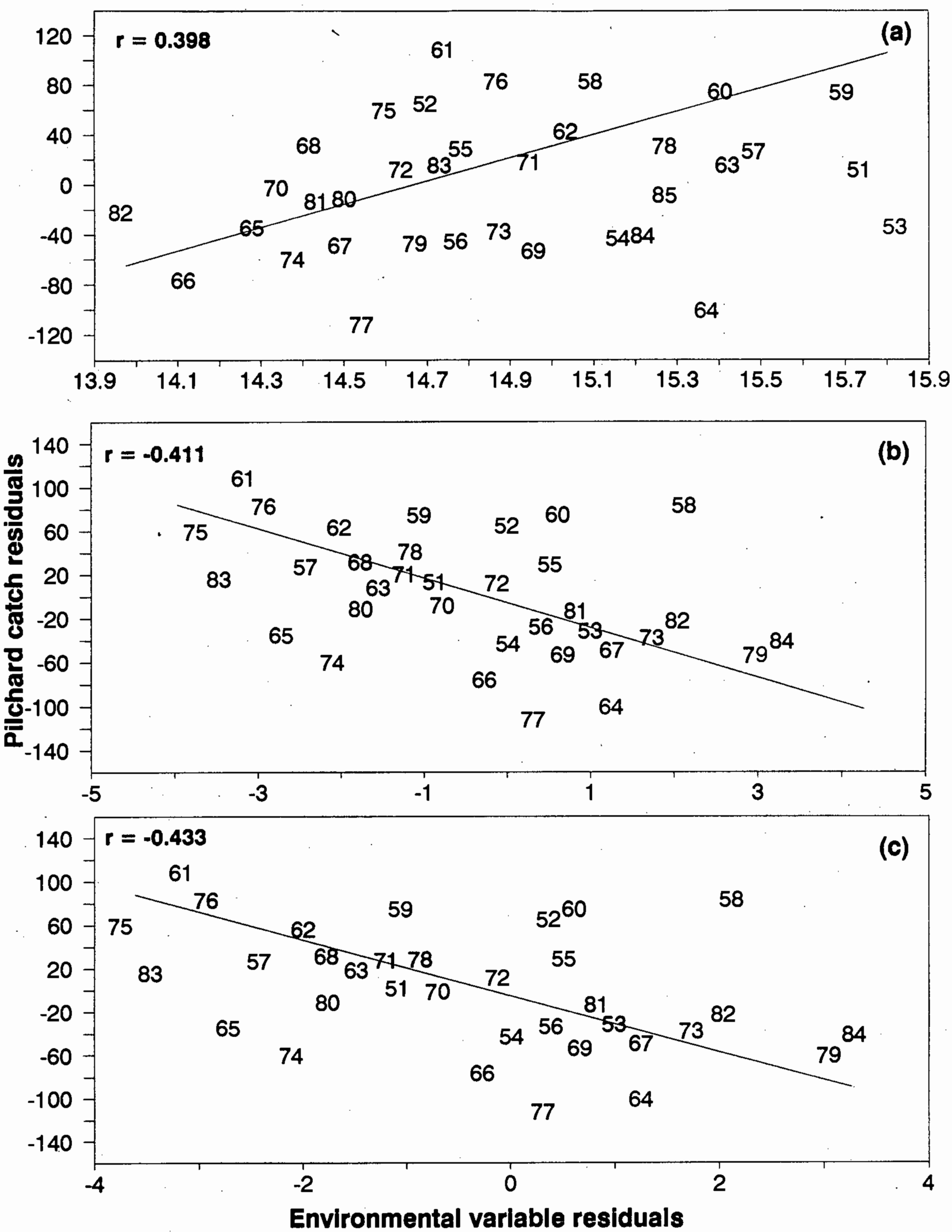


Figure 6.3 Cross-correlation relationships between annual pilchard catches residuals and monthly (a) September sea surface temperature residuals, (b) June north-south wind component residuals lagged one year and (c) May west-east wind component, both wind components lagged one year, in the south western Cape area. A linear regression line is fitted to depict the trend.

Agulhas Bank area and pilchard catch

There is no significant relationship between annual pilchard catch and sea surface temperature in the Agulhas Bank area (Table 6.13). The pilchard stock arrives in this area in spring to start spawning (Crawford 1981d). It is interesting to note, the high but non-significant cross-correlation coefficient for the months of January and February with a two year lag. Also, from January to March and the months of August and November the cross-correlations at the zero year lag are high but not significant. July and August show a high, not significant, cross-correlation coefficient for a one year lag.

Table 6.13 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the south coast area, 1951-1985.

Months	Lags 0	Lags 1	Lags 2
January	-0.2775	-0.0787	-0.3222
February	-0.3077	-0.2157	-0.2452
March	-0.2491	-0.0866	-0.1514
April	-0.1417	-0.0281	-0.1366
May	-0.0902	-0.0718	-0.1380
June	0.0259	0.0579	-0.0222
July	0.2067	0.2528	0.0801
August	0.3268	0.2678	0.1321
September	0.2203	0.1448	0.0560
October	-0.1239	0.0540	-0.1095
November	-0.2778	0.0882	-0.0890
December	-0.1718	0.0151	-0.0356

It is also interesting to note that the signs of all the largest cross-correlation are negative. According to Armstrong *et al.* (1987b), pilchard availability to the fishermen is increased in this area. This effect may be due to two factors. Firstly pilchard will tend to avoid the warming and stratification of the offshore Agulhas Bank waters during summer and concentrate in the cooler inshore area. Secondly the increase of upwelling and plankton production rates at the inshore capes will retain the fish shoals inshore (Armstrong *et al* 1987a). Thus, it seems that although pilchard spawn in this area to take advantage of the warmer temperatures, which could benefit egg and larval survival (King *et al* 1978), they prefer to situate themselves in the cooler and more productive inshore areas.

In the pooled months results of the cross-correlations between annual pilchard catch and sea surface temperature for the south coast, there is a significant cross-correlation in the period December to February (Table 6.14). During these months, pilchards spawn in this area. The results indicate an enhancement of pilchard catch two years after there were cooler temperatures during summer.

<u>Table 6.14</u> Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the south coast area, 1951-1985. (* = $P<0.05$).

		Lags	
Months	0	1	2
May-July	0.0203	0.0945	-0.0762
December-February	-0.2048	-0.0687	-0.3647*
March-April	-0.2019	-0.0591	-0.1493
August-November	0.0599	0.1654	0.0056
October-April	-0.2451	-0.0412	-0.3229

The December to February cross-correlation has a two year lag associated with the regression. This lag may indicate that conditions during spawning influence eggs and larvae. This effect is only reflected in the catch two years later, in the age-class at which juveniles begin to mature (Armstrong *et al.* 1987b), becoming part of the spawning stock. The period October-April although not significant, also has a high correlation coefficient, indicating a similar relationship with sea surface temperature.

In the relationship between annual pilchard catch and the north-south wind component in the south coast area, there are three significant cross-correlations (Table 6.15). Two of them, viz January and October have a two year lag, the other, in May, has a one year lag. The two year lag results agree remarkably well with the sea surface temperature correlations (Table 6.13). In both of them the effect of the environmental variables on the fish and its reflection on the catches is found during the spring and summer months. The sign of these north-south cross-correlations with pilchard catch is positive, indicating southerly winds as being favourable. According to Lutjeharms and Meeuwis (1987), south and south-westerly winds are responsible for most of the upwelling in this area. The two year lag can still be explained by the effect of the environmental conditions, in this case southerly winds, on the eggs and larvae of pilchard and its reflection on the catches two year later.

Table 6.15 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the south coast area, 1951-1985. (* = P<0.05).

		Lags	
Months	0	1	2
January	0.2023	0.1516	0.3628*
February	-0.1558	-0.1601	0.2882
March	-0.1628	0.2555	0.2007
April	0.0344	-0.0582	0.2369
May	0.0350	-0.3382*	0.1623
June	0.3100	-0.0091	0.2248
July	0.2735	-0.0086	0.1771
August	-0.0101	0.0603	0.0291
September	0.1872	0.0358	-0.1380
October	0.1543	-0.0623	0.3838*
November	-0.2511	0.1048	0.0975
December	-0.1624	0.0951	0.2520

In contrast to the above result, the cross-correlation between pilchard catches and north-south wind component the previous year in May has a negative sign

(Table 6.15), indicating northerly winds to be more important. This relates to the statement made by Armstrong *et al.* (1987b) that northerly winds benefit pilchard catches during winter, purely due to the availability of the fish stock to the fishery.

In the pooled months analysis, there are two periods of significant cross-correlations (Table 6.16). The first one is found during December to February with a two year lag indicating increased catches with southerly winds two years previously. This result is consistent with the results obtained in the individual month analysis. Therefore, the previous explanation for this effect of the two year lag and southerly winds still applies. The second period of significant cross-correlations is found in May to July with no lag. This indicates an immediate favouring of pilchard catches with southerly winds during late autumn and winter.

Table 6.16 Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the south coast area, 1951-1985. (* = $P < 0.05$).

	Lags		
Months	0	1	2
May-July	0.3249*	-0.1794	0.2936
December-February	0.1271	0.0580	0.3693*
March-April	0.0271	0.0263	0.0386
August-November	-0.0823	0.1263	0.2927
October-April	-0.1171	0.0986	0.2773

In the cross-correlations between annual pilchard catch and west-east wind components there are four very significant relationships. One with a no lag value in the month of July and three with a one year lag in the months of May, October and December (Table 6.17).

The cross-correlation between pilchard catch and west-east wind component in the month of May indicates improved catches with westerly winds, and complements the result obtained between pilchard catch and the north-south wind component, in terms of lag and month. The cross-correlation with the same lag in the month of December, indicates easterly winds during the summer months to be important. This cross-correlation in the spawning months may suggest the favouring of catches with easterly winds, which may not necessarily promote upwelling in this area (Lutjeharms and Meeuwis 1986).

<u>**Table 6.17**</u> Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component for all months and for the first three lags in the Agulhas Bank area, 1951-1985. (* = P<0.05, ** = P<0.025, *** = P<0.01).

		Lags	
Months	0	1	2
January	0.2635	-0.2471	0.1519
February	-0.0775	-0.0754	0.0388
March	-0.1944	0.2319	0.1184
April	-0.0199	-0.1423	0.1544
May	0.0056	-0.4507***	0.1854
June	0.1811	-0.1553	0.0564
July	0.4094**	0.1212	0.2195
August	-0.0343	-0.1039	0.1531
September	0.2012	0.2246	-0.0797
October	0.0770	-0.3362*	-0.0470
November	-0.0286	0.0251	-0.1111
December	0.0985	0.4416***	0.1809

It is interesting to note that the cross-correlation between pilchard catches and west-east wind component at lag zero in the month of July is positive, indicating easterly winds to be favourable (Table 6.17). In the north-south relationships (Table 6.15), a high but non significant relationship in the same month was found. Therefore, it seems that south-easterly winds in July immediately benefit the pilchard catch. These wind components might be responsible for the shoreward migration of the fish stock, thus making the fish available to the fishing industry. The cross-correlation in October with a one year lag indicates westerly winds as being favourable.

In the pooled months analysis between annual pilchard catch and west-east wind component in the Agulhas Bank area, there is only one significant cross-correlation. This cross-correlation is found in the period May-July (Table 6.18). It has a positive sign and has no lag. The positive sign indicates improved pilchard catch in this area with easterly winds. This result, therefore, agrees well with the analysis of individual months.

__Table 6.18__ Cross-correlation coefficients between annual pilchard (*Sardinops ocellatus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the Agulhas Bank area, 1951-1985. (* = $P<0.05$).

Months	Lags 0	Lags 1	Lags 2
May-July	0.3278*	-0.2339	0.1843
December-February	0.2165	-0.0832	0.1121
March-April	0.0019	-0.0896	-0.0033
August-November	-0.1393	0.0571	0.1784
October-April	-0.0303	-0.0497	0.2581

__6.3.2 Horse mackerel and environmental variables__

__Namaqualand area and horse mackerel catch__

The relationship between annual horse mackerel catches and sea surface temperature shows two principal periods of high correlations, one at lag 0, the other at lag one. The immediate response of the fish, reflected in the catches in this area, corresponds to the winter months, establishing a significant cross-correlation with the month of August (r = -0.3374, P< 0.05; Table 6.19) and fairly high correlations with the months of June, July and September, although not significant. The largest catches of the older age-classes of horse mackerel are made in this area from late summer to winter (Crawford 1981b), and it is therefore not surprising that there is a good significant cross-correlation here in the winter months. This relationship is therefore associated with the older age-classes present during winter (Figure 6.4). A more significant relationship exits between horse mackerel catches and sea surface temperatures of the previous year. This relationship is found in the months of February and March, January also being positive correlated (Table 6.19). While the zero lag relationship has a negative sign, suggesting good catches with cool conditions in August, the relationships with a one year lag have a positive sign from January to March. These relationships are similar, but of different sign, to those of pilchard catches and sea surface temperature.

Table 6.19 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05, ** = P<0.025).

	Lags		
Months	0	1	2
January	-0.2499	0.3223	-0.1501
February	-0.1625	0.3953**	-0.1564
March	-0.0659	0.3784*	-0.1996
April	0.0395	0.1714	-0.0875
May	-0.1364	0.0354	0.0591
June	-0.3159	-0.0944	0.0120
July	-0.3099	-0.1021	-0.0233
August	-0.3374*	-0.1443	0.0080
September	-0.3254	-0.1604	0.0016
October	-0.1862	-0.1629	-0.0208
November	-0.0573	-0.1386	0.0586
December	-0.1778	0.2009	0.2253

According to Crawford (1981b), one-year-old horse mackerel are most available in this area during summer. Also, horse mackerel spawn south of this area during summer and early autumn (Crawford 1981b), so that increased temperatures may benefit eggs and larvae (King *et al.* 1977). The lag indicates that these conditions are only reflected in the catch the next year.

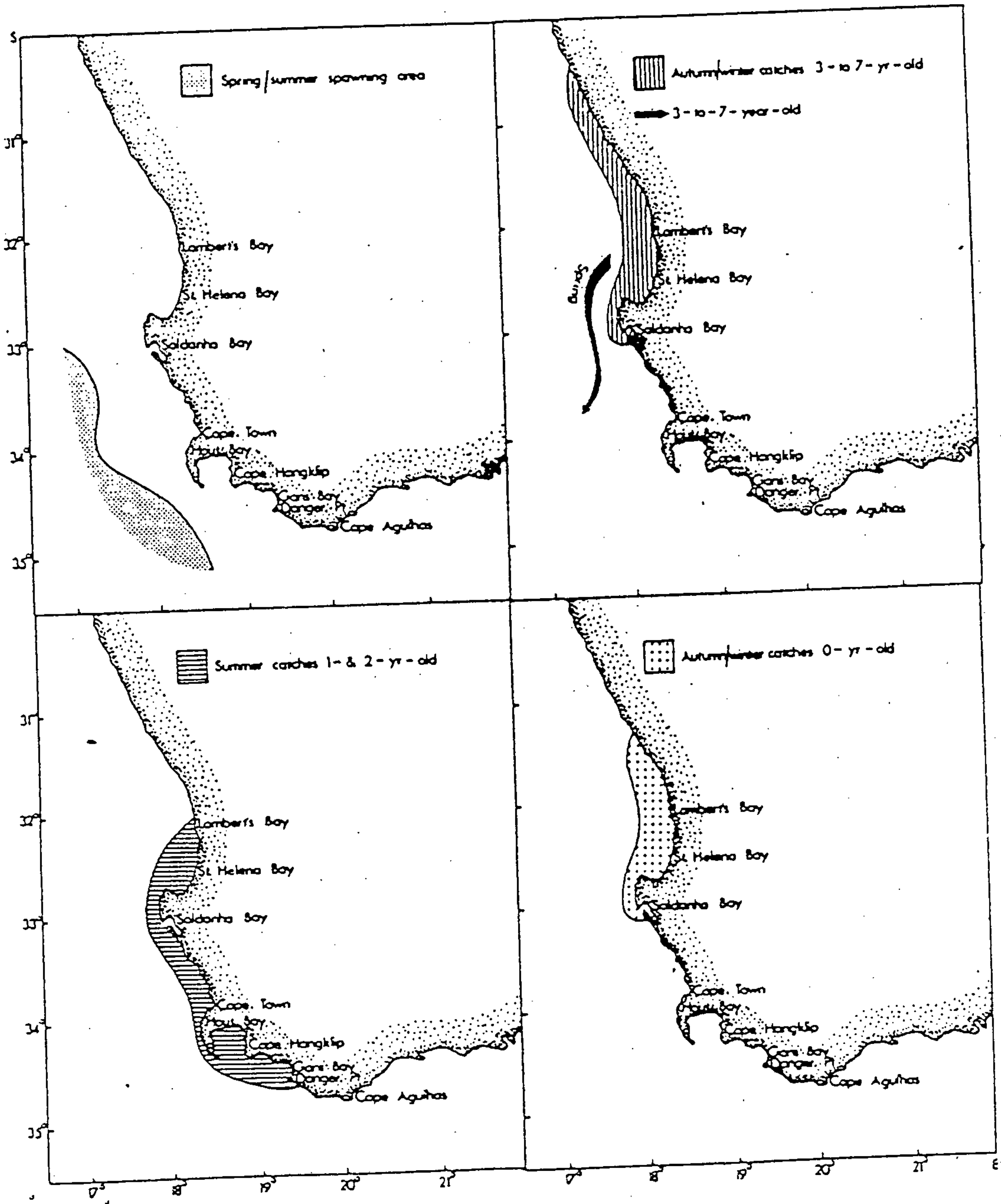


Figure 6.4 The main spawning area and catch locations for different age components of horse mackerel *Trachurus trachurus* population (After Crawford *et al.* 1983).

In the pooled months analysis, the relationship between annual horse mackerel catch and sea surface temperature has a significant correlation in the period August-November of the previous year (r = 0.3441, P< 0.05; Table 6.20). The lag of this relationship is one year and the sign indicates improved catches with warmer conditions.

Table 6.20 Cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05).

Months	Lags 0	1	2
May-July	-0.2771	-0.0583	-0.0014
December-February	-0.0910	0.2104	-0.0271
March-April	-0.0714	0.3101	-0.1580
August-November	-0.2277	0.3441*	-0.1113
October-April	-0.1981	-0.1787	-0.0171

Although Crawford (1981b) did not believe the good catch rates of three to seven year-old horse mackerel in the month of September to be a true reflection of the horse mackerel population distribution in that month, my results indicate that the relationship may in fact exist. Therefore, it seems that horse mackerel catch is improved by warm sea surface temperature conditions prevalent in the spring months the previous year.

In the relationship between annual horse mackerel catches and north-south wind component there is a significant cross-correlation in the month of October (Table 6.21). The cross-correlation in October has a negative sign and no lag. Since the fishing season closes in October, there is no hard evidence for the availability of the horse mackerel stock from October to December. However, the high catch rates of September (Crawford 1981b) may indicate availability of horse mackerel during these months. Whatever the cause, horse mackerel catches seem to be improved by northerly winds during the spring months.

Table 6.21 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the Namaqualand area, 1951-1985. (** = P<0.025).

	Lags		
Months	0	1	2
January	-0.0937	-0.1706	-0.0174
February	-0.1506	0.1905	-0.1105
March	-0.0301	-0.1459	0.2698
April	-0.0092	-0.1901	-0.0562
May	0.1612	-0.1035	-0.2130
June	-0.0898	0.0247	-0.1181
July	0.1254	-0.0732	-0.2811
August	-0.2459	-0.2696	0.1753
September	-0.1767	-0.1574	-0.1717
October	-0.4264**	0.1754	0.0133
November	-0.3127	0.1487	-0.3006
December	0.0941	-0.1430	0.1472

In the analysis of pooled months, there is a very high cross-correlation coefficient between annual horse mackerel catch and north-south wind component in the period October to April (Table 6.22). This agrees with the previous result and corroborates improved horse-mackerel catches in this area during the period October to April. During these months horse-mackerel spawn offshore off Saldanha Bay, near the southern limit of this area, and this suggests northerly winds may benefit catches immediately. The northerly wind brings about a change in ocean conditions which are primarily manifested in the cessation of upwelling, this being important for the faster development and better survival of eggs and larvae of most pelagic species. This fact was also in evidence in the results of cross-correlations during the horse mackerel spawning months, when positive SST influences were found.

The May-July cross-correlation with two year lag has a positive sign (Table 6.22). The sign suggests southerly winds as being most important.

Table 6.22 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05, ** P < 0.025).

	Lags		
Months	0	1	2
May-July	0.1929	0.0904	0.3790*
December-February	-0.2467	0.0896	-0.1283
March-April	-0.1146	-0.1736	0.2395
August-November	0.0332	-0.1775	-0.0299
October-April	-0.4367**	-0.0975	-0.0546

With regard to the west-east wind component, there are two significant cross-correlations. These cross-correlations are found in the months of March and November, both with a two year lag (Table 6.23).

Table 6.23 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05).

	Lags		
Months	0	1	2
January	-0.1201	0.0321	0.2433
February	-0.3222	0.0714	0.2257
March	-0.0090	-0.2537	0.3499*
April	-0.0708	0.1532	-0.0628
May	0.0456	0.0180	0.1914
June	0.0798	-0.0632	-0.1172
July	-0.0184	0.1464	0.1323
August	-0.2770	-0.1402	0.0181
September	-0.1037	0.0426	0.0702
October	-0.1470	0.2105	-0.1755
November	-0.1576	-0.1987	-0.3783*
December	0.1474	-0.1373	0.0093

The cross correlation between horse mackerel catches and west-east wind component in November is negative, indicating increased catches with westerly winds. The cross correlation in March, however, is positive, indicating easterly winds to be favourable. The November cross-correlation, therefore, also indicates non upwelling conditions during spring to be favourable for the catch. This is further evidenced by the high and positive cross-correlation coefficients of January and February (Table 6.23). The lag of two years is particularly interesting. The effect of the west-east wind component during March and November on the catch is only reflected two years later. A noticeable feature of horse mackerel catch in the latter part of the record was the young age structure of the landings (Crawford 1981b). This reduction in the estimated main age at capture (Table 1.2) may have something to do with the two year lag present here. Therefore, it seems plausible to invoke the effect of the wind component on the eggs and larvae, which is reflected in the catch as two-year-olds.

Table 6.24 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05, ** = P<0.025).

Months	Lags 0	1	2
May-July	0.1431	0.0470	0.1429
December-February	-0.4398**	0.0007	0.2343
March-April	-0.0624	-0.0342	0.1663
August-November	-0.1690	-0.2635	0.0367
October-April	-0.3706*	-0.0342	-0.2124

There are two highly significant cross-correlations between annual horse mackerel catches and west-east wind component in the pooled months analysis in this area (Table 6.24). These are found in the periods of December-February and October-April, both of them at zero lag. Both of these periods include the horse mackerel spawning season and both have a negative sign indicating improved catches with westerly winds. As a result, in this area, there seem to be indications of increase in horse mackerel catch with westerly winds and thus a cessation of upwelling, benefiting catch residuals immediately. The main age-class affected in these months will be the nought-year old horse mackerel (Crawford *et al* 1983).

South western Cape area and annual horse mackerel catches

In the South western Cape area, there are two significant cross-correlations between annual horse mackerel catch and sea surface temperature (Table 6.25). These two cross-correlations are found in the months of March and April, both having positive signs and a one year lag. In these months warmer waters seem to have an important effect on the catch, which becomes apparent the following year.

Table 6.25 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus)* catch residuals and sea surface temperature residuals for all months and for the first three lags in the south western Cape area, 1951-1985. (* = P<0.05).

Months	Lags 0	1	2
January	0.0028	0.2525	0.0104
February	0.0095	0.3181	-0.0334
March	0.1049	0.3765*	-0.1080
April	0.0439	0.3800*	-0.1028
May	0.0995	0.0874	0.0386
June	0.0203	-0.0005	0.0651
July	-0.0650	0.0210	-0.0557
August	-0.0730	0.0279	0.0654
September	-0.0731	0.1097	0.2073
October	0.0121	-0.0165	0.2367
November	0.0835	-0.0706	0.1852
December	-0.0415	-0.0738	0.2352

Reinforcing such a result and making it more plausible, it is important to note that the cross-correlations in the months of January and February are also large, although not significant.

It seems that there is a good indication of the prevailing warmer conditions experienced in this, the spawning area, during the summer months. These conditions will benefit the horse mackerel eggs and larvae and will appear to be reflected in the catches the following year. This hypothesis is confirmed by the distribution of the main one and two-year-old horse mackerel catch as shown by Crawford *et al.* (1983; Figure 6.4). The beneficial effect of warmer temperatures for horse mackerel was also found by a study of the correlation between horse mackerel catch and sea surface temperature performed by Buys (1959). More recently Shannon *et al.* (1988) arrived at the same conclusion after establishing a positive relationship between horse mackerel year-class strength and SST off Namibia. Thus, this effect appears to be consistent in all analyses.

Table 6.26 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985. (** = P<0.025).

Months	0	Lags 1	2
May-July	0.0314	0.0440	0.0284
December-February	-0.0343	0.3024	-0.0270
March-April	0.0246	0.4209**	-0.0951
August-November	0.0218	-0.0663	0.2414
October-April	-0.0437	0.4138	-0.0838

Results of the pooled months analysis, show that the cross-correlation between annual horse mackerel catch and sea surface temperature is again highly significant during the months of March and April (Table 6.26). Here, again, the sign of the cross-correlation indicates increased catches with warmer conditions.

The lag of the March-April cross-correlation is one year, reflecting the effect of the sea surface temperature in the catches the following year. This makes plausible the hypothesis that conditions during the spring months will benefit eggs and larvae and this benefit will be reflected in the catches of one and two-year-olds. In the north-south wind relationships with annual horse mackerel catches there are no significant cross-correlations (Table 6.27).

<u>Table 6.27</u> Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the south western Cape area, 1951-1985.

Months	Lags 0	1	2
January	-0.1375	-0.1497	-0.0339
February	-0.2301	-0.2219	0.0851
March	0.1370	0.1041	0.0317
April	0.1773	-0.1247	-0.1768
May	0.1386	0.0115	-0.0849
June	-0.0136	0.2737	-0.2002
July	0.0098	-0.0859	-0.1729
August	-0.1486	-0.3037	0.1773
September	-0.1634	-0.0996	0.1555
October	-0.1862	-0.0511	-0.0583
November	-0.0385	0.1576	-0.0257
December	0.1126	-0.1904	-0.1060

In the pooled months analysis of the relationships between annual horse mackerel catch and north-south wind component, there is a significant cross-correlation in the period October-April. The lag of this relationship is one year and the sign indicates northerly winds favouring catches.

As was the case of the sea surface temperature, the effect of the wind is again evident in the spawning months (Table 6.28). Newly spawned eggs and larvae may benefit from warmer conditions, as shown by the sea surface temperature relationship and northerly winds.

Table 6.28 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985. (* = P< 0.05).

		Lags	
Months	0	1	2
May-July	-0.1019	-0.0395	-0.2601
December-February	-0.2993	-0.1624	0.0842
March-April	0.2287	0.0349	-0.1362
August-November	-0.2928	-0.0551	0.0778
October-April	-0.1046	-0.3834*	0.0857

Table 6.29 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component residuals for all months and for the first three lags in the south western Cape area, 1951-1985.

		Lags	
Months	0	1	2
January	0.0182	-0.2311	-0.0056
February	0.0711	-0.3210	0.1966
March	0.0693	0.0206	0.1206
April	0.0332	-0.0588	-0.1503
May	0.1265	0.0629	-0.1048
June	-0.0734	-0.0012	-0.2825
July	-0.1570	0.0278	0.1684
August	0.0039	-0.1260	0.3376
September	-0.2986	0.1947	0.2853
October	0.2689	0.0063	0.1534
November	-0.1403	-0.0387	-0.1502
December	0.0677	-0.0498	-0.0368

In the relationship with west-east wind component, there are no significant cross-correlations (Table 6.29).

The cross-correlation coefficients, however, show large values in January and February with a one year lag. The sign of these cross-correlations is negative, suggesting westerly winds as possibly influencing the catches. This possible effect of the westerly winds on horse mackerel catches has a one year lag.

In the pooled months analysis, there are no significant cross-correlation values. Here again the cross-correlation coefficient values for the periods October-April and December-February are quite high and have a one year lag (Table 6.30).

<u>Table 6.30</u>. Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the south western Cape area, 1951-1985.

		Lags	
Months	0	1	2
May-July	-0.0591	0.0452	-0.1233
December-February	-0.0221	-0.3196	0.2147
March-April	0.0671	-0.0136	0.0247
August-November	-0.0856	0.0460	0.2338
October-April	0.0441	-0.2346	0.0627

Therefore, horse mackerel catches are influenced by the westerly winds and cessation of upwelling the previous year, in the same way as in the Namaqualand area, presumably due to the effect on the newly spawned eggs and larvae.

Agulhas Bank area and horse mackerel catches

In the Agulhas Bank relationships between annual horse mackerel catches and sea surface temperature, there are four significant cross-correlation coefficients (Table 6.31). These cross-correlations are found in the months of February, March, April and November, the highest corresponding to the month of March ($r = 0.4182$ $P < 0.005$). All three relationships have positive signs indicating warmer temperatures to be influencing the catches. The lag is zero and therefore the effect of the SST on the catch is expected to be immediate.

Figure 6.31 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and sea surface temperature residuals for all months and lags in the Agulhas Bank area, 1951-1985. (* = $P<0.05$, ** = $P<0.025$, *** = $P<0.01$).

		Lags	
Months	0	1	2
January	0.2184	0.0754	0.0753
February	0.3360*	0.1995	-0.1081
March	0.4182***	0.2366	-0.1330
April	0.3571*	0.1847	0.0045
May	0.1765	0.1463	0.0650
June	-0.0146	0.2642	-0.0462
July	-0.0991	0.3229	-0.0070
August	0.0363	0.2741	0.1214
September	0.0345	0.2492	0.1976
October	0.2078	0.1529	0.2339
November	0.4067**	0.0166	0.1330
December	0.2542	0.0484	0.0501

According to Crawford *et al.* (1983), in the western area of the Agulhas Bank, one and two-year-olds are caught during the summer months. It is therefore not unreasonable to expect an immediate response of those age-classes which have the highest representation in the catch (Crawford 1981b). The cross-correlation in November also shows a positive sign and a zero year lag (Table 6.31).

In the pooled months analysis, the cross-correlation between horse mackerel catch and SST in the period March-April is highly significant (Table 6.32). This relationship has a zero lag and a positive sign, indicating an immediate effect on the catches with warmer temperatures. It also confirms the individual month analysis results. The warm temperatures may affect one and two year-old horse mackerel in this area, and there is an indication that these age-classes have a preference for warmer waters (Naish 1990). Hence, this result agrees with those of Shannon *et al.* (1988) and Buys (1959), who indicated a beneficial effect on horse mackerel year-class strength and catch with warmer conditions.

__Table 6.32__ Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the Agulhas Bank area, 1951-1985. (** = P<0.025).

Months	Lags 0	Lags 1	Lags 2
May-July	-0.0132	0.2712	-0.0274
December-February	0.2340	0.1321	-0.0083
March-April	0.4018**	0.2182	-0.0656
August-November	0.1876	0.2042	0.1940
October-April	0.2343	0.2657	-0.0340

In the cross-correlations between horse mackerel and north-south wind component there is a highly significant cross-correlation coefficient evident in December (Table 6.33). This relationship has a zero lag and a positive sign, indicating an immediate response of the horse mackerel catch to northerly winds during the summer months. Southerly winds promote upwelling in this area (Lutjeharms and Meeuwis 1986), thus in this cross-correlation, upwelling unfavourable winds are in evidence and the results agrees with the positive relationship found between horse mackerel catches and temperature (Table 6.31, Table 6.32).

Table 6.33 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the Agulhas Bank area, 1951-1985. (*** = P < 0.01).

Months	Lags 0	1	2
January	0.0003	-0.0498	0.1403
February	-0.1231	0.0050	0.1194
March	-0.0640	-0.0722	0.0863
April	0.0023	-0.2108	0.1196
May	0.2223	-0.1132	0.1038
June	0.0349	0.0387	-0.1286
July	-0.0443	-0.0269	0.0028
August	-0.0148	-0.0175	0.1045
September	-0.2177	-0.0956	0.2255
October	-0.0588	0.0522	-0.1195
November	-0.0138	0.1571	-0.0063
December	0.4464***	-0.1281	-0.2561

Table 6.34 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the Agulhas Bank area, 1951-1985.

Months	Lags 0	1	2
May-July	0.1472	-0.0255	-0.0673
December-February	-0.1410	-0.0855	0.2285
March-April	-0.0159	0.0078	0.0403
August-November	-0.0400	-0.1912	0.1379
October-April	0.0252	-0.2987	0.1530

In the analysis of pooled months there is no significant cross-correlation between horse mackerel catches and north-south wind component in this area (Table 6.34).

There is a significant cross-correlation between horse mackerel catches and west-east wind component in the month of December with a one year lag (Table 6.35). The negative sign of this relationship establishes westerly winds as favouring catches. In the part of this area where concentration of one and two-year-old horse mackerel is demonstrated by Crawford *et al.* (1983), westerly winds are indicative of non-upwelling conditions (Lutjeharms and Meeuwis 1986). Therefore, it appears to corroborate the preference of horse mackerel for warmer waters.

Table 6.35 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component residuals for all months and for the first three lags in the Agulhas Bank area, 1951-1985. (* = P<0.05).

		Lags	
Months	0	1	2
January	0.1981	-0.0637	-0.0775
February	-0.0733	-0.2391	0.1195
March	-0.1777	-0.0927	0.1545
April	0.1420	-0.0138	-0.0572
May	0.0535	-0.0326	-0.2273
June	0.0069	-0.0114	-0.1736
July	-0.0437	0.1296	0.2795
August	-0.0305	0.1782	0.3020
September	-0.2945	0.1035	0.1806
October	0.1369	0.0420	-0.1548
November	-0.2367	-0.1579	0.0070
December	0.1490	-0.3428*	0.0532

Table 6.36 Cross-correlation coefficients between annual horse mackerel (*Trachurus trachurus*) catch residuals and west-east wind component residuals for pooled months and for the first three lags in the Agulhas Bank area, 1951-1985.

		Lags	
Months	0	1	2
May-July	0.1214	-0.0050	-0.0121
December-February	-0.0963	-0.2428	0.2348
March-April	-0.1147	0.0970	0.0516
August-November	-0.0221	-0.0693	0.0628
October-April	-0.0914	-0.2961	0.0860

In the analysis of pooled months, there is no significant relationship between annual horse mackerel catch and west-east wind component (Table 6.36).

Figures 6.5 and 6.6 show examples of the significant cross-correlations found in the Agulhas Bank area between annual horse mackerel catch residuals and environmental variables residuals.

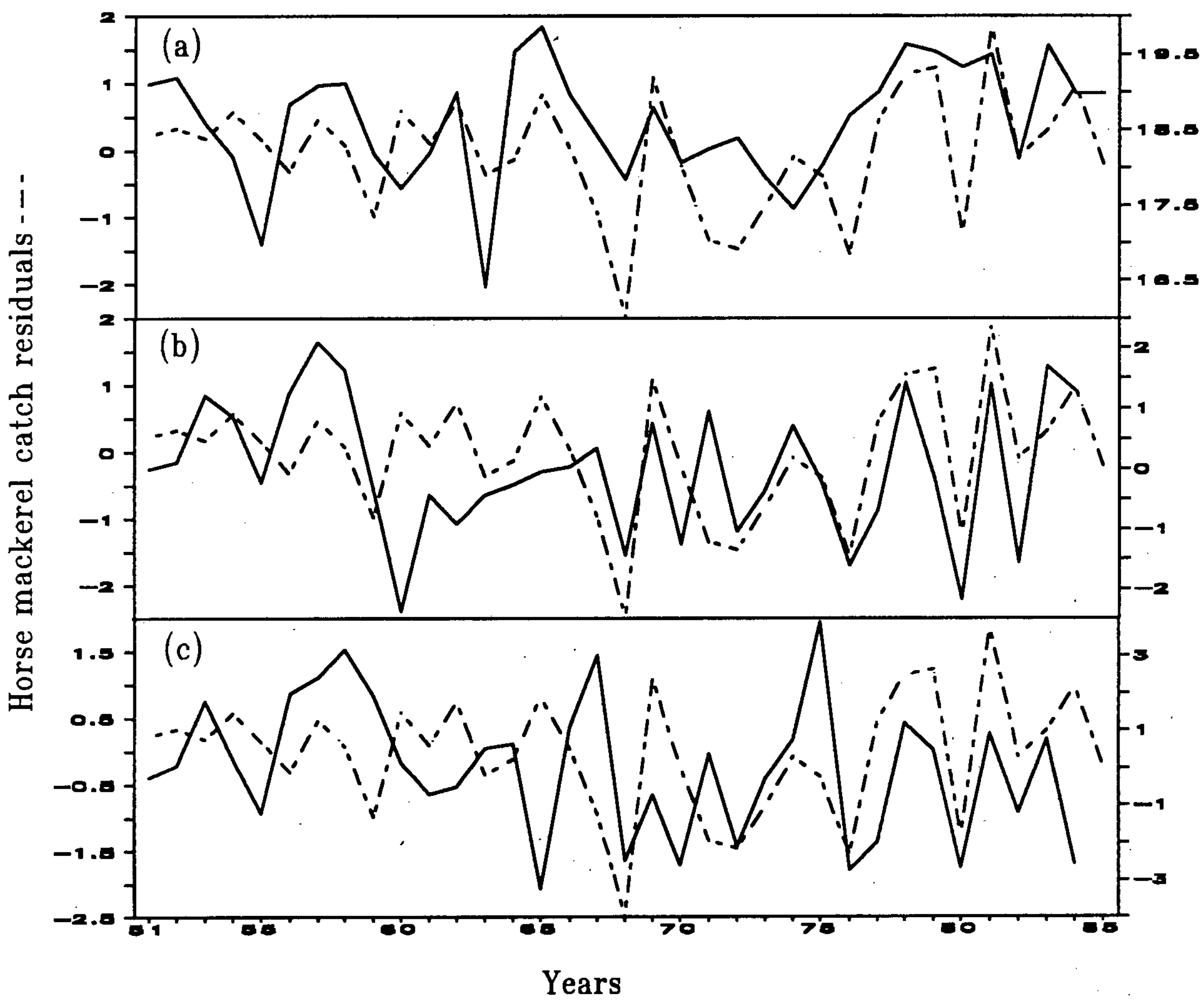


Figure 6.5 Horse mackerel catch residuals and (a) March-April sea surface temperature residuals, (b) December north-south wind component, (c) December-east wind component residuals lagged one year, in the Agulhas Bank area.

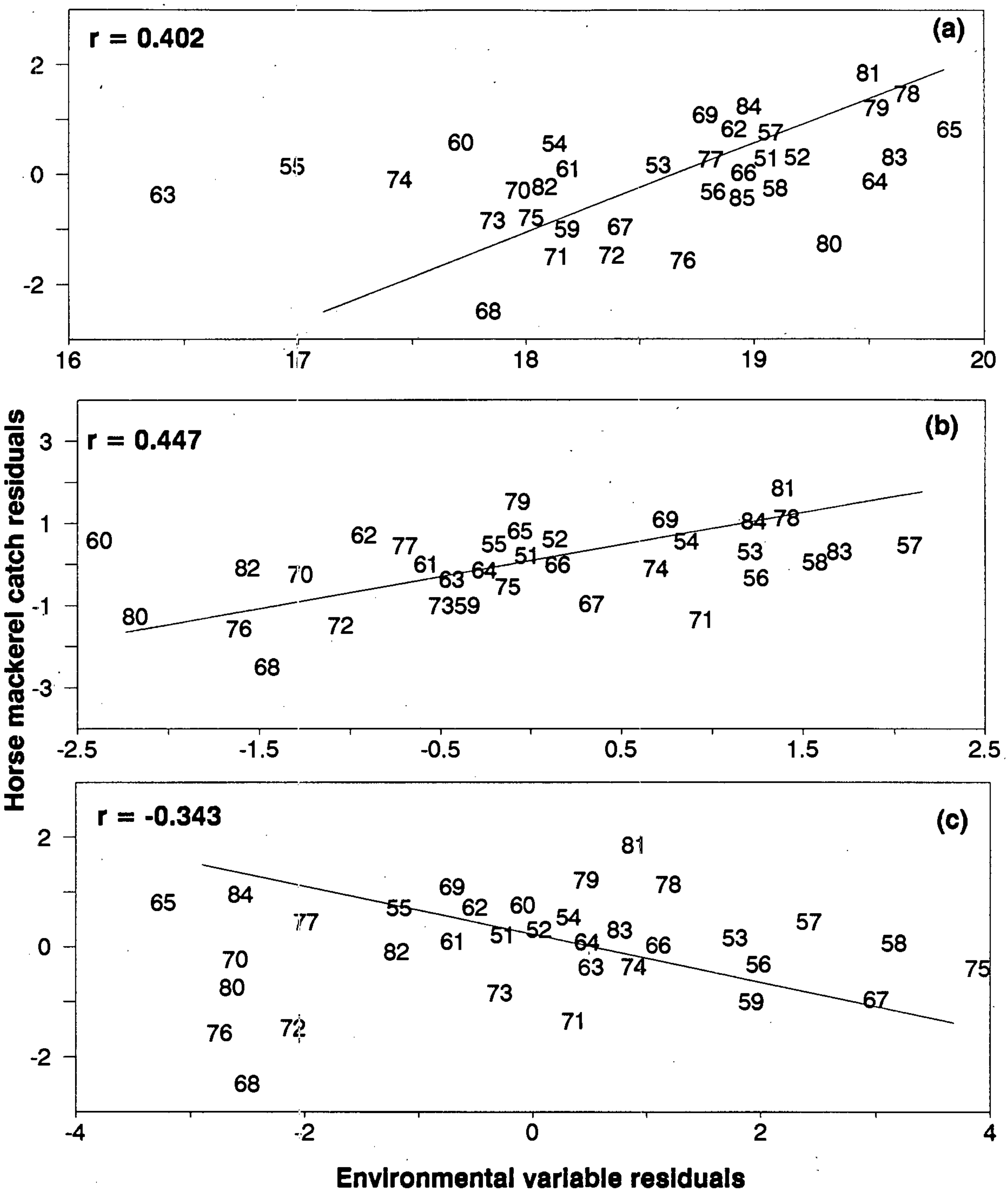


Figure 6.6 Cross-correlation relationships between annual horse mackerel catch residuals and (a) March-April sea surface temperature residuals, (b) December north-south wind component residuals (c) December west-east wind component lagged one year, in the Agulhas Bank area. A linear regression line is fitted to depict the trend.

6.3.3 Chub mackerel and environmental variables

Namaqualand area and chub mackerel catches

In the analysis of relationship between annual chub mackerel catches and sea surface temperature, three main sets of significant cross-correlations have emerged (Table 6.37). There are two very significant cross-correlations with no lag, *viz*. March to May and September to November. The other significant period is from April to August, with a one year lag.

Table 6.37 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the Namaqualand area, 1954-1985. (* = P<0.05, ** = P<0.025, *** = P<0.01, **** = P<0.005, ***** = P<0.0025).

		Lags	
Months	0	1	2
January	-0.1094	-0.2525	-0.0298
February	-0.2104	-0.3252	-0.0267
March	-0.4498***	-0.2251	-0.0658
April	-0.5162****	-0.3486*	0.0467
May	-0.4188**	-0.4889****	0.0793
June	-0.2603	-0.4994****	-0.1280
July	-0.3255	-0.4413**	-0.1366
August	-0.1616	-0.4630***	-0.1215
September	-0.4032**	-0.3109	-0.1446
October	-0.5517*****	-0.2204	-0.1578
November	-0.3474*	-0.0978	-0.1931
December	-0.1482	0.0283	-0.2546

Catches in this area are highly seasonal and depend on the age and status of the stock at any time. It has been established that nought-year-old mackerel recruit to the Namaqualand and south western Cape area fishery from January onwards, catches remaining fairly high until May (Crawford 1981c; Figure 6.3). From June onwards large chub mackerel migrate onshore resulting in large mackerel being available in greater quantities in this period. This migration has been linked to the spawning behaviour of the fish (Baird 1978a) and corresponds with the results obtained here.

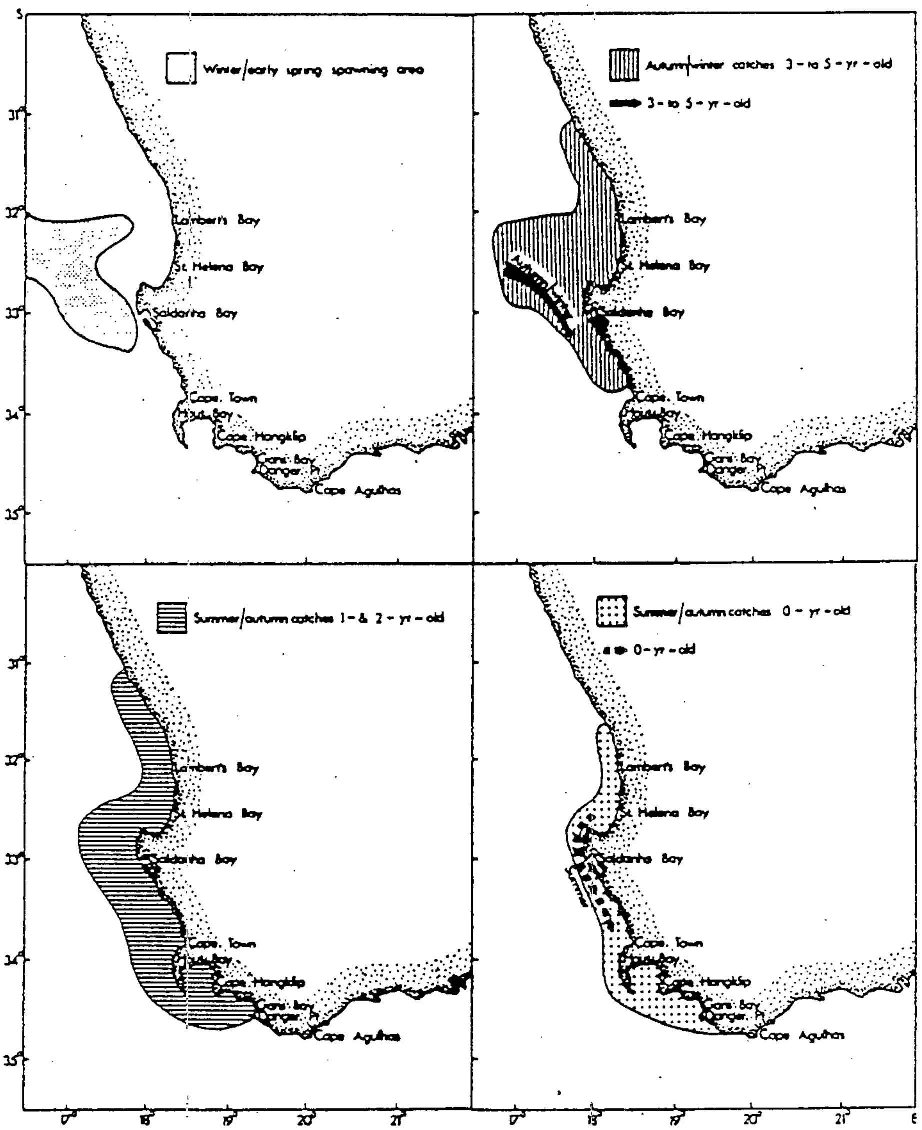


Figure 6.7 The main spawning area and catch locations for different age components of chub mackerel *Scomber japonicus* population (After Crawford *et al.* 1983).

The sign of all these cross-correlations is negative. Cool conditions may benefit the fish, especially 0-year-olds indicating the occurrence of upwelling and hence availability of nutrients for phytoplankton, after which zooplankton may develop.

Zooplankton are the main food of juveniles (Baird 1978b). Not much is known about the fishable stocks during the spring months, mainly due to the fact that little fishing takes place during the months of October to December. However, Crawford *et al.* (1983), do mention that large chub mackerel spawn actively during late winter and early spring. In my results, there was a highly significant zero-lag cross-correlation between chub mackerel catches and sea surface temperature during the months of September to November. These relationships are high and negative (Table 6.37), especially October ($r = -0.5517$, $P < 0.0025$). This indicates, again, that catches are favoured by cool conditions during the main upwelling periods, which may relate to food abundance and/or availability.

There are also very significant cross-correlations between annual chub mackerel catches and sea surface temperature of the previous year during late autumn and winter (Table 6.37). These relationships are negative, indicating a favouring of annual catches with cool conditions the previous year. Over this period, although upwelling does not usually occur, the water temperature has the lowest monthly average of the year. Therefore, these correlations may only reflect conditions and availability during this period. Large mackerel are mainly piscivorous and the one year lag coupled with the negative sign might indicate cool conditions favouring prey items like lantern fish, which predominate as food items in this size class (Baird 1978b). Also favourable environmental conditions for the spawning stock may benefit spawning *per se*, which will be reflected in catches of nought-year-old fish the following calendar year.

The cross-correlation between annual chub mackerel and pooled months sea surface temperature reflects the results of the individual month analysis very closely. The highest cross-correlation corresponds to the period May-July with a negative sign and a lag of one year (Table 6.38). This probably reflects improved catches of nought-year-old chub mackerel by the benefit of SST's on the large spawning mackerel found in this area during the winter months, i.e. during the spawning season. Here, again, there is a significant relationship between chub mackerel catches and sea surface temperature in late spring through summer.

With a one year lag there are significant cross-correlations between chub mackerel catch and sea surface temperature in December-February and August-November (Table 6.38). In conclusion, chub mackerel catches are generally favoured by cooler temperatures. This effect is immediate during the late autumn and summer months, and with a one year lag the rest of the year.

<u>Table 6.38</u> Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the Namaqualand area, 1954-1985. (* = P<0.05, *** = P<0.01, **** = P<0.005, ***** = P<0.0025).

	Lags		
Months	0	1	2
May-July	-0.2594	-0.5721*****	-0.1174
December-February	-0.0441	-0.3485*	0.0642
March-April	-0.4947****	-0.2920	-0.0124
August-November	-0.1962	-0.3748*	0.0219
October-April	-0.4425***	-0.2489	-0.1830

With regard to the north-south wind component correlations with chub mackerel catches, there is a very highly significant relationship in the month of January (Table 6.39, r = -0.6398, P< 0.001). This relationship is negative and has no lag. According to Crawford (1981c), nought-year-old fish are most available from January onwards. Furthermore, it seems that large offshore mackerel take advantage of the predominant northerly winds which bring warmer waters closer inshore allowing the fish to migrate and spawn. The negative sign signifying that northerly wind component favour catches, also reflects this hypothesis.

Table 6.39 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the Namaqualand area, 1954-1985. (* = P<0.05, ** = P<0.025, ****** P<0.001).

Months	Lags 0	1	2
January	-0.6398******	-0.3444	0.0302
February	-0.3728*	-0.0018	-0.0386
March	-0.1604	-0.3856*	-0.2235
April	-0.3907*	0.2600	-0.1839
May	-0.2948	-0.0423	-0.2515
June	-0.1091	0.1991	0.0643
July	-0.0392	-0.1220	-0.3072
August	-0.2359	-0.1432	0.0013
September	-0.0692	-0.1040	0.1350
October	-0.3669*	-0.2481	-0.2326
November	-0.0594	-0.0549	-0.1923
December	-0.2273	-0.4169**	-0.0070

In the pooled months analysis, the highest cross-correlation is found in the December-February period (r = -0.5388, P< 0.0025)(Table 6.40). This follows very closely the results found in the individual month analysis. The relationship is also negative and furthermore, the response is immediate as indicated by a no lag effect. Similar to the sea surface temperature, there is a significant relationship between annual chub mackerel catches and north-south wind component during the spring months (r = -0.4913, P< 0.005). This relationship is also negative and does not have a lag factor. It seems, therefore, that there is good agreement between environmental variables and chub mackerel catches during this period, perhaps related to availability of the fish to the fishery.

Table 6.40. Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the Namaqualand area, 1954-1985. (**** = P< 0.005 , ***** = P < 0.0025).

Months	Lags 0	1	2
May-July	-0.0372	0.0633	-0.0748
December-February	-0.5388*****	-0.1478	-0.0167
March-April	-0.0905	-0.1530	-0.1771
August-November	-0.4913****	-0.1032	-0.1133
October-April	-0.2378	-0.2793	0.0615

In the cross-correlations between chub mackerel and west-east wind component on the Namaqualand area, there are five significant correlation coefficients (Table 6.41). With a zero lag there are significant cross-correlations in the months of January, July, October and November. With a one year lag there is a highly significant cross-correlation in March. All correlations, with the exception of November, show negative values, indicating westerly winds being related to good catches. The highest cross-correlation exist in the month of March. This relationship is associated with the same kind of relationship between chub mackerel catch and north-south wind component discussed earlier. It would seem, therefore, that an influence of northerly and westerly winds in the month of March along the Namaqualand affects the catch favourably.

There is also very good agreement in January with regard to the north-south component. Here, again, there is an indication of northerly and westerly wind components benefiting the catches. The October correlation also has a counterpart in the north-south wind component, which shows a north-westerly direction as being important. The reversal of the sign of the correlation in

November can not be explained. July's cross-correlation is also highly significant and negative (Table 6.41).

<u>Table 6.41</u> Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component residuals for all months and for the first three lags in the Namaqualand area, 1951-1985. (* = P<0.05, ** = P<0.025, *** = P<0.01, ****** = P<0.001).

Months	Lags 0	1	2
January	-0.3779*	-0.3274	-0.1725
February	-0.2504	-0.0460	-0.0663
March	-0.0831	-0.5577******	-0.0841
April	0.1329	0.2401	-0.1753
May	-0.3399	0.0761	-0.1734
June	0.0587	-0.1026	0.1627
July	-0.4749***	-0.1179	0.0311
August	-0.2157	0.1590	0.0118
September	-0.0820	0.0785	0.2258
October	-0.3894*	0.0432	0.1004
November	0.4605**	-0.1705	-0.1879
December	-0.1519	-0.0123	0.1671

During the summer and autumn months, nought, one and two year-olds are caught all along the Namaqualand of South Africa (Figure 6.7, Crawford *et al.* 1983). The one year lag in the month of March may be an indication of the favourable environmental conditions for abundance of nought-year-olds. These conditions will be reflected in the catches the following year.

During winter and early spring chub mackerel spawn offshore in this area. The correlations in July and October may reflect favourable conditions during this period which affect chub mackerel eggs and larvae. The northerly and westerly winds will push warmer water masses onshore, so that eggs and larvae could take advantage of these wind directions and use them to be dispersed towards the rich inshore waters. The January cross-correlation may also be an indication of the highest availability of nought-year-olds in this area (Crawford 1981c).

Table 6.42 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component for pooled months and for the first three lags in the Namaqualand area, 1955-1985. (* = $P<0.05$, ***** = $P<0.0025$).

Months	Lags 0	1	2
May-July	-0.5225*****	-0.0940	-0.0405
December-February	-0.3586*	0.0305	-0.0658
March-April	0.0562	-0.1509	-0.1941
August-November	-0.1773	-0.0932	-0.2222
October-April	-0.0342	0.0242	-0.0260

In the combined months analysis of cross-correlations between annual chub mackerel catches and west-east wind components, there is also a significant relationship in the period December-February ($r = -0.3586$, $P < 0.05$; Table 6.42), similar to the one found in the north-south analysis. Here the sign indicates westerly winds to be the ones influencing catches favourably. The zero lag indicates an immediate effect of these winds on the catches, and as mentioned earlier this could be reflected in the nought-year-old catches. The largest cross-correlation is found in the combination May-July ($r = -0.5225$, $P < 0.0025$). Following the argument of the monthly analysis, this cross-correlation may suggest these north-westerly conditions favouring chub mackerel spawn availability in this area.

Figure 6.8 and 6.9 show examples of relationships between annual chub mackerel catch and selected environmental conditions during the summer and autumn periods.

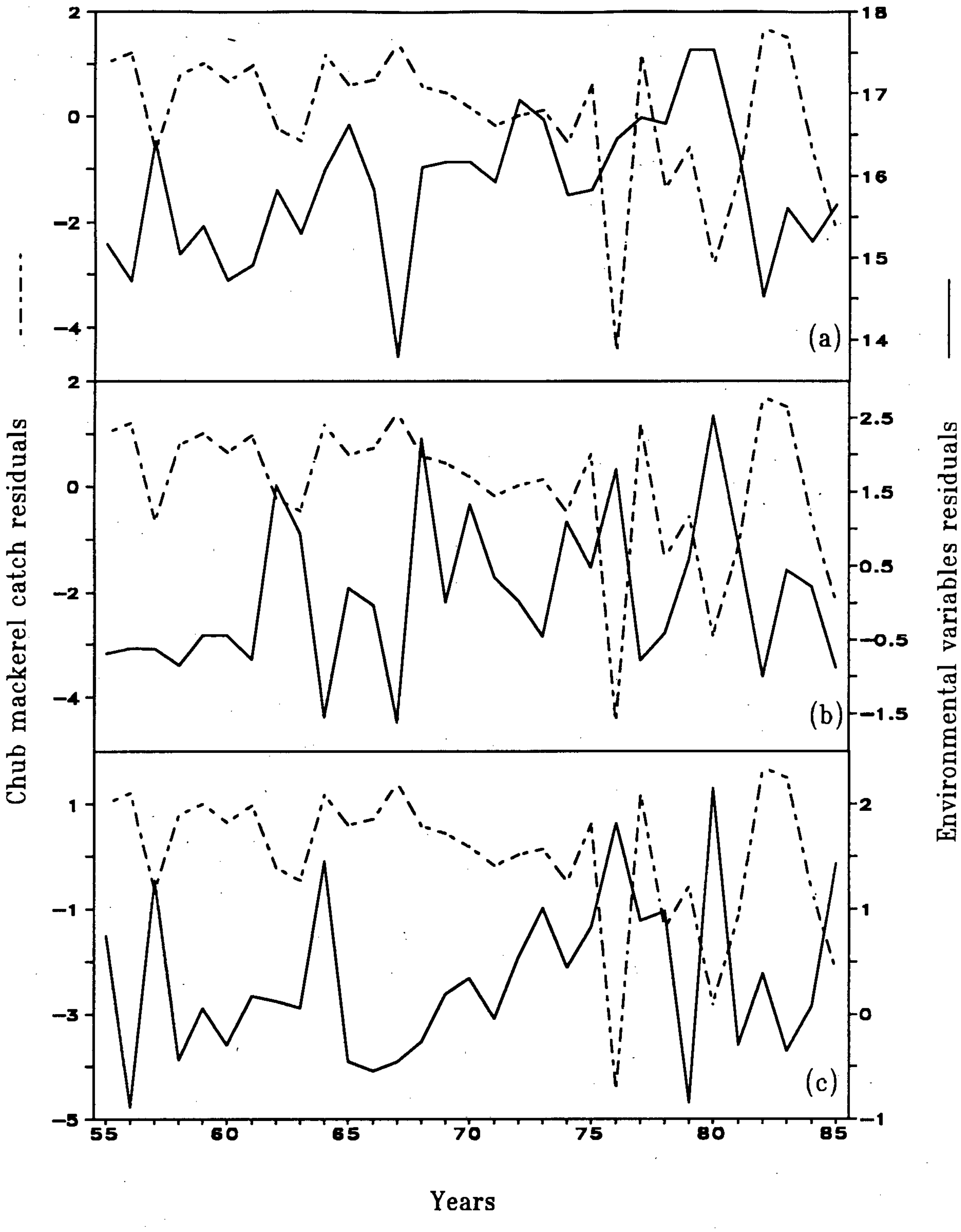


Figure 6.8 Chub mackerel catch residuals and (a) March-April sea surface temperature residuals, (b) December north-south wind component, (c) March west-east wind component residuals lagged one year in the Namaqualand area.

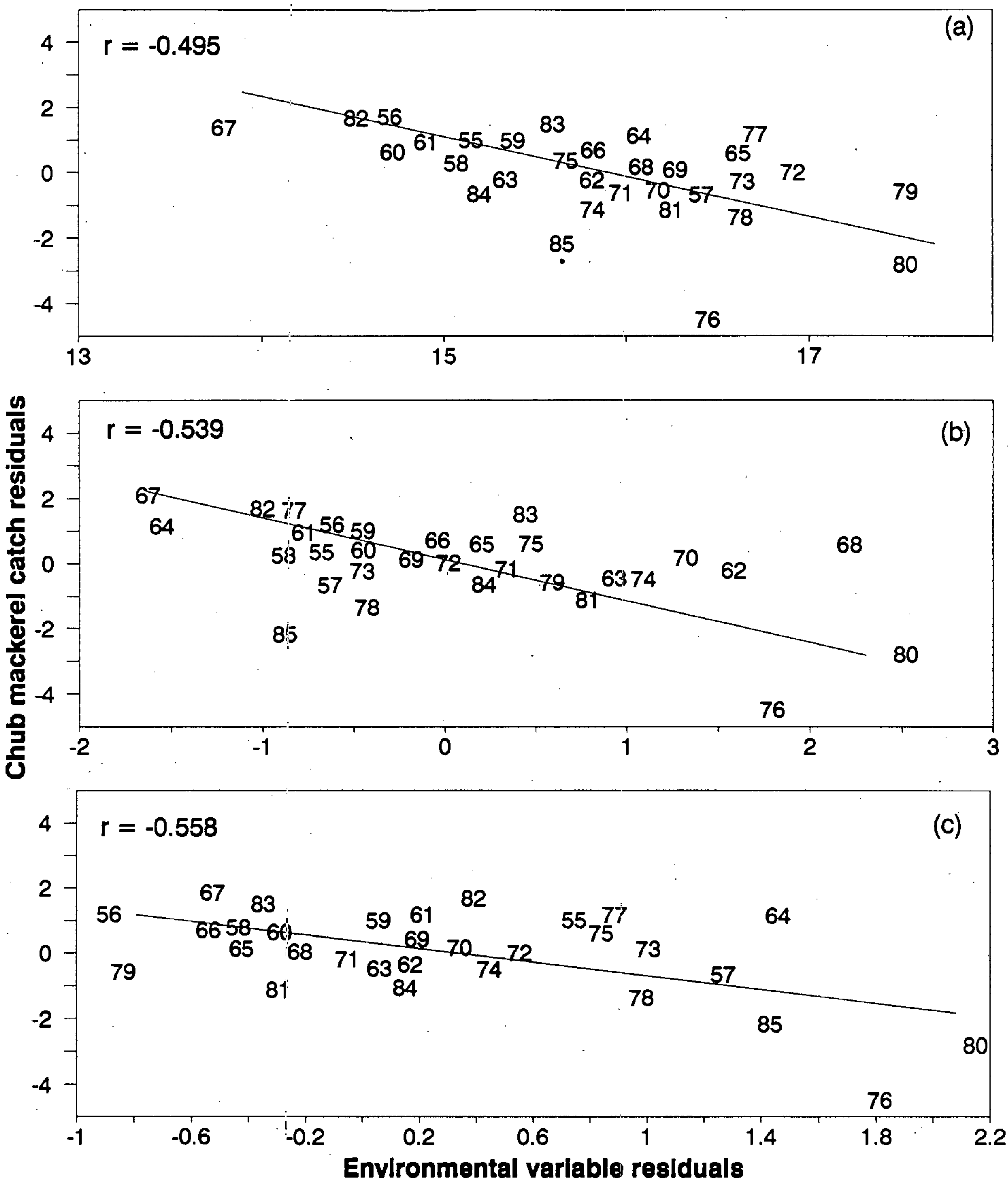


Figure 6.9 Cross-correlation relationships between annual chub mackerel catch residuals and (a) March-April sea surface temperature residuals, (b) December north-south wind component residuals, (c) March west-east wind component lagged one year in the Namaqualand area. A linear regression line is fitted to depict trend.

Figures 6.10 and 6.11 show relationships between chub mackerel and environmental conditions during the spring and winter period.

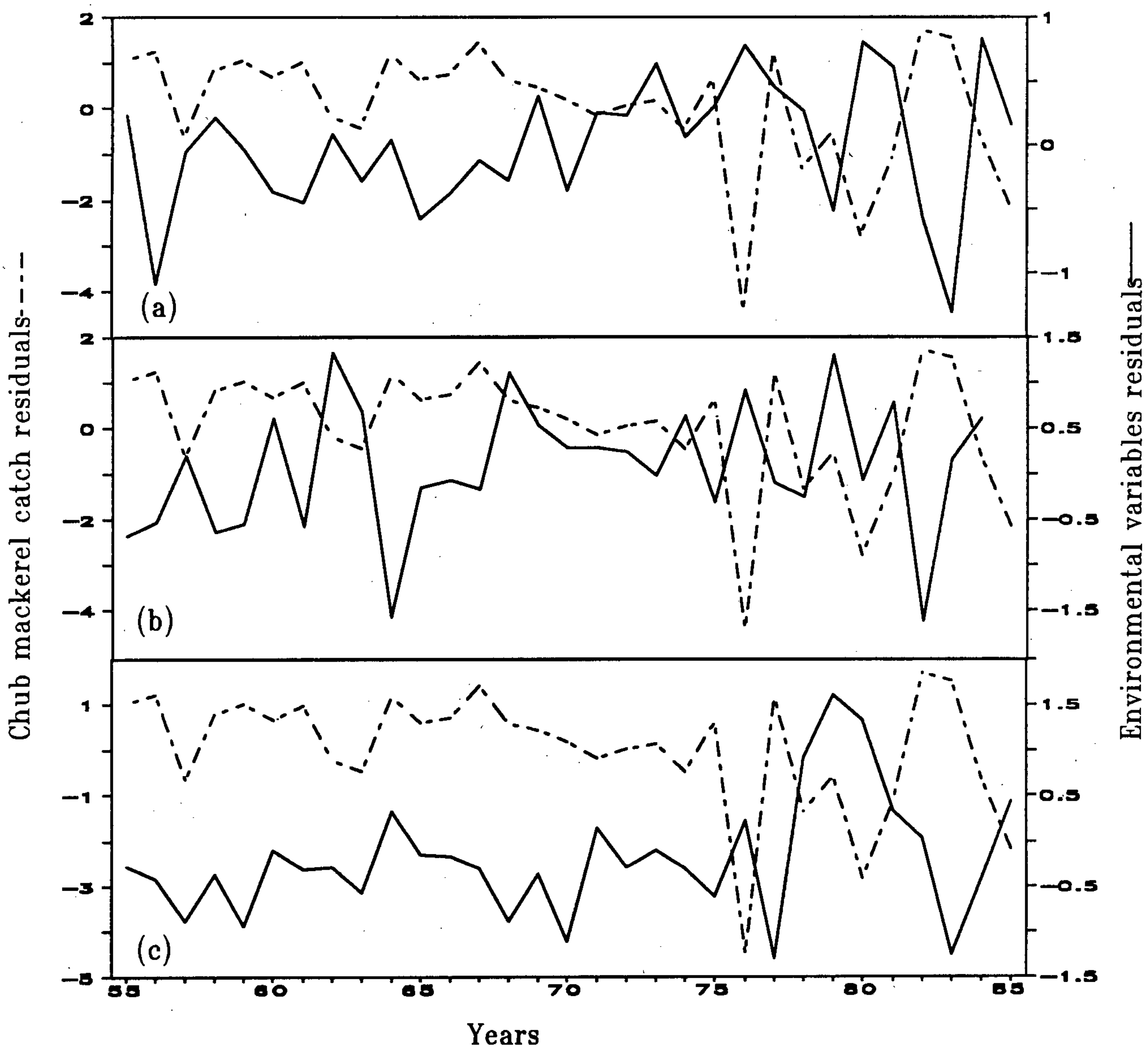


Figure 6.10 Chub mackerel catch residuals and (a) May-July sea surface temperature residuals lagged one year, (b) August-November north-south wind component, (c) May-July west-east wind component residuals in the Namaqualand area.

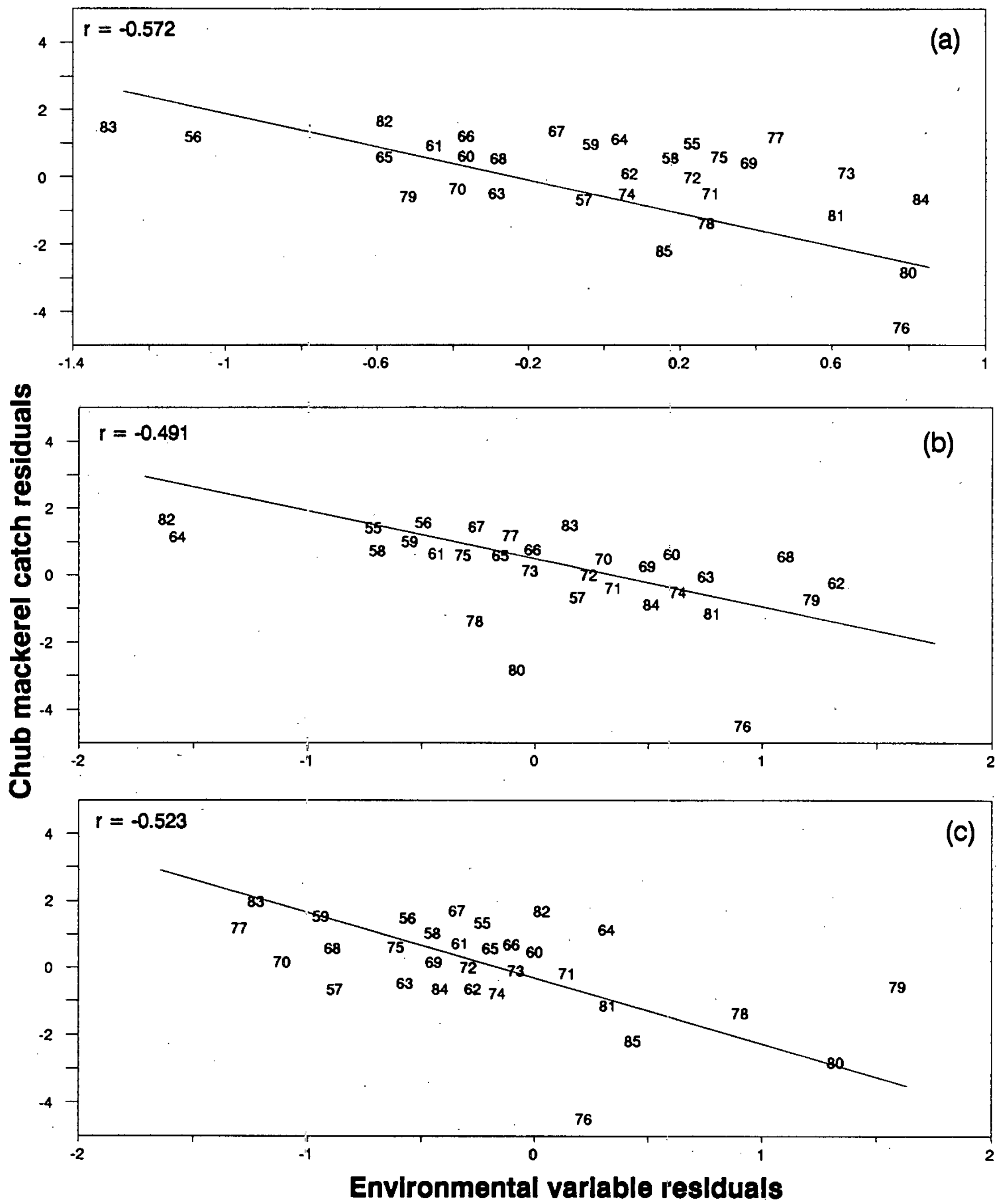


Figure 6.11 Cross-correlation relationships between annual chub mackerel catch residuals and (a) May-July sea surface temperature residuals, (b) August-November north-south wind component residuals, (c) May-July west-east wind component lagged one year in the Namaqualand area. A linear regression line is fitted to depict trend.

<u>South western Cape area and chub mackerel catches</u>

The largest cross-correlation between annual chub mackerel catches and sea surface temperature in this area is found in the months of May and June (r = -0.4616 and r = -0.4567 respectively, P< 0.01 for both; Table 6.43). Cooler conditions seem to be advantageous for chub mackerel during this period and their effect is reflected in the catches the following year. This result may also be explained in terms of the availability of larger chub mackerel during late autumn and winter (Crawford 1981c) which might affect the annual catch and it may reflect prevailing water temperature conditions.

<u>Table 6.43</u> Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus)* catch residuals and sea surface temperature residuals for all months and for the first three lags in the south western Cape area. 1955-1985. (*** = P<0.01).

Months	Lags 0	Lags 1	Lags 2
January	0.1185	-0.0946	0.1418
February	-0.0546	0.0557	0.0408
March	-0.1056	0.1308	0.0991
April	-0.2066	-0.1882	0.1757
May	-0.1138	-0.4616***	0.1554
June	-0.0501	-0.4567***	-0.0427
July	-0.0632	-0.3038	-0.0951
August	0.0796	-0.2194	-0.0384
September	0.3019	-0.1355	0.0441
October	0.1730	-0.2121	0.2732
November	0.0372	0.1025	0.2855
December	-0.0892	0.3050	0.1146

In the combined months analysis, the correlation between annual chub mackerel catches and sea surface temperature shows the same result as in the individual month analysis. The largest significant cross-correlation is found in the period May-July with a negative sign and a one year lag (r = -0.4622, P< 0.01; Table 6.44). This result, therefore, confirms the hypothesis that the cross-correlation may represent the water temperature conditions prevailing during the late autumn and winter months.

Table 6.44 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the south western Cape area, 1955-1985. (*** = P<0.01).

	Lags		
Months	0	1	2
May-July	-0.0659	-0.4622***	0.0154
December-February	0.0702	0.0517	0.0558
March-April	-0.1880	-0.0129	0.1170
August-November	0.2263	-0.1348	0.1482
October-April	-0.0822	0.0353	0.1219

In the relationship between chub mackerel catches and north-south wind component, there are three significant cross-correlations (Table 6.45). Two of the correlations have a one year lag, the other has no lag. In January with a no lag value the north-south wind component cross-correlation is negative, indicating northerly winds as being important. The same result is found in the one year relationships in January and September. The January no lag relationship seems to indicate improved catches of nought-year-olds with northerly winds in this area, when nought-year-old catches area highest. The same relationship with a one year lag may reveal that the conditions that benefit nought-year-olds may be carried over to the following year, increasing the catches by the proportion of one-year-olds. At the same time, during early spring, chub mackerel spawn in this area and wind conditions may favour eggs and larvae by affecting or improving their recruitment, increasing the number of nought-year-olds available for the fishery the following year.

<u>Table 6.45</u> Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the south western Cape area, 1955-1985. (* = P < 0.05, *** = P < 0.01, ****** = P < 0.001).

Months	Lags 0	1	2
January	-0.5861******	-0.3665*	-0.1301
February	-0.2951	0.0592	-0.1189
March	-0.1514	-0.3423	-0.1015
April	0.1304	0.0519	-0.3507
May	0.0286	0.0090	-0.0536
June	-0.1504	0.3062	0.0422
July	-0.0121	0.1510	-0.0046
August	0.0025	-0.2318	0.2007
September	0.1815	-0.4739***	-0.1417
October	-0.3153	-0.3178	-0.2502
November	0.0985	-0.2429	-0.2452
December	-0.0746	-0.2302	0.0428

In the pooled months analysis between chub mackerel catches and north-south wind component, there are two significant cross-correlations (Table 6.46). The first one is found in the period from December to February with no lag and negative sign. This cross-correlation supports the individual month analysis significant cross-correlation in January. It can be established, therefore, that there is good evidence of the effect of the northerly wind in the chub mackerel catch, here attributed to the nought-year-old class. The second cross-correlation is found in August-November with one year lag (Table 6.46). The distinction between the two cross-correlations is therefore based in the lag of the cross-correlation. It seems that the December-February correlation is reflecting northerly winds having an immediate effect on the nought and one-year-olds, whereas the August-November (spawning months) correlation indicates that environmental conditions affect newly spawned eggs and larvae, and are disclosed in the catches of nought-year-olds the following year. Alternatively, the second correlation may indicate an environmental effect on the nought-year-old chub mackerel and its effect on the one-year-olds catch the following year. The effect of the northerly wind can be seen as a mechanism for passive transport of chub mackerel pelagic eggs and larvae to the recruitment ground nearshore, where they become available to the fishery, and therefore, may just be a reflection of the fish availability rather than a physiological effect.

Table 6.46 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the south western Cape area, 1955-1985. (*** = P<0.01, **** = P<0.005).

Months	Lags 0	1	2
May-July	-0.1860	0.3265	0.0026
December-February	-0.4818****	-0.0378	0.0661
March-April	0.0685	-0.1654	-0.3144
August-November	0.1456	-0.5112****	-0.1037
October-April	-0.2513	-0.1398	-0.0982

In the west-east wind component analysis, there are two significant cross-correlations (Table 6.47). The first is found in December, with positive sign and zero lag. The easterly winds indicated may reveal that upwelling favourable winds may enhance the catch of chub mackerel in this area. The mechanism can be twofold. Firstly chub mackerel nought and one-year-olds, prey mainly on zooplankton (Baird 1978b). Easterly winds are upwelling favourable in December (Kamstra 1985) and will create a suitable environment for the development of plankton blooms through the upwelling of nutrients to the surface. Chub mackerel juveniles will take full advantage of this situation and will be present where food is abundant. Secondly, while in this area they will become available to the fishermen.

Table 6.48 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component for pooled months and for the first three lags in the south western Cape area, 1955-1985. (** = P<0.025).

Months	Lags 0	1	2
May-July	-0.2312	0.1743	0.0081
December-February	0.0283	0.0200	-0.0900
March-April	0.0272	-0.1283	-0.0895
August-November	0.0349	-0.4188**	0.1887
October-April	-0.0183	-0.0348	-0.2112

Agulhas Bank area and chub mackerel catches

Along the Agulhas Bank, there is one significant cross-correlation between chub mackerel catch and sea surface temperature (Table 6.49). This cross-correlation is found in June with one year lag and a negative sign.

Table 6.49 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and sea surface temperature residuals for all months and for the first three lags in the Agulhas Bank area, 1955-1985. (* = P<0.05).

Months	Lags 0	1	2
January	-0.0860	-0.1925	0.1083
February	-0.1038	-0.0214	0.0285
March	-0.1317	-0.1007	0.0777
April	-0.1861	-0.2650	0.1566
May	-0.1799	-0.3453	0.0484
June	-0.1017	-0.3514*	-0.1153
July	-0.0356	-0.3293	-0.0491
August	0.2527	-0.1933	0.0609
September	0.1977	-0.1741	0.1462
October	0.1582	-0.3063	0.0285
November	0.0925	-0.2564	-0.1579
December	-0.0406	-0.0740	-0.1786

The correlation in the month of June is positive (Table 6.47), indicating easterly winds to be favouring chub mackerel catch in two years time.

Table 6.47 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component for all months and for the first three lags in the south western Cape area, 1955-1985. (* = P<0.05, ** = P<0.025).

Months	Lags 0	1	2
January	-0.2130	0.0760	-0.0115
February	-0.0591	0.0804	-0.0613
March	0.0294	-0.1962	0.0721
April	0.1886	0.0723	-0.2745
May	-0.2346	0.1939	-0.1976
June	-0.1148	0.0056	0.3764*
July	0.0820	0.1223	-0.1284
August	-0.2013	-0.1482	0.1576
September	-0.0626	-0.2543	0.3139
October	-0.0150	-0.3403	0.1846
November	0.2740	0.0072	-0.0691
December	0.4137**	-0.0419	0.1297

In the pooled months analysis, there is one significant cross-correlation between chub mackerel catch and west-east wind component (Table 6.48). This correlation is found in August to November with one year lag and a negative sign. It is interesting to note, however, that during these months chub mackerel actively spawn in this area.

The westerly wind indicated in the cross-correlation may reveal, very much as in the north-south wind component analysis, that these winds help disperse the eggs and larvae towards the inshore region. These larvae will recruit to the fishery at the beginning of the following year (Baird 1977) and will thus be available to the fishery as nought year-olds. The one year lag is, therefore, a likely indication of this possibility.

The sign indicates a favouring of catches with cooler conditions from the previous year. Also, it is interesting to note the high but non-significant correlation coefficients of May and July, with the same sign and lag.

In the eastern part of this area, fish older than one year are caught by midwater and demersal trawlers (Crawford and De Villiers 1984) mainly from August to October, whereas in the western part, there is a peak in the availability of old fish during July.

The sea surface temperature result may be an indication that cooler conditions benefit catches. Since nought and one-year-olds are also abundant in the western part of this area, during autumn, it is possible that some will remain here during winter and environmental conditions benefiting these early age-classes will result in an increase in catches the following year. This hypothesis is supported by Crawford (1981c), who demonstrated that nought-year-olds seem to exhibit a shift in their distribution from summer along the north part of the Namaqualand towards the south western Cape and the Agulhas Bank in winter.

Table 6.50. Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and sea surface temperature residuals for pooled months and for the first three lags in the Agulhas Bank area, 1955-1985. (* = P<0.05).

	Lags		
Months	0	1	2
May-July	0.0003	-0.3873*	-0.1134
December-February	-0.0299	-0.2333	0.0714
March-April	-0.1218	-0.2091	0.0925
August-November	0.1822	-0.2519	0.0412
October-April	-0.1028	-0.3185	0.0517

In the pooled months analysis the same relationship between chub mackerel catches and sea surface temperature is observed in the winter months (Table 6.50). This indicates increased annual catches when cooler water temperatures were evident during the previous year in the winter months.

The relationship between chub mackerel catches and north-south wind component along the Agulhas Bank show two distinct cross-correlations. The first correlation is found in the month of September with no lag and a positive sign (Table 6.51). This correlation may indicate favourable conditions brought about by the southerly winds in this area in the older age-classes present during early spring.

__Table 6.51__ Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for all months and for the first three lags in the Agulhas Bank area, 1955-1985. (* = P<0.05).

Months	Lags 0	Lags 1	Lags 2
January	-0.1976	0.0382	0.1296
February	-0.0477	0.2979	-0.0197
March	0.3077	-0.1112	0.0535
April	0.2530	0.3771*	-0.2433
May	0.1296	0.0610	0.0221
June	-0.0529	0.2592	0.2428
July	0.1278	0.0096	-0.0264
August	0.1588	-0.0610	0.0789
September	0.3786*	-0.2344	-0.1104
October	0.0330	0.2520	-0.0233
November	0.2660	-0.2515	0.0017
December	0.1494	0.0366	0.0137

The second correlation in the month of April, with a lag of one year, may denote the influence of southerly winds on the younger age classes. This effect will be noticed in the catches the following year.

In the pooled months analysis between chub mackerel catches and north-south wind component, there is one significant positive cross-correlation in the period August-November with no lag (Table 6.52). The positive sign indicates improved chub mackerel catches with easterly winds in this area. Since there is usually no upwelling on the Agulhas Bank during spring (Lutjeharms and Meeuwis 1986), the easterly wind cannot be considered to be favourable or unfavourable for upwelling.

Table 6.52 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and north-south wind component residuals for pooled months and for the first three lags in the Agulhas Bank area, 1955-1985. (* = P < 0.05).

	Lags		
Months	0	1	2
May-July	0.1008	0.1774	0.1307
December-February	-0.2074	0.1409	0.0143
March-April	0.3411	-0.0497	-0.0079
August-November	0.3455*	0.1713	-0.1215
October-April	-0.0605	0.1843	-0.0528

In the relationship between chub mackerel catches and west-east wind component there are five significant cross-correlations (Table 6.53).

During January, there is a significant cross-correlation with a negative sign and no lag. This indicates westerly winds influencing the catch, presumably due to increased availability of nought and one-year-olds, pushed closer inshore by the wind induced currents. In the month of August there is a significant cross-correlation with a negative sign and no lag.

With a one year lag the cross-correlation between chub mackerel catches and west-east wind component is significant in May. This relationship is positive, indicating easterly winds as being favourable to the catch during autumn. This wind orientation during autumn sets conditions for upwelling at the Agulhas Bank capes, thus, it seems that upwelling-inducing winds favour catches the following year.

Table 6.53 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component for all months and for the first three lags in the Agulhas Bank area, 1951-1985. (* = P <0.05, ** = P < 0.025, ****** = P < 0.001).

Months	Lags 0	1	2
January	-0.6114******	-0.0772	-0.2174
February	-0.1445	0.0282	-0.0591
March	0.2025	-0.1303	-0.0148
April	0.1725	0.2321	-0.3585*
May	-0.1611	0.4355**	0.1373
June	0.1174	-0.0365	0.2342
July	-0.1325	0.0014	-0.0602
August	-0.3594*	0.0558	0.1959
September	0.0693	-0.2211	0.3789*
October	-0.0442	0.2791	0.3588
November	0.2624	-0.1993	0.0128
December	0.2996	-0.1654	0.0912

At the two year lag, April has a significant cross-correlation with a negative sign and a two year lag. Finally there is another significant cross-correlation in September with a positive sign and a two year lag (Table 6.53).

In the pooled months analysis between chub mackerel catches and west-east wind component, there are two significant cross-correlations (Table 6.54). The highest cross-correlation coefficient is found during the December to February period with a negative sign and no lag. Westerly winds, therefore, seem to be immediately favourable to the catch in this area. During summer and autumn, nought, one and two-year-olds are present in this area and it seems that these age-classes are being influenced by the westerly winds. The response may be one of aggregation of fish closer inshore, taking full advantage of the increased plankton productivity established by the westerly winds, and hence improving the catches. There is also another significant cross-correlation in the period October-April with a two year lag and a negative sign. This correlation, therefore, indicates the same wind direction to be beneficial to catches, but the response has a two year delay, presumably being manifested in older age-classes.

Table 6.54 Cross-correlation coefficients between annual chub mackerel (*Scomber japonicus*) catch residuals and west-east wind component for pooled months and for the first three lags in the Agulhas Bank area, 1955-1985. (* = P < 0.05, **** = P < 0.005).

Months	Lags 0	1	2
May-July	-0.1161	0.2120	0.0893
December-February	-0.4784****	-0.0140	-0.1469
March-April	-0.0351	0.0961	0.2069
August-November	0.2437	0.0733	-0.2498
October-April	-0.1209	0.0957	-0.3653*

6.4 Statistical significance

Sutcliffe *et al.* (1977) have advised caution with the use of correlations to relate environment to fluctuations in fish populations because of the chance of spurious relations. In order to assess this possibility, the numbers of significant cross-correlation and their associated probabilities are presented in Table 6.55, but it is emphasized that the true probability associated with each cross-correlation is unknown.

According to statistical theory, at the 5 % significance level there is a 1/20 probability of a Type I error, that is, one correlation out of twenty may be due to chance. When many relationships are tested, the problem becomes a philosophical one. All correlations were considered to be independent, thus the significance level is assumed to remain constant from correlation to correlation. Thus, one might expect 8 (7.65 to be exact) correlations to be significant in the 153 cross-correlations analysed in each area for each set of fish catch data at the 5 % significance level. There are indications of a real effect when the total number of cross-correlations significant at the 5% level exceeds this value (Table 6.55). Thus it appears that for pilchard catches there are consistent environmental effects on the Agulhas Bank, for horse mackerel catches in the Namaqualand area, and for chub mackerel catches in all areas.

Table 6.55 Numbers and estimated probabilities of significant relationships between all fish catches and joined environmental variables in all areas. The total number of cross-correlations for all fish catches in each area is 153.

		Probability	
Areas	0.05> P >0.01	P <0.01	Total
Pilchard			
Namaqualand	6	1	7
South western Cape	6	1	7
Agulhas Bank	9	2	11
Horse mackerel			
Namaqualand	11	0	11
South western Cape	4	0	4
Agulhas Bank	5	2	7
Chub mackerel			
Namaqualand	16	15	31
South western Cape	4	7	11
Agulhas Bank	10	2	12

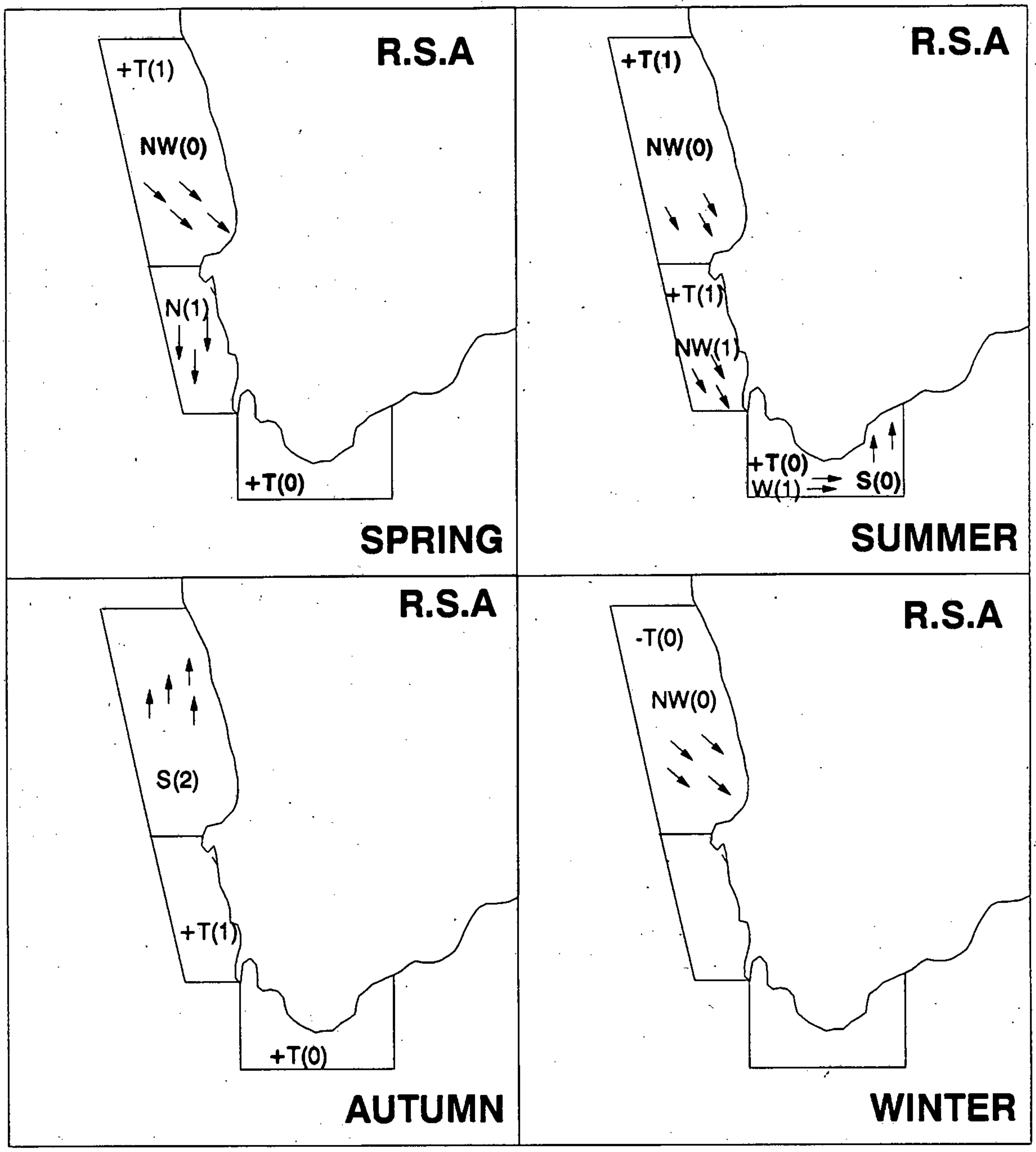


Figure 7.2 Charts showing the significant cross-correlation patterns between annual horse mackerel catch and monthly sea surface temperature (T), northerly (N), southerly (S), westerly (W) and easterly (E) winds for spring (September-November), summer (December-February), autumn (March-May) and winter (June-August). Brackets indicate the lag (in years) associated with the cross-correlations. The arrows depict the significant wind direction. The plus or minus signs next to the SST representation indicate positive or negative effect of the SST on the catch. Those relationships on which greater confidence is placed are given in bold.

CHAPTER 7

GENERAL DISCUSSION

AND

CONCLUSIONS

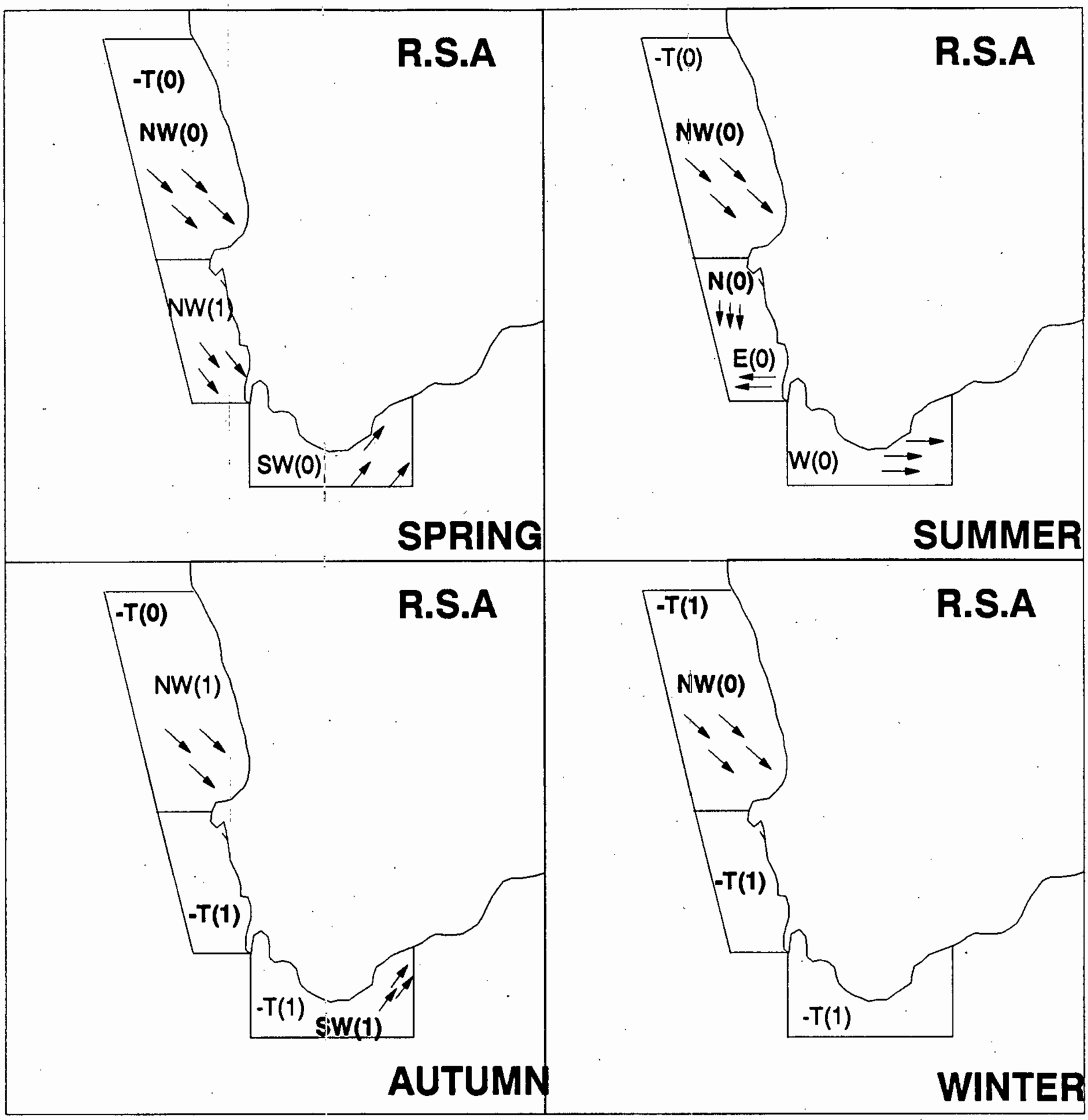
There is strong evidence that some of the cross-correlations of catch data with the environment, especially for chub mackerel, are not due to chance. Furthermore, great coherence in the results suggests that there are real underlying effects.

The wind components analyses suggest southerly and westerly winds during summer, with zero and one year-lag respectively. This is the main spawning area for horse mackerel, and warmer waters having a positive effect on catches agrees with previous results (Shannon *et al.* 1988) and recent studies (Naish 1990) in the southern Benguela region. Also, the suggested south-westerly wind agrees with Hecht (1989) and Naish (1990) whom stated that horse mackerel during January to June, tend to concentrate inshore and towards the east. The wind direction during summer will tend to aid the fish in that preferred direction. As a results, catches may be enhanced immediately through their availability to the fishery, hence the zero-year-lag.

7.3 Chub mackerel catch and monthly environmental variables

The relationships between chub mackerel catches and environmental conditions in the Namaqualand area show that chub mackerel catches improve with colder water temperatures in all seasons. The effect of these colder temperatures is immediate in all seasons but winter. These results are in evidence in all three statistical analyses. With regard to the relationship between chub mackerel catch and wind components, there is evidence to suggest improved catches with northerly and westerly winds throughout the year. The cross-correlations show significant values during summer, winter and spring, all with zero-lag.

There are a large number of cross-correlations which are significant, and the great coherence between them reduces the possibility of a statistical Type I error. In this area, purse-seine catch of chub mackerel is very important, and remain relatively constant throughout the year (Crawford and De Villiers 1984). Furthermore, chub mackerel spawns offshore in this area from winter and recruit to the fishery after only six months (Baird 1977).



<u>Figure 7.3</u> Charts showing the significant cross-correlation patterns between annual chub mackerel catch and monthly sea surface temperature (T), northerly (N), southerly (S), westerly (W) and easterly (E) winds for spring (September-November), summer (December-February), autumn (March-May) and winter (June-August). Brackets indicate the lag (in years) associated with the cross-correlations. The arrows depict the significant wind direction. The plus or minus signs next to the SST representation indicate positive or negative effect of the SST on the catch. Those relationships on which greater confidence is placed are given in bold.

North-westerly winds will tend to aid the recruitment of juveniles to the main stock and it will benefit the catch immediately by concentrating the fish inshore closer to the fishing grounds. It will also aid the southward migration of young-age-classes towards the south, via a counter-current close to the coast, generated remotely by longshore winds (Nelson and Hutchings 1987).

The response during the autumn also shows northerly and westerly conditions as important but it has a one-year-lag.

The relationships between chub mackerel catches and environmental conditions also produced highly significant and coherent results in the south western Cape analysis.

The sea surface temperature results indicate improved catches with cooler temperatures during autumn and winter the previous year. The wind component relationship with chub mackerel catches has a zero-lag during summer, with northerly and easterly winds presumably reflecting the effect of the winds on the 0-2-year-olds which are found to be abundant in this area. There are indications of improved catches with northerly and westerly winds during spring of the previous year. Thus, it seems that wind conditions favour 0-year-olds or the eggs and larvae during this period, with the benefit being reflected in catches of older age-classes the following year.

In the Agulhas Bank area, the environmental conditions affecting chub mackerel catches also show cooler temperatures being favourable during autumn and winter with one-year-lag. The wind components indicate an immediate improvement in the catches with southerly and westerly winds. South-westerly winds would presumably bring chub mackerel closer inshore, so that this preferred wind orientation will allow chub mackerel to feed on both fish and zooplankton closer inshore where they will become more available to the fishery. This effect has a zero-lag during spring and summer so that availability is a likely cause for the improvement in catches, but a one-year-lag during autumn. It is possible that during spring and summer the effect of the wind may be reflected in catches of juveniles that year, while during autumn and winter it may be revealing the effect on older-age classes before their offshore migration to the spawning grounds.

The major difficulty in the analysis of the results lies in the interpretation of the response of the catches to the environmental conditions. The total catch was used since the data on specific age-classes is either not yet available for the full period of the study or it is currently under revision. As a result, lags other than zero are difficult to interpret. Whatever the limitations, the results in general terms show high confidence statistically. Although evidence concerning mechanisms is lacking, different attempts have been made to link environmental effects to the total catch, and whenever possible to the different age-classes, have been made. Another problem which constrains the determination of strict hypothesis is the fact that, for example pilchards, have been shown to display different growth rates during different periods of the study (Armstrong *et al.* 1989) and this may have influenced the age at which maturity is reached, confounding interpretation of lags other than zero.

The study shows that all environmental effects on pilchard catches appear to be related to abundance of the stock, whereas the horse and chub mackerel relationships with zero lag suggest an environmental effect on catches due to availability of the fish. In the case of chub mackerel, it appears that there is a conflict between the sea surface temperature and the wind effect on the annual catch. The distinction might lie in the fact that chub mackerel are piscivorous and feed predominantly on fish that inhabit the cooler inshore areas. So on the one hand, negative sea surface temperature effects on the catch may relate to the preferred habitat of the prey, while on the other north-westerly winds may tend to move the oceanic front closer inshore and thus relate to availability of the stock to the inshore fishery.

This study has served to suggest a number of hypotheses concerning the availability, spawning and abundance of three important pelagic fish stocks. The empirical statistical relationships have in some cases been surprising, even counter-intuitive. These lead to a series of suggestions and hypotheses concerning the mechanisms which may have caused the empirical relationships found here. It is suggested that some of these hypotheses should be explored further using rule-based model or more conventional simulation models..

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9. APPENDICES

APPENDIX 9.1

SPEARMAN RANK CORRELATION RESULTS

TABLE 9.1.1 Spearman Rank correlation coefficients (r_s) between pilchard , *Sardinops ocellatus*, annual catch and different environmental variables for the period 1950-1985 in the Namaqualand area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.6237	-0.5346	-0.4224	-0.4847	-0.3055	-0.3730	**-0.7290**	**-0.6412**	-0.1568	-0.2716	-0.3413	-0.5135
1	-0.6655	-0.5989	-0.5499	-0.5213	-0.3725	-0.3784	-0.6585	-0.5700	-0.1322	-0.3120	-0.4471	-0.5824
2	-0.6694	-0.6736	-0.6807	-0.6587	-0.4735	**-0.4759**	-0.6452	-0.5676	-0.2513	-0.4500	-0.5991	-0.6306
3	-0.6962	-0.6661	-0.6888	-0.6908	-0.5475	-0.4609	-0.6006	-0.5779	-0.3710	-0.5495	-0.6471	-0.6795
4	**-0.7566**	-0.7328	-0.7423	**-0.7148**	**-0.5638**	-0.4685	-0.5374	-0.5905	-0.5290	-0.6023	-0.6804	-0.7038
5	-0.7367	**-0.7520**	**-0.7468**	-0.6782	-0.5633	-0.4516	-0.4702	-0.5238	-0.5355	-0.6185	-0.7601	-0.7802
6	-0.7224	-0.7112	-0.6970	-0.6236	-0.4986	-0.4016	-0.4354	-0.5253	**-0.5729**	**-0.6721**	**-0.7971**	**-0.8038**
7	-0.6305	-0.6695	-0.5901	-0.5108	-0.4153	-0.2833	-0.2828	-0.4074	-0.5414	-0.5818	-0.7616	-0.7709
8	-0.5435	-0.6125	-0.5134	-0.4242	-0.3465	-0.2140	-0.1702	-0.2945	-0.4308	-0.4921	-0.7044	-0.7263
9	-0.4786	-0.5818	-0.4499	-0.3272	-0.1984	-0.1581	-0.1074	-0.1813	-0.3523	-0.4188	-0.6325	-0.6368

NORTH-SOUTH WIND VECTOR

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.4479	-0.5230	-0.5897	-0.3279	-0.4942	-0.1305	-0.6144	-0.6623	-0.5004	-0.4736	-0.2273	-0.6327
1	-0.5877	-0.5966	-0.6683	-0.4655	-0.5034	0.0392	-0.5683	-0.6504	-0.5431	-0.5174	-0.2695	-0.6692
2	-0.6935	-0.6058	-0.6892	-0.5386	-0.5826	0.1972	-0.5560	-0.7018	-0.6281	-0.5523	-0.3558	-0.7125
3	-0.7741	-0.6541	-0.7182	-0.5535	-0.7052	0.3362	-0.6457	-0.6842	-0.6918	-0.6170	-0.4325	-0.7126
4	-0.8013	-0.7460	-0.7636	-0.5674	-0.7467	0.4142	-0.7064	-0.6598	-0.6968	-0.6712	-0.5062	-0.7100
5	-0.8294	-0.7105	-0.7931	-0.6790	-0.7996	0.5367	-0.6871	-0.7169	-0.6960	-0.7335	-0.5968	-0.7492
6	**-0.8429**	**-0.7673**	-0.8323	-0.7415	**-0.8069**	0.5657	-0.7295	-0.7553	-0.6707	-0.7486	-0.6200	-0.7281
7	-0.7690	-0.6631	**-0.8424**	-0.8034	-0.7847	0.6714	**-0.8276**	-0.7783	-0.7463	-0.7966	-0.6995	-0.8187
8	-0.6951	-0.5851	-0.8221	**-0.8363**	-0.7570	**0.6968**	-0.8112	**-0.8243**	-0.7635	-0.8216	-0.7663	**-0.8303**
9	-0.6239	-0.4902	-0.7607	-0.8138	-0.6722	0.5995	-0.7253	-0.7894	**-0.7827**	**-0.8272**	**-0.7674**	-0.8193

WEST-EAST WIND VECTOR

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.1107	-0.0456	-0.4528	0.1483	-0.4376	0.1246	**-0.2484**	**-0.6762**	**-0.5547**	0.2826	0.1552	0.4414
1	0.1709	-0.0916	-0.5008	-0.0269	-0.4471	0.3339	-0.1686	-0.6056	-0.5146	0.3403	0.1370	0.5723
2	0.1694	-0.0879	-0.4872	-0.1071	-0.5701	0.4350	-0.1578	-0.5917	-0.4246	0.3717	0.2284	0.6483
3	0.1003	-0.0692	**-0.5354**	-0.2069	-0.7306	0.4569	-0.2029	-0.5448	-0.2704	0.3523	0.1277	0.6263
4	0.1243	-0.0854	-0.4945	-0.3878	-0.7284	0.4542	-0.2526	-0.5367	-0.0678	0.2801	-0.0238	**0.7672**
5	0.1661	-0.0351	-0.4452	-0.5310	-0.7250	0.5323	-0.2226	-0.5637	0.0601	0.3000	-0.0847	0.7605
6	0.1408	0.0194	-0.4763	-0.7001	**-0.7526**	0.6089	-0.2534	-0.5662	0.2516	0.3406	-0.2343	0.7482
7	0.3153	0.0882	-0.3650	-0.7542	-0.5655	0.7123	-0.2463	-0.4369	0.3448	**0.4335**	-0.3616	0.7818
8	0.3766	0.1357	-0.2764	-0.8336	-0.4893	**0.7263**	-0.2594	-0.4105	0.4220	0.3186	-0.4406	0.6508
9	**0.3944**	**0.1764**	-0.2009	**-0.8565**	-0.3010	0.6496	-0.1606	-0.4115	0.3913	0.3040	**-0.5336**	0.6142

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.6738**	**-0.7333**	-0.6358	**-0.6059**	**-0.4120**	-0.3422	-0.3860	-0.4281	-0.4016	-0.3279	-0.1423	-0.1012
1	-0.5144	-0.6449	**-0.6391**	-0.5093	-0.1802	-0.1872	**-0.4735**	**-0.4717**	**-0.4263**	**-0.3836**	**-0.3176**	-0.3443
2	-0.4454	-0.5937	-0.3310	-0.2623	-0.1258	-0.0632	-0.2222	-0.4249	-0.3364	-0.1806	-0.0417	-0.2128
3	-0.0743	-0.1541	-0.0597	-0.1207	-0.0590	-0.0199	-0.1612	-0.2651	-0.2428	-0.175	-0.0900	-0.1818
4	-0.3264	-0.3956	-0.1483	-0.2425	-0.2024	-0.1256	-0.3463	-0.3217	-0.2206	-0.1059	0.0774	-0.0341
5	-0.3348	-0.2736	-0.0906	-0.0320	-0.0911	-0.1854	-0.4664	-0.4740	-0.2294	-0.1531	-0.0930	-0.3625
6	-0.1885	-0.1333	-0.0032	-0.0660	-0.0739	-0.1644	-0.3317	-0.2854	-0.2531	-0.1898	-0.2704	-0.4334
7	-0.7583	-0.4628	-0.2163	-0.3596	-0.4769	**-0.5023**	-0.4053	-0.3561	-0.3917	-0.2935	-0.0853	-0.1467
8	-0.2639	-0.1207	-0.1329	0.0137	0.0718	-0.0308	-0.2564	-0.1728	-0.2110	-0.2345	-0.3111	**-0.6623**
9	-0.0865	-0.2817	-0.0422	0.1141	0.0859	0.1163	-0.1444	-0.1178	0.0224	0.1238	0.0725	-0.2556

TABLE 9.1.2 Spearman rank correlation coefficients (r_S) between pilchard, *Sardinops ocellatus*, annual catch and different environmental variables for the period 1950-1985 in the Namaqualand area. Highlighted are the largest correlation coefficients for each month period.

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.4183	-0.5745	-0.4067	-0.5066	-0.5375
1	-0.4555	-0.6515	-0.3840	-0.5319	-0.5916
2	-0.4686	-0.6901	-0.4289	-0.5991	-0.6244
3	**-0.5515**	-0.7303	-0.5588	-0.6862	-0.6691
4	-0.5279	**-0.7694**	-0.6283	**-0.7357**	**-0.7460**
5	-0.5117	-0.7544	-0.6569	-0.7028	-0.7238
6	-0.4768	-0.7014	**-0.7046**	-0.6618	-0.7041

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.6644	-0.5681	-0.5004	-0.4605	-0.4844
1	-0.6524	-0.6465	-0.4975	-0.5689	-0.5655
2	-0.5795	-0.7039	-0.5517	-0.6031	-0.6174
3	-0.6688	-0.7644	-0.5882	-0.6253	-0.6591
4	**-0.7251**	-0.8248	-0.6199	-0.6639	-0.7328
5	-0.7089	-0.8109	-0.6710	-0.7637	-0.7855
6	-0.7055	**-0.8291**	-0.7077	-0.8020	-0.8358
7	-0.6562	-0.7567	-0.7650	-0.8345	**-0.8389**
8	-0.6814	-0.6842	-0.8183	**-0.8544**	-0.8232
9	-0.5910	-0.5751	**-0.8321**	-0.8187	-0.7833

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.4510	0.1272	**-0.3874**	-0.0332	0.0584
1	-0.4092	0.2132	-0.3036	-0.1591	0.0493
2	-0.5007	0.2541	-0.1985	-0.2095	0.0408
3	**-0.6026**	0.3055	-0.1260	-0.3486	-0.0020
4	-0.5744	0.2896	-0.1290	-0.5253	-0.0374
5	-0.5145	0.3302	-0.1137	-0.5774	-0.0407
6	-0.4994	0.3201	-0.1012	-0.7330	**-0.1012**
7	-0.1798	0.3759	0.0005	-0.6956	-0.0532
8	-0.0454	0.4116	-0.0246	**-0.7449**	-0.0175
9	0.2173	**0.4402**	-0.1038	-0.7283	-0.0012

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.2959	0.0900	0.1090	0.1390	0.1189
1	0.1358	0.0622	0.0238	-0.0305	0.1007
2	0.3621	0.0000	0.1315	-0.2431	0.1799
3	**0.5089**	**0.6719**	0.4539	**0.3669**	**0.6810**
4	0.1955	0.1264	**0.5300**	0.1295	0.1258
5	0.1193	-0.1411	-0.2646	0.1123	-0.0442
6	-0.0996	0.3509	-0.0441	0.0320	0.2958

TABLE 9.1.3 Spearman Rank correlation coefficients (r_S) for pilchard, *Sardinops ocellatus*, annual catch and different environmental variables for the period 1950-1985 in the south western cape area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.4247	-0.3112	0.0499	-0.0386	-0.3053	-0.4592	-0.2710	-0.0358	0.1701	0.2267	0.0099	-0.2561
1	-0.2599	-0.1140	0.2969	0.1745	-0.1286	-0.3182	-0.0692	0.1773	0.3532	0.3607	0.1056	-0.1350
2	-0.0555	0.0729	0.3907	0.2981	0.0136	-0.2196	0.0338	0.3250	0.4979	0.4566	0.1965	-0.0426
3	0.1170	0.2296	0.4576	0.3666	0.1618	-0.0354	0.2186	0.5010	0.5976	0.5963	0.4277	0.2199
4	0.1954	0.2885	0.4337	0.4282	0.2727	0.1470	0.3391	0.5649	0.6078	0.6421	0.5767	0.4234
5	0.3859	0.4480	0.4992	0.4871	0.3871	0.2601	0.4484	0.6153	0.6815	0.6557	0.5531	0.4798
6	0.4674	0.5190	0.5390	0.5123	0.4932	0.4162	0.5613	0.6169	0.6481	0.6003	0.5905	0.5867
7	0.5576	0.6064	0.6153	0.6049	0.5453	0.5182	**0.6310**	0.6616	0.6813	0.5789	0.6306	0.6478
8	0.6015	0.6524	0.6749	0.6836	0.5966	0.5123	0.6190	**0.6858**	**0.7362**	0.6672	0.6624	**0.6530**
9	**0.6392**	**0.7491**	**0.7613**	**0.7643**	**0.6563**	**0.5470**	0.6142	0.6722	0.7308	**0.7094**	**0.6764**	0.6276

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.6314	-0.7403	-0.5241	-0.3313	-0.2219	0.1272	0.4139	-0.2656	-0.6695	-0.6649	-0.6942	0.1354
1	-0.6104	**-0.8132**	-0.7062	-0.4627	-0.2669	-0.0305	**0.4266**	-0.3835	-0.6669	**-0.6899**	-0.7291	0.0303
2	-0.6049	-0.8047	-0.7076	-0.4866	-0.3143	-0.0118	0.2932	-0.5532	-0.7125	-0.6012	-0.7036	-0.1401
3	-0.6534	-0.7951	-0.6942	-0.4913	**-0.5501**	0.0247	0.1835	-0.6918	-0.6725	-0.5759	-0.6842	-0.3820
4	-0.7093	-0.7309	-0.7515	-0.5623	-0.4051	0.1378	0.1466	-0.7361	-0.6723	-0.5902	-0.7331	-0.4472
5	-0.7472	-0.6290	-0.7589	-0.6762	-0.3165	0.2746	0.0169	-0.6625	**-0.7456**	-0.5835	-0.7411	-0.5617
6	-0.7940	-0.6236	-0.8100	-0.6721	-0.3299	0.2841	-0.0603	**-0.7410**	-0.6156	-0.6031	-0.7646	-0.7268
7	**-0.8379**	-0.5404	-0.8128	-0.7488	-0.1300	0.3606	-0.2635	-0.6232	-0.6655	-0.6123	-0.7611	-0.8517
8	-0.6511	-0.4693	-0.8506	**-0.8019**	-0.0372	0.5140	-0.3350	-0.6409	-0.5720	-0.6174	-0.7646	**-0.9037**
9	-0.8101	-0.4133	**-0.8718**	-0.7857	0.0965	**0.5385**	-0.3755	-0.5342	-0.5818	-0.5977	**-0.7686**	-0.7241

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.5936	-0.2970	-0.3817	0.3358	-0.5668	0.2875	0.3508	-0.1578	-0.2806	-0.3060	-0.3313	**0.6834**
1	0.6580	-0.0818	-0.3826	0.1749	-0.5919	0.3359	**0.4675**	-0.2014	-0.3328	-0.1473	**-0.4216**	0.6437
2	**0.7485**	0.0365	-0.2596	0.1045	-0.5502	0.2736	0.3421	-0.2960	**-0.4304**	-0.0145	-0.2749	0.6385
3	0.6644	0.1795	-0.0535	-0.0047	-0.7383	0.1320	0.1387	**-0.3917**	-0.3366	-0.0431	-0.3178	0.5812
4	0.6353	0.3413	0.0894	-0.1131	-0.6679	-0.0213	0.0506	-0.3306	-0.1276	-0.0979	-0.4252	0.5411
5	0.6778	0.4319	0.2895	-0.1645	**-0.6855**	-0.0738	0.0169	-0.2657	-0.0968	0.0673	-0.3230	0.4278
6	0.4403	0.4719	0.2681	-0.2668	-0.6854	-0.2276	-0.1217	-0.2178	0.1115	0.0959	-0.3677	0.2770
7	0.3783	0.5315	0.4172	-0.3496	-0.4645	-0.3236	-0.1468	-0.0414	0.2350	0.2562	-0.3020	0.1034
8	0.3508	**0.5818**	**0.4532**	-0.3873	-0.4466	-0.3777	-0.1166	0.0706	0.3421	**0.4466**	-0.2791	0.0164
9	0.2790	0.5379	0.3236	**-0.4442**	-0.3291	**-0.4713**	-0.0549	0.1380	0.2772	0.4194	-0.2790	0.0263

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.1142	-0.0091	0.1326	0.2180	0.3545	0.2358	0.3088	-0.0969	-0.2512	0.2472	0.4148	0.5811
1	-0.1093	-0.0518	-0.0018	0.0867	0.2410	0.3581	0.1080	-0.1339	-0.2216	0.0191	0.2794	0.2086
2	-0.0814	-0.0248	-0.3764	-0.2031	0.0556	0.2785	0.5347	0.2776	0.0820	-0.0947	-0.0401	-0.0269
3	**0.6565**	**0.6571**	0.2740	0.4062	**0.4757**	**0.4331**	**0.5734**	0.3414	0.2943	**0.5706**	0.2870	0.0145
4	0.1108	-0.0384	0.0335	0.1414	0.1208	0.1399	0.2303	0.3815	0.3488	0.4572	**0.6646**	**0.6052**
5	-0.0992	-0.0364	-0.0036	0.1521	0.3318	0.0997	-0.0805	-0.3454	-0.3858	-0.2194	0.0730	0.2692
6	0.3608	0.4315	0.1764	-0.0926	-0.1651	0.1062	-0.0196	0.0056	0.0864	-0.0172	-0.2235	-0.0861
7	-0.4067	-0.2985	**-0.6794**	**-0.4959**	-0.4557	0.0247	0.3505	0.2878	0.2949	0.1574	0.2261	0.1383
8	-0.3764	-0.2572	-0.4924	-0.0171	0.2701	-0.1026	-0.2448	**-0.4781**	**-0.4641**	-0.0145	-0.1389	-0.3049
9	-0.2128	-0.4001	-0.2394	-0.0982	-0.3374	-0.3560	-0.2086	0.1122	0.0556	-0.2799	-0.3503	-0.2902

TABLE 9.1.4 Spearman rank correlation coefficients (r_S) between pilchard ,*Sardinops ocellatus* , annual catch and different environmental variables for the period 1950-1985 in the south western cape area. Highlighted are the highest correlation coefficients for each month period .

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3305	-0.3091	0.0510	0.0113	-0.1205
1	-0.1521	-0.1521	0.2538	0.2395	0.0773
2	-0.0387	0.0720	0.3928	0.3455	0.2807
3	0.1156	0.2550	0.5231	0.3994	0.4141
4	0.2507	0.2991	0.5861	0.4219	0.4216
5	0.3726	0.4565	0.6383	0.4867	0.4968
6	0.4928	0.5212	0.5172	0.5947	0.5284
7	0.5768	0.6049	0.5995	0.6108	0.5980
8	0.5796	0.6409	0.6732	0.6760	0.6349
9	**0.6056**	**0.6612**	**0.7253**	**0.7631**	**0.7234**

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.2149**	-0.6412	-0.2837	-0.5233	-0.6438
1	0.2092	-0.6625	-0.4437	-0.7140	-0.6941
2	0.1095	-0.7305	-0.5422	0.6923	-0.6941
3	-0.1628	-0.7179	-0.6751	-0.6658	-0.6962
4	-0.1001	-0.7518	-0.7005	-0.6873	-0.7335
5	-0.0476	-0.7645	-0.6976	-0.7476	-0.7685
6	-0.0692	-0.7749	**-0.7442**	-0.7535	-0.7873
7	0.0340	**-0.8044**	-0.7246	-0.7966	-0.8296
8	0.1210	-0.7143	-0.7050	**-0.8451**	**-0.8369**
9	0.1593	-0.6880	-0.6728	-0.8333	-0.8242

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.0677	0.4860	0.0293	-0.3086	0.0059
1	-0.0269	0.6272	-0.0930	**-0.4434**	0.1283
2	-0.1627	0.6544	-0.1563	-0.3341	0.3113
3	-0.4365	0.6237	-0.2627	-0.1698	0.4168
4	-0.4633	0.6976	-0.3204	-0.0576	0.5268
5	-0.5198	0.6879	**-0.3343**	0.1722	0.6387
6	**-0.5751**	0.6036	-0.2899	0.1159	0.5800
7	-0.5241	0.6882	-0.0867	0.2005	0.7719
8	-0.4822	**0.7685**	0.0914	0.1713	**0.7793**
9	-0.4652	0.6960	0.1154	-0.0623	0.5958

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.2959	0.0900	0.1090	0.1390	0.1189
1	0.1358	0.0622	0.0238	-0.0305	0.1007
2	0.3621	0.0000	0.1315	-0.2431	0.1799
3	**0.5089**	**0.6719**	0.4539	0.3669	**0.6810**
4	0.1955	0.1264	**0.5300**	0.1295	0.1258
5	0.1193	-0.1411	-0.2646	0.1123	-0.0442
6	-0.0996	0.3509	-0.0441	0.0320	0.2958
7	0.1340	-0.3699	0.1825	**-0.5366**	-0.3762
8	-0.1425	-0.3769	-0.4018	-0.1768	-0.4356
9	-0.3374	-0.2510	-0.0854	-0.1004	-0.2543

TABLE 9.1.5 Spearman Rank correlation coefficients (r_s) between pilchard , *Sardinops ocelltatus* , annual catch and different environmental variables for the period 1950-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.5861	-0.5761	-0.5060	-0.3748	-0.4697	-0.3588	-0.1017	-0.0350	-0.0548	-0.2368	-0.4329	-0.4041
1	-0.6731	-0.6650	-0.4429	-0.2639	-0.3151	-0.2238	0.0675	0.1230	0.0594	-0.1625	-0.4583	-0.4669
2	-0.7235	-0.7149	-0.4817	-0.2073	-0.2194	-0.0695	0.1921	0.2312	0.1525	-0.2103	-0.5053	-0.5554
3	-0.6674	-0.6808	-0.5074	-0.2420	-0.2096	0.0304	0.3199	0.3215	0.2316	-0.1999	-0.5541	-0.6150
4	-0.7511	-0.7463	-0.5909	-0.1910	-0.1384	0.0946	0.3732	0.3178	0.2141	**-0.2673**	-0.6184	-0.6056
5	-0.7746	**-0.7919**	**-0.6270**	-0.0855	-0.0175	0.2895	0.4815	**0.4371**	0.3135	-0.2307	-0.7359	-0.7230
6	-0.7820	-0.7611	-0.4923	0.0581	0.1604	0.4198	**0.5915**	0.4087	0.2514	-0.2536	-0.7588	-0.7041
7	**-0.7985**	-0.7759	-0.3212	0.2360	0.3059	0.5330	0.5833	0.4025	0.3537	-0.0692	-0.7857	**-0.7567**
8	-0.7362	-0.7126	-0.1943	0.4089	0.4489	0.6081	0.5255	0.4138	**0.3889**	0.0849	**-0.7893**	-0.7499
9	-0.6538	-0.6160	0.0904	**0.6150**	**0.6509**	**0.6490**	0.4750	0.3883	0.3569	0.1520	-0.6850	-0.6740

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.0175	-0.1951	0.5194	-0.0520	0.5071	0.6311	0.4355	0.1477	0.1073	0.2638	-0.4041	-0.1627
1	0.2182	-0.0658	0.5838	-0.1479	0.5409	0.6014	0.4930	0.1123	0.1599	0.4417	-0.3078	0.0367
2	0.3280	-0.0665	0.6703	-0.1966	0.6119	0.6321	**0.6330**	0.0652	0.1462	0.5869	-0.0894	0.3121
3	0.3747	0.0374	0.7172	0.0043	0.5090	0.6574	0.6026	0.0050	0.2323	0.6638	0.0916	0.3854
4	0.4406	0.2694	0.7056	0.0638	0.5924	0.7430	0.5773	-0.0887	0.3317	0.6463	0.1730	0.4641
5	0.5190	0.3754	**0.7306**	0.0415	0.6472	0.7190	0.5879	-0.1661	0.3653	**0.6895**	0.3653	0.5883
6	0.5150	0.3633	0.6997	-0.0060	0.5893	0.7860	0.4848	**-0.3766**	0.4105	0.6756	0.3713	0.6231
7	0.6133	0.5153	0.7315	-0.0897	0.7429	**0.7916**	0.4424	-0.1611	0.4429	0.6808	**0.4227**	0.7079
8	0.6190	0.5309	0.7291	-0.1111	**0.7718**	0.7417	0.4198	-0.1845	**0.5534**	0.6579	0.3755	0.7094
9	**0.6331**	**0.5440**	0.7137	**-0.2357**	0.7271	0.6899	0.2753	-0.0183	0.4548	0.6361	0.3321	**0.7369**

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.1511**	**-0.5238**	0.0180	0.1658	**0.5333**	0.3431	0.3897	-0.2628	0.0059	0.0620	-0.2342	0.6559
1	-0.0095	-0.4826	-0.0804	0.0507	0.4681	0.5429	0.4941	-0.1305	-0.1056	-0.0403	**-0.2605**	0.6062
2	0.0985	-0.4472	-0.1199	0.0604	0.4167	0.6501	0.5945	-0.0527	-0.1416	-0.1251	-0.0561	**0.6846**
3	0.0963	-0.3954	-0.0996	-0.0879	0.2904	0.6233	0.5782	-0.0087	0.0211	-0.0030	-0.0264	0.5551
4	0.0568	-0.2771	-0.1140	-0.2786	0.3295	0.6771	0.5931	0.0979	0.1173	0.0484	-0.1037	0.6708
5	0.0633	-0.2302	-0.1403	-0.3665	0.2883	0.7508	0.6315	0.2218	0.2359	0.1887	0.0238	0.6593
6	-0.0634	-0.1279	-0.2792	-0.4759	0.3028	0.7571	0.5840	0.2934	0.3887	0.2071	-0.0723	0.6111
7	-0.0626	-0.0207	-0.3079	-0.5246	0.4261	0.8360	**0.6360**	0.5049	0.4887	0.3532	-0.1059	0.5833
8	-0.0941	0.0350	-0.3361	-0.5276	0.3924	**0.8851**	0.6065	0.5933	**0.5829**	0.5419	-0.1138	0.4450
9	-0.0891	0.1300	**-0.3687**	**-0.6612**	0.4921	0.8425	0.6074	**0.6197**	0.5159	**0.5952**	-0.2167	0.3926

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.5206	-0.5146	-0.3995	-0.4297	-0.1373	-0.1492	-0.2196	-0.3582	-0.2871	-0.3580	-0.3031	-0.2884
1	-0.5833	**-0.5785**	**-0.6310**	-0.4802	-0.2852	-0.2201	-0.3634	-0.4560	**-0.4225**	**-0.4581**	-0.3644	-0.4872
2	-0.3650	-0.4091	-0.5253	-0.4506	-0.3538	-0.3199	-0.3366	-0.3855	-0.4157	-0.4280	-0.3816	-0.4965
3	-0.1471	-0.0998	-0.2976	-0.3562	-0.2823	-0.2678	-0.3713	-0.3184	-0.2535	-0.2501	-0.2258	-0.3169
4	**-0.6784**	-0.6078	-0.6213	**-0.6437**	**-0.5326**	-0.4505	-0.5553	**-0.5461**	-0.4348	-0.2937	-0.1685	-0.2550
5	-0.5192	-0.4665	-0.6249	-0.4706	-0.4274	**-0.5318**	**-0.6640**	-0.4562	-0.4622	-0.4615	**-0.5190**	**-0.5957**
6	-0.2045	-0.1122	-0.2557	-0.4328	-0.4113	-0.4923	-0.5380	-0.4101	-0.1907	-0.2186	-0.3103	-0.4492
7	-0.0728	-0.0930	-0.3349	-0.4519	-0.3988	-0.3278	-0.3197	-0.2965	-0.1663	-0.0990	-0.0309	-0.0357
8	-0.0107	0.0134	-0.1912	-0.0435	-0.0068	-0.0780	-0.0647	-0.1181	-0.1519	-0.1304	-0.0785	-0.0304
9	-0.2387	-0.3369	-0.2955	-0.0312	0.0442	0.0768	0.1090	0.0511	0.0178	0.0603	0.2396	0.1766

TABLE 9.1.6 Spearman rank correlation coefficients (r_s) between pilchard, *Sardinops ocellatus*, annual catch and environmental variables for the period 1950-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month period.

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3120	-0.5735	0.6435	**-0.4589**	-0.5125
2	-0.1490	-0.6473	**0.6465**	-0.3714	-0.4955
3	0.0471	-0.6835	0.4886	-0.3971	-0.5822
4	0.1188	-0.7694	0.3746	-0.3724	**-0.7056**
5	0.2702	-0.7690	0.2665	-0.3411	-0.6895
6	0.4198	-0.7744	0.0478	-0.1729	-0.6147
7	0.5414	**-0.8015**	0.0138	0.1335	-0.4680
8	0.6327	-0.7323	0.1609	0.2189	-0.2950
9	**0.6966**	-0.6575	0.4835	0.2173	-0.0794

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.6057	-0.0466	0.2813	0.3225	0.1418
1	0.6515	0.2120	0.3339	0.3521	0.3980
2	0.7299	0.2999	0.3723	0.4124	0.4270
3	0.6678	0.3553	0.4047	0.5545	0.4799
4	0.7210	0.4457	0.4344	0.5744	0.5843
5	0.7464	0.5468	0.4786	**0.6673**	0.6444
6	0.7259	0.5315	0.4434	0.6521	0.6445
7	0.8266	0.6172	0.5355	0.6369	**0.6645**
8	**0.8407**	**0.6388**	**0.5567**	0.5829	0.6557
9	0.8132	0.6068	0.5348	0.4927	0.6123

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.5184	**-0.3115**	-0.2916	0.0595	**-0.2142**
1	0.6132	-0.0577	-0.1491	-0.0692	-0.0303
2	0.6648	0.0188	-0.0863	-0.0952	0.0390
3	0.5973	0.0441	0.4047	**0.5545**	0.0451
4	0.6514	0.0953	0.0828	-1.7930	0.0799
5	0.7036	0.0843	0.2988	-0.2802	0.0528
6	0.7112	0.1657	0.4398	-0.3740	0.0176
7	0.8177	0.2473	0.6552	-0.4030	0.0557
8	0.8117	0.2682	**0.8057**	-0.4412	-0.0279
9	**0.8217**	0.3632	0.7558	-0.5488	0.0201

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.0939	-0.5267	-0.3610	-0.4284	-0.4656
1	-0.2961	-0.5600	**-0.4708**	-0.5967	-0.5124
2	-0.3466	0.3781	-0.4503	-0.5239	-0.3888
3	-0.2952	-0.1338	-0.2697	-0.3336	-0.2195
4	-0.5266	**-0.6319**	-0.3840	**-0.6339**	**-0.6043**
5	**-0.5477**	-0.4893	-0.5022	-0.5644	-0.4458
6	-0.4823	-0.1185	-0.2835	-0.3473	-0.2206
7	-0.3274	-0.0762	-0.3688	-0.1517	-0.2414
8	-0.0233	0.0916	-0.1028	-0.1307	0.0158
9	0.0861	-0.1670	-0.1252	0.0494	-0.0923

TABLE 9.1.7 Spearman rank correlation coefficients (r_s) between horse mackerel ,*Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the Namaqualand area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.7259	-0.6824	-0.5081	-0.5063	-0.2502	-0.1933	**-0.5694**	**-0.5624**	-0.1632	-0.3174	-0.5632	-0.7521
1	-0.7165	-0.7378	-0.5891	-0.5134	-0.3162	-0.2104	-0.5053	-0.4916	-0.0972	-0.3104	-0.6162	-0.7669
2	-0.7415	-0.7837	-0.7241	-0.6449	-0.4267	-0.2984	-0.4732	-0.4564	-0.1707	-0.4218	-0.7360	-0.7904
3	**-0.7600**	-0.8028	**-0.7677**	**-0.6755**	-0.5371	-0.3449	-0.4288	-0.4485	-0.2898	-0.4933	-0.7807	-0.8178
4	-0.7595	**-0.8094**	-0.7522	-0.6580	**-0.5707**	**-0.4021**	-0.4142	-0.4454	-0.3915	-0.5235	**-0.8024**	-0.8321
5	-0.7415	-0.8040	-0.7218	-0.6363	-0.5698	-0.4028	-0.3940	-0.4351	**-0.4399**	**-0.5315**	-0.8020	-0.8391
6	-0.7179	-0.7784	-0.6872	-0.6004	-0.5275	-0.3735	-0.3464	-0.3971	-0.4380	-0.5266	-0.7993	**-0.8403**
7	-0.6985	-0.7754	-0.6680	-0.5606	-0.4739	-0.3483	-0.3069	-0.3640	-0.4532	-0.5197	-0.7956	-0.8232
8	-0.6563	-0.7400	-0.6486	-0.5189	-0.4258	-0.3279	-0.2638	-0.3300	-0.4505	-0.5244	-0.7876	-0.8134
9	-0.6252	-0.7228	-0.6074	-0.4683	-0.3694	-0.2875	-0.2534	-0.3248	-0.4603	-0.5275	-0.7827	-0.7967

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.6891	-0.6842	-0.8692	-0.6716	-0.7696	0.4185	**-0.8901**	**-0.9470**	-0.8499	-0.8458	-0.5624	-0.9689
1	-0.7927	-0.6513	-0.9294	-0.7961	-0.7305	0.5218	-0.8821	-0.9244	-0.8616	-0.8653	-0.5846	-0.9678
2	-0.8270	-0.6724	-0.9166	-0.8545	-0.8096	0.5667	-0.8811	-0.9316	-0.8906	-0.8854	-0.6550	**-0.9752**
3	**-0.8463**	-0.6848	**-0.9332**	-0.8897	-0.8292	0.5451	-0.8894	-0.9215	-0.8944	-0.9338	-0.7540	-0.9693
4	-0.8361	**-0.6855**	-0.9223	-0.9047	-0.8457	0.5620	-0.8625	-0.9278	-0.8867	-0.9494	-0.7991	-0.9674
5	-0.8347	-0.6661	-0.9246	-0.9250	-0.8238	**0.5988**	-0.8605	-0.9460	-0.9290	-0.9508	-0.8226	-0.9706
6	-0.8234	-0.6534	-0.9172	-0.9315	**-0.8478**	0.5746	-0.8291	-0.9248	-0.9408	-0.9453	-0.8443	-0.9711
7	-0.8079	-0.6448	-0.8936	**-0.9453**	-0.8473	0.5251	-0.7980	-0.9079	**-0.9635**	-0.9483	-0.8941	-0.9626
8	-0.7882	-0.6185	-0.8900	-0.9458	-0.8484	0.4828	-0.7958	-0.9124	-0.9579	-0.9491	-0.9037	-0.9606
9	-0.7772	-0.6087	-0.8712	-0.9457	-0.8425	0.4328	-0.8462	-0.9017	-0.9597	**-0.9554**	**-0.9396**	-0.9481

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.3629	**0.3097**	-0.3871	-0.2121	-0.5148	0.6165	**-0.5462**	**-0.7521**	-0.1508	**0.5848**	0.0607	0.7972
1	0.3759	0.2751	-0.4521	-0.3227	-0.4311	**0.6524**	-0.4560	-0.6773	-0.0997	0.5216	0.0812	**0.8622**
2	0.3195	0.2220	-0.4582	-0.4310	-0.5642	0.6040	-0.4014	-0.6495	-0.0332	0.4671	0.1040	0.8454
3	0.2978	0.1541	**-0.5217**	-0.5348	-0.5896	0.5615	-0.3412	-0.6086	0.0438	0.4398	0.0164	0.8412
4	0.3068	0.0773	-0.4875	-0.6686	**-0.5964**	0.6246	-0.2647	-0.5832	0.0543	0.4157	-0.0850	0.7999
5	0.3262	0.0581	-0.4782	-0.7399	-0.5456	0.6516	-0.2048	-0.5891	0.0661	0.4149	-0.1843	0.8101
6	0.3459	0.0647	-0.4367	-0.8647	-0.5511	0.6681	-0.1408	-0.5689	0.1043	0.3869	-0.2957	0.7664
7	0.4015	0.0645	-0.3611	**-0.9350**	-0.5291	0.6246	-0.0808	-0.5557	0.1483	0.3177	-0.4286	0.8212
8	0.4663	0.0914	-0.3328	-0.9015	-0.4899	0.5665	-0.0285	-0.5649	0.1702	0.2999	-0.5315	0.7904
9	**0.5140**	0.1313	-0.2582	-0.8895	-0.4634	0.5415	0.0263	-0.5201	**0.2106**	0.2747	**-0.6947**	0.8114

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.5435	**-0.6473**	-0.4003	**-0.3623**	-0.2455	-0.2107	**-0.4476**	**-0.4600**	**-0.4060**	-0.2425	0.0135	-0.1242
1	-0.4466	-0.5547	-0.3674	-0.3302	-0.2360	-0.1994	-0.4173	-0.4579	-0.4007	-0.2436	-0.1114	-0.1868
2	-0.4256	-0.5606	-0.3218	-0.2807	-0.2260	-0.2456	-0.4344	-0.4037	-0.3318	-0.1932	-0.0029	-0.1659
3	-0.5171	-0.6341	**-0.4303**	-0.3271	**-0.2804**	**-0.2981**	-0.4388	-0.4220	-0.3829	**-0.2671**	-0.0512	-0.1521
4	-0.4761	-0.5705	-0.4081	-0.2905	-0.1561	-0.0659	-0.3579	-0.3687	-0.2541	-0.2255	**-0.1639**	-0.2418
5	**-0.7184**	-0.6496	-0.2630	-0.2241	-0.2670	-0.2437	-0.2769	-0.1861	-0.0527	0.0276	0.0717	-0.2236
6	-0.5410	-0.5093	-0.3690	-0.2862	-0.0427	-0.1196	-0.3829	-0.3238	-0.0767	-0.0283	-0.1727	**-0.4600**
7	-0.5876	-0.5596	-0.1463	-0.1122	0.0271	-0.0688	-0.2843	-0.2196	0.0368	0.1751	0.1675	-0.2556
8	-0.5277	-0.5219	-0.2532	-0.1832	-0.1015	-0.1359	-0.3264	-0.3098	-0.0749	-0.0248	-0.0753	-0.3978
9	-0.3792	-0.3043	-0.1839	-0.1231	-0.1141	-0.0559	-0.1534	-0.0344	0.1896	0.0522	-0.0829	-0.2489

TABLE 9.1.8 Spearman rank correlation coefficients (r_s) between horse mackerel, *Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the Namaqualand area. Highlighted are the highest correlation coefficients for each month period.

		POOLED MONTHS			
SEA SURFACE TEMPERATURE					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3158	-0.6664	-0.4847	-0.5529	-0.6015
1	-0.3728	-0.7073	-0.4342	-0.5336	-0.5992
2	-0.3589	-0.7372	-0.4564	-0.6083	-0.6449
3	-0.4689	**-0.7684**	-0.5752	**-0.7169**	-0.6828
4	**-0.4773**	-0.7599	-0.5986	-0.7042	**-0.6972**
5	-0.4698	-0.7323	**-0.6117**	-0.6665	-0.6718
6	-0.4412	-0.7108	-0.6009	-0.6365	-0.6565
NORTH-SOUTH WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.8118	-0.8072	-0.8584	-0.8147	-0.8371
1	-0.7938	-0.8062	-0.8454	-0.9188	-0.8720
2	-0.7809	-0.8136	-0.8833	-0.9187	-0.8949
3	-0.8215	**-0.8215**	-0.9011	**-0.9509**	**-0.9098**
4	**-0.8244**	-0.7973	-0.9260	-0.9359	-0.9047
5	-0.7754	-0.7855	-0.9351	-0.9532	-0.8992
6	-0.7909	-0.7722	-0.9355	-0.9511	-0.8968
7	-0.7857	-0.7448	-0.9394	-0.9360	-0.8901
8	-0.8144	-0.7154	-0.9469	-0.9442	-0.8894
9	-0.8156	-0.6926	**-0.9737**	-0.9371	-0.8816
WEST-EAST WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3876	0.5122	-0.1076	-0.2880	**0.3048**
1	-0.2840	**0.5263**	-0.0266	-0.3756	0.2583
2	**-0.4005**	0.4848	0.0313	-0.4652	0.1933
3	-0.3656	0.4559	0.0424	-0.5792	0.1360
4	-0.3090	0.4205	-0.0033	-0.7071	0.0770
5	-0.2044	0.3823	-0.0560	-0.7706	0.0226
6	-0.1546	0.4016	-0.1115	**-0.8287**	-0.0469
7	-0.0773	0.4163	-0.1882	-0.8133	-0.0852
8	-0.0301	0.4598	-0.2578	-0.7991	-0.0712
9	-0.0330	0.4817	**-0.3150**	-0.7680	-0.0354
SEA LEVEL					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.3769	0.0185	0.1986	0.0680	0.1644
1	**0.4218**	0.2457	0.3009	0.2496	**0.3833**
2	0.0197	0.0072	**0.4423**	-0.2939	0.1416
3	0.1953	-0.1663	0.0737	-0.0133	0.0358
4	-0.1704	-0.1840	-0.0483	-0.2975	0.2583
5	-0.0862	-0.2462	-0.3153	-0.2807	0.3370
6	0.2075	**0.3825**	-0.1738	0.1781	0.3310
7	0.4656	-0.1781	0.4597	0.1829	0.0734
8	0.1655	-0.0669	-0.1096	-0.0427	0.0429
9	-0.0798	0.1841	0.3171	**0.4770**	0.2712

TABLE 9.1.9 Spearman Rank correlation coefficients (r_S) between horse mackerel, *Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the south western Cape area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.0924	0.1501	0.4311	0.3495	0.0641	-0.0878	0.0734	0.3166	0.5176	0.6129	0.4227	0.2644
1	0.2154	0.2801	0.5829	0.4697	0.1644	-0.0134	0.1647	0.4331	0.6487	0.6409	0.4895	0.3370
2	0.2706	0.3461	0.5887	0.5364	0.2727	0.0769	0.2599	0.5511	0.7623	0.6986	0.5684	0.4029
3	0.3389	0.3941	0.6253	0.5892	0.3676	0.1578	0.3529	0.6541	0.7858	0.7140	0.6383	0.4549
4	0.3996	0.4916	0.6628	0.6642	0.4567	0.2570	0.4432	0.7027	0.7951	0.7147	0.6465	0.5136
5	0.4706	0.6149	0.7407	0.7266	0.5258	0.3315	0.5173	0.7258	0.8145	0.7378	0.6694	0.5323
6	0.5137	0.6850	0.7878	0.7713	0.6071	0.4318	0.6672	0.8176	0.8812	0.7838	0.6895	0.5875
7	0.5350	0.6961	0.7818	0.8025	0.7059	0.5404	0.7527	0.8576	0.9113	0.8481	0.7484	0.5892
8	0.6130	0.7439	0.8095	**0.8144**	0.7252	0.5824	0.8079	**0.9097**	**0.9617**	0.8511	0.7253	0.5889
9	**0.6893**	**0.7717**	**0.8138**	0.8144	**0.7717**	**0.6319**	**0.8199**	0.8987	0.9371	**0.8516**	**0.7741**	**0.6496**

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.9614**	**-0.8255**	-0.8973	-0.6201	0.0106	0.3727	0.0927	-0.4314	-0.8239	**-0.8404**	**-0.9642**	-0.2710
1	-0.9370	-0.7798	**-0.9633**	-0.7866	-0.0193	0.2770	0.0246	0.4952	-0.7986	-0.8084	-0.9479	-0.3835
2	-0.9432	-0.7760	-0.9450	-0.7876	-0.1230	0.2535	-0.200	-0.6287	-0.8084	-0.8011	-0.9312	-0.4759
3	-0.9539	-0.7373	-0.9418	-0.8419	-0.1852	0.2664	-0.0866	-0.7493	-0.8292	-0.8225	-0.9382	-0.5749
4	-0.9582	-0.7518	-0.9468	-0.8809	-0.1162	0.2269	-0.0616	-0.7489	-0.8383	-0.8292	-0.9252	-0.6774
5	-0.9577	-0.7056	-0.9415	-0.9105	-0.0907	0.3448	-0.1226	-0.7512	**-0.8690**	-0.8169	-0.9181	-0.7649
6	-0.9440	-0.6859	-0.9390	-0.9279	**-0.2022**	0.4024	-0.1582	**-0.7548**	-0.8207	-0.7864	-0.9021	**-0.8861**
7	-0.9271	-0.6635	-0.9365	-0.9340	-0.1936	0.4030	-0.2064	-0.7360	-0.8217	-0.7621	-0.9010	-0.8517
8	-0.9239	-0.6388	-0.9157	**-0.9349**	-0.1834	**0.4532**	-0.3257	-0.7094	-0.7920	-0.7406	-0.8949	-0.8489
9	-0.9353	-0.5885	-0.8993	-0.9304	-0.1227	0.3437	**-0.4096**	-0.6740	-0.7650	-0.7247	-0.8773	-0.8510

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**0.6113**	0.2229	-0.2682	0.1048	**-0.6154**	0.0250	0.0041	0.0746	-0.1817	-0.0373	**-0.4049**	**0.4798**
1	0.5899	0.3238	-0.2062	-0.0078	-0.5546	0.0936	0.1277	0.0342	-0.1303	0.0672	-0.3395	0.3902
2	0.5618	0.3500	-0.1172	-0.0674	-0.6037	-0.0050	0.0524	-0.0383	-0.0906	0.1523	-0.2840	0.3305
3	0.5605	0.4074	-0.0378	-0.1628	-0.5468	-0.0826	-0.0017	-0.1073	-0.0207	0.1705	-0.2807	0.3252
4	0.5389	0.4315	0.0319	-0.2315	-0.5396	-0.1459	0.1074	**-0.1144**	0.0227	0.1668	-0.2771	0.2511
5	0.5371	0.4375	0.1153	-0.3466	-0.4391	-0.1972	0.1363	-0.1012	0.0286	0.2589	-0.2625	0.2633
6	0.5008	0.4848	0.2263	-0.4470	-0.5026	-0.2716	**0.1439**	-0.1106	0.1164	0.3731	-0.2792	0.1235
7	0.5177	0.5167	0.3463	-0.4909	-0.4931	-0.4236	0.1054	-0.0562	0.1355	0.4360	-0.3404	0.1064
8	0.4707	0.5194	0.4373	-0.4842	-0.5074	-0.5490	0.1122	-0.0241	0.1943	**0.5151**	-0.4226	0.1062
9	0.4054	**0.5775**	**0.4811**	**-0.5840**	-0.4780	**-0.6789**	0.0849	0.0604	**0.2448**	0.5177	-0.4567	0.0867

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.1371	0.0561	-0.0358	0.0955	0.2606	0.3400	0.3956	0.1075	-0.0326	0.2184	0.1315	0.2843
1	0.0815	0.1777	0.1615	0.2489	**0.3207**	0.3804	**0.4172**	0.1810	0.1332	0.3397	0.3738	0.0050
2	-0.1854	-0.1829	**-0.4522**	-0.2531	-0.1645	-0.0470	0.2380	**0.3933**	**0.3490**	**0.3801**	0.2777	0.2448
3	-0.1989	-0.1874	-0.1804	0.0807	0.1975	0.0915	0.2219	-0.0015	-0.2107	0.0595	0.2133	0.1414
4	**-0.2803**	**-0.3410**	-0.3576	-0.2756	-0.2309	-0.1958	-0.0961	-0.1570	-0.0690	0.0892	0.0434	0.0289
5	-0.2381	-0.3362	-0.3659	-0.2258	-0.1751	-0.0997	0.0179	-0.3117	-0.3189	-0.2287	-0.0872	0.1068
6	0.2679	0.3280	0.1114	0.2902	0.3609	0.2495	0.0671	-0.2794	-0.2312	0.0801	0.0610	0.1306
7	-0.1589	0.0280	-0.0748	**0.3933**	0.2363	**0.5989**	0.4567	0.4192	0.2451	0.3441	**0.5287**	**0.3653**
8	-0.0251	0.0878	-0.2867	-0.0256	0.4220	0.1453	-0.1201	-0.2878	-0.2274	0.3187	-0.0096	-0.3003
9	0.2724	0.2809	0.3676	0.3683	0.0241	-0.0859	0.0245	0.4301	0.3581	0.0586	-0.0324	-0.1358

TABLE 9.1.10 Spearman Rank correlation coefficients (r_S) between horse mackerel, *Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the south western Cape area. Highlighted are the highest correlation coefficients for each month period.

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.0162	0.2000	0.4378	0.3941	0.3346
1	0.1078	0.3289	0.5549	0.5269	0.4577
2	0.2040	0.3736	0.6519	0.5701	0.5050
3	0.3051	0.4352	0.6875	0.6116	0.5632
4	0.4168	0.4754	0.7031	0.6620	0.6048
5	0.4827	0.5540	0.7246	0.7258	0.6653
6	0.5871	0.6142	0.7855	0.7726	0.7032
7	0.6704	0.6167	0.8502	0.7956	0.7143
8	0.7083	0.6804	**0.8982**	**0.8161**	0.7597
9	**0.7454**	**0.7308**	0.8877	0.8126	**0.7808**

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.3568**	**-0.9408**	-0.5259	-0.8409	**-0.9799**
1	0.3381	-0.8894	-0.6342	-0.9714	-0.9770
2	0.2535	-0.8879	-0.7650	-0.9578	-0.9649
3	0.1902	-0.8854	-0.8670	-0.9682	-0.9666
4	0.2716	-0.8765	-0.8724	-0.9743	-0.9648
5	0.2835	-0.8815	**-0.8758**	-0.9702	-0.9629
6	0.1996	-0.8398	-0.8754	-0.9773	-0.9524
7	0.1153	-0.8266	-0.8650	-0.9650	-0.9443
8	0.0005	-0.8259	-0.8588	**-0.9953**	-0.9480
9	-0.0763	-0.8065	-0.8535	-0.9353	-0.9426

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3642	0.8178	**0.1992**	-0.3529	0.4597
1	-0.2706	0.7810	0.1471	**-0.3669**	0.4050
2	-0.4053	0.8225	0.1044	-0.3082	0.5129
3	-0.4285	0.8041	0.0404	-0.2467	0.5912
4	-0.4032	0.8358	-0.0165	-0.2152	0.6884
5	-0.3730	0.7790	-0.0681	-0.1734	0.6407
6	-0.4345	0.7967	-0.1070	-0.0994	0.6934
7	-0.5473	**0.8409**	-0.0793	-0.0596	**0.7463**
8	-0.6185	0.8227	-0.0613	0.0646	0.7422
9	**-0.6856**	0.8297	0.0079	0.0085	0.7125

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.3769**	0.0185	0.1986	0.0680	0.1644
1	0.4218	0.2457	0.3009	0.2496	**0.3833**
2	0.0197	0.0072	**0.4423**	-0.2939	0.1416
3	0.1953	-0.1663	0.0737	-0.0133	0.0358
4	-0.1704	-0.1840	-0.0483	-0.2975	0.2583
5	-0.0862	-0.2462	-0.3153	-0.2807	0.3370
6	0.2075	**0.3825**	-0.1738	0.1781	0.3310
7	0.4656	-0.1781	0.4597	0.1829	0.0734
8	0.1655	-0.0669	-0.1096	-0.0427	0.0429
9	-0.0798	0.1841	0.3171	**0.4770**	0.2712

TABLE 9.1.11 Spearman Rank correlation coefficients (r_s) between horse mackerel ,*Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.8764	-0.8726	**-0.5490**	-0.1840	-0.2144	-0.0839	0.0103	-0.0291	-0.0973	**- 0.3783**	**-0.8674**	-0.8435
1	**-0.8773**	-0.8818	-0.4882	-0.0989	-0.1305	0.0025	0.0944	0.0826	0.0186	-0.2909	-0.8549	**-0.8496**
2	-0.8625	**-0.8839**	-0.4432	-0.0139	-0.0518	0.0851	0.1743	0.1725	0.1174	-0.2200	-0.8307	-0.8212
3	-0.8747	-0.8810	-0.3957	0.0685	0.0393	0.1905	0.2767	0.2734	0.2044	-0.1339	-0.8215	-0.8108
4	-0.8519	-0.8710	-0.3218	0.1639	0.1446	0.2874	0.3809	0.3761	0.2898	-0.0480	-0.7936	-0.7962
5	-0.8520	-0.8407	-0.2274	0.2883	0.2785	0.4222	0.4980	0.4911	0.3754	0.0417	-0.7629	-0.7665
6	-0.8189	-0.8398	-0.1773	0.3642	0.3798	0.5546	0.6601	0.6169	0.5035	0.1477	-0.7415	-0.7713
7	-0.8374	-0.8355	-0.0956	0.4764	0.5124	0.6739	0.7182	0.6709	0.6168	0.2454	-0.6936	-0.7158
8	-0.8281	-0.8484	-0.0750	0.5359	0.5466	**0.7625**	**0.7641**	**0.7225**	**0.6955**	0.3389	-0.7094	-0.7406
9	-0.8339	-0.8419	-0.1040	**0.6013**	**0.6039**	0.7540	0.7332	0.6917	0.6564	0.4100	-0.6618	-0.7082

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.3457	0.2649	**0.8746**	0.0857	**0.8901**	**0.8764**	0.4852	0.1560	**0.5441**	0.6921	-0.1743	0.3153
1	0.4843	0.3597	0.8723	-0.0857	0.8838	0.7905	0.4499	0.0924	0.4919	0.6908	-0.1157	0.4199
2	0.4924	0.3137	0.8619	-0.1456	0.8692	0.7775	0.5447	0.0640	0.4509	0.6984	-0.0277	0.5319
3	0.5501	0.3456	0.8416	-0.1544	0.8673	0.7741	0.5578	-0.0090	0.4195	**0.7219**	0.0508	0.5969
4	0.5909	0.3922	0.8339	-0.2122	0.8600	0.7625	**0.6364**	-0.0528	0.3779	0.7199	0.1301	0.6353
5	0.6383	0.4500	0.8214	-0.3194	0.8847	0.7621	0.6117	-0.1323	0.2722	0.6968	0.2230	0.7149
6	0.6930	0.4812	0.8145	-0.4278	0.8314	0.7455	0.6093	**-0.2374**	0.2810	0.7255	0.2970	0.6943
7	0.7300	**0.4916**	0.8074	-0.4542	0.8547	0.7325	0.6010	-0.1640	0.2847	0.7227	0.3325	0.7813
8	0.7455	0.4636	0.8112	**-0.4631**	0.7986	0.7072	0.5517	-0.0914	0.3722	0.7531	0.3678	0.7778
9	**0.7643**	0.5024	0.8425	-0.4090	0.7973	0.6709	0.4878	-0.0079	0.4261	0.7582	**0.3944**	**0.8046**

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.4021**	**-0.2551**	0.0458	-0.0636	**0.7112**	0.8106	0.6154	0.0067	0.3181	0.3115	**-0.3102**	**0.7127**
1	-0.3146	-0.1908	-0.0465	-0.1930	0.7076	0.8952	0.6238	0.1160	0.2759	0.2787	-0.2314	0.6179
2	-0.2678	-0.2021	-0.1181	-0.2648	0.6709	0.8833	0.6437	0.1933	0.3018	0.2376	-0.1789	0.5966
3	-0.2146	-0.1464	-0.2136	-0.3763	0.7055	0.8897	0.6531	0.2891	0.4208	0.3606	-0.1614	0.5996
4	-0.1474	-0.1444	-0.2933	-0.4223	0.6928	0.9084	0.7064	0.3750	0.4036	0.4754	-0.1078	0.5473
5	-0.0879	-0.1008	-0.4065	-0.5585	0.6802	**0.9121**	0.7641	0.4839	0.3141	0.5270	-0.0141	0.5746
6	0.0194	-0.0741	-0.5226	-0.6957	0.6102	0.8954	0.7851	0.5595	0.3628	**0.5519**	-0.0154	0.4434
7	0.1207	-0.0557	**-0.5882**	**-0.7296**	0.5808	0.8837	0.8074	0.6074	0.3645	0.5103	-0.1030	0.4892
8	0.1658	-0.0569	-0.5583	-0.6453	0.4981	0.8604	**0.8139**	0.6448	0.4937	0.5189	-0.2014	0.4707
9	0.1484	0.0049	-0.4860	-0.5836	0.4310	0.8284	0.8034	**0.7051**	**0.5446**	0.4835	-0.2906	0.4805

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.5389**	**-0.5059**	-0.4712	**-0.5729**	-0.2736	-0.3213	-0.3549	**-0.5063**	**-0.4496**	**-0.4232**	**-0.3226**	**-0.4227**
1	-0.4248	-0.4171	-0.5657	-0.5121	-0.3874	-0.3213	-0.3634	-0.4273	-0.4277	-0.4260	-0.2921	-0.3581
2	-0.4112	-0.3882	-0.5416	-0.5183	-0.4143	-0.4163	-0.4910	-0.4478	-0.3286	-0.2808	-0.1941	-0.2850
3	-0.4219	-0.4409	-0.5562	-0.4814	**-0.4183**	-0.4207	-0.4655	-0.4206	-0.3354	-0.3470	-0.2390	-0.2425
4	-0.4700	-0.4798	-0.5800	-0.5060	-0.4139	**-0.4395**	**-0.5438**	-0.4850	-0.3592	-0.3246	-0.2479	-0.2949
5	-0.3668	-0.4056	-0.5620	-0.4820	-0.3624	-0.3245	-0.3591	-0.2997	-0.2074	-0.2991	-0.2069	-0.2546
6	-0.2642	-0.2890	-0.4720	-0.3558	-0.1774	-0.1639	-0.3341	-0.2919	-0.1755	-0.2133	-0.1632	-0.2472
7	-0.4817	-0.4796	**-0.6238**	-0.5203	-0.2950	-0.2117	-0.3716	-0.3566	-0.2369	-0.0868	0.1051	-0.0517
8	-0.3455	-0.3986	-0.5959	-0.4425	-0.3227	-0.3113	-0.4317	-0.3918	-0.3862	-0.3414	-0.2561	-0.3185
9	-0.2429	-0.2351	-0.4045	-0.4072	-0.3823	-0.3732	-0.4528	-0.3827	-0.2442	-0.3656	-0.2227	-0.2591

TABLE 9.1.12 Spearman Rank correlation coefficients (r_S) between horse mackerel, *Trachurus trachurus*, annual catch and different environmental variables for the period 1950-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month period.

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.0528	**-0.8919**	**0.4994**	**-0.3444**	**-0.5918**
1	0.0412	-0.8838	0.4700	-0.2804	-0.5104
2	0.1261	-0.8720	0.4882	-0.2061	-0.4680
3	0.2326	-0.8733	0.4522	-0.1417	-0.4291
4	0.3387	-0.8523	0.4531	-0.0466	-0.3757
5	0.4669	-0.8456	0.3798	0.0734	-0.3169
6	0.6031	-0.8238	0.3028	0.1413	-0.2587
7	0.7335	-0.8399	0.4143	0.2621	-0.2167
8	**0.8254**	-0.8276	0.5249	0.3032	-0.1861
9	0.8211	-0.8407	0.5305	0.3724	-0.1789

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.9580	0.3431	**0.6389**	**0.7218**	0.5284
1	0.9605	0.4773	0.5997	0.6751	0.5840
2	0.9401	0.4992	0.5875	0.6565	0.5777
3	0.9489	0.5535	0.5575	0.6086	0.6103
4	0.9652	0.6019	0.5598	0.5799	0.6598
5	**0.9706**	0.6359	0.5202	0.5214	0.6657
6	0.9608	0.7130	0.5017	0.4705	0.7086
7	0.9635	0.7251	0.5187	0.4473	0.7241
8	0.9453	0.7367	0.5627	0.4220	0.7296
9	0.9231	**0.7613**	0.5977	0.4628	**0.7576**

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.8548	-0.0561	0.0474	-0.0440	0.0008
1	0.9011	0.0650	0.1739	-0.1644	**0.0975**
2	0.8790	0.1267	0.2504	-0.2391	0.0732
3	0.9158	0.1691	0.3797	-0.3519	0.0572
4	0.9505	0.2335	0.4820	-0.4223	0.0587
5	**0.9794**	0.2125	0.5944	-0.5589	-0.0093
6	0.9595	0.3286	0.6943	-0.6943	-0.0420
7	0.9655	0.3768	0.6621	**-0.7291**	-0.0813
8	0.9371	0.3711	0.6700	-0.6760	-0.0870
9	0.9225	**0.4451**	**0.7009**	-0.6044	0.0256

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.2378	**-0.4825**	**-0.4522**	-0.5321	**-0.4947**
1	-0.3551	-0.3803	-0.4295	**-0.5530**	-0.3877
2	-0.4460	-0.3528	-0.2969	-0.5379	-0.4319
3	-0.4299	-0.3953	-0.3829	-0.5252	-0.3997
4	**-0.4647**	-0.3975	-0.3569	-0.5566	-0.4092
5	-0.3440	-0.3583	-0.3160	-0.5264	-0.3429
6	-0.2161	-0.1864	-0.2421	-0.4230	-0.1799
7	-0.3020	-0.4483	-0.1629	-0.5907	-0.5257
8	-0.3471	-0.3172	-0.3686	-0.5365	-0.4258
9	-0.4025	-0.1670	-0.2901	-0.4083	-0.3095

TABLE 9.1.13 Spearman Rank correlation coefficients (r_S) for chub mackerel, *Scomber japonicus*, annual catch and different environmental variables for the period 1950-1985 in the Namaqualand area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.0521	0.1609	0.1463	0.0202	0.1968	0.1994	-0.2496	-0.1191	0.5297	0.4564	0.3842	0.2482
1	-0.0927	-0.0202	-0.0477	-0.1411	-0.0330	0.0242	-0.3178	-0.1606	0.4879	0.3193	0.2251	0.0924
2	-0.2482	-0.2027	-0.3182	-0.4289	-0.3112	-0.2379	-0.4043	-0.2533	0.3035	0.0883	0.0040	-0.0630
3	-0.4117	-0.3746	-0.4985	-0.6019	-0.5909	-0.4501	-0.5026	-0.3856	0.0367	-0.1730	-0.1932	-0.2093
4	-0.5550	-0.4938	-0.6221	-0.7023	-0.7383	-0.6400	-0.6019	-0.5191	-0.2449	-0.3728	-0.3460	-0.3490
5	-0.6435	-0.6016	-0.6891	-0.7669	-0.8278	-0.7718	-0.6964	-0.6077	-0.4097	-0.4843	-0.4581	-0.4621
6	-0.7273	-0.6819	-0.7273	-0.8011	-0.8714	-0.8567	-0.7851	-0.6974	-0.5600	-0.5907	-0.5595	-0.5604
7	-0.8020	-0.7103	-0.7700	-0.8389	-0.8911	-0.8882	-0.8360	-0.7507	-0.6576	-0.6813	-0.6483	-0.6429
8	-0.8599	-0.7630	-0.8424	-0.8960	**-0.8949**	**-0.8938**	-0.8593	-0.7909	-0.7455	-0.7685	-0.7329	-0.7214
9	**-0.8968**	**-0.8223**	**-0.8773**	**-0.9035**	-0.8767	-0.8706	**-0.8620**	**-0.8126**	**-0.7778**	**-0.8138**	**-0.7998**	**-0.7961**

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.0777	0.0920	-0.1701	0.3922	0.1415	0.0766	-0.2797	-0.2313	0.0517	0.0587	**0.6320**	-0.3658
1	-0.1470	-0.0645	-0.3270	0.1913	0.1147	0.1213	-0.2430	-0.2412	-0.0473	-0.0473	0.5678	-0.3629
2	-0.2823	-0.2262	-0.3339	0.0055	-0.0652	0.1294	-0.2163	-0.2526	-0.1422	-0.1327	0.4197	-0.3556
3	-0.3985	-0.3724	-0.3669	-0.1162	-0.2460	0.0334	-0.2064	-0.2533	-0.1899	-0.2639	0.2342	-0.3607
4	-0.4784	-0.5169	-0.4256	-0.2137	-0.3281	-0.0040	-0.2313	-0.3050	-0.2031	-0.3251	0.0726	-0.3625
5	-0.5649	-0.5770	-0.4903	-0.3331	-0.4169	-0.0185	-0.2649	-0.4077	-0.2992	-0.4258	-0.0859	-0.4351
6	-0.6178	-0.6196	-0.5382	-0.4229	-0.5195	-0.1034	-0.2765	-0.4661	-0.3909	-0.4768	-0.2320	-0.4768
7	-0.6685	-0.6980	-0.5773	-0.4931	-0.6074	-0.1941	-0.2877	-0.5360	-0.4601	-0.5064	-0.3675	-0.5059
8	-0.7384	-0.7674	-0.6218	-0.5435	-0.6820	**-0.2797**	-0.3317	-0.6092	-0.5495	-0.5517	-0.4756	-0.5402
9	**-0.8144**	**-0.8077**	**-0.6557**	**-0.5812**	**-0.7668**	-0.2723	**-0.4127**	**-0.6563**	**-0.6270**	**-0.5977**	-0.5556	**-0.5897**

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.2610	0.3717	0.0242	**0.6345**	-0.0429	0.0374	**-0.8061**	-0.2918	-0.5059	0.3486	0.8728	0.1939
1	-0.4139	0.1507	-0.2463	0.5092	-0.0799	0.0598	-0.7507	-0.3149	-0.5264	0.1367	0.8827	0.2911
2	-0.5953	-0.0828	-0.4212	0.3438	-0.3163	-0.0726	-0.6147	-0.2874	-0.5099	-0.0466	**0.8988**	0.2419
3	**-0.7229**	-0.3152	-0.6331	0.1782	-0.5330	**-0.1771**	-0.4410	-0.2870	-0.4795	-0.1551	0.8163	0.1661
4	-0.7042	-0.5407	-0.7841	0.0103	-0.6041	-0.1107	-0.3882	-0.3229	-0.4388	-0.2287	0.6426	0.1254
5	-0.6742	-0.6629	**-0.8597**	-0.1673	-0.6222	-0.0528	-0.2371	-0.3661	-0.5137	-0.3081	0.4831	0.0948
6	-0.5826	-0.7357	-0.8590	-0.3539	-0.6498	-0.0376	-0.0287	-0.4425	-0.5671	-0.3482	0.3019	0.1052
7	-0.4468	**-0.7704**	-0.8350	-0.4882	-0.7025	-0.0025	0.1039	-0.5729	**-0.5680**	**-0.3916**	0.0872	0.1670
8	-0.2813	-0.7417	-0.7975	-0.4970	**-0.7438**	-0.0099	0.2677	**-0.6721**	-0.5643	-0.3689	-0.1204	0.2354
9	-0.0934	-0.6593	-0.7521	-0.4890	-0.7705	0.0788	0.4115	-0.6636	-0.5110	-0.2729	-0.2492	**0.3132**

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.0470	-0.1357	-0.0532	-0.1038	**-0.1096**	-0.1282	**-0.4401**	**-0.5426**	**-0.5368**	**-0.3023**	0.1249	0.2890
1	0.1513	-0.1598	-0.0604	-0.0175	-0.0822	-0.1222	-0.3690	-0.4108	-0.3632	-0.0725	0.2392	**0.3996**
2	0.0906	-0.2149	-0.0894	0.0006	-0.0296	-0.0739	-0.3172	-0.3483	-0.3592	-0.1069	0.2614	0.3109
3	-0.0223	-0.3481	-0.1552	0.0587	0.0629	0.0115	-0.2248	-0.2287	-0.2592	-0.0296	**0.3487**	0.4082
4	-0.1172	-0.3857	-0.1722	0.0534	0.0568	**0.2238**	0.0179	-0.0554	-0.1107	-0.0229	0.2534	0.2967
5	-0.3127	-0.4436	-0.1589	0.0516	0.0080	0.1510	0.0511	0.1315	0.1089	0.1184	0.2630	0.1497
6	-0.5721	-0.5407	-0.2863	-0.1248	-0.0146	-0.0329	-0.1359	-0.0397	0.0515	0.0388	0.0385	-0.1911
7	**-0.6985**	**-0.6199**	**-0.3308**	**-0.2432**	-0.0500	-0.1106	-0.3155	-0.2568	-0.1355	-0.0818	-0.0759	-0.3978
8	-0.6053	-0.5659	-0.2507	-0.1446	-0.0854	-0.1160	-0.3339	-0.2651	-0.1061	-0.067	-0.0901	-0.4400
9	-0.4235	-0.4175	-0.2864	-0.1756	-0.1378	-0.1007	-0.1950	-0.0544	0.1911	0.1342	-0.0474	-0.2489

TABLE 9.1.14 Spearman Rank correlation coefficients (r_S) between chub mackerel, *Scomber japonicus*, annual catch and different environmental variables for the period 1954-1985 in the Namaqualand area. Highlighted are the highest correlation coefficients for each month period.

POOLED MONTHS

SEA SURFACE TEMPERATURE

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.1224	0.0620	0.3754	0.0561	0.1008
1	-0.1144	-0.1195	0.2687	-0.0898	-0.0506
2	-0.2500	-0.3068	0.1050	-0.3024	-0.2478
3	-0.5348	-0.4802	-0.1734	-0.5477	-0.4391
4	-0.6635	-0.6052	-0.3735	-0.6730	-0.6030
5	-0.7710	-0.6685	-0.4879	-0.7254	-0.6601
6	-0.8452	-0.7299	-0.5938	-0.7588	-0.7175
7	-0.8793	-0.7961	-0.6901	-0.8039	-0.7926
8	**-0.8916**	**-0.8730**	**-0.7838**	**-0.8697**	**0.8588**

NORTH-SOUTH WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.0433	-0.1228	0.1015	0.0418	0.0418
1	0.0315	-0.2793	0.0711	-0.1569	0.1155
2	-0.0070	-0.3743	-0.0352	-0.2390	0.2449
3	-0.1466	-0.4413	-0.1463	-0.2991	0.3270
4	-0.2683	-0.5466	-0.2280	-0.3460	0.4128
5	-0.3431	-0.5895	-0.3544	-0.4222	0.4802
6	-0.4434	-0.6298	-0.4194	-0.4763	0.5195
7	-0.5857	-0.6823	-0.4650	-0.5118	0.5631
8	-0.7302	-0.7362	-0.5326	-0.5583	0.6234
9	**-0.7912**	**-0.7808**	**-0.6032**	**-0.5946**	**0.6618**

WEST-EAST WIND COMPONENT

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.3941	0.1360	0.2973	0.5150	0.5018
1	-0.4084	-0.0268	0.2801	0.3523	0.2848
2	-0.6492	-0.2199	0.2592	0.1668	0.0370
3	**-0.7251**	-0.3820	0.1690	-0.0055	0.2126
4	-0.6862	-0.5150	0.0444	-0.3065	0.4388
5	-0.6044	**-0.6052**	-0.1637	-0.4899	0.6125
6	-0.5128	-0.5907	-0.3887	-0.5951	0.7646
7	-0.4847	-0.5281	-0.5995	-0.6300	**0.8350**
8	-0.4877	-0.4149	-0.7739	**-0.6349**	0.7942
9	-0.4707	-0.2643	**-0.8425**	-0.6142	0.7118

SEA LEVEL

LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.4069**	0.1885	0.2188	0.1419	0.2637
1	0.3824	0.1436	0.2389	0.0539	0.2826
2	0.3522	0.1799	**0.3243**	-0.0110	0.3628
3	0.3521	-0.0421	0.3242	-0.0354	0.1613
4	0.0610	-0.1220	0.1468	-0.0413	0.1038
5	-0.2586	-0.1328	-0.1830	-0.2351	0.2486
6	-0.0111	0.0070	-0.1931	-0.0457	0.0493
7	-0.0423	-0.4292	-0.0842	**-0.5488**	0.4220
8	-0.0184	**-0.5532**	-0.3105	-0.2927	**0.5461**
9	-0.0429	0.1506	0.0305	0.2092	0.1695

TABLE 9.1.15 Spearman Rank correlation coefficients (r_s) between chub mackerel, *Scomber japonicus*, annual catch and different environmental variables for the period 1950-1985 in the south western Cape area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.7335**	**-0.7412**	**-0.6408**	**-0.7474**	**-0.8519**	-0.7885	**-0.8116**	**-0.7027**	**-0.5535**	**-0.3140**	**-0.5417**	**-0.5484**
1	-0.7034	-0.6895	-0.5587	-0.6859	-0.8365	**-0.8024**	-0.7698	-0.5869	-0.3820	-0.2876	-0.5193	-0.4923
2	-0.6895	-0.6492	-0.5209	-0.6004	-0.7896	-0.7779	-0.6873	-0.4461	-0.1913	-0.2315	-0.4425	-0.4578
3	-0.6598	-0.6070	-0.4509	-0.4952	-0.7076	-0.7471	-0.5825	-0.2936	-0.0894	-0.2031	-0.3618	-0.4406
4	-0.5784	-0.4644	-0.3123	-0.3248	-0.5927	-0.7071	-0.4718	-0.1804	-0.0103	-0.1928	-0.3056	-0.4087
5	-0.4617	-0.2536	-0.1044	-0.1254	-0.4347	-0.6484	-0.3484	-0.0423	0.1169	-0.1087	-0.2087	-0.3444
6	-0.3789	-0.0932	0.0594	0.0478	-0.2650	-0.5333	-0.1835	0.1048	0.2467	0.0180	-0.0732	-0.2481
7	-0.3113	0.0039	0.1478	0.1768	-0.0788	-0.3670	0.0187	0.2453	0.3670	0.1522	0.0236	-0.2005
8	-0.1554	0.1346	0.2693	0.2967	0.0712	-0.2184	0.1697	0.3733	0.4691	0.2594	0.0903	-0.1527
9	0.0549	0.2845	0.3852	0.3962	0.2957	-0.0647	0.3114	0.5092	0.5702	0.3321	0.1825	-0.0263

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.2379	-0.3189	-0.2361	0.4318	0.2823	-0.2416	0.6756	0.2621	-0.0836	-0.1294	-0.3823	**0.4927**
1	-0.2555	-0.3295	-0.3721	0.2328	0.0433	-0.3614	0.7559	0.0744	-0.1169	-0.2067	-0.3640	0.3515
2	-0.2687	-0.3691	-0.3490	0.1089	-0.2056	-0.3644	0.7793	-0.1452	-0.1767	-0.2504	-0.3603	0.2225
3	-0.3196	-0.4289	-0.3394	0.0026	-0.4505	**-0.4109**	0.7878	-0.3614	-0.3127	-0.3559	-0.3757	0.0894
4	-0.3706	-0.5777	-0.3702	-0.1433	-0.4604	-0.3028	**0.7925**	-0.5077	-0.3757	-0.5403	-0.4483	-0.0246
5	-0.4371	-0.6766	-0.4121	-0.2714	-0.5065	-0.1919	0.7355	-0.6165	-0.4972	-0.6468	-0.5065	-0.1798
6	-0.4692	-0.7161	-0.4452	-0.3962	-0.6414	-0.0914	0.6939	-0.6819	-0.6245	-0.6743	-0.5399	-0.3264
7	-0.5064	-0.8128	-0.5005	-0.4644	-0.7261	0.0044	0.6611	-0.7330	-0.7034	-0.7291	-0.5892	-0.3532
8	-0.5545	-0.8823	-0.5616	-0.5227	-0.7455	0.0717	0.5473	-0.7953	-0.7581	**-0.7482**	**-0.6316**	-0.3755
9	**-0.6081**	**-0.9066**	**-0.5928**	**-0.5665**	**-0.7509**	0.0726	0.3791	**-0.8352**	**-0.8083**	-0.7253	-0.6288	-0.4322

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	0.2863	-0.4186	**-0.8185**	0.8320	-0.0751	0.6371	-0.0876	0.0374	-0.7317	-0.7643	0.2511	0.2870
1	0.2452	-0.4032	-0.8178	**0.8371**	-0.0803	**0.8306**	0.0891	-0.1998	**-0.7617**	**- 0.8090**	0.3402	0.3471
2	0.2683	-0.4252	-0.7918	0.8210	-0.2020	0.8222	0.1180	-0.4384	-0.6811	-0.7742	0.4377	0.3853
3	0.2918	-0.4402	-0.7031	0.7636	-0.2991	0.7801	0.1419	-0.6415	-0.5568	-0.7504	**0.4663**	0.4315
4	0.2507	-0.4820	-0.6529	0.6412	-0.3281	0.7148	0.2771	-0.7214	-0.3710	-0.6961	0.2460	-0.5315
5	0.3294	**-0.5222**	-0.5262	0.4974	-0.3431	0.6024	0.4573	-0.7984	-0.3484	-0.5851	0.1786	0.6109
6	0.4483	-0.4897	-0.3210	0.3280	-0.4465	0.4776	0.5684	**-0.8380**	-0.3077	-0.4638	0.1141	0.6258
7	0.5158	-0.4281	-0.1468	0.2495	-0.5729	0.3502	0.6089	-0.8281	-0.2660	-0.3256	-0.0458	0.6256
8	0.5550	-0.3158	-0.0279	0.1525	**-0.6141**	0.1374	**0.6502**	-0.7800	-0.2447	-0.1773	-0.2310	**0.7148**
9	**0.5690**	-0.1648	0.1038	-0.0534	-1.3432	-0.0495	0.6447	-0.6935	-0.2088	-0.0543	-0.3523	0.7143

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.0198	0.0758	0.0626	0.1784	**0.3128**	0.3549	**0.4341**	0.0933	0.0116	0.2888	0.2266	**0.3265**
1	-0.0204	0.0518	-0.0399	0.1067	0.2790	**0.3997**	0.4078	0.0879	0.0012	0.2468	**0.3751**	0.2843
2	0.0249	0.1107	-0.2027	0.0890	0.2667	0.3707	0.4250	0.2738	0.1671	0.3007	0.3317	0.2015
3	-0.0430	0.0655	-0.2561	0.0556	0.2198	0.3125	0.4006	0.2441	0.0818	**0.3290**	0.3134	0.1759
4	-0.1243	-0.1513	-0.1956	-0.0459	0.0355	-0.0252	0.1034	0.0310	0.0745	0.2509	0.2077	-0.0089
5	-0.1587	-0.2858	-0.3375	-0.2719	-0.3042	-0.3986	-0.2215	-0.2400	-0.1449	-0.0878	-0.0919	0.1112
6	-0.0893	-0.0677	-0.1253	0.0370	-0.0183	-0.0508	-0.0420	-0.2514	-0.2089	-0.0972	0.0319	0.2222
7	**-0.5376**	-0.3404	**-0.7480**	**-0.4018**	-0.2363	0.0247	-0.0319	-0.1457	-0.1528	0.1501	0.1677	0.1631
8	-0.4893	**-0.4140**	-0.6233	-0.0684	0.1941	0.0513	-0.0785	**-0.3481**	**-0.4316**	-0.0435	-0.1533	-0.3465
9	0.1362	-0.0426	0.0684	0.2332	0.1928	-0.1596	-0.0859	0.0873	0.0864	0.0846	-0.2790	-0.4075

TABLE 9.1.16 Spearman Rank correlation coefficients (r_s) between chub mackerel, *Scomber japonicus*, annual catch and environmental variables for the period 1954-1985 in the south western Cape area. Highlighted are the highest correlation coefficients for each month period.

		POOLED MONTHS			
SEA SURFACE TEMPERATURE					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**-0.8471**	**-0.7075**	**-0.6257**	**-0.7038**	**-0.7067**
1	-0.8431	-0.6657	-0.5227	-0.6364	-0.6562
2	-0.8024	-0.6400	-0.3937	-0.5693	-0.6096
3	-0.7254	-0.6023	-0.2958	-0.4776	-0.5440
4	-0.6210	-0.5224	-0.2137	-0.3259	-0.4234
5	-0.4923	-0.3774	-0.0944	-0.1266	-0.2427
6	-0.3259	-0.2516	0.0420	0.0452	-0.1043
7	-0.1291	-0.1842	0.1828	0.1709	-0.0143
8	0.0186	-0.0389	0.3186	0.2923	0.1237
9	0.1593	0.1429	0.4096	0.3950	0.2827
NORTH-SOUTH WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.5744**	-0.2969	0.2716	-0.1591	-0.3629
1	0.5268	-0.2969	0.0711	-0.3281	-0.3570
2	0.4410	-0.3134	-0.1081	-0.3218	-0.3534
3	0.2988	-0.3603	-0.2614	-0.3211	-0.3607
4	0.2768	-0.4765	-0.3897	-0.3325	-0.3930
5	0.2488	-0.5456	-0.5000	-0.3980	-0.4476
6	0.1840	-0.5568	-0.5782	-0.4505	-0.4741
7	0.0828	-0.6167	-0.6502	-0.5020	-0.5153
8	-0.0717	**-0.6760**	-0.7110	-0.5441	-0.5698
9	-0.2222	-0.7210	**-0.7393**	**-0.5708**	**-0.6087**
WEST-EAST WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.4384	0.1206	0.3493	**-0.5630**	-0.2830
1	**0.5480**	0.0059	0.0858	-0.5055	**-0.3985**
2	0.4487	-0.0110	-0.1364	-0.3413	-0.3109
3	0.3356	0.0103	-0.2804	-0.2317	-0.1840
4	0.3354	0.0132	-0.4578	-0.1639	-0.0942
5	0.3060	0.0270	-0.6077	-0.0690	-0.0625
6	0.1884	0.0785	-0.7295	0.0496	0.0340
7	0.0241	0.2069	**-0.7517**	0.1576	0.1882
8	-0.1242	0.2819	-0.7400	0.2211	0.2414
9	-0.2894	**0.3810**	-0.6899	0.1844	0.3083
SEA LEVEL					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**0.4069**	0.1885	0.2188	0.1419	0.2637
1	0.3824	0.1436	0.2389	0.0539	0.2826
2	0.3522	0.1799	**0.3243**	-0.0110	0.3628
3	0.3521	-0.0421	0.3242	-0.0354	0.1613
4	0.0610	-0.1220	0.1468	-0.0413	0.1038
5	-0.2586	-0.1328	-0.1830	-0.2351	0.2486
6	-0.0111	0.0070	-0.1931	-0.0457	0.0493
7	-0.0423	-0.4292	-0.0842	**-0.5488**	0.4220
8	-0.0184	**-0.5532**	-0.3105	-0.2927	**0.5461**
9	-0.0429	0.1506	0.0305	0.2092	0.1695

TABLE 9.1.17 Spearman Rank correlation coefficients (r_S) between chub mackerel , *Scomber japonicus* , annual catch and different environmental variables for the period 1950-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month.

SEA SURFACE TEMPERATURE.

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	-0.2669	-0.3072	-0.5466	-0.8394	-0.8654	**-0.9040**	**-0.8299**	**-0.7716**	**-0.8051**	**-0.7851**	**-0.5257**	**-0.4509**
1	-0.2254	-0.2900	-0.5213	**-0.8724**	**-0.9009**	-0.8985	-0.7203	-0.6298	-0.6667	-0.7504	-0.4593	-0.3695
2	-0.1998	-0.2830	**-0.5579**	-0.8387	-0.8874	-0.8380	-0.5726	-0.4475	-0.4920	-0.7079	-0.3878	-0.2658
3	-0.2031	-0.2892	-0.5462	-0.7357	-0.8041	-0.7416	-0.3974	-0.2375	-0.2663	-0.5714	-0.3109	-0.1778
4	-0.1855	-0.2331	-0.4457	-0.5678	-0.6705	-0.6206	-0.1895	-0.0711	-0.1026	-0.4619	-0.2628	-0.1012
5	-0.1843	-0.2161	-0.3024	-0.3724	-0.5085	-0.4629	0.0294	0.1734	0.1190	-0.3164	-0.2137	-0.0694
6	-0.2018	-0.2405	-0.2335	-0.2240	-0.3573	-0.2712	0.2605	0.4056	0.3564	-0.1566	-0.1666	-0.0474
7	-0.2438	-0.2798	-0.1931	-0.0872	-0.2141	-0.0670	0.4690	0.5640	0.5626	0.0236	-0.1355	-0.0330
8	-0.3498	-0.3479	-0.1834	0.0345	-0.0616	0.1483	0.6497	0.7143	0.7168	0.2132	-0.1111	-0.0432
9	**-0.4219**	**-0.4640**	-0.1764	0.1267	0.0525	0.2625	0.7729	0.7242	0.7222	0.3566	-0.1001	-0.1111

NORTH-SOUTH WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.6994**	-0.3152	**0.3211**	**0.5077**	**0.4227**	0.3633	-0.0084	0.2199	0.2581	0.0257	**-0.7746**	**-0.6499**
1	-0.6540	-0.2724	0.2405	0.4216	0.3996	0.3468	0.0011	0.0070	0.0715	-0.0693	-0.7705	-0.5913
2	-0.6294	-0.4498	0.1664	0.2841	0.3182	0.3383	0.2445	-0.2328	-0.0693	-0.1206	-0.7298	-0.5018
3	-0.5587	-0.4875	0.1221	0.2885	0.2738	0.3552	0.4468	-0.3805	-0.1749	-0.0949	-0.5968	-0.3981
4	-0.4604	**-0.5176**	0.0887	0.1782	0.2636	0.4549	0.5341	-0.5070	-0.2427	-0.1342	-0.6144	-0.2793
5	-0.3444	-0.4609	0.1298	-0.0440	0.2923	0.4754	0.6250	-0.6327	-0.4117	-0.1149	-0.5355	-0.1347
6	-0.1711	-0.4011	0.1564	-0.3095	0.3232	0.4901	0.7201	**-0.7762**	**-0.5186**	-0.0394	-0.3660	-0.0323
7	-0.0365	-0.3670	0.1660	-0.4463	0.3365	0.5374	0.7640	-0.7202	-0.4709	0.0276	-0.2419	0.0665
8	0.0963	-0.3202	0.2211	-0.5233	0.3530	0.5577	0.7975	-0.6431	-0.3695	0.1325	-0.1024	0.1812
9	0.2479	-0.2076	0.3291	-0.4695	0.3718	**0.5702**	**0.8162**	-0.4451	-0.2485	**0.2680**	0.0781	0.2686

WEST-EAST WIND COMPONENT

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.7449**	-0.1924	0.5092	**0.4351**	0.5872	0.1569	-0.4864	**-0.9179**	-0.2698	-0.0407	0.0462	0.1488
1	-0.7130	-0.3032	0.3383	0.2346	0.5993	0.2874	-0.4670	-0.9113	**-0.4359**	-0.0894	0.2438	0.0949
2	-0.6298	-0.4501	0.1290	0.0880	0.5825	0.2896	-0.3772	-0.8449	-0.3471	-0.1195	0.4223	0.0821
3	-0.5249	-0.5528	-0.0572	-0.0110	0.6184	0.2727	-0.2826	-0.7273	-0.1738	0.0319	0.5044	0.1448
4	-0.4523	-0.6642	-0.3061	-0.1008	0.6107	0.3130	-0.1532	-0.5909	-0.0806	0.2203	0.4318	0.2687
5	-0.3194	-0.7419	-0.5129	-0.2315	**0.6310**	0.3472	0.0206	-0.4254	-0.1685	0.3980	**0.5141**	0.3052
6	-0.0456	-0.7615	-0.6908	-0.4051	0.6196	0.3611	0.1840	-0.2632	-0.1924	**0.4603**	0.4861	0.3228
7	0.1744	**-0.7823**	-0.8049	-0.4113	0.5650	0.3892	0.3167	-0.1369	-0.1877	0.4015	0.3310	0.4015
8	0.3361	-0.7575	**-0.8440**	-0.3388	0.4669	0.4127	0.4767	0.0077	-0.1341	0.3240	0.1823	0.5107
9	0.4499	-0.7216	-0.7711	-0.3016	0.3004	**0.4280**	**0.6337**	0.1905	-0.0452	0.2369	0.0745	**0.5537**

SEA LEVEL

LAG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
0	**-0.4117**	**-0.3185**	-0.0686	-0.3189	-0.1039	-0.1829	-0.1667	**-0.4188**	**-0.3941**	**-0.3245**	**-0.2267**	**-0.2245**
1	-0.3162	-0.2839	-0.3069	**-0.3835**	**-0.3311**	-0.2701	-0.2235	-0.3808	-0.3492	-0.2801	-0.1099	-0.1361
2	-0.2193	-0.1990	-0.2644	-0.3430	-0.2880	**-0.3282**	**-0.3168**	-0.3777	-0.2283	-0.1613	-0.0238	-0.0801
3	-0.1796	-0.2126	-0.2949	-0.2965	-0.2096	-0.2393	-0.2512	-0.3171	-0.1475	-0.0648	0.1342	0.0915
4	-0.1746	-0.2330	-0.2996	-0.2460	-0.1556	-0.1772	-0.1961	-0.2282	-0.1046	-0.0654	0.1277	0.1158
5	-0.0825	-0.1390	-0.2325	-0.1371	-0.0126	-0.0279	-0.0856	-0.0413	0.1105	0.0102	0.1406	0.1247
6	-0.1218	-0.1529	-0.2270	-0.1151	0.0598	0.0754	-0.0566	0.0363	0.1993	0.1002	0.1908	0.1607
7	-0.3071	-0.3189	-0.4101	-0.2703	-0.0394	-0.0105	-0.2013	-0.1301	0.0257	0.1464	0.2346	0.1300
8	-0.3061	-0.3539	**-0.4803**	-0.3082	-0.1724	-0.1378	-0.2315	-0.2308	-0.1954	-0.1857	-0.0404	-0.1011
9	-0.2081	-0.2907	-0.4630	-0.3323	-0.2876	-0.2479	-0.2933	-0.2608	-0.2442	-0.3217	-0.1571	-0.1713

TABLE 9.1.18 Spearman Rank correlation coefficients (r_s) between chub mackerel, *Scomber japonicus*, annual catch and different environmental variables for the period 1954-1985 in the Agulhas Bank area. Highlighted are the highest correlation coefficients for each month period.

			POOLED MONTHS		
SEA SURFACE TEMPERATURE					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	**-0.9095**	**-0.3226**	0.0532	-0.7251	**-0.4545**
1	-0.8889	-0.2544	0.0180	-0.7694	-0.4047
2	-0.8094	-0.2199	0.0070	**-0.7749**	-0.4498
3	-0.6829	-0.2133	0.0927	-0.7097	-0.4732
4	-0.5213	-0.1837	0.1415	-0.5740	-0.4175
5	-0.3375	-0.1762	0.2077	-0.3996	-0.3327
6	-0.1533	-0.1911	0.2263	-0.2788	-0.2925
7	0.0626	-0.2212	0.4305	-0.1882	-0.2670
8	0.2852	-0.3038	0.6398	-0.1177	-0.2786
9	0.3877	-0.3097	**0.7692**	-0.0678	-0.3077
NORTH-SOUTH WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.3416	**-0.6935**	0.1246	**0.4051**	**-0.4054**
1	0.3281	-0.6375	-0.0488	0.3182	-0.3955
2	0.3120	-0.5993	-0.2049	0.2181	-0.4186
3	0.3215	-0.5275	-0.3054	0.2108	-0.3765
4	0.3530	-0.4384	-0.3959	0.1389	-0.2951
5	0.4214	-0.3165	-0.4552	0.0524	-0.2165
6	0.4674	-0.1546	**-0.4821**	0.0327	-0.0874
7	0.4956	-0.0335	-0.3695	-0.0956	0.0084
8	0.5375	0.0744	-0.2299	-0.1171	0.1095
9	**0.5836**	0.2143	-0.0525	-0.0379	0.2369
WEST-EAST WIND COMPONENT					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	0.0253	-0.6254	**-0.6268**	0.4487	0.0048
1	0.1199	-0.6862	-0.5495	0.2434	-0.0627
2	0.1452	-0.7295	-0.4175	0.0733	-0.2082
3	0.1954	**-0.7588**	-0.2438	-0.0891	-0.3383
4	0.2980	-0.7416	-0.0814	-0.2489	-0.4982
5	0.3867	-0.7298	0.0855	-0.4347	-0.5919
6	0.4492	-0.5742	0.1822	-0.6294	-0.5978
7	0.4990	-0.4212	0.1379	**-0.6916**	**-0.6547**
8	0.5430	-0.3010	0.1357	-0.6864	-0.6196
9	**0.5818**	-0.1294	0.1984	-0.6349	-0.4915
SEA LEVEL					
LAG	MAY-JULY	DECEMBER FEBRUARY	AUGUST NOVEMBER	MARCH APRIL	OCTOBER APRIL
0	-0.0627	**-0.3149**	**-0.3723**	-0.1810	-0.2199
1	-0.2680	-0.2406	-0.3131	-0.3386	-0.1867
2	**-0.3074**	-0.1239	-0.2083	-0.2921	-0.0893
3	-0.2267	-0.0936	-0.1306	-0.2851	-0.0770
4	-0.1663	-0.0872	-0.1171	-0.2644	-0.0396
5	-0.0334	-0.0078	0.0079	-0.1730	0.0688
6	0.0338	-0.0491	0.0830	-0.1730	0.0713
7	-0.0761	-0.2581	0.0752	-0.3551	-0.2472
8	-0.1649	-0.2775	-0.1979	**-0.4080**	**-0.3271**
9	-0.2715	-0.1494	-0.2460	-0.4074	-0.2549

APPENDIX 9.2

MULTIPLE REGRESSION ANALYSES RESULTS

TABLE 9.2.1 Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus monthly sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the Namaqualand area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P< 0.05) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
JANUARY	0	0.7230	0.6437	11.9806	**-0.6078**	0.6558	0.4626	-0.0521	0.0008
	1	0.8219	0.7671	16.5421	**-0.9061**	0.1623	**0.7832**	0.0003	0.0001
	2	0.7299	0.6398	2.5277	0.1255	-0.4288	**1.0655**	0.0026	0.0021
	3	0.7887	0.7119	-4.4095	0.6442	**-0.7992**	0.7175	0.0659	0.0010
	4	0.3775	0.1285	1.7063	0.1154	-0.2912	0.6369	0.0060	0.2700
	5	0.3433	0.0515	-6.8764	0.6354	-0.3734	-0.3866	-0.0570	0.3835
FEBRUARY	0	0.7398	0.6820	5.1513	-0.1157	-0.3061	0.4591	**-0.0822**	0.0000
	1	0.7892	0.7396	-0.5247	0.3034	**-0.4943**	0.3155	**-0.0656**	0.0000
	2	0.8178	0.7723	-17.9700	**1.4738**	**-0.9018**	-0.0623	**-0.0627**	0.0000
	3	0.8502	0.8103	-8.4116	**0.8843**	**-0.8501**	0.4030	**0.0603**	0.0000
	4	0.7329	0.6566	11.2091	-0.4468	-0.3571	**1.2717**	-0.0298	0.0006
	5	0.4622	0.2967	17.1979	-0.8935	-0.0826	**1.1519**	-0.0097	0.0711
MARCH	0	0.7442	0.6903	10.3529	**-0.4584**	**-0.2381**	**0.8093**	**-0.0786**	0.0000
	1	0.7611	0.7080	8.9176	-0.3515	**-0.3021**	**0.8838**	**-0.0602**	0.0000
	2	0.6687	0.5907	-2.2824	0.4060	**-0.4781**	0.3394	-0.0074	0.0006
	3	0.6105	0.5131	0.9513	0.2063	**-0.5129**	0.7851	0.0549	0.0031
	4	0.5902	0.4809	11.8220	-0.5320	**-0.3685**	**1.5653**	0.0182	0.0067
	5	0.6144	0.5043	13.0992	-0.6201	**-0.3582**	**1.7495**	0.0048	0.0067
APRIL	0	0.7686	0.7199	8.2244	-0.0335	**-0.0286**	**0.4319**	-0.0536	0.0000
	1	0.6332	0.5516	4.8514	-0.0913	-0.4183	**0.4418**	-0.0316	0.0008
	2	0.5941	0.4987	0.5824	0.2319	**-0.6652**	**0.7493**	0.0186	0.0028
	3	0.5999	0.4999	-1.9010	0.4172	**-0.8112**	**1.0357**	0.0349	0.0038
	4	0.8900	0.2261	7.6920	-0.3439	-0.1492	0.4744	-0.0286	0.0973
	5	0.3000	0.0999	6.5364	-0.2668	-0.1593	0.3765	-0.0047	0.2554
MAY	0	0.4517	0.3363	-0.2966	0.1766	-0.2559	-0.0541	-0.0556	0.0175
	1	0.4622	0.3427	-13.9796	**1.1167**	**-0.6919**	-0.0524	-0.0129	0.0190
	2	0.3906	0.2472	-9.2731	0.7680	-0.3604	-0.3896	-0.0155	0.0640
	3	0.6461	0.5576	-15.2179	**1.1645**	**-0.4610**	**-0.5436**	-0.0085	0.0010
	4	0.5811	0.4694	-11.2357	0.8844	-0.3194	-0.0501	-0.0396	0.0075
	5	0.4690	0.3172	-8.8592	0.7213	-0.2438	-0.4733	-0.0101	0.0510
	6	0.6504	0.5428	0.0026	0.1042	0.1002	**-0.6187**	-0.0063	0.0056
	7	0.5586	0.4228	6.1293	-0.3270	0.3196	**-0.5364**	**-0.0512**	0.2280
JUNE	0	0.4589	0.3236	10.7179	**-0.5754**	**-0.4442**	0.7139	-0.0562	0.0343
	1	0.4328	0.2815	12.0754	**-0.6426**	-0.5699	**1.6728**	-0.0183	0.0604
	2	0.3667	0.1857	9.4624	-0.4674	-0.3611	**1.5233**	-0.0199	0.1457
	3	0.4312	0.2562	12.0735	**-0.6446**	-0.4145	1.6776	-0.0208	0.0972
	4	0.4533	0.2711	10.1408	-0.5325	-0.2413	1.0787	-0.0404	0.0993
	5	0.1974	0.0000	7.1670	-0.3499	-0.1757	0.2849	-0.0216	0.6222
	6	0.6224	0.4851	10.4704	**-0.5636**	0.2246	0.3507	-0.0026	0.0209
	7	0.5177	0.3424	4.9760	-0.2238	**0.5522**	-0.6152	-0.0438	0.0697
	8	0.3628	0.1079	8.5423	-0.4422	0.3146	0.3882	0.0084	0.2956
	9	0.4763	0.2435	11.6608	**-0.6453**	0.4089	0.4779	0.0411	0.1711

Table 9.2.1. (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JULY	0	0.6423	0.5581	19.8743	**-1.2406**	0.1171	0.1260	-0.0194	0.0010
	1	0.6590	0.5737	16.1332	**-0.9591**	-0.1487	0.1543	-0.0338	0.0011
	2	0.6376	0.5410	13.9695	**-0.8031**	-0.2270	-0.1106	-0.0031	0.0029
	3	0.5908	0.4739	15.6874	**-0.9236**	-0.2792	-0.0582	-0.0019	0.0099
	4	0.5894	0.4631	11.9516	-0.6897	-0.0961	-0.0475	-0.0654	0.0148
	5	0.3934	0.1912	6.4734	-0.3084	-0.1327	-0.1821	-0.0619	0.1674
AUGUST	0	0.7194	0.6534	-14.8267	1.2906	**-0.6480**	**0.5405**	0.0011	0.0001
	1	0.7021	0.6277	4.4595	-0.0837	**-0.4708**	**0.5341**	-0.0431	0.0004
	2	0.7436	0.6753	-26.0721	2.0654	**-0.6278**	0.3635	-0.0109	0.0002
	3	0.6318	0.5266	-7.8335	0.7450	-0.4227	0.0245	-0.0084	0.0050
	4	0.5828	0.4544	-12.8581	1.0944	-0.4427	0.1355	-0.0343	0.0163
	5	0.5801	0.4401	-39.6470	2.9725	**-0.5340**	0.0067	-0.0435	0.0246
SEPTEMBER	0	0.6023	0.5186	1.7889	0.0743	**-0.3225**	**-0.2747**	-0.0277	0.0011
	1	0.7618	0.7089	11.8781	-0.6708	-0.1516	**-0.5431**	**-0.0728**	0.0000
	2	0.6722	0.5951	3.8787	-0.0779	**-0.3163**	-0.3539	-0.0379	0.0005
	3	0.6210	0.5263	-3.5671	0.4917	**-0.4985**	0.0964	-0.0232	0.0025
	4	0.6867	0.6031	-11.4440	**1.0596**	**-0.6045**	0.2916	-0.0275	0.0010
	5	0.5672	0.4435	-7.9098	0.7927	**-0.4848**	0.3633	-0.0423	0.0141
OCTOBER	0	0.6625	0.5914	12.0469	-0.5882	-0.2098	**0.6119**	-0.0060	0.0002
	1	0.7832	0.7350	17.0091	**-0.9438**	-0.1085	**0.8559**	-0.0350	0.0000
	2	0.7392	0.6778	18.6537	**-1.0555**	-0.0830	**1.1023**	0.0266	0.0001
	3	0.6443	0.5554	18.7094	**-1.0755**	-0.0259	**1.2576**	0.0257	0.0016
	4	0.4487	0.3016	10.0311	-0.4683	-0.1640	1.0155	0.0256	0.0502
	5	0.3228	0.1293	1.4622	0.1042	-0.2573	0.0596	-0.0267	0.2129
NOVEMBER	0	0.4283	0.3013	24.1106	**-1.6833**	**0.7632**	-0.4984	-0.0455	0.0317
	1	0.4361	0.3107	20.1812	**-1.3720**	0.5903	-0.2956	**-0.0761**	0.0284
	2	0.4131	0.2750	13.6695	-0.7993	0.1471	0.1653	-0.0217	0.0486
	3	0.4740	0.3425	-2.8976	0.5713	-0.7382	0.8299	-0.0050	0.0281
	4	0.4442	0.2960	-8.5207	1.0071	**-0.9665**	**0.8992**	0.0354	0.0529
	5	0.3899	0.2156	-1.0650	0.3662	-0.5035	0.5830	-0.0044	0.1173
DECEMBER	0	0.7933	0.7297	7.6612	-0.2726	**-0.2308**	-0.1111	-0.0007	0.0002
	1	0.7266	0.6425	5.8464	-0.1603	-0.2063	0.2312	-0.0563	0.0012
	2	0.7450	0.6665	4.4907	-0.0511	**-0.2992**	0.1082	-0.0351	0.0008
	3	0.6045	0.4726	3.6841	-0.0166	-0.2365	0.3823	-0.0316	0.0177
	4	0.7174	0.6146	7.1501	-0.3068	0.1113	**1.8593**	0.0243	0.0047
	5	0.6729	0.5421	4.3087	-0.1115	0.0183	**1.6253**	-0.0266	0.0163

TABLE 9.2.2 Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combination of months in the Namaqualand area. Adj R^2 is adjusted for degrees of freedom regression coefficient. Highlighted are the significant environmental contributions (P< 0.05) to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
MAY-JULY	0	0.6165	0.5398	9.9854	**-0.5167**	**-0.3201**	-0.1009	-0.0543	0.0005
	1	0.6047	0.5214	-3.5403	0.4455	**-1.2085**	-0.0597	-0.0027	0.0010
	2	0.4012	0.2681	1.6935	0.0550	-0.6627	-0.2704	-0.0101	0.0456
	3	0.5223	0.4099	-2.9366	0.3744	**-0.8633**	-0.4018	0.0031	0.0102
	4	0.5827	0.4783	-4.4235	0.4547	-0.6728	-0.5587	-0.0502	0.0052
	5	0.5910	0.4819	-11.2555	**0.9249**	**-0.9439**	**-0.7485**	-0.0172	0.0067
DECEMBER-FEBRUARY	0	0.7569	0.7030	11.5475	-0.5717	0.0185	0.7600	**-0.1101**	0.0000
	1	0.7740	0.7208	3.8359	-0.0018	-0.3188	0.4957	-0.0522	0.0000
	2	0.7863	0.7329	-10.9358	**1.0229**	**-0.7661**	-0.1183	-0.0450	0.0000
	3	0.7797	0.7210	0.8778	0.2411	**-0.5119**	0.8123	**0.0709**	0.0001
	4	0.7333	0.6571	12.8530	-0.6342	-0.0129	**1.5574**	-0.0234	0.0006
	5	0.5614	0.4265	19.2544	-1.1280	0.3100	**1.4585**	-0.0277	0.0219
MARCH-APRIL	0	0.7874	0.7426	9.6301	**-0.4301**	**-0.2048**	**0.4840**	**-0.0670**	0.0000
	1	0.7156	0.6524	-0.4967	0.2844	**-0.4827**	0.1914	-0.0433	0.0001
	2	0.7024	0.6324	-5.6984	0.6712	**-0.7176**	0.3340	0.0159	0.0002
	3	0.6940	0.6175	-8.1084	**0.8614**	**-0.8954**	**0.7724**	0.0563	0.0005
	4	0.4809	0.3424	7.4207	-0.2760	-0.3334	**1.0628**	-0.0039	0.0337
	5	0.4509	0.2940	9.7902	-0.4431	-0.2830	1.2607	0.0026	0.0625
AUGUST-NOVEMBER	0	0.6363	0.5597	-8.0525	0.8402	**-0.6473**	-0.0882	-0.0306	0.0005
	1	0.7214	0.6595	-11.5942	**1.0845**	**-0.6954**	-0.2352	**-0.0796**	0.0001
	2	0.6595	0.5794	-14.5522	**1.3295**	**-0.8411**	0.1205	-0.0272	0.0007
	3	0.6680	0.5850	-18.8531	**1.6193**	**-0.8709**	-0.0205	-0.0362	0.0009
	4	0.6632	0.5734	-31.8689	**2.5563**	**-1.1267**	0.0768	-0.0235	0.0017
	5	0.5683	0.4450	-24.4509	**1.9949**	**-0.8851**	0.1094	-0.0543	0.0139
OCTOBER-APRIL	0	0.7906	0.7525	11.8956	-0.5898	-0.0697	**0.7132**	**-0.0731**	0.0000
	1	0.7411	0.6918	3.9233	0.0000	-0.3806	0.5732	-0.0492	0.0000
	2	0.7696	0.7235	-16.1985	**1.4622**	**-1.0809**	-0.0474	-0.0419	0.0000
	3	0.7446	0.6908	-15.6295	**1.4380**	**-1.1161**	0.2857	0.0307	0.0000
	4	0.5731	0.4782	5.3761	-0.1249	-0.2835	**1.0310**	-0.0212	0.0029
	5	0.5535	0.4484	15.6831	-0.8805	0.0865	**1.5619**	-0.0116	0.0060

TABLE 9.2.3 Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus monthly sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the south western Cape area. Adj.R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P< 0.05) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JANUARY	0	0.2703	0.0049	8.7010	-0.4267	0.0691	-0.1700	-0.0096	0.4396
	1	0.5101	0.3141	13.7321	-0.7710	0.2171	-0.0165	-0.0334	0.1002
	2	0.4381	0.1883	-15.0156	1.0601	-0.2069	**1.8286**	-0.0014	0.2221
	3	0.7398	0.6242	1.8480	0.0843	-0.2682	0.6560	**0.1071**	0.0101
	4	0.3857	0.1127	27.9574	-1.5712	0.0855	-1.1684	0.0209	0.3054
	5	0.1616	0.0000	17.2819	-0.9162	-0.0006	-0.3145	-0.0009	0.8135
FEBRUARY	0	0.6610	0.5378	11.1648	**-0.7971**	**0.8407**	**-1.5625**	0.0012	0.0121
	1	0.3146	0.0404	8.6254	-0.3666	-0.1472	0.3484	-0.0133	0.3892
	2	0.1236	0.0000	1.4391	0.1345	-0.3822	0.5467	-0.0116	0.8594
	3	0.8838	0.8322	9.3671	-0.3169	**-0.3816**	-0.5432	**0.1005**	0.0003
	4	0.4372	0.1870	3.7104	0.0182	-0.5152	1.5119	-0.0203	0.2234
	5	0.5137	0.2705	11.6173	-0.7037	0.3334	0.1572	-0.0230	0.1709
MARCH	0	0.3082	0.0567	4.6994	-0.1585	-0.0616	-0.0245	-0.0063	0.3551
	1	0.2596	0.0000	2.8462	2.8462	2.8462	2.8462	2.8462	0.5114
	2	0.5337	0.3264	-7.3807	0.6124	-0.0691	-0.2449	-0.0479	0.1098
	3	0.5873	0.4038	-3.4279	0.3116	0.1422	-0.4470	**0.0687**	0.0679
	4	0.2353	0.0000	5.9228	-0.3009	0.2172	-0.3689	0.0168	0.6638
	5	0.5490	0.2913	17.0117	-0.8684	-0.3820	0.4750	-0.0023	0.1799
APRIL	0	0.3393	0.0751	7.9421	-0.3174	-0.3972	0.2002	0.0023	0.3394
	1	0.4194	0.1613	4.1467	-0.1691	0.1046	0.0821	0.0138	0.2500
	2	0.2795	0.0000	-4.8933	0.3370	0.3778	0.4744	-0.0032	0.5708
	3	0.7278	0.5918	-9.6979	**0.6760**	0.0844	**1.2385**	**0.0917**	0.0215
	4	0.3870	0.0367	5.2603	-0.3396	0.6125	-0.2131	0.0070	0.4247
	5	0.6414	0.4023	20.7385	**-1.1005**	-0.4846	-0.6174	-0.0068	0.1349
MAY	0	0.2566	0.0000	4.8994	-0.1988	-0.0004	-0.0473	0.0036	0.4721
	1	0.6450	0.5031	0.3800	0.0603	0.3272	-0.5459	0.0210	0.0238
	2	0.4428	0.1952	6.5041	-0.2935	0.2502	0.3805	-0.0052	0.2153
	3	0.4195	0.1293	2.9238	-0.1005	0.1654	-0.4386	0.0417	0.3041
	4	0.3619	0.0000	15.3227	-0.8232	-0.6781	0.4810	-0.0176	0.4703
	5	0.3213	0.0000	7.2633	-0.3923	0.2492	-0.6036	0.0262	0.6140
JUNE	0	0.3387	0.1182	5.5598	-0.2229	0.2894	0.0760	-0.0045	0.2537
	1	0.5329	0.3630	5.2520	-0.2287	-0.2902	0.0566	0.0108	0.0598
	2	0.3811	0.1336	5.1069	-0.1810	0.2645	0.2679	-0.0019	0.2638
	3	0.4175	0.1586	9.8717	-0.5458	-0.0609	-0.1656	0.0373	0.2530
	4	0.2459	0.0000	14.7706	-0.8961	-0.2969	-0.4306	0.0250	0.6415
	5	0.1574	0.0000	14.4022	-0.8565	-0.1215	-0.2807	0.0301	0.8517
JULY	0	0.3184	0.1087	6.1867	**-0.2960**	-0.1383	-0.0529	-0.0111	0.2541
	1	0.2656	0.0208	5.0114	-0.2002	0.1221	0.2057	-0.0049	0.4069
	2	0.3972	0.1780	7.2611	-0.3501	0.0718	0.2480	0.0422	0.1968
	3	0.3515	0.0921	5.2162	-0.2348	0.1118	-0.0363	0.0407	0.3163
	4	0.2192	0.0000	4.8181	-0.2444	0.0342	-0.5242	0.0038	0.6524
	5	0.4213	0.1320	12.1146	-0.7701	-0.2935	-0.9683	-0.0080	0.3011

TABLE 9.2.3 (continued)

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
AUGUST	0	0.3388	0.1353	7.5727	-0.3573	-0.2502	0.2102	-0.0297	0.2176
	1	0.3495	0.1327	1.5450	-0.0376	0.4285	-0.2447	-0.0178	0.2346
	2	0.2980	0.0427	10.8481	-0.6035	-0.1278	0.0898	0.0195	0.3770
	3	0.3236	0.0530	13.7556	-0.7417	-0.5730	0.4479	0.0365	0.3707
	4	0.3450	0.0539	9.4739	-0.5457	0.1059	-0.0518	0.0713	0.3802
	5	0.7452	0.6178	-3.8397	0.0064	**2.5709**	**-2.2210**	-0.0188	0.0168
	6	0.0762	0.0000	7.4593	-0.4563	0.3872	-0.4132	0.0029	0.9598
SEPTEMBER	0	0.4897	0.3196	21.7794	**-1.2843**	-0.2327	0.6721	-0.0039	0.0695
	1	0.3666	0.1363	10.8917	-0.6875	0.3036	-0.1468	-0.0372	0.2447
	2	0.5449	0.3628	3.8468	-0.2043	0.1107	**-1.0361**	-0.0216	0.0727
	3	0.2451	0.0000	5.9241	-0.3456	0.1919	-0.5600	0.0315	0.5933
	4	0.2845	0.0000	0.5021	0.1286	-0.2859	-0.3310	0.0485	0.5054
	5	0.2043	0.0000	-27.6467	2.0118	-0.1632	-0.6096	-0.0608	0.7285
OCTOBER	0	0.2841	0.0450	3.2363	-0.1320	0.1128	-0.5668	-0.0061	0.3642
	1	0.3187	0.0709	11.6912	-0.7475	0.3313	-0.4525	-0.0310	0.3336
	2	0.2922	0.0090	53.5470	-3.4954	0.2794	-0.2454	-0.0087	0.4373
	3	0.2488	0.0000	-14.5402	1.0927	-0.0707	-0.1678	0.0477	0.5851
	4	0.5981	0.4195	-68.3923	4.6099	0.0248	-0.9829	0.0075	0.0611
	5	0.3550	0.0326	-59.9835	4.0425	0.0738	-0.8760	-0.0690	0.4188
NOVEMBER	0	0.2556	0.0074	-0.4997	0.1948	-0.1400	-0.1389	0.0273	0.4312
	1	0.3746	0.1472	-4.3949	0.5052	-0.3305	-0.3571	-0.0287	0.2316
	2	0.5184	0.3258	44.5845	**-2.7508**	0.1141	0.2919	0.0034	0.0930
	3	0.2874	0.0000	23.3738	-1.4274	0.1604	0.4454	0.0808	0.4992
	4	0.6501	0.4946	-33.1306	2.2377	-0.0944	0.0868	0.0861	0.0348
	5	0.4650	0.1974	39.1581	-2.0884	**-0.8470**	-0.8516	0.0373	0.2344
DECEMBER	0	0.4580	0.2609	-9.2341	0.6580	0.0573	0.2198	0.0417	0.1212
	1	0.3063	0.0541	11.6548	-0.6439	0.1393	-0.2203	0.0141	0.3592
	2	0.5445	0.3623	34.0855	-1.8223	-0.3991	0.3651	0.0178	0.0730
	3	0.3310	0.0337	24.0184	-1.1374	-0.6267	0.6326	0.0263	0.4078
	4	0.6317	0.4475	2.7873	0.0610	-0.3694	0.4088	0.1074	0.0649
	5	0.1555	0.0000	15.0802	-0.8146	0.2034	0.0382	0.0518	0.8250

TABLE 9.2.4 Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combinations of months in the south western Cape area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P < 0.05$) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY-JULY	0	0.2968	0.0959	6.5850	-0.3127	-0.0781	-0.0356	-0.0064	0.2616
	1	0.2720	0.0481	5.4005	-0.2087	-0.0645	0.3863	-0.0073	0.3515
	2	0.3544	0.1392	5.7858	-0.2381	0.1217	0.3520	0.0171	0.2264
	3	0.4266	0.2182	7.5638	-0.3749	-0.2114	0.0722	0.0432	0.1570
	4	0.3325	0.0655	11.0020	-0.6992	0.7462	-1.4545	0.0153	0.3528
	5	0.3437	0.0519	12.2278	-0.7832	0.9191	-1.4760	0.0273	0.3829
DECEMBER-FEBRUARY	0	0.4236	0.2314	14.8420	**-0.8008**	0.0789	-1.1636	-0.0190	0.1299
	1	0.5510	0.3877	11.0319	-0.6118	0.1948	0.6573	-0.0187	0.0493
	2	0.1980	0.0000	5.6118	-0.1158	-0.3496	0.5952	0.0041	0.6604
	3	0.8201	0.7402	1.4928	0.1617	**-0.4564**	0.8403	**0.1160**	0.0021
	4	0.2561	0.0000	18.1232	-0.9750	-0.0072	-0.2206	0.0268	0.5686
	5	0.2161	0.0000	14.9930	-0.8313	0.1208	0.4831	-0.0047	0.7040
MARCH-APRIL	0	0.3148	0.0657	5.8807	-0.2352	-0.0653	-0.0824	-0.0038	0.3414
	1	0.2775	0.0000	1.5235	0.0935	-0.2786	-0.0600	-0.0137	0.4746
	2	0.4498	0.2053	-3.7367	0.4147	-0.0761	-0.8836	-0.0505	0.2056
	3	0.4227	0.1661	2.4113	-0.0415	0.1123	-0.5553	0.0555	0.2449
	4	0.3025	0.0000	9.2767	-0.5684	0.4681	-0.5188	0.0103	0.5230
	5	0.5194	0.2448	15.5369	-0.8529	-0.1474	0.3514	0.0200	0.2168
AUGUST-NOVEMBER	0	0.3039	0.1051	6.2797	-0.2241	-0.2684	0.5094	0.0060	0.2476
	1	0.3667	0.1718	-9.3782	0.8649	-0.3931	1.2827	-0.0336	0.1738
	2	0.4838	0.3117	55.1026	**-3.7061**	0.5578	-1.5485	0.0074	0.0739
	3	0.2896	0.0312	10.5523	-0.5448	-0.1354	0.3750	0.0588	0.3954
	4	0.4317	0.2044	-8.4887	0.8233	-0.4867	1.4459	**0.0925**	0.1872
	5	0.0954	0.0000	-7.9791	0.7194	-0.2681	0.5255	-0.0389	0.9102
OCTOBER-APRIL	0	0.3473	0.1465	7.5091	-0.3394	-0.0057	-0.7212	-0.0296	0.2035
	1	0.3713	0.1617	17.3139	-1.0174	0.1849	0.1904	-0.0125	0.1993
	2	0.1608	0.0000	5.5781	-0.1635	-0.2077	-0.7696	-0.0099	0.7184
	3	0.6558	0.5181	5.1710	-0.1213	-0.2901	-0.4993	**0.1035**	0.0207
	4	0.2719	0.0000	18.8733	-1.0545	0.0228	-1.0051	0.0068	0.5332
	5	0.3859	0.0789	28.3026	-1.7160	0.1922	0.7832	0.0213	0.3617

TABLE 9.2.5 Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus monthly sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the Agulhas Bank area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P < 0.05$) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
JANUARY	0	0.5319	0.4428	34.5657	**-1.6033**	-0.3042	0.0518	-0.0051	0.0023
	1	0.6594	0.5912	39.6569	**-1.9082**	0.0014	0.1295	-0.0020	0.0002
	2	0.6465	0.5720	38.1694	**-1.7694**	-0.4825	0.3724	-0.0068	0.0004
	3	0.4761	0.3597	31.5925	**-1.4451**	-0.4278	0.2770	-0.0106	0.0157
	4	0.6080	0.5157	21.3227	-0.9759	-0.0682	0.0219	**-0.0337**	0.0022
	5	0.5544	0.4430	25.9183	**-1.1707**	-0.3544	0.0821	-0.0274	0.0085
FEBRUARY	0	0.6750	0.6131	29.0986	**-1.4982**	0.9969	**-0.3001**	0.0270	0.0001
	1	0.7554	0.7065	22.8449	**-1.1265**	0.6027	**-0.3499**	0.0079	0.0000
	2	0.6049	0.5217	10.8996	-0.3634	-0.5976	-0.1277	-0.0282	0.0010
	3	0.4819	0.3667	14.7704	-0.6164	-0.2060	-0.1306	-0.0137	0.0144
	4	0.6215	0.5324	19.5867	-1.0007	0.7869	-0.1908	-0.0113	0.0016
	5	0.5916	0.4895	21.9057	**-1.1051**	0.6688	-0.1476	-0.0034	0.0044
MARCH	0	0.6048	0.5295	4.7264	-0.2502	**1.0510**	**-0.3345**	0.0007	0.0004
	1	0.6954	0.6345	-5.1789	0.2198	**1.4514**	**-0.3394**	-0.0071	0.0001
	2	0.7694	0.7208	-12.7481	0.5877	**1.6550**	**-0.2973**	-0.0158	0.0000
	3	0.7073	0.6457	-6.8997	0.3052	**1.4105**	**-0.2337**	-0.0138	0.0001
	4	0.7032	0.6372	3.8172	-0.1887	0.7782	-0.1333	**-0.0242**	0.0001
	5	0.6930	0.6207	13.2473	-0.6294	0.3271	-0.1422	**-0.0196**	0.0003
	6	0.5051	0.3814	14.5163	-0.7139	0.4410	-0.1328	-0.0061	0.0181
APRIL	0	0.3588	0.2367	7.5589	-0.2651	-0.5423	0.3892	-0.0151	0.0448
	1	0.4385	0.3262	17.3498	-0.7097	**-1.5673**	0.2534	-0.0102	0.0168
	2	0.5623	0.4702	15.5579	-0.5992	**-1.7456**	0.4061	-0.0171	0.0025
	3	0.5406	0.4439	14.5774	-0.5841	**-1.3213**	0.3020	-0.0224	0.0038
	4	0.6354	0.5544	12.6786	-0.5467	-0.4999	-0.1765	**-0.0348**	0.0008
	5	0.5913	0.4951	16.6985	**-0.7497**	-0.7842	-0.0090	**-0.0235**	0.0030
MAY	0	0.4283	0.3194	5.5983	-0.1757	0.1109	0.3138	-0.0082	0.0155
	1	0.3685	0.2421	-1.2269	0.2185	0.5478	0.2365	-0.0133	0.0473
	2	0.4446	0.3276	-4.2363	0.3727	1.3467	0.0378	-0.0131	0.0196
	3	0.3483	0.2111	4.5965	-0.1633	0.6840	-0.0671	-0.0225	0.0738
	4	0.5116	0.4031	4.2245	-0.1297	0.3566	0.0673	**-0.0358**	0.0089
	5	0.4917	0.3721	6.2424	-0.2619	0.4297	-0.0288	**-0.0317**	0.0165
JUNE	0	0.7389	0.6866	-5.3674	0.3860	**1.7392**	**-0.7853**	0.0183	0.0000
	1	0.5302	0.4362	-0.4090	0.1587	0.9978	-0.1660	0.0097	0.0033
	2	0.6994	0.6362	-7.3577	0.6146	**1.0477**	-0.0430	0.0054	0.0001
	3	0.6519	0.5786	-6.6322	0.5363	**1.0891**	-0.2224	-0.0050	0.0003
	4	0.6737	0.6012	-0.1448	0.0987	**1.0902**	-0.3811	-0.0118	0.0003
	5	0.6264	0.5385	0.1306	0.1141	**0.5251**	-0.0766	-0.0294	0.0015
JULY	0	0.5657	0.4788	15.4798	**-0.8259**	**0.7647**	0.2413	0.0148	0.0016
	1	0.7518	0.7021	15.4843	**-0.8203**	**0.8198**	**0.2834**	0.0098	0.0000
	2	0.6729	0.6041	22.3193	**-1.2422**	**0.6272**	**0.4573**	0.0147	0.0002
	3	0.5414	0.4449	16.6830	-0.8952	0.3924	0.3674	-0.0050	0.0037
	4	0.6379	0.5574	15.8155	-0.8514	0.3267	0.3087	-0.0207	0.0007
	5	0.6215	0.5325	2.0061	-0.0019	0.2639	0.0181	**-0.0412**	0.0016

TABLE 9.2.5. (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
AUGUST	0	0.3095	0.1840	-6.2080	0.5241	0.0545	-0.1171	-0.0093	0.0749
	1	0.6795	0.6185	-20.0647	**1.4070**	**0.3213**	**-0.2787**	-0.0104	0.0001
	2	0.6478	0.5773	-19.6608	**1.3719**	**0.2591**	**-0.3303**	-0.0105	0.0002
	3	0.6223	0.5428	-17.3593	**1.2198**	0.2272	**-0.3200**	-0.0192	0.0007
	4	0.5553	0.4565	-11.3303	**0.8272**	0.1807	-0.2652	**-0.0357**	0.0041
	5	0.6486	0.5659	-9.7394	**0.7169**	0.1527	**-0.2864**	**-0.0403**	0.0009
SEPTEMBER	0	0.0627	0.0000	5.0930	-0.1909	-0.0574	0.0688	-0.0202	0.8289
	1	0.1484	0.0000	1.4987	0.0157	-0.0286	-0.2226	-0.0284	0.4735
	2	0.3744	0.2492	-13.8516	0.9130	0.8698	**-0.6689**	-0.0132	0.0436
	3	0.4224	0.3008	-17.2705	1.1171	1.1539	**-0.6222**	-0.0127	0.0273
	4	0.4216	0.2931	-9.6733	0.6678	0.6370	-0.4813	-0.0304	0.0347
	5	0.5071	0.3911	-9.2006	0.6690	0.5060	-0.1794	**-0.0378**	0.0130
OCTOBER	0	0.3479	0.2345	9.6295	**-0.5351**	0.6229	0.1334	0.0081	0.0366
	1	0.4277	0.3237	8.8063	**-0.5190**	0.8999	0.1354	0.0034	0.0123
	2	0.5641	0.4811	9.9602	-0.6244	**1.1777**	0.1403	0.0087	0.0011
	3	0.6044	0.5253	6.8744	-0.4463	**1.2687**	0.1685	0.0097	0.0007
	4	0.5753	0.4859	7.1362	-0.4541	**1.1383**	0.0481	0.0058	0.0019
	5	0.6135	0.5276	8.8542	-0.4979	**0.6047**	0.1255	-0.0302	0.0013
NOVEMBER	0	0.3829	0.2756	8.0499	-0.2765	-0.4574	0.0669	-0.0243	0.0210
	1	0.3416	0.2219	7.8561	-0.2870	-0.3126	-0.0087	-0.0033	0.0480
	2	0.3429	0.2178	15.4865	-0.7715	0.0049	0.0043	-0.0275	0.0559
	3	0.4122	0.2953	23.0343	**-1.2604**	0.3844	0.0237	-0.0145	0.0250
	4	0.4065	0.2815	23.9375	**-1.3197**	0.4283	-0.0323	-0.0099	0.0342
	5	0.6245	0.5410	16.7848	-0.8351	-0.1178	-0.0329	**-0.0489**	0.0010
DECEMBER	0	0.4644	0.3623	13.2677	-0.6145	0.2549	**0.3637**	0.0204	0.0084
	1	0.6093	0.5311	-3.0342	0.2949	-0.0200	**0.7276**	-0.0016	0.0006
	2	0.7814	0.7377	2.1320	-0.0032	0.1583	**0.7414**	0.0014	0.0000
	3	0.6056	0.5225	23.1788	-1.6249	0.3645	0.2443	0.0001	0.0010
	4	0.5429	0.4413	15.2530	-0.7185	0.1864	0.3617	-0.0062	0.0051
	5	0.6846	0.6104	18.4483	-0.8667	-0.0311	0.2609	**-0.0339**	0.0004

TABLE 9.2.6.: Multiple regression results of pilchard (*Sardinops ocellatus*) annual catch versus sea surface temperature (SST), north-south wind vector (N/S), west-east wind vector (W/E) and sea level for combination of months at different lags (years) in the Agulhas Bank area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P< 0.05) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF.	TEMP	WIND N/S	WIND W/E	SEALEVEL	P<
MAY-JULY	0	0.5907	0.5127	7.8687	-0.2724	0.1993	**0.5853**	0.0125	0.0006
	1	0.6517	0.5820	5.7422	-0.1446	0.3897	0.5459	0.0094	0.0002
	2	0.6909	0.6258	-1.2724	0.2347	1.1392	0.0959	0.0032	0.0001
	3	0.5594	0.4666	-3.8965	0.3393	1.4722	-0.3232	-0.0115	0.0026
	4	0.6214	0.5372	5.1875	-0.1449	0.1289	0.3840	-0.0260	0.0011
	5	0.6139	0.5231	-2.9997	0.2627	1.1233	-0.3970	**-0.0324**	0.0019
DECEMBER-FEBRUARY	0	0.5992	0.5228	27.6500	**-1.4294**	0.8683	**-0.6659**	0.0079	0.0005
	1	0.6313	0.5576	32.4435	**-1.6941**	**0.9750**	-0.4773	0.0079	0.0003
	2	0.5679	0.4770	29.4059	**-1.5195**	0.8233	-0.4456	0.0016	0.0022
	3	0.4715	0.3540	25.2997	-1.2926	0.6855	-0.3293	-0.0005	0.0169
	4	0.6497	0.5673	17.9145	-0.8770	0.3956	-0.2672	-0.0309	0.0009
	5	0.5690	0.4612	20.2166	-0.9682	0.1814	-0.2155	-0.0235	0.0066
MARCH-APRIL	0	0.3405	0.2149	9.0995	-0.4436	0.6797	-0.2679	-0.0086	0.0578
	1	0.4290	0.3148	-8.2224	0.3399	**2.1440**	**-0.4922**	-0.0198	0.0195
	2	0.4271	0.3065	-8.5226	0.3807	1.8828	-0.4420	-0.0273	0.0254
	3	0.4860	0.3778	-5.9328	0.2492	1.7690	-0.3872	**-0.0271**	0.0101
	4	0.6942	0.6262	0.5633	-0.0468	1.2484	**-0.3976**	**-0.0346**	0.0002
	5	0.6233	0.5346	9.6676	-0.4489	0.3612	-0.2598	**-0.0274**	0.0016
AUGUST-NOVEMBER	0	0.2782	0.1527	-3.6891	0.3939	-0.6680	-0.4196	-0.0234	0.0988
	1	0.4799	0.3853	-11.5276	**0.9244**	-0.6483	0.3090	**-0.0367**	0.0047
	2	0.4049	0.2915	-8.4931	0.7029	-0.3141	0.3183	-0.0353	0.0226
	3	0.3407	0.2088	-5.1006	0.4642	-0.2005	0.0892	**-0.0380**	0.0684
	4	0.3765	0.2452	-4.0544	0.3843	-0.1885	-0.0912	**-0.0391**	0.0515
	5	0.5360	0.4329	-3.0552	0.3259	-0.2179	-0.0064	**-0.0562**	0.0058
OCTOBER-APRIL	0	0.5936	0.5230	20.2408	**-1.1125**	**1.1395**	**-1.3318**	0.0153	0.0002
	1	0.6396	0.5741	22.8568	**-1.2967**	**1.4835**	**-1.5979**	0.0159	0.0001
	2	0.6050	0.5298	21.1989	**-1.2045**	**1.4219**	**-1.3603**	0.0103	0.0004
	3	0.6734	0.6081	21.5500	**-1.2441**	**1.5638**	**-1.3524**	0.0121	0.0001
	4	0.7209	0.6622	18.0300	**-0.9479**	0.6587	-0.7766	-0.0194	0.0000
	5	0.7226	0.6610	24.3877	**-1.2878**	0.6027	**-0.7825**	-0.0108	0.0001

TABLE 9.2.7 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus monthly sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the Namaqualand area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P < 0.05$) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
JANUARY	0	0.8577	0.8171	50.3806	**-3.0526**	**0.5515**	1.3083	0.0497	0.0000
	1	0.8464	0.7992	33.3949	-1.7881	-0.2471	**1.6527**	0.0192	0.0000
	2	0.9314	0.9086	37.0414	**-2.0530**	-0.1170	**1.6239**	0.0915	0.0000
	3	0.9267	0.9000	16.8281	-0.6752	-0.7559	0.5535	0.0102	0.0000
	4	0.9317	0.9044	22.3063	-1.0759	-0.5067	1.1349	0.0491	0.0000
	5	0.9882	0.9829	9.3496	-0.2132	**-0.8037**	**1.0786**	-0.0309	0.0000
	6	0.9870	0.9812	3.5208	0.1599	**-0.9164**	**0.9670**	-0.0314	0.0000
	7	0.9407	0.9143	8.5322	-0.2597	-0.5384	**1.1504**	-0.0056	0.0000
	8	0.9226	0.8882	-4.0884	0.5796	**-0.8748**	0.4973	-0.0443	0.0001
	9	0.8871	0.8370	-13.9700	**1.2648**	**-1.2408**	-0.1228	-0.0196	0.0003
FEBRUARY	0	0.8324	0.7952	-0.0511	0.6143	**-1.6401**	1.0508	-0.1674	0.0000
	1	0.8873	0.8608	29.7251	-1.3996	**-0.9221**	**1.7320**	-0.1231	0.0000
	2	0.9490	0.9363	35.3414	**-1.7716**	**-0.8384**	**1.6913**	-0.0318	0.0000
	3	0.9748	0.9680	27.1279	**-1.2782**	**-0.8679**	**1.3761**	**-0.0752**	0.0000
	4	0.9629	0.9522	15.5752	-0.4987	**-1.1783**	**1.2849**	-0.0474	0.0000
	5	0.9576	0.9445	6.1352	0.1121	**-1.3448**	**1.2377**	-0.0706	0.0000
	6	0.9651	0.9535	-0.4069	0.5001	**-1.3489**	0.9781	-0.0490	0.0000
	7	0.9453	0.9271	0.9511	0.3648	**-1.1891**	1.0767	-0.0381	0.0000
	8	0.9490	0.9321	-2.4534	0.5506	**-1.1494**	**1.0302**	-0.0401	0.0000
MARCH	0	0.8688	0.8411	35.5569	**-1.7412**	**-1.3363**	**3.6527**	-0.0061	0.0000
	1	0.9542	0.9440	9.0928	-0.0881	**-1.1956**	0.2921	-0.0242	0.0000
	2	0.9282	0.9113	19.4367	-0.7784	**-1.1358**	1.3857	-0.0313	0.0000
	3	0.9463	0.9329	20.8429	-0.9374	**-0.9241**	1.2216	-0.0727	0.0000
	4	0.9421	0.9267	17.4764	-0.7134	**-1.0304**	**1.6066**	-0.0511	0.0000
	5	0.9206	0.8979	10.0880	-0.1903	**-1.3044**	**2.0900**	-0.0518	0.0000
	6	0.9220	0.8979	7.9113	-0.0157	**-1.5234**	**2.9630**	-0.0585	0.0000
	7	0.9434	0.9260	5.3981	0.1567	**-1.6173**	**3.1999**	-0.0062	0.0000
	8	0.8904	0.8539	5.6315	0.0758	**-1.4012**	**2.7871**	0.0185	0.0000
	9	0.8646	0.8154	10.7879	-0.3405	**-1.0841**	**2.4852**	0.0566	0.0001
APRIL	0	0.9421	0.9299	40.7383	**-2.2735**	**-0.9661**	**1.9185**	0.0166	0.0000
	1	0.9624	0.9540	26.9940	**-1.2817**	**-1.5229**	**1.9593**	0.0142	0.0000
	2	0.9500	0.9383	22.5816	**-0.9855**	**-1.6365**	**1.9898**	0.0062	0.0000
	3	0.9315	0.9144	20.3150	-0.8791	**-1.5136**	**1.9137**	-0.0219	0.0000
	4	0.9328	0.9149	15.2457	-0.5486	**-1.5992**	**2.0652**	-0.0065	0.0000
	5	0.9085	0.8823	10.9719	-0.2798	**-1.6322**	**2.2235**	-0.0209	0.0000
	6	0.8961	0.8642	-2.6644	0.5696	**-1.4287**	-0.0089	-0.0220	0.0000
	7	0.8175	0.7613	-4.1830	0.5857	**-1.0313**	-1.2215	-0.0035	0.0001
	8	0.7840	0.7121	0.4208	0.2787	**-1.1311**	0.6567	-0.0016	0.0006
	9	0.7421	0.6483	6.6083	-0.1910	**-0.8710**	1.2354	0.0054	0.0029
MAY	0	0.5589	0.4660	-0.9882	0.2589	**-0.8314**	-0.7320	-0.1101	0.0026
	1	0.5648	0.4681	-24.7064	1.9022	**-1.7499**	-0.3719	-0.1159	0.0034
	2	0.7317	0.6686	-13.7068	1.1195	**-1.2475**	-1.1020	-0.0798	0.0001
	3	0.8413	0.8016	-9.6007	0.8450	**-1.2091**	-0.9959	-0.0431	0.0000
	4	0.8563	0.8180	-3.0212	0.4021	**-1.1245**	-0.6299	-0.0278	0.0000
	5	0.8551	0.8136	-1.4933	0.2977	**-1.1181**	-0.2980	-0.0610	0.0000
	6	0.9612	0.9493	-14.8019	**1.2074**	**-1.5078**	-0.0072	-0.0247	0.0000
	7	0.9144	0.8880	-19.5324	**1.4730**	**-1.2492**	-0.4735	-0.0056	0.0000
	8	0.8928	0.8571	-17.6792	**1.3060**	**-0.9393**	-0.6572	-0.0246	0.0000
	9	0.8759	0.8307	-11.6302	0.8681	**-0.6327**	-0.7734	-0.0149	0.0001

TABLE 9.2.7 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JUNE	0	0.5703	0.4629	48.8582	**-3.0842**	**-1.5831**	**4.0495**	-0.1009	0.0065
	1	0.5871	0.4770	47.4700	**-2.9930**	-1.3926	**4.2369**	-0.1203	0.0071
	2	0.6028	0.4894	48.4331	**-3.0857**	-0.8558	3.1568	-0.1093	0.0081
	3	0.5951	0.4705	44.4274	**-2.8606**	-0.5019	1.4469	-0.0896	0.0137
	4	0.7367	0.6490	47.3098	**-3.0346**	-0.6755	2.3431	-0.0219	0.0018
	5	0.8776	0.8331	43.2803	**-2.7613**	-0.7371	**2.5827**	-0.0557	0.0001
	6	0.8441	0.7874	38.2457	**-2.4192**	-0.9230	**3.2360**	-0.0485	0.0002
	7	0.8155	0.7472	35.5437	**-2.2430**	-0.5512	**3.1285**	-0.0264	0.0005
	8	0.6673	0.5342	26.1909	**-1.6611**	-0.5823	1.7479	-0.0534	0.0177
	9	0.7532	0.6436	22.5452	**-1.4219**	-0.7404	1.8744	-0.0459	0.0081
JULY	0	0.9289	0.9121	83.8713	**-5.7792**	**1.3901**	**-0.5873**	-0.0792	0.0000
	1	0.9341	0.9177	76.1410	**-5.1945**	0.7080	-0.2510	-0.0748	0.0000
	2	0.9417	0.9261	71.6786	**-4.8462**	0.1251	-0.0256	-0.0666	0.0000
	3	0.9218	0.8994	63.8442	**-4.2843**	-0.2311	-0.1324	-0.0711	0.0000
	4	0.9217	0.8976	55.8360	**-3.6927**	-0.7680	-0.0204	-0.0324	0.0000
	5	0.9003	0.8670	45.3821	**-2.9375**	-1.2448	0.0973	-0.0379	0.0000
	6	0.8448	0.7931	38.4446	**-2.4843**	-1.0680	0.1656	-0.0695	0.0001
	7	0.7817	0.7089	36.9869	**-2.4349**	-0.6247	-0.1558	-0.0788	0.0006
	8	0.7442	0.6512	27.9727	**-1.8106**	-0.7227	-0.1227	-0.0755	0.0028
	9	0.7674	0.6743	24.1894	**-1.5622**	-0.6710	-0.1705	-0.0625	0.0033
AUGUST	0	0.9195	0.9006	-55.7820	**4.4479**	**-2.3884**	**1.9818**	0.0247	0.0000
	1	0.9469	0.9336	19.4158	-0.9343	**-1.6703**	**1.4724**	-0.0246	0.0000
	2	0.9509	0.9378	6.1385	-0.0096	**-1.7464**	**1.4568**	-0.0273	0.0000
	3	0.9657	0.9559	-22.1439	1.9876	**-1.9416**	**1.6067**	-0.0297	0.0000
	4	0.9477	0.9316	-31.7872	2.6287	**-1.8998**	**1.2517**	-0.0443	0.0000
	5	0.9169	0.8892	-14.7680	1.3847	**-1.5769**	1.1420	-0.0328	0.0000
	6	0.8974	0.8632	-39.3472	3.0862	**-1.6094**	0.9653	-0.0595	0.0000
	7	0.8987	0.8650	-65.4628	**4.9144**	**-1.7251**	0.9407	-0.0508	0.0000
	8	0.8664	0.8178	-64.2037	4.7765	**-1.5110**	0.6754	-0.0651	0.0001
	9	0.7786	0.6900	-30.7541	2.3555	-1.0343	0.3429	-0.0418	0.0026
SEPTEMBER	0	0.8809	0.8559	6.7919	-0.0806	**-1.4018**	**-1.0248**	-0.0838	0.0000
	1	0.8945	0.8711	17.9108	-0.9438	**-1.1009**	**-1.5191**	-0.0877	0.0000
	2	0.9217	0.9033	12.6989	-0.5289	**-1.2993**	**-0.9948**	**-0.1047**	0.0000
	3	0.9099	0.8874	10.9154	-0.3998	**-1.3111**	-0.6969	**-0.1160**	0.0000
	4	0.9032	0.8774	17.6740	-0.9246	**-1.0937**	-0.7664	**-0.1265**	0.0000
	5	0.9154	0.8913	18.2513	-0.9664	**-1.0543**	-0.5128	-0.0766	0.0000
	6	0.9358	0.9161	27.1281	-1.5066	**-1.1104**	0.7847	-0.0566	0.0000
	7	0.9080	0.8797	9.1825	-0.2603	**-1.2166**	0.8076	-0.0555	0.0000
	8	0.9582	0.9443	5.8458	-0.0763	**-1.0917**	0.6491	**-0.0873**	0.0000
	9	0.9015	0.8656	11.8505	-0.5183	**-0.9315**	0.8956	-0.0553	0.0000
OCTOBER	0	0.9511	0.9408	25.2021	**-1.0711**	**-1.4518**	**1.9498**	0.0228	0.0000
	1	0.9693	0.9625	37.6565	**-1.9891**	**-1.1294**	**2.5755**	0.0468	0.0000
	2	0.9482	0.9360	41.2218	**-2.2730**	**-0.9708**	**2.9779**	0.0672	0.0000
	3	0.9360	0.9200	43.4657	**-2.4812**	**-0.8008**	**3.0273**	0.0515	0.0000
	4	0.9595	0.9487	43.0789	**-2.4980**	**-0.6962**	**2.9749**	0.0170	0.0000
	5	0.9474	0.9324	43.8433	**-2.5821**	**-0.5795**	**3.3951**	0.0402	0.0000
	6	0.8902	0.8564	45.8161	**-2.8571**	-0.2124	**2.2609**	0.0171	0.0000
	7	0.8273	0.7742	27.8407	-1.5261	-0.6503	**2.9140**	0.0309	0.0001
	8	0.7954	0.7272	32.0216	-1.9824	-0.1881	1.4224	-0.0092	0.0004
	9	0.8293	0.7673	42.2856	**-2.9477**	0.5743	-0.9654	-0.0246	0.0003

TABLE 9.2.7 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
NOVEMBER	0	0.6889	0.6197	77.9777	**-5.6371**	**2.1741**	-0.5823	-0.0620	0.0002
	1	0.6374	0.5568	81.2048	**-5.9623**	**2.4769**	-1.0887	-0.0820	0.0007
	2	0.7723	0.7187	59.9144	**-4.1019**	1.0523	0.2313	-0.0600	0.0000
	3	0.8275	0.7844	27.9586	-1.4364	-0.7256	1.4188	0.0172	0.0000
	4	0.8589	0.8213	17.7857	-0.6485	-1.1359	**1.4872**	-0.0104	0.0000
	5	0.8276	0.7784	16.6916	-0.6363	-0.9940	1.0790	0.0177	0.0000
	6	0.8983	0.8670	17.5290	-0.8075	-0.6771	0.3001	-0.0078	0.0000
	7	0.8057	0.7459	12.5769	-0.4647	-0.7753	0.6144	0.0116	0.0001
	8	0.8595	0.8127	-0.1480	0.5094	**-1.2457**	0.9211	0.0087	0.0000
	9	0.8705	0.8235	-4.9892	0.8401	**-1.3279**	1.0813	0.0007	0.0001
DECEMBER	0	0.9836	0.9785	19.8308	**-0.8028**	**-0.8642**	0.3069	0.0148	0.0000
	1	0.9768	0.9697	20.5666	**-0.8912**	**-0.7525**	0.4318	-0.0029	0.0000
	2	0.9510	0.9359	18.9703	**-0.8011**	**-0.7471**	0.6188	-0.0365	0.0000
	3	0.9804	0.9739	21.2008	**-0.9995**	**-0.5448**	**1.0647**	-0.0079	0.0000
	4	0.9818	0.9752	19.2784	**-0.8922**	**-0.5298**	**1.1875**	-0.0213	0.0000
	5	0.9718	0.9606	15.0192	**-0.5908**	**-0.6537**	**1.5956**	-0.0227	0.0000
	6	0.9551	0.9352	21.3002	-1.2010	0.0325	**1.5749**	-0.0555	0.0000
	7	0.9497	0.9274	18.5200	-1.0445	0.0625	**1.6877**	-0.0471	0.0000
	8	0.9474	0.9240	14.3435	-0.7774	0.0113	**1.7180**	-0.0425	0.0000
	9	0.9316	0.9012	7.3149	-0.2626	-0.2609	**1.9588**	-0.0374	0.0000

TABLE 9.2.8 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combination of months in the Namaqualand area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P< 0.05$) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY-JULY	0	0.8372	0.8046	39.1059	**-2.4729**	**-0.8629**	**-1.6171**	-0.1037	0.0000
	1	0.8504	0.8189	17.6053	-0.9372	**-2.4271**	**-1.1713**	-0.0794	0.0000
	2	0.8392	0.8035	9.0068	-0.3604	**-2.5837**	**-1.3074**	-0.0595	0.0000
	3	0.9098	0.8885	17.3622	-0.9555	**-2.0898**	**-1.2357**	-0.0297	0.0000
	4	0.8972	0.8714	13.1880	-0.6701	**-2.2461**	-0.8927	-0.0010	0.0000
	5	0.8449	0.8036	16.9467	-0.9588	**-1.7230**	-0.5553	-0.0562	0.0000
	6	0.8454	0.8012	9.0396	-0.4106	**-1.9944**	-0.0675	-0.0324	0.0000
	7	0.7277	0.6499	8.0863	-0.3904	**-1.5337**	-0.4517	-0.0219	0.0007
	8	0.8077	0.7486	-5.5168	0.5424	**-1.9721**	-0.4275	-0.0399	0.0003
	9	0.8323	0.7764	-4.5052	0.4448	**-1.6366**	-0.5385	-0.0342	0.0001
DECEMBER-FEBRUARY	0	0.8030	0.7593	-11.6948	1.3644	**-1.7586**	-0.2822	-0.1751	0.0000
	1	0.9325	0.9166	16.3154	-0.5174	**-1.0933**	1.4058	-0.0414	0.0000
	2	0.9679	0.9598	17.0683	-0.5905	**-1.0484**	**1.1579**	-0.0006	0.0000
	3	0.9811	0.9761	26.8404	-1.3262	**-0.6017**	**1.5092**	-0.0287	0.0000
	4	0.9794	0.9735	18.3064	-0.7335	**-0.8702**	**1.5330**	-0.0050	0.0000
	5	0.9870	0.9829	5.9463	0.1128	**-1.2014**	**1.6098**	**-0.0514**	0.0000
	6	0.9859	0.9813	12.2372	-0.3414	**-0.9536**	**2.4050**	-0.0375	0.0000
	7	0.9705	0.9607	10.5637	-0.2839	**-0.8346**	**2.3133**	-0.0264	0.0000
	8	0.9647	0.9529	6.2558	-0.0325	**-0.8358**	**2.1082**	-0.0193	0.0000
	9	0.9283	0.9043	5.0844	0.0256	**-0.8370**	**1.7839**	0.0465	0.0000
MARCH-APRIL	0	0.9424	0.9303	37.3313	**-1.9510**	**-1.1532**	**2.5560**	0.0465	0.0000
	1	0.9775	0.9725	11.5936	-0.1662	**-1.7521**	**1.4850**	0.0223	0.0000
	2	0.9630	0.9543	6.3708	0.1758	**-1.8389**	**1.4429**	0.0093	0.0000
	3	0.9600	0.9500	10.9370	-0.2094	**-1.5115**	**1.4119**	-0.0351	0.0000
	4	0.9694	0.9613	6.5835	0.0810	**-1.6332**	**1.7677**	-0.0135	0.0000
	5	0.9646	0.9545	2.4049	0.3826	**-1.8605**	**2.5210**	-0.0181	0.0000
	6	0.9485	0.9326	2.2276	0.4143	**-2.0462**	**3.6185**	-0.0170	0.0000
	7	0.8802	0.8433	-1.6613	0.6184	**-1.8748**	**2.8610**	0.0223	0.0000
	8	0.8785	0.8380	4.6529	0.1450	**-1.6533**	**3.4177**	0.0263	0.0000
	9	0.8721	0.8255	12.9348	-0.4771	**-1.3100**	**3.6057**	0.0429	0.0001
AUGUST-NOVEMBER	0	0.9065	0.8868	-43.3948	**3.8621**	**-3.0955**	1.1122	-0.0181	0.0000
	1	0.9004	0.8783	-46.7559	**4.0045**	**-2.9421**	-0.0919	-0.0684	0.0000
	2	0.9471	0.9347	-44.3419	**3.8703**	**-2.9797**	0.8628	-0.0560	0.0000
	3	0.9611	0.9514	-29.8586	**2.8076**	**-2.6276**	**1.1757**	-0.0407	0.0000
	4	0.9506	0.9375	-23.5137	2.3008	**-2.3534**	1.1766	-0.0668	0.0000
	5	0.9377	0.9199	-25.4722	2.3755	**-2.2059**	0.7482	-0.0449	0.0000
	6	0.9486	0.9328	-20.6312	1.8883	**-1.7127**	-0.2380	**-0.1004**	0.0000
	7	0.9281	0.9060	-46.6079	**3.8134**	**-2.3602**	0.6712	**-0.0777**	0.0000
	8	0.9250	0.9000	-39.8288	**3.2667**	**-2.0379**	0.6585	**-0.0917**	0.0000
	9	0.8691	0.8215	-27.6671	2.3465	**-1.6461**	0.8084	-0.0686	0.0001
OCTOBER-APRIL	0	0.9538	0.9454	49.9730	**-2.8664**	-0.3623	**3.4258**	0.0644	0.0000
	1	0.9532	0.9443	16.0393	-0.4390	**-1.4430**	**2.1205**	0.0068	0.0000
	2	0.9594	0.9513	12.7912	-0.2518	**-1.4340**	**1.6743**	-0.0002	0.0000
	3	0.9711	0.9650	19.1631	-0.7876	**-1.0161**	**1.5248**	-0.0538	0.0000
	4	0.9598	0.9509	13.6358	-0.4226	**-1.1117**	**1.5256**	-0.0501	0.0000
	5	0.9589	0.9492	-3.5222	0.7926	**-1.6211**	**1.3361**	**-0.0944**	0.0000
	6	0.9463	0.9329	-8.1652	1.1375	**-1.8190**	**1.9890**	-0.0657	0.0000
	7	0.9435	0.9284	2.3363	0.4077	**-1.5771**	**3.5922**	-0.0352	0.0000
	8	0.9649	0.9549	6.0051	0.1552	**-1.5141**	**4.4564**	0.0004	0.0000
	9	0.9716	0.9629	14.5502	-0.4656	**-1.2432**	**4.9888**	**0.0642**	0.0000

TABLE 9.2.9 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus monthly sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the south western Cape area. Adj.R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P<0.05$) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JANUARY	0	0.5970	0.4504	-18.4504	1.4398	**-0.9086**	1.7757	-0.0179	0.0289
	1	0.7742	0.6838	3.9177	0.1421	**-0.9936**	0.4797	0.0283	0.0029
	2	0.7317	0.6125	15.9503	-0.6453	**-0.7712**	-0.3166	-0.0061	0.0115
	3	0.7357	0.6182	7.6121	-0.2354	**-0.5338**	0.3426	-0.0190	0.0108
	4	0.8631	0.8022	7.2374	-0.1933	**-0.6066**	**1.0745**	-0.0003	0.0006
	5	0.8359	0.7538	12.8562	-0.5055	**-0.6776**	1.1043	0.0238	0.0032
	6	0.8090	0.6998	20.3402	-0.9755	**-0.5999**	1.0796	**0.0773**	0.0117
	7	0.7193	0.5322	37.2537	-2.0659	-0.3275	0.4033	0.0813	0.0698
	8	0.5924	0.2664	46.4930	-2.5627	-0.4912	0.7498	0.1085	0.2631
	9	0.2887	0.0000	-12.1563	0.8043	-0.1899	-0.3007	-0.0042	0.7981
FEBRUARY	0	0.4168	0.2047	4.6038	-0.0323	-0.6512	1.2587	-0.0420	0.1697
	1	0.6028	0.4439	9.4074	-0.2496	-0.8087	0.2014	0.0203	0.0397
	2	0.4118	0.1504	11.1711	-0.4472	-0.5115	-0.2926	0.0099	0.2619
	3	0.4698	0.2342	10.6428	-0.5221	-0.1958	-0.3970	-0.0066	0.1792
	4	0.8425	0.7725	16.9172	**-0.8156**	**-0.4635**	-0.3492	0.0139	0.0012
	5	0.6504	0.4756	17.8636	-0.8607	-0.5243	-0.1792	0.0006	0.0538
	6	0.2974	0.0000	10.9667	-0.5525	-0.2144	-0.1844	0.0519	0.5934
	7	0.7568	0.5947	20.4740	**-1.0277**	-0.5655	0.5538	0.0283	0.0470
	8	0.6729	0.4112	32.8764	**-1.6961**	-0.8129	0.6027	0.0374	0.1641
	9	0.7815	0.5631	35.4767	-1.6714	**-1.4812**	**1.9710**	0.0406	0.1223
MARCH	0	0.5728	0.4175	16.6871	-0.8826	-0.3230	0.1148	-0.0246	0.0386
	1	0.6493	0.5090	1.7232	0.1930	**-0.8908**	0.4674	-0.0263	0.0225
	2	0.4420	0.1940	5.6336	-0.1528	-0.5572	0.3458	-0.0309	0.2165
	3	0.5658	0.3728	4.7773	-0.1968	-0.1659	-0.1066	-0.0330	0.0831
	4	0.5759	0.3638	5.6526	-0.2679	-0.1108	-0.1845	-0.0116	0.1069
	5	0.8230	0.7219	-1.5463	0.1951	-0.1309	-0.3562	-0.0429	0.0090
	6	0.9394	0.8990	-2.1867	**0.4301**	**-1.1062**	**1.2133**	0.0543	0.0008
	7	0.2456	0.0000	1.9895	-0.0508	-0.1181	-0.1107	0.0095	0.7978
	8	0.3900	0.0000	8.9433	-0.4311	-0.2295	-0.5769	0.0011	0.5740
	9	0.6933	0.3867	13.6180	-0.6019	-0.6738	-0.4916	0.0820	0.2244
APRIL	0	0.6403	0.4964	16.2994	-0.8313	-0.7772	0.5215	-0.0129	0.0253
	1	0.7947	0.7035	-2.2208	0.3525	**-1.0861**	**2.2144**	0.0655	0.0037
	2	0.7874	0.6811	-1.6388	0.2744	**-0.8907**	**2.0774**	0.0624	0.0085
	3	0.7779	0.6668	-0.1863	0.0979	-0.4447	**1.5833**	0.0388	0.0100
	4	0.8396	0.7479	-1.6643	0.1946	-0.5100	**1.7730**	0.0514	0.0065
	5	0.7570	0.5950	-3.1597	0.1572	0.1833	1.3788	0.0184	0.0469
	6	0.7112	0.4801	0.8117	0.0502	-0.5129	1.0603	**0.1064**	0.1246
	7	0.2592	0.0000	0.8251	-0.0441	0.0916	0.1736	0.0126	0.8333
	8	0.4642	0.0000	2.8076	-0.2376	0.2732	0.8258	0.0255	0.5537
	9	0.9640	0.9159	6.9311	**-0.5882**	**0.6114**	**1.1629**	0.0489	0.0167

TABLE 9.2.9.:(continued)

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY	0	0.5580	0.3973	12.0094	-0.7049	0.0205	-0.1252	-0.0071	0.0456
	1	0.6563	0.5188	21.5222	-1.2509	-0.5196	1.1606	-0.0177	0.0205
	2	0.6347	0.4724	14.9978	-0.8982	-0.1328	0.0875	-0.0151	0.0415
	3	0.7591	0.6387	18.1226	-1.0678	-0.6669	0.5751	-0.0223	0.0136
	4	0.6973	0.5243	7.9393	-0.5281	0.5461	-0.9494	0.0009	0.0525
	5	0.8563	0.7604	14.0493	-0.8566	0.1596	0.3040	-0.0254	0.0106
	6	0.8070	0.6527	13.0908	-0.8075	0.2211	0.2146	0.0336	0.0494
	7	0.6869	0.3737	5.0792	-0.2560	-0.3380	0.5917	0.0131	0.2328
	8	0.5851	0.1703	18.9669	-1.1986	0.0937	0.0733	0.0523	0.3735
	9	0.7996	0.5325	25.0156	-1.6322	0.2358	-0.7996	0.0265	0.1973
JUNE	0	0.5149	0.3531	13.9561	-0.8358	-0.0541	0.0686	0.0023	0.0533
	1	0.7171	0.6142	8.6601	-0.4468	-0.0653	0.6788	-0.0254	0.0048
	2	0.6702	0.5383	12.7560	-0.7424	0.0688	0.3576	-0.0146	0.0170
	3	0.7019	0.5694	18.3836	-1.1433	0.1598	-0.0041	0.0012	0.0179
	4	0.7345	0.6017	19.0149	-1.2228	-0.3194	-0.1526	0.0095	0.0196
	5	0.8745	0.8028	25.5650	-1.6436	-0.0608	-0.1796	-0.0084	0.0028
	6	0.8770	0.7949	26.6804	-1.7154	0.0847	-0.1590	0.0335	0.0068
	7	0.8288	0.6918	-10.9076	0.7847	-0.2579	0.7060	0.0242	0.0373
	8	0.6665	0.3330	-12.6598	0.9030	-0.5503	1.0408	0.0429	0.2595
	9	0.8542	0.6599	34.8078	-2.3392	-1.0101	-0.5567	0.0458	0.1270
JULY	0	0.8848	0.8494	5.6733	-0.3446	1.2706	-0.4857	-0.0008	0.0000
	1	0.8312	0.7749	10.0065	-0.6250	0.9161	-0.2295	-0.0086	0.0001
	2	0.7396	0.6449	13.4932	-0.8520	0.6088	-0.0024	0.0012	0.0031
	3	0.6724	0.5414	13.8376	-0.9150	0.1148	-0.4363	-0.0012	0.0164
	4	0.6903	0.5526	16.5743	-1.0842	0.1240	-0.1653	0.0031	0.0210
	5	0.8658	0.7986	22.2616	-1.4607	0.0743	-0.0474	-0.0100	0.0014
	6	0.7418	0.5942	24.7094	-1.6357	0.0824	-0.0944	0.0170	0.0315
	7	0.8063	0.6771	-18.9604	1.3178	0.6917	0.1670	0.0367	0.0249
	8	0.7007	0.4613	-33.0821	2.2394	1.0933	-0.1513	0.0292	0.1348
	9	0.9438	0.8877	-40.2046	2.6736	1.4902	-0.6701	0.0155	0.0091
AUGUST	0	0.9181	0.8929	38.2426	-2.5034	-0.6555	-0.2170	0.0330	0.0000
	1	0.8889	0.8518	36.6952	-2.4028	-0.5887	-0.0772	0.0097	0.0000
	2	0.7374	0.6419	30.3635	-1.9322	-0.7989	0.3675	0.0302	0.0032
	3	0.6760	0.5464	21.1531	-1.4259	0.0423	-0.2777	0.0306	0.0156
	4	0.7886	0.6947	16.7816	-1.2285	0.7420	-0.8241	0.0104	0.0042
	5	0.9127	0.8691	31.2384	-2.0486	-0.4211	0.3105	0.0091	0.0003
	6	0.6459	0.4435	33.5525	-2.3451	0.5059	-0.4082	0.0087	0.0862
	7	0.4991	0.1652	8.8258	-0.6313	0.3337	-0.3656	0.0720	0.3138
	8	0.3917	0.0000	-25.3431	1.7689	-0.1042	-0.3135	-0.0057	0.5712
	9	0.7433	0.4866	-34.0160	2.2950	0.2894	-0.8102	0.0187	0.1639

TABLE 9.2.9.: (continued)

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
SEPTEMBER	0	0.6765	0.5687	9.5851	-0.4537	-0.8031	-0.7440	0.0434	0.0058
	1	0.7601	0.6729	25.1744	-1.4970	-0.9203	-0.6502	0.0535	0.0020
	2	0.6393	0.4950	42.4384	-2.7421	-0.5133	-0.1066	0.0703	0.0256
	3	0.6664	0.5182	17.7266	-1.0362	-0.6239	-0.0289	0.0071	0.0286
	4	0.6634	0.5138	48.6423	-3.2728	-0.0064	0.0643	0.0398	0.0297
	5	0.8455	0.7682	29.8693	-1.9781	-0.2416	-0.6665	-0.0053	0.0025
	6	0.5275	0.2575	0.3074	0.0605	-0.4166	-0.8936	-0.0410	0.2064
	7	0.6314	0.3857	5.1440	-0.3179	-0.1134	-0.4726	0.0633	0.1449
	8	0.4940	0.0892	-37.0036	2.5750	-0.3356	-1.0983	-0.0451	0.4071
	9	0.2653	0.0000	-21.3524	1.4623	-0.1076	-0.9651	0.0049	0.8262
OCTOBER	0	0.6564	0.5419	1.3961	0.0297	-0.3290	-1.4207	0.0170	0.0081
	1	0.6670	0.5459	37.0679	-2.3523	-0.2253	-0.8961	0.0498	0.0110
	2	0.4392	0.2149	77.2364	-5.1176	0.1755	-0.9398	0.0584	0.1773
	3	0.6757	0.5315	-5.4233	0.4822	-0.3394	-0.0468	-0.0034	0.0255
	4	0.6061	0.4310	52.2720	-3.4694	0.1389	-0.9756	0.0303	0.0563
	5	0.5878	0.3818	9.1978	-0.6430	0.1720	-1.4140	-0.0287	0.0967
	6	0.2074	0.0000	-40.3012	2.7330	-0.1847	-0.5581	-0.0373	0.7650
	7	0.6660	0.4434	32.8980	-2.1700	0.0938	-0.0937	0.0994	0.1117
	8	0.3014	0.0000	-69.6795	4.7592	-0.4598	0.3530	-0.0008	0.7152
	9	0.3209	0.0000	-81.8985	5.5570	-0.4686	-0.1828	-0.0635	0.7572
NOVEMBER	0	0.8709	0.8279	10.1741	-0.2690	-0.9779	0.4042	-0.0779	0.0000
	1	0.8695	0.8221	44.1629	-2.6267	-0.3932	0.8024	0.0563	0.0001
	2	0.7796	0.6915	35.3473	-2.0662	-0.4044	0.4373	0.0344	0.0025
	3	0.8481	0.7806	3.5745	-0.0519	-0.4131	0.1718	-0.0135	0.0010
	4	0.7932	0.7012	22.3824	-1.1909	-0.5801	-0.1344	0.0074	0.0038
	5	0.4621	0.1932	8.0818	-0.4093	-0.2271	0.3288	-0.0151	0.2384
	6	0.4711	0.1689	22.3193	-1.3656	-0.0746	0.4410	0.0381	0.2850
	7	0.7579	0.5965	39.0272	-2.4413	-0.0302	0.2866	0.1282	0.0465
	8	0.4296	0.0000	47.5998	-2.9062	-0.2805	0.1468	0.1129	0.5097
	9	0.3801	0.0000	-30.5067	2.0885	-0.3941	-0.1193	-0.0772	0.6764
DECEMBER	0	0.6037	0.4596	34.1159	-1.5679	-1.2641	1.9516	0.0346	0.0266
	1	0.5542	0.3921	17.7213	-0.7386	-0.7920	1.5065	0.0112	0.0476
	2	0.5179	0.3251	43.3322	-2.2895	-0.8546	1.0381	0.0694	0.0935
	3	0.6352	0.4730	24.9583	-1.2177	-0.7367	1.0691	0.0541	0.0413
	4	0.6247	0.4370	8.8858	-0.3023	-0.5841	0.7441	0.0065	0.0694
	5	0.9187	0.8780	14.2117	-0.6173	-0.5784	1.3279	0.0511	0.0002
	6	0.6122	0.3906	33.2847	-1.7168	-0.7865	1.1888	0.1115	0.1142
	7	0.6710	0.4516	15.8543	-0.8204	-0.4060	-0.6288	0.0425	0.1073
	8	0.3595	0.0000	27.3633	-1.4475	-0.6175	-0.2896	0.0286	0.6235
	9	0.6157	0.2314	-3.8231	0.3932	-0.5105	-0.9782	-0.0509	0.3295

TABLE 9.2.10 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combinations of months in the south western Cape area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P<0.05$) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY-JULY	0	0.5373	0.4051	8.6154	-0.4599	0.6520	0.4407	-0.0109	0.0216
	1	0.6271	0.5123	7.0528	-0.4120	1.2924	-0.2625	-0.0032	0.0083
	2	0.7662	0.6883	7.1094	-0.5559	3.0381	-2.3188	0.0077	0.0009
	3	0.7251	0.6251	13.1667	**-0.9334**	2.0904	-1.8934	0.0017	0.0041
	4	0.7261	0.6165	15.8119	**-1.0745**	1.2190	-1.2768	0.0025	0.0071
	5	0.9112	0.8718	16.9437	**-1.0904**	0.6184	-0.3221	-0.0213	0.0001
	6	0.8653	0.7980	19.8607	**-1.2525**	0.1415	0.2302	0.0215	0.0015
	7	0.5309	0.2628	8.8889	-0.6196	1.3860	-1.0281	0.0459	0.2021
	8	0.4090	0.0149	18.2194	-1.2112	0.3482	-0.6193	0.0505	0.4598
	9	0.6673	0.4011	27.7630	-1.8946	0.2888	-1.5159	0.0073	0.1704
DECEMBER-FEBRUARY	0	0.6984	0.5978	15.3723	-0.4307	**-1.3469**	-1.7850	-0.0187	0.0039
	1	0.8987	0.8619	26.5029	**-0.9632**	**-1.7766**	-0.8818	0.0155	0.0000
	2	0.8113	0.7358	32.3660	**-1.5347**	**-1.1023**	-1.5363	0.0021	0.0012
	3	0.7667	0.6630	16.8861	-0.7264	**-0.7544**	-0.3421	-0.0222	0.0064
	4	0.8579	0.7948	9.4645	-0.2668	**-0.8216**	**1.6368**	0.0122	0.0007
	5	0.7062	0.5594	23.5798	-1.1155	**-0.8174**	-0.0684	0.0170	0.0285
	6	0.5775	0.3361	23.9316	-1.2251	-0.5545	0.1889	0.0776	0.1481
	7	0.8155	0.6925	34.0167	**-1.8525**	**-0.4947**	1.2233	**0.0800**	0.0216
	8	0.5916	0.2648	46.7560	-2.5158	-0.8231	1.7601	0.1008	0.2643
	9	0.5221	0.0443	11.0071	-0.3579	-0.8883	3.1178	0.0824	0.4668
MARCH-APRIL	0	0.6391	0.5078	24.0981	**-1.2955**	-0.7961	0.8863	-0.0077	0.0166
	1	0.7040	0.5856	10.0080	-0.2305	**-1.5034**	0.8376	-0.0118	0.0103
	2	0.5148	0.2991	10.2535	-0.4002	-0.8906	0.6358	-0.0142	0.1281
	3	0.5526	0.3537	9.3047	-0.4415	-0.3857	-0.0838	-0.0297	0.0935
	4	0.5987	0.3981	7.5588	-0.2787	-0.6457	0.1121	-0.0147	0.0880
	5	0.7362	0.5854	3.0571	-0.0047	-0.4787	-0.6200	-0.0540	0.0337
	6	0.9448	0.9080	-0.2709	0.3026	**-1.0815**	0.4901	**0.0662**	0.0006
	7	0.3367	0.0000	4.9344	-0.1776	-0.2745	-0.7359	0.0149	0.6599
	8	0.2267	0.0000	10.0784	-0.5346	-0.2732	-0.1690	0.0062	0.8239
	9	0.3682	0.0000	12.9758	-0.6934	-0.4174	0.0091	0.0464	0.6932
AUGUST-NOVEMBER	0	0.8659	0.8276	14.1041	-0.2357	**-2.4023**	**4.0945**	0.0629	0.0000
	1	0.9345	0.9143	43.4259	**-2.3905**	**-1.7229**	**2.2756**	**0.0735**	0.0000
	2	0.9062	0.8749	5.3295	0.2080	**-1.8946**	**3.6236**	**0.0696**	0.0000
	3	0.7904	0.7142	10.4074	-0.2537	**-1.4430**	**2.9245**	0.0563	0.0010
	4	0.7871	0.7019	27.8719	-1.5566	**-0.9274**	**2.0380**	0.0543	0.0022
	5	0.7765	0.6771	45.3978	**-2.7886**	**-0.6795**	1.7396	0.0423	0.0000
	6	0.4991	0.2487	24.8742	-1.3987	-0.7918	1.9134	0.0272	0.1886
	7	0.6616	0.4682	-6.1283	0.5549	-0.4740	0.4924	**0.0972**	0.0748
	8	0.3048	0.0000	-22.6178	1.5120	-0.0134	-1.0159	-0.0002	0.6432
	9	0.6340	0.3412	-22.9125	1.4188	0.3166	-2.5732	-0.0267	0.2095
OCTOBER-APRIL	0	0.9740	0.9660	11.0997	-0.0704	**-1.9387**	**0.8572**	0.0095	0.0000
	1	0.9611	0.9481	-1.1996	0.6665	**-1.7870**	**-1.0995**	0.0010	0.0000
	2	0.8485	0.7935	6.6417	0.0202	**-1.2167**	-2.0459	-0.0223	0.0002
	3	0.7741	0.6837	12.0251	-0.4356	**-0.8030**	-2.4238	-0.0491	0.0029
	4	0.6949	0.5593	16.3081	-0.8326	**-0.5391**	1.1437	0.0168	0.0197
	5	0.7709	0.6563	8.8724	-0.2307	**-0.7655**	**-4.4926**	-0.0835	0.0113
	6	0.7279	0.5724	8.9161	-0.3403	**-0.5762**	-1.1472	0.0649	0.0373
	7	0.6965	0.4941	20.1278	-1.2553	-0.0544	3.4355	**0.1237**	0.0864
	8	0.4939	0.0890	26.7696	-1.6479	-0.1795	4.3051	0.1346	0.4072
	9	0.7999	0.5998	35.6623	-2.1740	-0.4031	6.5139	**0.2406**	0.1041

TABLE 9.2.11 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) in the Agulhas Bank area. Adj.R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
JANUARY	0	0.6381	0.5691	104.7393	**-4.8278**	-2.7136	0.6424	-0.0865	0.0002
	1	0.5890	0.5068	100.2860	**-4.7216**	-1.9108	0.4151	-0.0770	0.0009
	2	0.6473	0.5731	104.7740	**-4.7226**	**-3.6550**	1.3788	-0.0916	0.0004
	3	0.6942	0.6262	116.3507	**-5.3280**	**-3.5879**	**1.4618**	-0.0746	0.0002
	4	0.7253	0.6606	131.1541	**-6.1138**	**-3.3909**	**1.3991**	-0.0505	0.0001
	5	0.7584	0.6979	145.7526	**-6.9269**	**-2.9129**	**1.1283**	-0.0493	0.0001
	6	0.7314	0.6597	120.4898	**-5.7661**	-2.0980	0.8577	-0.0576	0.0003
	7	0.7691	0.7076	113.0830	**-5.4137**	-1.9840	0.7510	-0.0593	0.0001
	8	0.8350	0.7878	106.9511	**-5.1024**	**-2.0252**	**0.7172**	**-0.0534**	0.0000
	9	0.7055	0.6149	99.7035	**-4.7912**	-1.6501	0.4110	-0.0467	0.0020
FEBRUARY	0	0.7696	0.7257	81.9002	**-4.3335**	2.2568	**-0.8712**	0.0297	0.0000
	1	0.9427	0.9312	45.1505	**-2.4021**	**1.8513**	**-1.4879**	-0.0022	0.0000
	2	0.9578	0.9489	37.9234	**-1.8704**	0.5451	**-1.2221**	-0.0342	0.0000
	3	0.9575	0.9480	33.6987	**-1.5198**	-0.5564	**-0.9512**	**-0.0595**	0.0000
	4	0.9516	0.9402	38.7326	**-1.8397**	-0.1599	**-0.9032**	-0.0413	0.0000
	5	0.9081	0.8852	39.3731	**-1.9519**	0.3420	**-0.8531**	-0.0419	0.0000
	6	0.8994	0.8726	36.9058	**-1.9758**	1.3732	**-0.8846**	-0.0263	0.0000
	7	0.8563	0.8180	42.3542	**-2.1773**	0.7111	**-0.6281**	-0.0324	0.0000
	8	0.8475	0.8039	39.0518	**-1.8759**	-0.3648	-0.3453	-0.0483	0.0000
	9	0.7825	0.7156	36.4833	**-1.8408**	0.2904	-0.3939	-0.0225	0.0003
MARCH	0	0.8667	0.8413	13.8697	-1.0588	**4.2353**	**-1.4749**	-0.0261	0.0000
	1	0.8452	0.8142	-6.3907	-0.0722	**4.7226**	**-1.3198**	-0.0382	0.0000
	2	0.9467	0.9354	26.7622	-1.5866	**3.0687**	**-1.7896**	**-0.0358**	0.0000
	3	0.9496	0.9390	11.6323	-0.8742	**3.5575**	**-1.5734**	**-0.0421**	0.0000
	4	0.9518	0.9411	10.8890	-0.8269	**3.3733**	**-1.4635**	**-0.0398**	0.0000
	5	0.9286	0.9118	-2.6014	-0.1543	**3.4660**	**-1.1885**	**-0.0482**	0.0000
	6	0.9438	0.9297	-6.6168	0.1049	**2.9549**	**-1.0227**	**-0.0582**	0.0000
	7	0.9482	0.9352	0.6937	-0.2786	**2.7938**	**-0.8596**	**-0.0548**	0.0000
	8	0.9505	0.9373	3.5710	-0.3896	**2.3624**	**-0.7488**	**-0.0489**	0.0000
	9	0.9194	0.8964	17.4683	-1.0903	**2.0183**	**-0.6693**	**-0.0316**	0.0000
APRIL	0	0.4525	0.3482	26.9449	-1.3368	-0.6720	0.4588	**-0.1025**	0.0103
	1	0.6626	0.5951	77.1226	**-3.6269**	**-5.9910**	0.4041	-0.0439	0.0001
	2	0.6950	0.6308	74.9763	**-3.4953**	**-5.9943**	-0.3358	-0.0452	0.0001
	3	0.7057	0.6438	69.0773	**-3.1969**	**-5.8859**	0.0387	-0.0507	0.0001
	4	0.6952	0.6275	61.5274	**-2.8292**	**-5.4673**	0.1759	-0.0549	0.0002
	5	0.6657	0.5871	54.1643	**-2.4927**	**-4.8705**	0.4515	-0.0612	0.0006
	6	0.6978	0.6222	29.6318	-1.2216	**-3.7468**	-0.1549	**-0.0714**	0.0005
	7	0.7208	0.6510	24.0492	-0.9919	**-2.8868**	-0.4921	**-0.0779**	0.0002
	8	0.7162	0.6405	27.8097	-1.2325	**-2.7040**	-0.2878	**-0.0680**	0.0005
	9	0.6330	0.5281	27.0566	-1.2724	-2.0886	0.2944	**-0.0622**	0.0049

TABLE 9.2.11 (continued)

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY	0	0.7357	0.6853	-3.2888	0.4941	0.9812	**1.6694**	**-0.0853**	0.0000
	1	0.6866	0.6239	0.0615	0.2774	0.6324	**1.5834**	**-0.0917**	0.0001
	2	0.6118	0.5300	-1.5096	0.3635	-0.1701	**1.6019**	**-0.1059**	0.0009
	3	0.5817	0.4936	1.6091	0.1431	-0.0422	**1.3606**	**-0.1055**	0.0017
	4	0.6058	0.5182	-16.8463	1.2241	0.5691	**1.3237**	**-0.1062**	0.0015
	5	0.5729	0.4724	-15.5129	1.0993	1.2738	0.9839	**-0.0938**	0.0042
	6	0.5024	0.3780	-23.7272	1.5730	0.5294	0.9031	**-0.1003**	0.0189
	7	0.5323	0.4153	-15.5765	1.0622	0.6585	0.7382	**-0.0992**	0.0120
	8	0.5347	0.4106	-20.0303	1.3090	0.2946	0.6235	**-0.0946**	0.0161
	9	0.5332	0.3998	-0.3114	0.0888	0.9121	0.2253	**-0.0753**	0.0229
JUNE	0	0.8522	0.8227	-4.3081	0.5143	**3.5975**	-0.0530	0.0110	0.0000
	1	0.8489	0.8187	-6.0608	0.5511	**3.9110**	-0.4699	0.0090	0.0000
	2	0.8520	0.8209	-23.4414	1.6002	**4.0520**	-0.6544	0.0002	0.0000
	3	0.8718	0.8448	-23.8765	**1.5610**	**4.3023**	-1.0183	-0.0049	0.0000
	4	0.8481	0.8143	-17.5063	1.1710	**3.8769**	-0.8273	-0.0140	0.0000
	5	0.8414	0.8040	-17.5323	1.1578	**3.6318**	-0.8128	-0.0155	0.0000
	6	0.9097	0.8871	-56.7861	**3.6302**	**3.0748**	-0.6022	-0.0114	0.0000
	7	0.9258	0.9073	-46.5268	**2.9882**	**2.7877**	-0.4859	-0.0216	0.0000
	8	0.9203	0.8991	-43.4567	**2.8048**	**2.2433**	-0.2829	-0.0272	0.0000
	9	0.8346	0.7873	-20.3963	1.3694	**1.6667**	-0.0731	**-0.0380**	0.0000
JULY	0	0.8805	0.8566	49.4752	**-2.9918**	**4.1196**	0.2859	-0.0095	0.0000
	1	0.8725	0.8470	51.0477	**-3.0696**	**3.6807**	**0.5381**	-0.0017	0.0000
	2	0.8513	0.8200	36.6319	**-2.1617**	**3.3242**	0.4461	-0.0180	0.0000
	3	0.8077	0.7673	39.0011	**-2.3096**	**2.9056**	0.5859	-0.0207	0.0000
	4	0.9295	0.9139	23.0726	-1.2991	2.7030	**0.4860**	**-0.0300**	0.0000
	5	0.9333	0.9176	28.9690	**-1.6579**	2.2335	**0.7350**	**-0.0121**	0.0000
	6	0.9430	0.9288	-9.2142	0.7572	1.4847	0.3874	-0.0290	0.0000
	7	0.9100	0.8875	0.2203	0.1307	**1.4195**	0.3823	**-0.0450**	0.0000
	8	0.8950	0.8670	-21.2305	1.4697	**0.9727**	0.0987	**-0.0515**	0.0000
	9	0.8715	0.8347	-13.5151	0.9556	**0.8558**	0.0800	**-0.0546**	0.0000
AUGUST	0	0.5435	0.4605	-28.6440	**1.8580**	-0.2552	**-1.0651**	-0.0891	0.0013
	1	0.7816	0.7400	-72.1790	**4.6361**	**0.6516**	**-1.5136**	-0.0500	0.0000
	2	0.8406	0.8087	-76.6911	**4.9305**	**0.4528**	**-1.4986**	-0.0554	0.0000
	3	0.8783	0.8527	-74.9118	**4.8196**	0.4290	**-1.3974**	**-0.0593**	0.0000
	4	0.8749	0.8471	-73.0043	**4.6809**	**0.6497**	**-1.3640**	**-0.0636**	0.0000
	5	0.8164	0.7732	-68.0592	**4.3577**	**0.7961**	**-1.2520**	**-0.0573**	0.0000
	6	0.8690	0.8362	-43.3845	**2.9897**	-0.6750	0.0980	**-0.0481**	0.0000
	7	0.8113	0.7641	-41.0245	**2.7574**	-0.3148	-0.2187	**-0.0651**	0.0000
	8	0.8492	0.8090	-35.4394	**2.3882**	-0.2927	-0.1688	**-0.0601**	0.0000
	9	0.8365	0.7897	-29.7273	**1.9889**	-0.2530	-0.2402	**-0.0593**	0.0000
SEPTEMBER	0	0.2101	0.0665	0.8465	-0.0283	0.4836	-0.7160	-0.1245	0.2472
	1	0.2716	0.1329	6.4040	-0.2885	-1.2245	-0.8298	-0.1363	0.1382
	2	0.3113	0.1736	-32.8260	2.0583	0.8370	-1.4276	-0.0946	0.0987
	3	0.3309	0.1900	-40.0894	2.5658	0.8590	-0.8639	-0.0980	0.0911
	4	0.4350	0.3095	-29.3897	2.0406	-0.9159	-0.2138	**-0.1266**	0.0288
	5	0.5714	0.4706	-46.9745	**3.0940**	-0.4946	-0.9282	-0.0651	0.0044
	6	0.7675	0.7093	-65.7924	**4.2736**	0.3874	-0.6780	-0.0380	0.0001
	7	0.7119	0.6399	-57.3209	**3.6868**	0.5451	-0.8537	-0.0442	0.0003
	8	0.7828	0.7249	-48.2235	**3.0896**	1.0683	-0.3172	-0.0419	0.0002

TABLE 9.2.11 (continued)

MONTH	LAG	R^2	ADJ.R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
OCTOBER	0	0.5332	0.4521	26.0870	**-1.7684**	**2.6357**	0.7867	-0.0261	0.0011
	1	0.5372	0.4530	33.2860	**-2.2008**	**2.5475**	**1.0837**	-0.0378	0.0014
	2	0.4860	0.3881	40.1674	**-2.6402**	**2.5681**	0.9516	-0.0297	0.0056
	3	0.5665	0.4798	24.4932	-1.7413	**3.1562**	**1.2943**	-0.0182	0.0016
	4	0.5986	0.5141	16.4486	-1.2423	**3.0446**	**1.2720**	-0.0263	0.0011
	5	0.5878	0.4962	12.3555	-1.0000	**2.9981**	**1.0759**	-0.0166	0.0022
	6	0.6527	0.5709	-0.6790	-0.2006	**2.9347**	**0.9674**	-0.0243	0.0008
	7	0.6791	0.5989	-21.0984	1.0092	**3.2176**	0.6730	0.0180	0.0007
	8	0.7566	0.6917	-44.2760	2.5234	**2.4681**	**0.7273**	-0.0126	0.0002
	9	0.8015	0.7447	-38.0860	2.2041	**1.8713**	**0.6760**	-0.0321	0.0001
NOVEMBER	0	0.5493	0.4709	31.1137	**-1.3746**	**-2.0472**	**0.5333**	-0.1470	0.0008
	1	0.4855	0.3919	35.5346	-1.7075	-1.5404	0.4226	-0.1309	0.0042
	2	0.4231	0.3132	30.3163	-1.4394	-1.3924	0.3659	-0.1349	0.0169
	3	0.3968	0.2761	27.3678	-1.3086	-1.1923	0.3425	-0.1363	0.0317
	4	0.3742	0.2424	27.7447	-1.3722	-0.9441	0.2104	-0.1306	0.0531
	5	0.3342	0.1862	31.3244	-1.6486	-0.5089	0.2113	-0.1123	0.1030
	6	0.3797	0.2338	30.6954	-1.6765	-0.1417	0.3299	-0.1148	0.0730
	7	0.3595	0.1994	48.7238	-2.7311	-0.0314	0.2407	-0.1029	0.1097
	8	0.4002	0.2402	46.0490	-2.5405	-0.3005	-0.0443	-0.1115	0.0866
	9	0.4478	0.2900	31.7822	-1.7430	-0.2060	-0.0339	**-0.1043**	0.0648
DECEMBER	0	0.5819	0.5023	51.4587	-2.6986	0.9302	**1.1988**	0.0121	0.0008
	1	0.5857	0.5028	9.0195	-0.3494	0.2887	**2.0302**	-0.0040	0.0010
	2	0.6461	0.5754	-3.8216	0.3536	0.0960	**2.2327**	-0.0161	0.0002
	3	0.7040	0.6417	-5.3330	0.4271	0.1006	**2.3238**	-0.0183	0.0001
	4	0.7385	0.6804	6.4050	-0.1758	-0.0925	**2.4122**	-0.0143	0.0000
	5	0.7497	0.6908	22.3916	-1.0252	-0.1587	**2.3572**	-0.0024	0.0001
	6	0.7624	0.7030	44.2146	-2.1432	-0.5424	**2.3154**	-0.0246	0.0001
	7	0.7890	0.7327	-0.4924	0.0399	0.6654	1.3466	-0.0245	0.0001
	8	0.7888	0.7325	40.1798	-2.0220	-0.1124	1.5522	-0.0332	0.0001
	9	0.7092	0.6261	32.0824	-1.6488	0.1433	0.9453	-0.0387	0.0010

TABLE 9.2.12 Multiple regression results of horse mackerel (*Trachurus trachurus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level for combination of months at different lags (years) in the Agulhas Bank area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant ($P<0.05$) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
MAY-JULY	0	0.8985	0.8792	14.2220	-0.4472	**1.6515**	**1.9528**	-0.0019	0.0000
	1	0.9144	0.8973	0.5446	0.1489	**4.9627**	-0.0642	0.0087	0.0000
	2	0.8959	0.8740	-18.1150	1.2067	**5.7916**	-0.7808	-0.0059	0.0000
	3	0.8675	0.8397	-17.7824	1.1569	**5.6615**	-0.8964	-0.0151	0.0000
	4	0.9103	0.8904	-12.2351	0.9774	3.0925	0.5550	-0.0233	0.0000
	5	0.9081	0.8864	-7.5551	0.7478	1.7796	1.1673	-0.0232	0.0000
	6	0.9250	0.9063	-43.5701	**2.8458**	2.6812	0.1293	-0.0299	0.0000
	7	0.9106	0.8883	-35.9143	**2.3269**	2.7930	-0.1014	**-0.0410**	0.0000
	8	0.8984	0.8713	-41.6717	**2.6198**	**2.8780**	-0.5077	**-0.0444**	0.0000
	9	0.8491	0.8060	-24.8205	1.5487	2.7275	-0.5848	**-0.0476**	0.0000
DECEMBER-FEBRUARY	0	0.7763	0.7337	78.2746	**-4.4321**	**3.8801**	**-3.0388**	0.0067	0.0000
	1	0.8177	0.7813	57.1675	**-3.2319**	**3.0098**	**-3.6229**	-0.0508	0.0000
	2	0.7745	0.7270	62.1080	**-3.4684**	**2.7935**	**-3.2258**	-0.0506	0.0000
	3	0.7529	0.6980	63.0667	**-3.5064**	**2.6301**	**-2.7563**	-0.0444	0.0000
	4	0.7386	0.6770	63.0437	**-3.5432**	**2.8342**	**-2.4410**	-0.0258	0.0001
	5	0.7536	0.6921	47.6975	-2.7827	**2.9859**	**-2.3218**	-0.0381	0.0001
	6	0.7777	0.7184	16.8804	-1.3105	**3.7685**	**-2.2193**	-0.0307	0.0001
	7	0.7677	0.7058	41.4457	-2.4111	2.4733	**-1.5865**	-0.0365	0.0001
	8	0.7765	0.7127	57.5249	-3.0818	1.2518	**-1.1204**	-0.0426	0.0002
	9	0.7558	0.6806	47.0914	-2.5681	1.3833	**-1.1945**	-0.0295	0.0006
MARCH-APRIL	0	0.6606	0.5959	29.9838	**-1.8851**	**4.1587**	**-1.9079**	-0.0609	0.000?
	1	0.6073	0.5287	-4.4192	-0.2717	**6.3089**	**-1.8956**	**-0.0776**	0.0006
	2	0.7332	0.6770	20.2075	-1.3626	**4.3738**	**-2.6424**	**-0.0692**	0.0000
	3	0.6994	0.6361	9.6564	-0.8516	**4.7024**	**-2.3311**	**-0.0766**	0.0001
	4	0.7239	0.6625	7.6376	-0.6489	3.8020	**-2.3521**	**-0.0803**	0.0001
	5	0.7169	0.6503	-14.8991	0.5191	4.0859	**-2.0804**	**-0.0924**	0.0002
	6	0.7987	0.7484	-29.1970	1.3831	**3.2114**	**-2.0986**	**-0.0986**	0.0000
	7	0.8404	0.8005	-23.2164	1.0317	**3.3085**	**-1.8426**	**-0.0955**	0.0000
	8	0.8345	0.7903	-19.6487	0.8697	**2.8432**	**-1.5454**	**-0.0855**	0.0000
AUGUST-NOVEMBER	0	0.5037	0.4174	-30.6096	**2.2548**	**-3.8634**	**-2.1856**	**-0.1665**	0.0022
	1	0.6562	0.5936	-58.7578	**4.1590**	**-3.6714**	0.6607	**-0.1679**	0.0001
	2	0.6530	0.5869	-58.5505	**4.1142**	**-3.2365**	0.9333	**-0.1565**	0.0001
	3	0.6418	0.5702	-55.7559	**3.8941**	-2.7794	1.0265	**-0.1518**	0.0003
	4	0.6416	0.5662	-51.3379	**3.5767**	-2.3107	1.2107	**-0.1486**	0.0004
	5	0.5718	0.4766	-45.8261	**3.1622**	-1.7560	1.0451	**-0.1316**	0.0030
	6	0.4971	0.3787	-38.7744	2.6501	-1.2042	0.8763	**-0.1398**	0.0152
	7	0.4887	0.3609	-51.8031	**3.3658**	-0.6194	0.2782	**-0.0960**	0.0229
	8	0.6421	0.5466	-56.6427	**3.6240**	-0.1115	0.4124	**-0.0838**	0.0026
	9	0.6833	0.5928	-45.1898	**2.8921**	0.2480	0.7531	**-0.0755**	0.0018
OCTOBER-APRIL	0	0.7644	0.7234	64.4794	**-3.7205**	**3.1681**	**-4.9039**	-0.0093	0.0000
	1	0.9002	0.8821	81.3603	**-4.5875**	**3.0477**	**-7.7888**	-0.0184	0.0000
	2	0.9003	0.8813	77.5710	**-4.4151**	**3.1915**	**-7.4169**	-0.0210	0.0000
	3	0.8940	0.8727	74.7457	**-4.2874**	**3.2537**	**-6.8286**	-0.0119	0.0000
	4	0.8635	0.8347	68.0388	**-3.9670**	**3.4314**	**-6.0055**	-0.0121	0.0000
	5	0.8347	0.7979	56.5195	**-3.3650**	**3.4532**	**-5.1996**	-0.0111	0.0000
	6	0.8765	0.8475	38.1200	**-2.4956**	**4.3839**	**-4.9902**	0.0099	0.0000
	7	0.9134	0.8917	21.2287	-1.5177	**3.7787**	**-4.3204**	-0.0130	0.0000
	8	0.9117	0.8882	21.1724	-1.4299	**2.9810**	**-3.5784**	-0.0204	0.0000
	9	0.8874	0.8552	41.3640	-2.4688	**2.4046**	**-2.0071**	-0.0113	0.0000

TABLE 9.2.13 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
NOVEMBER	0	0.6826	0.6120	12.7128	-0.8898	0.8316	1.8960	-0.0998	0.0002
	1	0.6354	0.5544	61.8982	-4.9369	3.3591	-0.2393	-0.0806	0.0008
	2	0.8510	0.8159	65.1440	-4.8558	2.5409	1.2888	-0.0578	0.0000
	3	0.8917	0.8646	35.3395	-2.1005	0.1080	3.6892	0.0425	0.0000
	4	0.8838	0.8529	9.6058	0.2852	-2.0154	5.3875	0.0365	0.0000
	5	0.8520	0.8097	46.8108	-2.6577	-0.4444	3.7279	0.0070	0.0000
	6	0.8861	0.8511	74.8218	-4.9186	0.8738	1.2171	-0.0195	0.0000
	7	0.8433	0.7950	108.0360	-7.5629	2.2904	0.1969	-0.0384	0.0000
	8	0.8586	0.8115	61.1897	-3.5541	-0.6102	2.2492	0.1342	0.0000
	9	0.8819	0.8389	70.4659	-4.2702	-0.3135	1.7314	0.1979	0.0000
DECEMBER	0	0.8603	0.8173	-25.7900	2.4085	-1.7033	2.3575	0.0580	0.0000
	1	0.8787	0.8414	-24.4205	2.3327	-1.8079	1.4229	0.0652	0.0000
	2	0.8402	0.7910	-32.1546	2.9666	-2.4205	0.2605	-0.0236	0.0000
	3	0.8783	0.8377	-27.3736	2.7277	-2.6572	-0.2169	0.0713	0.0000
	4	0.7894	0.7129	-20.6580	2.4001	-2.8603	1.1303	0.1089	0.0010
	5	0.8539	0.7954	-22.6735	2.7560	-3.7723	-0.4162	0.0682	0.0004
	6	0.8116	0.7278	-5.2286	1.4478	-3.1664	-1.6634	0.0276	0.0025
	7	0.9029	0.8597	25.1656	-1.0081	-1.4271	-2.9833	-0.0144	0.0001
	8	0.9313	0.9077	40.8158	-2.2638	-0.5029	-2.7610	0.0181	0.0000
	9	0.9363	0.9079	37.7875	-1.9273	-0.8566	-0.6438	0.1693	0.0000

TABLE 9.2.14 Multiple regression results of chub mackerel (*Scomber japonicus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combination of months in the Namaqualand area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF	SST	WIND N/S	WIND W/E	SEALEVEL	P<
MAY-JULY	0	0.6403	0.5683	-31.4498	**2.2997**	-0.6878	**-4.1593**	-0.1489	0.0003
	1	0.2943	0.1458	-19.6861	1.5219	-0.9777	**-3.6373**	-0.1702	0.1383
	2	0.5889	0.4976	-23.2849	1.6624	0.1070	**-6.4008**	-0.1062	0.0023
	3	0.8975	0.8734	19.5392	-1.3141	1.4409	**-7.8190**	0.0287	0.0000
	4	0.8790	0.8488	15.0427	-0.9221	-0.1852	**-7.6406**	0.0736	0.0000
	5	0.8572	0.8191	71.6829	**-4.8249**	1.8209	**-5.7561**	-0.0512	0.0000
	6	0.9214	0.8989	102.0480	**-6.8199**	**1.9920**	**-2.3347**	-0.0544	0.0000
	7	0.8127	0.7592	122.0380	**-8.2055**	2.4873	-1.9505	-0.0496	0.0001
	8	0.8175	0.7613	96.2416	**-6.3285**	0.0648	-1.4057	0.0501	0.0001
	9	0.9097	0.8796	89.4084	**-5.8025**	-1.0602	-0.7616	0.1180	0.0000
DECEMBER-FEBRUARY	0	0.3958	0.2615	-58.3634	4.4942	-3.3654	0.9108	-0.2127	0.0490
	1	0.5819	0.4835	-26.2011	2.4863	-2.0207	3.3543	0.0276	0.0036
	2	0.5895	0.4869	-41.9332	3.7039	**-2.9720**	1.5690	0.2769	0.0046
	3	0.4726	0.3320	-3.7192	1.1005	-2.0855	2.0965	0.3260	0.0374
	4	0.5166	0.3785	25.2581	-0.9416	-1.2997	0.8588	0.3617	0.0284
	5	0.6493	0.5414	-44.1131	3.7019	-3.0474	-5.0661	0.0093	0.0058
	6	0.9354	0.9139	15.2179	0.7290	-0.4057	**-5.7371**	-0.0536	0.0000
	7	0.9333	0.9111	17.4691	-0.8038	-0.5708	**-4.3674**	-0.1444	0.0000
	8	0.8957	0.8609	15.8875	-0.4954	-1.2117	-2.8769	0.0286	0.0000
	9	0.9106	0.8808	45.0030	2.2770	-1.1165	-0.0604	**0.3567**	0.0000
MARCH-APRIL	0	0.7580	0.7071	30.0042	-1.4817	-0.9741	**4.7385**	0.2060	0.0000
	1	0.7653	0.7131	43.6578	-2.2975	-1.2408	**6.5259**	0.2602	0.0000
	2	0.6220	0.5331	30.0789	-1.2112	**-2.1608**	**6.8084**	0.3077	0.0016
	3	0.6413	0.5516	100.4009	**-6.1783**	-0.1886	**7.0954**	0.2424	0.0017
	4	0.7675	0.7055	122.6666	**-7.7088**	0.2924	**6.7210**	0.2229	0.0001
	5	0.7508	0.6795	97.4126	**-5.8886**	-0.5464	5.5287	0.1571	0.0004
	6	0.9513	0.9363	30.4369	-1.8734	1.0216	**-7.9179**	-0.0140	0.0000
	7	0.8663	0.8252	-4.3515	0.6699	-0.3486	**-8.6009**	-0.0286	0.0000
	8	0.8725	0.8300	-4.8864	1.0264	-1.8507	-4.3617	0.1871	0.0000
	9	0.8430	0.7859	30.4389	-1.3200	-1.6551	-1.0174	0.2116	0.0002
AUGUST-NOVEMBER	0	0.7228	0.6645	-159.5330	**12.1220**	**-4.4469**	1.8376	-0.0939	0.0000
	1	0.5441	0.4428	-156.4110	**11.8258**	**-4.2550**	**0.7713**	-0.0320	0.0050
	2	0.7835	0.7325	-145.7210	**11.5332**	**-5.2840**	**6.8650**	0.0478	0.0000
	3	0.8100	0.7625	-94.7464	**8.1841**	**-5.2440**	**10.4849**	0.1613	0.0000
	4	0.8302	0.7850	-22.3485	3.1454	-4.3928	**12.4572**	0.1848	0.0000
	5	0.8412	0.7959	3.1574	1.3413	-4.1459	**11.6067**	0.2786	0.0000
	6	0.8974	0.8658	86.4677	-4.9712	-1.7147	**8.0509**	0.1825	0.0000
	7	0.8073	0.7480	-11.3265	2.2850	-4.4782	**8.4854**	0.0882	0.0001
	8	0.8204	0.7606	-33.6493	3.8167	-4.8803	**6.3662**	0.1054	0.0002
	9	0.8478	0.7924	81.6533	-5.0428	-1.0736	0.7498	0.1934	0.0002
OCTOBER-APRIL	0	0.8548	0.8284	69.9982	**-4.3238**	0.7411	**7.8267**	**0.3651**	0.0000
	1	0.8060	0.7691	61.9406	-3.6210	0.0732	**8.4831**	**0.3795**	0.0000
	2	0.7744	0.7293	54.2978	-2.9459	-0.6147	**8.2355**	**0.4770**	0.0000
	3	0.7314	0.6748	107.2347	-6.7440	0.9923	**9.2099**	**0.4607**	0.0000
	4	0.7725	0.7219	139.9759	**-9.0940**	1.9633	**8.9275**	**0.4779**	0.0000
	5	0.6989	0.6281	90.3430	-5.4220	-0.0122	**7.2081**	0.3003	0.0003
	6	0.7332	0.6665	24.4709	-0.7366	-2.0395	1.9912	0.2647	0.0002
	7	0.7809	0.7225	36.4686	-1.7375	-1.2829	-0.1547	0.2137	0.0001
	8	0.8623	0.8230	39.8581	-1.9797	-1.2300	-0.7671	**0.3179**	0.0000
	9	0.9362	0.9165	50.6518	-2.6534	-1.2699	0.4083	**0.4469**	0.0000

TABLE 9.2.15 Multiple regression results of chub mackerel (*Scomber japonicus*) annual catch versus monthly sea surface temperature (SST), north-south wind vector (N/S), west-east wind vector (W/E) and sea level at different lags (years) in the south western Cape area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	W/E	SEALEVEL	P<
JANUARY	0	0.7629	0.6767	25.6339	-1.1178	-0.6069	4.2349	0.2175	0.0019
	1	0.8440	0.7816	121.3445	**-6.4918**	-1.4907	-1.9082	**0.3257**	0.0005
	2	0.6790	0.5364	145.8443	**-7.8380**	-1.8510	-3.6114	0.2985	0.0244
	3	0.6449	0.4870	142.2308	-7.5563	-2.1242	-3.9337	0.1541	0.0370
	4	0.7721	0.6709	118.0595	-5.6598	**-3.6461**	0.1966	0.0750	0.0059
	5	0.9364	0.9045	114.7015	**-5.0926**	**-4.8717**	0.2479	0.0708	0.0001
	6	0.9404	0.9063	162.5255	**-7.7861**	**-5.3406**	**2.2102**	**0.2509**	0.0002
	7	0.8931	0.8219	221.6429	**-11.4570**	**-4.8462**	5.1656	0.2519	0.0045
	8	0.9524	0.9143	225.8934	**-11.5740**	**-5.3676**	10.6154	0.4886	0.0017
	9	0.6072	0.2145	33.6520	-0.6536	-4.0951	7.6646	0.3793	0.3416
FEBRUARY	0	0.7611	0.6742	64.0873	**-3.3965**	-1.0487	4.2087	0.0016	0.0020
	1	0.7855	0.6997	81.7865	**-3.9841**	-2.3783	2.0908	0.2101	0.0022
	2	0.5803	0.3938	72.2949	-3.5704	-1.9341	1.7258	0.2346	0.0726
	3	0.5650	0.3716	71.7581	-3.4108	-2.3890	1.9491	0.1491	0.0837
	4	0.6825	0.5414	94.1851	-4.5776	-2.9716	1.7260	0.0329	0.0233
	5	0.6234	0.4351	129.6963	**-6.6815**	-2.9378	-0.8649	0.0054	0.0703
	6	0.3797	0.0253	143.1819	-7.8749	-1.6083	-4.2568	0.1880	0.4377
	7	0.8775	0.7958	177.2191	**-9.0225**	**-4.6059**	-0.9383	-0.0607	0.0067
	8	0.9133	0.8438	177.4975	**-8.7610**	**-5.6876**	**0.7841**	0.0202	0.0073
	9	0.8737	0.7474	84.0413	-2.9307	**-6.9004**	**6.8283**	0.0411	0.0438
MARCH	0	0.8925	0.8534	69.1071	**-3.7009**	**-1.4047**	0.4583	0.0249	0.0000
	1	0.9587	0.9422	33.7753	-1.0666	**-3.0155**	**1.2486**	-0.0012	0.0000
	2	0.8246	0.7467	43.9358	-1.8620	**-2.5161**	1.1007	0.0328	0.0019
	3	0.7138	0.5867	57.3000	-3.0813	-1.0099	-0.3814	-0.0397	0.0151
	4	0.7332	0.5999	84.7834	**-4.4612**	-2.6848	1.9030	-0.0584	0.0199
	5	0.7555	0.6158	59.9154	-2.7339	-3.3701	2.1039	-0.2573	0.0263
	6	0.7674	0.6124	35.5303	-0.6483	-5.9885	5.4234	-0.0251	0.0415
	7	0.7789	0.6021	7.6863	1.1874	**-6.4233**	5.6551	-0.1163	0.0677
	8	0.7694	0.5850	15.4198	0.7768	-5.9437	1.1542	0.0273	0.0746
	9	0.7483	0.4967	2.8455	1.5218	-5.9500	1.3814	0.3409	0.1581
APRIL	0	0.8602	0.8043	59.6566	**-3.7052**	0.5595	-0.3278	0.0515	0.0003
	1	0.8671	0.8080	42.8682	-2.4856	-0.7241	2.8840	0.1821	0.0006
	2	0.8183	0.7274	44.6611	-2.5170	-1.2410	3.0173	0.1862	0.0047
	3	0.8679	0.8018	31.0691	-1.8141	-0.8483	5.2416	0.1569	0.0014
	4	0.9038	0.8488	43.7387	-2.3060	-2.8442	**7.1289**	0.1679	0.0012
	5	0.9530	0.9221	41.4603	-2.2078	**-2.9586**	**8.4983**	0.0846	0.0004
	6	0.7237	0.5027	43.3520	-2.1308	-4.0145	8.1729	0.3086	0.1127
	7	0.9319	0.8639	-20.8580	1.9355	**-3.8341**	**8.8472**	0.0670	0.0133
	8	0.7156	0.4311	-35.5048	2.1543	-0.8835	**10.7754**	0.2581	0.1967
	9	0.9532	0.8907	-39.1212	1.8754	1.3105	**11.2344**	**0.3523**	0.0246
MAY	0	0.8082	0.7385	43.6412	**-2.6182**	0.1567	-0.6058	0.0939	0.0006
	1	0.9397	0.9156	82.4828	**-4.8852**	-1.4087	**3.5784**	0.0520	0.0000
	2	0.8568	0.7932	70.6602	**-4.3294**	-0.0670	0.3646	0.0891	0.0008
	3	0.9014	0.8521	101.6297	**-6.1308**	**-3.8572**	1.9824	-0.0493	0.0004
	4	0.8301	0.7330	119.0827	**-7.4320**	-2.7824	-0.7848	-0.1201	0.0079
	5	0.9017	0.8362	126.0056	**-7.8755**	-1.9446	0.3946	**-0.2507**	0.0035
	6	0.8265	0.6876	142.4479	**-9.0932**	0.9603	-0.1575	-0.1492	0.0385
	7	0.5888	0.1776	117.3075	-7.5363	2.1877	0.1231	-0.0085	0.3682
	8	0.7298	0.4596	152.0591	**-9.8414**	3.0559	0.8311	0.2966	0.1796
	9	0.6710	0.2324	159.3425	-10.3173	1.5849	0.2829	0.2345	0.3786

TABLE 9.2.15 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JUNE	0	0.7508	0.6678	53.9157	**-3.4358**	-1.9193	-0.5531	0.1345	0.0013
	1	0.9357	0.9123	38.6499	**-2.2526**	**-2.4122**	**2.0527**	0.0752	0.0000
	2	0.8307	0.7630	39.7203	-2.2995	-1.8071	2.3178	0.0984	0.0007
	3	0.7002	0.5670	55.9235	-3.5200	-2.7794	1.0837	0.1033	0.0184
	4	0.7552	0.6328	66.3461	-4.3057	**-4.1160**	0.6454	0.0136	0.0144
	5	0.8712	0.7975	98.6743	-6.3605	**-3.1689**	0.9302	-0.1380	0.0031
	6	0.9014	0.8357	137.6864	-8.8644	-2.0366	1.1465	-0.0643	0.0035
	7	0.9261	0.8670	22.6445	-1.0413	-1.0470	**5.0292**	-0.0391	0.0049
	8	0.8855	0.7709	37.3588	-2.1064	-2.0615	5.1782	0.2293	0.0363
	9	0.7443	0.4033	226.0093	-15.0551	-2.5644	-2.5212	0.1993	0.2737
JULY	0	0.8867	0.8518	34.5427	**-2.2782**	**2.2824**	**-2.3834**	0.0517	0.0000
	1	0.9254	0.9006	51.4360	**-3.4020**	**2.7216**	**-2.0751**	0.0371	0.0000
	2	0.8267	0.7636	52.6088	**-3.4855**	**2.8652**	-1.7480	0.1274	0.0004
	3	0.9083	0.8716	23.4777	-1.8461	**2.4274**	**-5.8428**	0.0015	0.0000
	4	0.8254	0.7478	64.1740	**-4.5889**	1.5678	**-5.7221**	-0.0874	0.0018
	5	0.9538	0.9307	89.5853	**-6.2177**	**1.9923**	**-4.5400**	**-0.2692**	0.0000
	6	0.9591	0.9358	173.5895	**-11.8078**	1.3249	**-3.1771**	**-0.1714**	0.0001
	7	0.8906	0.8177	27.8242	-1.7518	**4.6489**	0.5990	-0.0406	0.0048
	8	0.8671	0.7608	-75.9696	5.2295	**6.6927**	1.3589	0.2016	0.0204
	9	0.8396	0.6791	-150.1110	10.0330	**8.0281**	-0.6051	0.1603	0.0690
AUGUST	0	0.7892	0.7244	74.9305	**-5.2116**	1.4802	-2.4075	0.1439	0.0002
	1	0.8146	0.7528	104.8873	**-7.2697**	1.3884	-2.4003	0.1146	0.0002
	2	0.7014	0.5928	122.5783	**-8.2232**	-0.4954	-0.5781	0.2289	0.0063
	3	0.7388	0.6343	101.7463	**-7.2131**	1.8547	-3.4937	0.3322	0.0057
	4	0.9015	0.8577	69.2025	**-5.8464**	**7.5477**	**-8.9033**	0.1043	0.0001
	5	0.9114	0.8672	134.4116	**-9.8006**	3.9052	**-5.5416**	-0.0376	0.0003
	6	0.9419	0.9087	208.2520	**-14.7048**	2.7865	-3.8345	-0.0425	0.0002
	7	0.7152	0.5254	183.7685	-12.9704	2.1617	-3.3533	0.0733	0.0726
	8	0.5329	0.1592	79.6349	-5.4722	-0.3354	-1.4882	-0.0306	0.3478
	9	0.7031	0.4063	-76.6921	5.4958	-2.3722	-0.8290	0.0816	0.2120
SEPTEMBER	0	0.7785	0.7046	21.3437	-1.5000	0.1354	**-5.4759**	-0.0229	0.0007
	1	0.8459	0.7899	51.1257	-3.5171	-0.3660	**-7.1628**	0.0274	0.0002
	2	0.6988	0.5783	100.2156	-6.9934	0.3683	**-6.0879**	0.2117	0.0111
	3	0.4962	0.2722	31.2333	-1.9027	-1.3501	-4.7772	0.1940	0.1479
	4	0.4772	0.2449	172.4898	-11.5683	-0.8925	-2.7073	0.2416	0.1700
	5	0.5960	0.3940	166.6339	-11.0209	-1.8556	-3.4404	0.0833	0.0902
	6	0.6394	0.4334	226.1753	-15.0538	-2.0563	-3.0493	0.0003	0.0912
	7	0.6725	0.4542	156.1597	-10.0701	-3.0197	-2.2249	0.2281	0.1060
	8	0.6909	0.4436	-42.1325	3.2635	-3.1325	-6.8202	-0.3444	0.1449
	9	0.6463	0.2926	-109.6330	7.7285	-2.7845	-7.5109	-0.0484	0.2868
OCTOBER	0	0.8055	0.7407	-149.4730	9.3756	1.9986	-10.0934	-0.1355	0.0003
	1	0.7480	0.6564	-23.9732	1.0617	**2.0512**	**-9.4876**	-0.0338	0.0026
	2	0.5365	0.3511	174.6841	-12.2092	**2.5941**	**-8.4590**	0.1761	0.0788
	3	0.7023	0.5700	-274.6880	18.6032	-1.5765	**-5.5462**	—0.0951	0.0178
	4	0.7447	0.6313	-118.6250	8.0108	-0.7716	**-8.0986**	—0.0350	0.0093
	5	0.8946	0.8419	-100.4000	6.7992	-0.8811	**-8.9989**	—-0.1636	0.0006
	6	0.7377	0.5878	-122.8200	8.3599	-1.2052	-7.8245	-0.2282	0.0331
	7	0.6918	0.4863	235.5223	-14.7593	-2.5727	3.2056	0.5616	0.0900
	8	0.5653	0.2175	-366.8100	25.9949	-5.8680	8.6333	-0.0935	0.3007
	9	0.5365	0.0730	-132.6700	10.0505	-4.2881	6.8928	0.1424	0.4454

TABLE 9.2.15 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
NOVEMBER	0	0.7942	0.7255	-2.7942	1.4287	**-3.2400**	-0.3468	-0.0550	0.0004
	1	0.8249	0.7612	177.1713	**-10.6284**	-1.3994	2.2902	0.3661	0.0004
	2	0.8531	0.7943	237.4576	**-14.4741**	-1.3836	**2.5410**	0.3805	0.0004
	3	0.8538	0.7889	-27.6893	2.5066	**-1.9895**	**2.3612**	0.1283	0.0008
	4	0.9320	0.9018	-53.1860	4.7982	**-4.0524**	0.1711	-0.0662	0.0000
	5	0.8538	0.7806	-119.2590	8.7083	**-3.3320**	1.6833	-0.3580	0.0020
	6	0.8381	0.7455	-133.8210	9.0385	-1.6420	3.5619	-0.2655	0.0067
	7	0.8371	0.7285	159.3257	-9.6240	-1.4440	2.9781	0.3361	0.0152
	8	0.7869	0.6165	300.5781	-18.5658	-1.5808	2.7142	0.5097	0.0622
	9	0.5649	0.1298	177.7689	-11.0033	-0.9478	2.6932	0.2736	0.4032
DECEMBER	0	0.7269	0.6276	119.6050	-6.0836	**-2.7702**	**4.4665**	**0.3648**	0.0040
	1	0.6365	0.5044	94.4115	-4.8231	-2.0083	4.0970	0.3374	0.0172
	2	0.5489	0.3685	254.2079	-14.0189	-3.6832	3.5890	0.4602	0.0699
	3	0.5584	0.3628	173.5504	-8.6199	**-5.2151**	**6.1735**	0.4442	0.0884
	4	0.5776	0.3664	31.8454	-0.1459	**-4.9513**	**5.6094**	0.1568	0.1054
	5	0.7008	0.5513	-12.3064	2.4691	**-4.6579**	**8.0356**	0.1758	0.0305
	6	0.5764	0.3344	17.7205	0.7129	**-4.9670**	7.8114	0.3333	0.1492
	7	0.5804	0.3007	72.5611	-2.8388	-4.7791	0.4684	0.1993	0.2025
	8	0.6744	0.4139	198.2482	-10.3042	**-4.9412**	5.9451	0.2328	0.1625
	9	0.9027	0.8055	137.1009	-6.6233	**-5.2340**	1.8912	0.0506	0.0265

TABLE 9.2.16 Multiple regression results of chub mackerel (*Scomber japonicus*) annual catch versus sea surface temperature (SST), north-south wind component (N/S), west-east wind component (W/E) and sea level at different lags (years) for combinations of months in the south western Cape area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

						WIND			
MONTH	LAG	R^2	ADJ R^2	COEFF	SST	N/S	W/E	SEALEVEL	P<
MAY-JULY	0	0.7685	0.7024	47.8024	**-2.9343**	0.2074	-0.2813	0.1167	0.0002
	1	0.8206	0.7654	60.3912	**-3.5757**	-1.2527	2.7545	0.1309	0.0001
	2	0.7917	0.7222	61.2381	**-4.0596**	4.6921	-3.5777	0.2277	0.0005
	3	0.7458	0.6534	78.5407	**-5.5114**	5.8380	-8.1718	0.1778	0.0027
	4	0.7687	0.6762	123.9034	**-8.5373**	4.2127	-8.7090	0.0616	0.0032
	5	0.9011	0.8571	148.3599	**-10.0445**	3.8373	-7.0030	-0.1011	0.0002
	6	0.9190	0.8785	195.5108	**-12.8362**	1.1048	-1.8839	-0.1131	0.0002
	7	0.7790	0.6527	187.6763	**-12.0792**	0.6852	2.5944	0.0980	0.0189
	8	0.7671	0.6118	138.6553	-9.2581	6.2037	-3.0838	0.1927	0.0417
	9	0.6767	0.4180	137.8518	-9.4847	6.4100	-7.2229	0.0432	0.1600
DECEMBER-FEBRUARY	0	0.6888	0.5851	62.3577	-3.2404	-0.9462	-1.5215	0.1614	0.0047
	1	0.8031	0.7315	117.1359	**-5.5287**	**-4.0527**	-0.0083	0.2043	0.0007
	2	0.8197	0.7476	138.6699	**-6.8734**	**-3.9266**	-2.6617	0.2742	0.0010
	3	0.6950	0.5594	122.1481	-5.7291	**-4.4694**	-0.7845	0.1481	0.0197
	4	0.8028	0.7152	103.5300	-4.2434	**-5.7083**	4.9273	0.0835	0.0031
	5	0.8074	0.7112	137.3803	-6.0611	**-6.4245**	-0.1363	0.0346	0.0058
	6	0.7951	0.6781	204.3351	**-10.3659**	**-5.5491**	-8.5233	0.1751	0.0147
	7	0.8606	0.7676	216.7088	**-11.0855**	**-5.6993**	1.6097	0.1164	0.0097
	8	0.9081	0.8345	225.8881	**-11.3167**	**-6.8440**	9.5736	0.3146	0.0084
	9	0.8681	0.7361	31.4523	0.0395	**-6.0521**	**15.1438**	0.3640	0.0476
MARCH-APRIL	0	0.8681	0.8201	73.4542	**-4.0835**	-1.4805	0.6656	0.0529	0.0001
	1	0.9070	0.8698	54.6477	**-2.4896**	**-3.0453**	0.3153	0.0432	0.0000
	2	0.8028	0.7151	62.0891	**-3.0806**	-2.7148	0.6944	0.0770	0.0000
	3	0.7382	0.6219	85.4942	**-5.0144**	-0.9351	0.2174	-0.0156	0.0104
	4	0.8079	0.7119	95.6120	**-5.1191**	-3.8886	4.1893	0.0026	0.0058
	5	0.8298	0.7325	75.9927	-3.5454	**-5.0879**	3.2094	-0.2072	0.0079
	6	0.8613	0.7688	42.1752	-0.8098	**-7.6741**	3.9988	0.0289	0.0096
	7	0.8901	0.8022	15.4683	0.9932	**-7.9982**	2.9196	-0.0225	0.0129
	8	0.5713	0.2283	45.6308	-0.5684	-8.3923	-3.5740	0.1493	0.2922
	9	0.3351	0.0000	-17.4043	1.8843	-4.3400	7.4931	0.2243	0.7384
AUGUST-NOVEMBER	0	0.6942	0.6069	74.3102	-3.9705	-2.8629	5.3252	0.2232	0.0015
	1	0.7221	0.6365	208.3071	-13.2586	-1.7629	0.7497	0.2947	0.0014
	2	0.6844	0.5792	228.8506	-14.4753	-2.3148	2.5802	0.4171	**0.0050**
	3	0.6614	0.5382	208.0347	-12.9932	-2.8275	3.1157	0.5688	**0.0120**
	4	0.6392	0.4949	265.2053	-16.7946	-2.9570	2.7182	0.4284	0.0256
	5	0.7046	0.5733	310.9927	**-19.8320**	-3.0871	2.4544	0.18228	0.0173
	6	0.8059	0.7089	247.8539	-15.4112	-4.0399	3.7096	0.0846	0.0060
	7	0.8225	0.7210	172.4529	-10.2341	**-4.6448**	5.9808	0.4067	0.0091
	8	0.6651	0.4419	-19.8677	2.3237	-3.9484	2.8486	-0.0703	0.1125
	9	0.7012	0.4622	-67.5856	4.7269	-1.5624	-5.9232	-0.0185	0.1344
OCTOBER-APRIL	0	0.8586	0.8151	64.8827	**-2.8513**	**-3.3502**	0.0123	0.1430	0.0000
	1	0.8696	0.8262	91.4040	**-4.4702**	**-3.4116**	-1.5913	0.1793	0.0000
	2	0.9030	0.8678	112.1668	**-5.8595**	**-3.2995**	1.7218	**0.3869**	0.0000
	3	0.8265	0.7572	125.6793	**-6.5718**	**-3.6297**	-1.6523	0.1635	0.0008
	4	0.9003	0.8560	120.4303	**-6.2913**	**-4.0598**	9.4456	0.1785	0.0002
	5	0.9189	0.8784	92.7589	-3.8602	**-5.5837**	-11.6283	-0.2671	0.0002
	6	0.9347	0.8973	101.1360	-4.1636	**-6.0660**	**-19.5985**	-0.1621	0.0003
	7	0.7486	0.5811	-68.5733	-3.1220	**-4.2093**	11.0299	0.1946	0.0516
	8	0.6711	0.4080	21.7698	-0.4411	-3.7361	15.6383	0.2277	0.1661
	9	0.8762	0.7524	-21.6019	1.9825	**-3.4888**	27.1566	0.7855	0.0422

TABLE 9.2.17 Multiple regression results of chub mackerel (*Scomber japonicus*) annual catch versus monthly sea surface temperature (SST), north-south wind vector (N/S), west-east wind vector (W/E) and sea level at different lags (years) in the Agulhas Bank area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
JANUARY	0	0.8765	0.8530	109.7955	**-5.0644**	-2.2224	-0.0360	-0.0403	0.0000
	1	0.8856	0.8627	93.7771	**-4.2812**	-1.9716	**-1.2629**	-0.0859	0.0000
	2	0.8164	0.7777	144.3847	**-6.3578**	**-5.5776**	0.1488	-0.0844	0.0000
	3	0.8588	0.8274	183.8058	**-8.2922**	**-6.0689**	0.1510	-0.0490	0.0000
	4	0.8725	0.8425	247.3569	**-11.4534**	**-6.5486**	0.1695	-0.0335	0.0000
	5	0.8017	0.7522	284.7508	**-13.3090**	**-6.8929**	0.0073	-0.0707	0.0000
	6	0.5982	0.4911	289.6812	**-13.4793**	**-7.5749**	0.6497	-0.0878	0.0059
	7	0.6015	0.4952	342.4077	**-15.7884**	**-10.3640**	1.7817	-0.1469	0.0056
	8	0.6897	0.6010	363.4159	**-16.4969**	**-13.0790**	**3.1236**	-0.1869	0.0016
	9	0.5935	0.4684	390.3998	**-17.7124**	**-14.3128**	**3.3752**	-0.2077	0.0140
FEBRUARY	0	0.5440	0.4572	104.0562	**-5.1102**	0.1601	-0.5818	0.0533	0.0018
	1	0.4999	0.3999	171.5362	**-9.3275**	5.9013	-0.8817	0.2043	0.0059
	2	0.5298	0.4308	129.2738	-5.9894	-2.9205	0.1437	0.0454	0.0046
	3	0.5079	0.5085	131.9058	-5.8469	-4.9752	0.2875	0.0300	0.0018
	4	0.6535	0.5720	147.3787	**-6.8110**	-3.6089	-0.2372	0.0514	0.0008
	5	0.5765	0.4706	108.4482	-5.2053	-0.7985	-1.1636	0.0394	0.0058
	6	0.7495	0.6827	51.2502	-2.9559	4.1941	**-2.3803**	0.1277	0.0002
	7	0.7067	0.6285	78.9035	-4.3813	4.2620	**-2.4891**	0.1032	0.0006
	8	0.7780	0.7146	10.1850	-0.3009	-0.1791	**-2.0346**	-0.0666	0.0002
	9	0.8334	0.7821	-45.7827	2.7920	-2.1108	**-1.8686**	-0.1544	0.0001
MARCH	0	0.8405	0.8102	77.3430	**-4.0811**	**1.4859**	0.2017	0.0956	0.0000
	1	0.7156	0.6587	77.2128	**-4.0889**	1.4892	0.3415	0.0694	0.0000
	2	0.7637	0.7139	164.0926	**-8.2254**	-1.2335	**-1.1905**	**0.1044**	0.0000
	3	0.7749	0.7275	170.2887	**-8.7943**	0.8541	**-1.6409**	**0.1493**	0.0000
	4	0.8743	0.8464	209.4051	**-10.6742**	-0.2014	**-2.4768**	**0.1661**	0.0000
	5	0.7150	0.6479	172.7402	**-9.0174**	1.9034	**-2.5119**	**0.1423**	0.0002
	6	0.8384	0.7980	115.9242	**-5.7512**	0.1303	**-3.3219**	0.0686	0.0000
	7	0.8406	0.8008	135.6890	**-6.7352**	-0.1647	**-3.8566**	0.0419	0.0000
	8	0.9194	0.8980	85.5920	**-4.2021**	0.2814	**-4.0917**	-0.0237	0.0000
	9	0.8899	0.8585	86.4935	-4.2778	0.7989	**-4.0868**	-0.0412	0.0000
APRIL	0	0.8839	0.8618	69.0563	**-3.7931**	**1.6065**	-0.2565	0.0343	0.0000
	1	0.8444	0.8132	100.9543	**-5.3262**	-1.0339	-0.0221	0.0482	0.0000
	2	0.8837	0.8592	132.1673	**-6.8431**	**-2.8155**	**-2.0430**	**0.0785**	0.0000
	3	0.8141	0.7749	164.2835	**-8.4843**	**-4.5809**	-1.6249	**0.1090**	0.0000
	4	0.7628	0.7101	176.9490	**-9.1231**	**-5.3059**	-1.8625	**0.1180**	0.0000
	5	0.5971	0.5024	192.8167	**-9.8946**	**-6.9239**	-0.7437	0.1093	0.0027
	6	0.5235	0.4044	101.7658	-4.8637	-5.6714	-3.5047	0.0585	0.0138
	7	0.6638	0.5798	132.9269	**-6.3253**	**-8.5234**	**-4.1057**	0.0534	0.0010
	8	0.6488	0.5551	133.8348	-6.2760	**-9.7416**	**-4.0447**	0.0230	0.0023
	9	0.4823	0.3344	155.2719	-7.4710	**-10.6033**	-1.7415	-0.0080	0.0436
MAY	0	0.8772	0.8538	67.4395	**-3.7528**	0.3981	0.3506	0.0260	0.0000
	1	0.9114	0.8937	79.3323	**-4.4467**	0.5373	0.4861	0.0212	0.0000
	2	0.8268	0.7903	89.8973	**-4.9743**	-2.6658	**1.4538**	-0.0183	0.0000
	3	0.8286	0.7925	120.1801	**-6.7506**	-3.5864	**1.7354**	-0.0167	0.0000
	4	0.8751	0.8474	102.1476	**-5.6197**	-2.4984	**2.4288**	-0.0164	0.0000
	5	0.8765	0.8474	101.8038	**-5.6032**	-0.6121	**2.5182**	-0.0084	0.0000
	6	0.8286	0.7858	28.3253	-1.1342	-1.9086	**3.5904**	-0.0594	0.0000
	7	0.7751	0.7188	31.4063	-1.3245	-0.1960	**3.7253**	-0.0684	0.0000
	8	0.6594	0.5686	2.4889	0.3291	1.8101	**3.2805**	-0.0871	0.0018
	9	0.5430	0.4125	23.6775	-0.9792	0.9087	2.8982	-0.1251	0.0200

TABLE 9.2.17 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	N/S	WIND W/E	SEALEVEL	P<
JUNE	0	0.8133	0.7760	90.9700	**-5.1065**	-1.8041	**2.4300**	-0.0129	0.0000
	1	0.9076	0.8892	103.4071	**-5.9626**	-0.7931	**1.8135**	-0.0040	0.0000
	2	0.7591	0.7083	95.0729	**-5.5694**	1.1163	0.7632	0.0241	0.0000
	3	0.7795	0.7331	109.8316	**-13.2470**	**3.0893**	-0.2771	0.0522	0.0000
	4	0.8138	0.7724	132.5976	**-7.9556**	2.9802	0.3329	0.0598	0.0000
	5	0.8536	0.8192	165.4631	**-10.0420**	**4.1013**	0.0287	0.0631	0.0000
	6	0.7976	0.7470	130.1985	**-7.8189**	**4.8126**	0.0200	0.0724	0.0000
	7	0.8414	0.8017	120.4391	**-7.1120**	**5.4577**	0.5389	0.0883	0.0000
	8	0.7425	0.6378	78.2726	-4.3747	**5.2832**	1.2132	0.0768	0.0003
	9	0.6452	0.5438	84.8411	-4.9516	**6.1918**	0.2071	0.0293	0.0039
JULY	0	0.8323	0.7987	72.9110	**-4.6003**	**2.7964**	**-0.7455**	-0.0640	0.0000
	1	0.9004	0.8805	98.1858	**-6.1866**	**3.3579**	-0.4005	-0.0386	0.0000
	2	0.7614	0.7112	61.9343	**-3.9617**	**4.3027**	**-1.2526**	-0.0719	0.0000
	3	0.6945	0.6302	74.8830	**-4.8430**	**5.5445**	-1.4942	-0.0697	0.0001
	4	0.8371	0.8009	75.8584	**-4.8959**	**6.8311**	**-1.4823**	-0.0447	0.0000
	5	0.8171	0.7741	104.4607	**-6.6535**	**7.3362**	-0.8065	0.0033	0.0000
	6	0.8533	0.8166	29.8579	-1.8532	**6.6980**	-1.0914	0.0153	0.0000
	7	0.8769	0.8462	97.3271	-6.1194	**8.1177**	-0.2689	0.0263	0.0000
	8	0.8669	0.8314	25.5978	-1.5369	**7.4940**	-0.6937	0.0097	0.0000
	9	0.8145	0.7615	-57.7219	3.7598	**6.2654**	-1.3216	-0.0445	0.0001
AUGUST	0	0.9012	0.8832	33.4382	**-2.1678**	**-0.5098**	**-1.2648**	-0.0578	0.0000
	1	0.8875	0.8661	10.4633	-0.7338	-0.0489	**-1.6907**	-0.0404	0.0000
	2	0.8089	0.7707	-16.1856	0.9156	0.0197	**-2.3411**	-0.0199	0.0000
	3	0.8979	0.8765	-35.4265	**2.0737**	-0.5958	**-3.0994**	-0.0073	0.0000
	4	0.8427	0.8077	-57.2841	**3.3961**	-0.0430	**-3.6783**	0.0075	0.0000
	5	0.7135	0.6461	-75.8905	**4.5589**	0.4713	**-3.9288**	0.0215	0.0002
	6	0.8284	0.7855	-8.7218	1.2073	**-5.8109**	1.4632	0.0940	0.0000
	7	0.7010	0.6263	-32.9838	2.6119	**-5.0117**	0.5289	0.0496	0.0004
	8	0.8492	0.8089	-49.4860	**3.7438**	**-5.1136**	0.8034	0.0472	0.0000
	9	0.9117	0.8860	-82.9986	**5.6587**	**-3.7155**	-0.6267	0.0047	0.0000
SEPTEMBER	0	0.7139	0.6618	45.8594	**-2.9736**	2.3853	-0.5987	-0.0358	0.0000
	1	0.7240	0.6714	73.3440	**-4.5677**	-0.8038	-0.9110	-0.0794	0.0000
	2	0.4455	0.3346	61.3579	-3.9187	0.1763	-1.5095	-0.0686	0.0150
	3	0.1714	0.0000	42.4919	-2.6783	0.8195	-0.5795	-0.0769	0.4406
	4	0.1319	0.0000	68.4374	-3.8889	-3.7170	1.4960	-0.1617	0.6125
	5	0.1325	0.0000	45.7945	-2.3556	-5.5133	0.7059	-0.0998	0.6351
	6	0.4093	0.2616	-10.4279	1.4139	**-6.2122**	1.4089	-0.0391	0.0633
	7	0.4331	0.2914	-17.7553	1.8026	-6.7815	0.0737	-0.0560	0.0476
	8	0.5431	0.4212	-77.0074	5.4151	-4.0245	-0.4214	-0.0448	0.0143
	9	0.6292	0.5232	-97.9994	**6.7121**	-3.0152	-0.2798	-0.0592	0.0052
OCTOBER	0	0.8153	0.7832	86.8110	**-5.0785**	-0.3517	0.4590	-0.0341	0.0000
	1	0.8540	0.8274	103.6926	**-6.0735**	-0.7648	0.4749	-0.0557	0.0000
	2	0.7456	0.6972	137.6416	**-8.1403**	-1.0516	0.3952	-0.0479	0.0000
	3	0.6209	0.5451	142.3972	**-8.5748**	0.2537	1.0233	0.0069	0.0004
	4	0.6378	0.5615	150.3171	**-9.0405**	0.3092	**2.1191**	-0.0147	0.0005
	5	0.6451	0.5662	161.2563	**-9.7365**	0.6171	**2.8305**	-0.0293	0.0006
	6	0.6160	0.5257	151.8923	**-9.2227**	1.2196	**3.3913**	-0.0568	0.0018
	7	0.4690	0.3362	95.7952	-6.0161	3.2701	**3.3462**	0.0548	0.0301
	8	0.5405	0.4180	-87.8349	5.4238	2.4774	**4.0230**	-0.0411	0.0148
	9	0.6640	0.5681	-159.7770	9.9410	1.7816	**4.1113**	-0.1223	0.0027

TABLE 9.2.17 (continued)

MONTH	LAG	R^2	ADJ R^2	COEFF.	SST	WIND N/S	WIND W/E	SEALEVEL	P<
NOVEMBER	0	0.8730	0.8509	72.1027	-3.5977	-2.2726	0.3165	-0.0606	0.0000
	1	0.9044	0.8870	109.1117	-5.8225	-1.5689	0.5077	-0.0191	0.0000
	2	0.8233	0.7897	102.8325	-5.3397	-2.4953	0.6130	-0.0475	0.0000
	3	0.8391	0.8069	100.9723	-5.1908	-2.9126	1.1287	-0.0377	0.0000
	4	0.8320	0.7966	97.5052	-4.8240	-4.0790	0.7492	-0.0710	0.0000
	5	0.7838	0.7358	107.0793	-5.2753	-4.8241	0.7600	-0.1242	0.0000
	6	0.7041	0.6345	113.0141	-5.6528	-4.6993	1.1313	-0.1656	0.0002
	7	0.5201	0.4001	129.4607	-6.7306	-3.9078	1.5198	-0.1430	0.0145
	8	0.3322	0.1541	65.4580	-3.1082	-3.7843	1.8471	-0.2154	0.1690
	9	0.2671	0.0577	30.3775	-1.0683	-4.0083	1.3395	-0.2858	0.3260
DECEMBER	0	0.8535	0.8256	116.7958	-5.8110	-1.4374	0.2309	0.0065	0.0000
	1	0.7339	0.6807	124.6894	-6.2698	-1.2822	-0.2795	-0.0357	0.0000
	2	0.7299	0.6759	94.0544	-4.5101	-2.1357	0.7629	-0.0445	0.0000
	3	0.6363	0.5598	102.9400	-4.9732	-2.0466	1.5951	0.0253	0.0005
	4	0.5962	0.5065	136.3266	-6.7052	-2.2011	2.5161	0.0998	0.0018
	5	0.6079	0.5157	180.5986	-8.8211	-3.6494	4.3853	0.1295	0.0022
	6	0.6127	0.5158	247.7509	-12.0682	-5.7200	6.4669	0.1165	0.0030
	7	0.4090	0.2514	194.1170	-9.3590	-4.7687	6.2785	0.0985	0.0787
	8	0.3790	0.2134	188.7454	-9.1101	-4.5601	6.5679	0.0627	0.1079
	9	0.2619	0.0510	55.5451	-2.4583	-1.9207	4.1890	-0.0098	0.3381

TABLE 9.2.18 Multiple regression results of chub mackerel (*Scomber japonicus*) annual catch versus sea surface temperature (SST), north -south wind vector (N/S), west-east wind vector (W/E) and sea level at different lags (years) for combination of months in the Agulhas Bank area. Adj R^2 is the adjusted for degrees of freedom regression coefficient. Highlighted are the significant (P<0.05) environmental contributions to the overall regression.

MONTH	LAG	R^2	ADJ R^2	COEFF	SST	WIND N/S	W/E	SEALEVEL	P<
MAY-JULY	0	0.8460	0.8167	67.7685	**-3.9506**	0.5463	0.2782	-0.0126	0.0000
	1	0.9064	0.8877	67.5588	**-4.1739**	**4.6943**	-1.7407	0.0121	0.0000
	2	0.8204	0.7826	36.2868	-2.5816	**10.0717**	**-4.6456**	0.0272	0.0000
	3	0.8782	0.8526	17.5441	-1.8397	**16.6620**	**-8.1195**	0.0502	0.0000
	4	0.8681	0.8388	61.2732	**-4.2228**	**13.7526**	**-5.4351**	0.0768	0.0000
	5	0.8737	0.8440	107.9821	**-6.7005**	**9.6220**	-2.0117	**0.0918**	0.0000
	6	0.8499	0.8124	108.0856	**-6.3958**	6.6440	0.4725	**0.0940**	0.0000
	7	0.9047	0.8821	132.5690	**-7.7117**	5.7528	2.1206	**0.1002**	0.0000
	8	0.8569	0.8187	63.8452	-3.7192	**9.5884**	-0.1137	0.0843	0.0000
	9	0.7613	0.6931	46.4971	-2.7306	10.0199	-0.6767	0.0355	0.0003
DECEMBER-FEBRUARY	0	0.8680	0.8428	124.3142	**-5.7187**	**-3.6369**	0.3928	-0.0396	0.0000
	1	0.8025	0.7630	106.5566	**-4.7605**	**-3.9114**	-1.5200	-0.1055	0.0000
	2	0.7868	0.7419	126.9389	**-5.8841**	**-3.3743**	-2.0504	-0.0593	0.0000
	3	0.8632	0.8328	155.5525	**-7.4604**	-2.6086	**-3.0832**	-0.0147	0.0000
	4	0.9034	0.8807	197.7611	**-9.6858**	-2.2452	**-3.7177**	-0.0051	0.0000
	5	0.9151	0.8939	151.7857	**-7.6022**	-0.1583	**-5.5755**	-0.0583	0.0000
	6	0.8674	0.8321	32.7693	-2.1615	**4.8973**	**-7.0377**	-0.0239	0.0000
	7	0.7015	0.6219	90.6775	-5.0042	3.7332	**-6.6152**	-0.0709	0.0007
	8	0.7085	0.6252	76.4099	-4.1578	2.8186	**-6.4989**	-0.1447	0.0011
	9	0.6147	0.4962	29.2980	-1.9009	3.9632	**-6.8137**	-0.1507	0.0101
MARCH-APRIL	0	0.8864	0.8648	74.8370	**-4.1078**	**2.4609**	-0.4402	**0.0755**	0.0000
	1	0.7912	0.7494	89.4559	**-4.7864**	1.2146	0.0154	0.0554	0.0000
	2	0.8708	0.8436	146.4789	**-7.5465**	-0.9174	**-2.0037**	**0.0898**	0.0000
	3	0.8379	0.8038	149.0023	**-8.0038**	2.2112	**-2.7919**	**0.1174**	0.0000
	4	0.9009	0.8788	158.7755	**-8.5506**	2.7890	**-3.9595**	**0.1287**	0.0000
	5	0.7377	0.6760	125.0466	**-6.9825**	5.1317	**-4.2375**	0.0947	0.0001
	6	0.8631	0.8289	50.3950	-2.7174	3.6886	**-5.5774**	0.0384	0.0000
	7	0.8622	0.8277	78.1298	**-3.9545**	1.4656	**-6.2619**	0.0090	0.0000
	8	0.9133	0.8902	39.8483	-1.9517	2.1667	**-6.6908**	-0.0448	0.0000
	9	0.8039	0.7479	51.7378	-2.7155	3.1172	**-6.7956**	-0.0655	0.0001
AUGUST-NOVEMBER	0	0.6796	0.6238	3.1086	-0.0741	-0.6844	**-2.5248**	-0.0519	0.0000
	1	0.6124	0.5420	-5.9148	0.5221	-1.4456	-3.0564	-0.0704	0.0002
	2	0.5812	0.5014	-18.7758	1.4180	**-3.7021**	**-4.8328**	-0.0914	0.0008
	3	0.4765	0.3718	-47.1198	3.2933	**-4.1988**	-3.7020	-0.0736	0.0089
	4	0.4325	0.3130	-72.2204	**4.9763**	-4.4423	-1.9658	-0.0826	0.0235
	5	0.3999	0.2665	-88.7966	**6.1163**	-4.6581	-0.3685	-0.1002	0.0464
	6	0.6162	0.5258	46.5995	-1.7202	**-7.8649**	4.5841	**-0.2276**	0.0018
	7	0.4858	0.3572	-22.4137	2.4352	**-7.5510**	2.8031	-0.1549	0.0239
	8	0.6148	0.5121	-101.776	**7.2507**	**-6.8629**	1.8037	-0.1617	0.0044
	9	0.6826	0.5920	-131.007	**8.9625**	**-5.8705**	1.6913	-0.1767	0.0019
OCTOBER-APRIL	0	0.8874	0.8678	148.3064	**-7.3650**	**-3.7224**	-0.7945	-0.0028	0.0000
	1	0.8434	0.8149	165.0704	**-8.3147**	**-3.3922**	-1.3219	-0.0006	0.0000
	2	0.8309	0.7987	184.4924	**-9.4211**	**-2.6857**	-4.3320	0.0114	0.0000
	3	0.8970	0.8763	206.9794	**-10.6196**	**-2.6979**	-6.1150	0.0141	0.0000
	4	0.9043	0.8841	236.6784	**-12.2491**	**-2.5209**	-7.0465	0.0258	0.0000
	5	0.8267	0.7882	256.9458	**-13.3906**	**-2.1772**	-7.9688	0.0181	0.0000
	6	0.7756	0.7228	234.2405	**-12.6022**	**1.5156**	-10.6282	0.0778	0.0000
	7	0.7021	0.6276	171.6442	**-9.2738**	**2.1238**	-11.9049	0.0150	0.0004
	8	0.7856	0.7284	95.5687	-5.2343	**2.9498**	-13.4280	-0.0417	0.0001
	9	0.7439	0.6707	95.8186	-5.2803	**3.1135**	-13.7370	-0.0624	0.0004

APPENDIX 9.3

AUTOREGRESSIVE MODELS

TABLE 9.3.1 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the biological variables.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
Pilchard	1,0	1951-1985	0.74		4.51	50	50
Horse mackerel	1,1	1951-1985	1.01	0.81	16.13	73	27
Chub mackerel	1,1	1955-1985	1.02	-0.61	8.76	51	49

TABLE 9.3.2 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the sea surface temperature records in the west coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	1,1	1951-1985	0.48	0.50	16.55	37	63
February	0,1	1951-1985	-.-	0.30	16.43	5	95
March	1,0	1951-1985	0.32	-.-	16.04	7	93
April	0,0	1950-1985	-.-	-.-	-.-	--	100
May	0,0	1950-1985	-.-	-.-	-.-	--	100
June	0,1	1950-1985	-.-	0.35	14.86	8	92
July	0,1	1950-1985	-.-	0.42	14.50	12	88
August	0,0	1950-1984	-.-	-.-	-.-	--	100
September	0,0	1950-1984	-.-	-.-	-.-	--	100
October	0,0	1950-1984	-.-	-.-	-.-	--	100
November	1,0	1951-1984	0.49	-.-	15.44	21	79
December	1,0	1951-1984	0.69	-.-	16.16	46	54

TABLE 9.3.3 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the north-south wind component records in the west coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	2,0	1952-1985	0.36	-.-	4.88	9	91
February	2,0	1952-1985	0.39	-.-	4.64	13	87
March	2,1	1952-1985	0.34	0.27	4.81	13	87
April	1,0	1951-1985	0.33	-.-	3.08	8	92
May	2,0	1952-1985	0.36	-.-	1.38	8	92
June	0,0	1950-1985	-.-	-.-	-.-	-.-	100
July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August	0,0	1950-1984	-.-	-.-	-.-	-.-	100
September	1,1	1951-1984	0.89	-0.78	3.57	18	82
October	1,0	1951-1984	0.34	-.-	4.23	9	91
November	1,0	1951-1984	0.39	-.-	4.87	14	86
December	1,0	1951-1984	0.44	-.-	5.27	18	82

TABLE 9.3.4 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the west-east wind component records in the west coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,0	1950-1985	-.-	-.-	-.-	-.-	100
February	1,2	1951-1985	0.49	-1.54	-0.17	23	77
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,2	1950-1985	-.-	0.47	-0.27	12	88
June	0,2	1950-1985	-.-	-0.38	-0.31	11	89
July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August	0,0	1950-1985	-.-	-.-	-.-	-.-	100
September	0,1	1950-1985	-.-	0.61	-0.48	24	76
October	0,0	1950-1985	-.-	-.-	-.-	-.-	100
November	0,0	1950-1985	-.-	-.-	-.-	-.-	100
December	0,0	1950-1985	-.-	-.-	-.-	-.-	100

TABLE 9.3.5 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to all the environmental variables combined months in the west coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
SST							
May-July	0,1	1950-1985	0.36	-.-	14.88	9	91
December-February	1,2	1951-1985	0.80	-0.44	16.33	41	59
March-April	0,1	1950-1985	-.-	0.35	15.85	8	92
August-November	1,0	1951-1984	0.58	-.-	15.84	31	69
October-April	1,0	1951-1985	0.40	-.-	14.81	12	88
N/S							
May-July	0,1	1950-1985	-.-	0.90	0.88	46	54
December-February	1,0	1951-1985	0.67	-.-	4.77	44	56
March-April	2,0	1952-1985	0.62	-.-	4.23	34	66
August-November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October-April	1-2,0	1952-1985	0.31,0.39	-.-	3.82	42	58
W/E							
May-July	0,0	1950-1984	-.-	-.-	-.-	-.-	100
December-February	1,0	1951-1985	0.48	-.-	-0.31	25	75
March-April	0,0	1950-1984	-.-	-.-	-.-	-.-	100
August-November	0,1	1950-1985	-.-	0.31	-0.44	6	94
October-April	1,0	1951-1985	0.61	-.-	-0.22	32	68

TABLE 9.3.6 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the sea surface temperature in the western Cape area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,1	1950-1985	-.-	0.48	17.22	17	83
February	0,1	1950-1985	-.-	0.29	17.02	4	96
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	1,0	1951-1985	0.44	-.-	16.06	18	82
May	1,0	1951-1985	0.43	-.-	15.89	16	84
June	1,0	1951-1985	0.38	-.-	15.53	11	89
July	1,0	1950-1985	0.68	-.-	15.26	27	73
August	1,0	1951-1984	0.35	-.-	14.79	10	90
September	1,0	1951-1984	0.29	-.-	14.85	6	94
October	0,0	1950-1985	-.-	-.-	-.-	-.-	100
November	0,0	1950-1985	-.-	-.-	-.-	-.-	100
December	0,1	1950-1984	-.-	0.47	16.65	16	84

TABLE 9.3.7 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the north-south wind component in the western Cape area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,0	1950-1985	-.-	-.-	-.-	-.-	100
February	0,0	1950-1985	-.-	-.-	-.-	-.-	100
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,4	1950-1985	-.-	-0.40	0.26	11	89
June	1,0	1951-1985					
July	0,2	1950-1985	-.-	0.45	0.16	14	86
August	2,0	1952-1985	0.44	-.-	0.62	14	86
September	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October	0,0	1950-1984	-.-	-.-	-.-	-.-	100
November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
December	0,0	1950-1984	-.-	-.-	-.-	-.-	100

TABLE 9.3.8 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the west-east wind component in the western Cape area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,0	1950-1985	-.-	-.-	-.-	-.-	100
February	0,1	1950-1985	-.-	0.40	0.76	10	90
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,0	1950-1985	-.-	-.-	-.-	-.-	100
June	0,0	1950-1985	-.-	-.-	-.-	-.-	100
July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August	2,0	1952-1985	0.45	-.-	-1.34	12	88
September	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October	0,2	1950-1984	-.-	-0.43	-0.27	13	87
November	0,2	1950-1984	-.-	-0.39	0.06	10	90
December	1,0	1951-1984	-0.52	-.-	-0.19	17	83

TABLE 9.3.9 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to all the environmental variables combined months in the western Cape Area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
SST							
May-July	1,0	1951-1985	0.45	-.-	15.51	16	84
December-February	0,1	1950-1985	-.-	0.45	16.98	15	85
March-April	1,0	1951-1985	0.33	-.-	16.23	8	92
August-November	1,0	1951-1984	0.38	-.-	15.19	13	87
October-April	1,0	1951-1985	0.41	-.-	16.34	15	85
N/S							
May-July	0,2	1950-1985	-.-	-0.42	0.05	20	80
December-February	0,4	1950-1985	-.-	0.86	4.79	46	54
March-April	0,3	1950-1985	-.-	0.52	3.65	10	90
August-November	2,0	1952-1984	0.53	-.-	2.85	32	68
October-April	2,2	1952-1985	1.04	-0.96	1.03	52	48
W/E							
May-July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
December-February	0,0	1950-1985	-.-	-.-	-.-	-.-	100
March-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August-November	0,0	1950-1985	-.-	-.-	-.-	-.-	100
October-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100

TABLE 9.3.10 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the sea surface temperature in the south coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	1,1	1951-1985	-0.47	0.81	19.71	8	92
February	0,0	1950-1985	-.-	-.-	-.-	-.-	100
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,0	1950-1985	-.-	-.-	-.-	-.-	100
June	0,0	1950-1985	-.-	-.-	-.-	-.-	100
July	0,1	1950-1985	-.-	0.31	15.51	5	95
August	1,0	1951-1984	0.30	-.-	15.22	5	95
September	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October	0,0	1950-1984	-.-	-.-	-.-	-.-	100
November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
December	0,0	1950-1984	-.-	-.-	-.-	-.-	100

TABLE 9.3.11 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the north-south wind component in the south coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,0	1950-1985	-.-	-.-	-.-	-.-	100
February	2,0	1952-1985	-0.36	-.-	2.91	11	89
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,0	1950-1985	-.-	-.-	-.-	-.-	100
June	0,0	1950-1985	-.-	-.-	-.-	-.-	100
July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August	0,0	1950-1985	-.-	-.-	-.-	-.-	100
September	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October	0,0	1950-1984	-.-	-.-	-.-	-.-	100
November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
December	0,1	1950-1984	-.-	0.42	2.81	13	87

TABLE 9.3.12 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to the west-east wind component in the south coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
January	0,1	1950-1985	-.-	0.37	0.48	8	92
February	0,0	1950-1985	-.-	-.-	-.-	-.-	100
March	0,0	1950-1985	-.-	-.-	-.-	-.-	100
April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
May	0,4	1950-1985	-.-	-0.53	-1.78	18	82
June	0,0	1950-1985	-.-	-.-	-.-	-.-	100
July	0,2	1950-1985	-.-	0.32	-2.06	6	94
August	0,0	1950-1985	-.-	-.-	-.-	-.-	100
September	0,4	1950-1984	-.-	-0.54	-0.99	18	82
October	0,1	1950-1984	-.-	0.31	-0.43	6	94
November	0,2	1950-1984	-.-	-0.91	-0.06	49	51
December	1,0	1951-1984	-0.49	-.-	-0.48	19	81

TABLE 9.3.13 Details of the auto-regressive (AR) and moving-average (MA) structure and residuals applied to all the environmental variables combined months in the south coast area.

Data Series	Order of AR,MA	Length of record in AR process	Coefficients AR	MA	C	Structure (%)	Residuals (%)
SST							
May-July	1,0	1950-1985	0.32	-.-	16.22	5	95
December-February	0,1	1950-1985	-.-	0.41	19.40	12	88
March-April	0,1	1950-1985	-.-	0.21	18.62	1	99
August-November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October-April	1,2	1951-1985	0.55	-0.40	18.44	20	80
N/S							
May-July	0,3	1950-1985	-.-	0.38	-0.18	9	91
December-February	1,2	1951-1985	0.59	-0.41	2.91	27	73
March-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August-November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
W/E							
May-July	0,0	1950-1985	-.-	-.-	-.-	-.-	100
December-February	0,0	1950-1985	-.-	-.-	-.-	-.-	100
March-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100
August-November	0,0	1950-1984	-.-	-.-	-.-	-.-	100
October-April	0,0	1950-1985	-.-	-.-	-.-	-.-	100

APPENDIX 9.4

TIME SERIES ANALYSES RESULTS

FIGURE 9.4.1 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1843	-0.1259	-0.2056	-0.1900	-0.0086	0.0723	0.1156	0.1846	0.1927	-0.0394	-0.2534	-0.3031
1	-0.2491	-0.2317	-0.3805	-0.3050	-0.0363	0.1040	0.1181	0.1278	-0.1485	-0.2508	-0.1626	-0.0920
2	-0.1968	-0.1992	-0.1297	-0.1575	-0.1616	-0.0613	-0.0670	-0.0854	-0.1277	-0.1588	-0.1556	-0.2958
3	0.0637	0.1779	0.0805	-0.0184	-0.0306	-0.0852	-0.0995	-0.0806	-0.1577	-0.1397	-0.0791	-0.1610
4	0.0107	-0.0971	-0.1267	-0.0034	0.0856	0.0485	-0.0577	-0.1170	-0.1842	-0.1410	-0.0490	0.0618
5	-0.1317	-0.2076	-0.0927	-0.1361	-0.1827	-0.0858	-0.2136	-0.2621	-0.1361	-0.0435	-0.0433	-0.0205
6	-0.0217	0.0791	0.1505	0.1317	-0.0370	-0.1563	-0.1873	-0.2010	-0.1318	-0.1528	-0.0567	-0.0611
7	0.1777	0.1337	0.0417	0.0121	-0.0320	-0.0358	0.0292	-0.1083	-0.1677	-0.1209	-0.1854	-0.1513
8	-0.1109	-0.1263	-0.0872	0.0027	0.0527	0.0418	0.0115	-0.0014	0.1042	0.0866	-0.0033	-0.1054
9	-0.2378	-0.1838	-0.1393	-0.0947	-0.0691	0.0600	-0.0154	0.1478	0.0964	0.0556	0.0686	0.0800

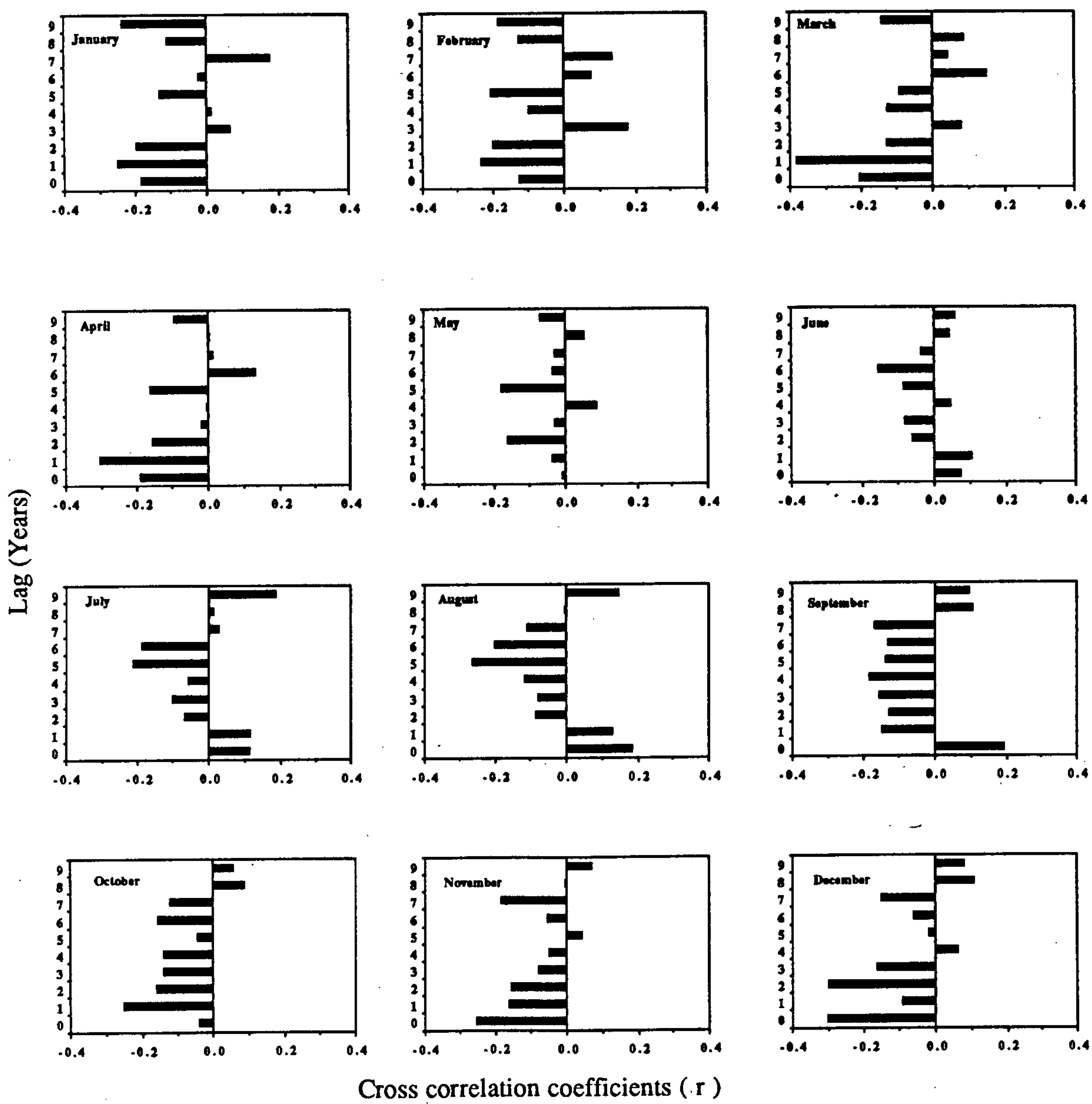


FIGURE 9.4.2 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.0463	-0.2361	-0.2050	-0.1042	-0.0076
1	0.0816	-0.2425	-0.3567	-0.3081	-0.1364
2	-0.0942	-0.1994	-0.1476	-0.1940	-0.1164
3	-0.0978	0.1518	0.0353	0.1009	-0.0655
4	0.0819	-0.1083	-0.0711	-0.0151	-0.0959
5	-0.1576	-0.1454	-0.1300	-0.2092	-0.0316
6	-0.1345	0.0042	0.1465	-0.0242	-0.1166
7	-0.0309	0.1687	0.0287	0.1092	-0.2100
8	0.0411	-0.1285	-0.0465	-0.0103	0.0083
9	0.0150	-0.2193	-0.1224	-0.2941	0.0673

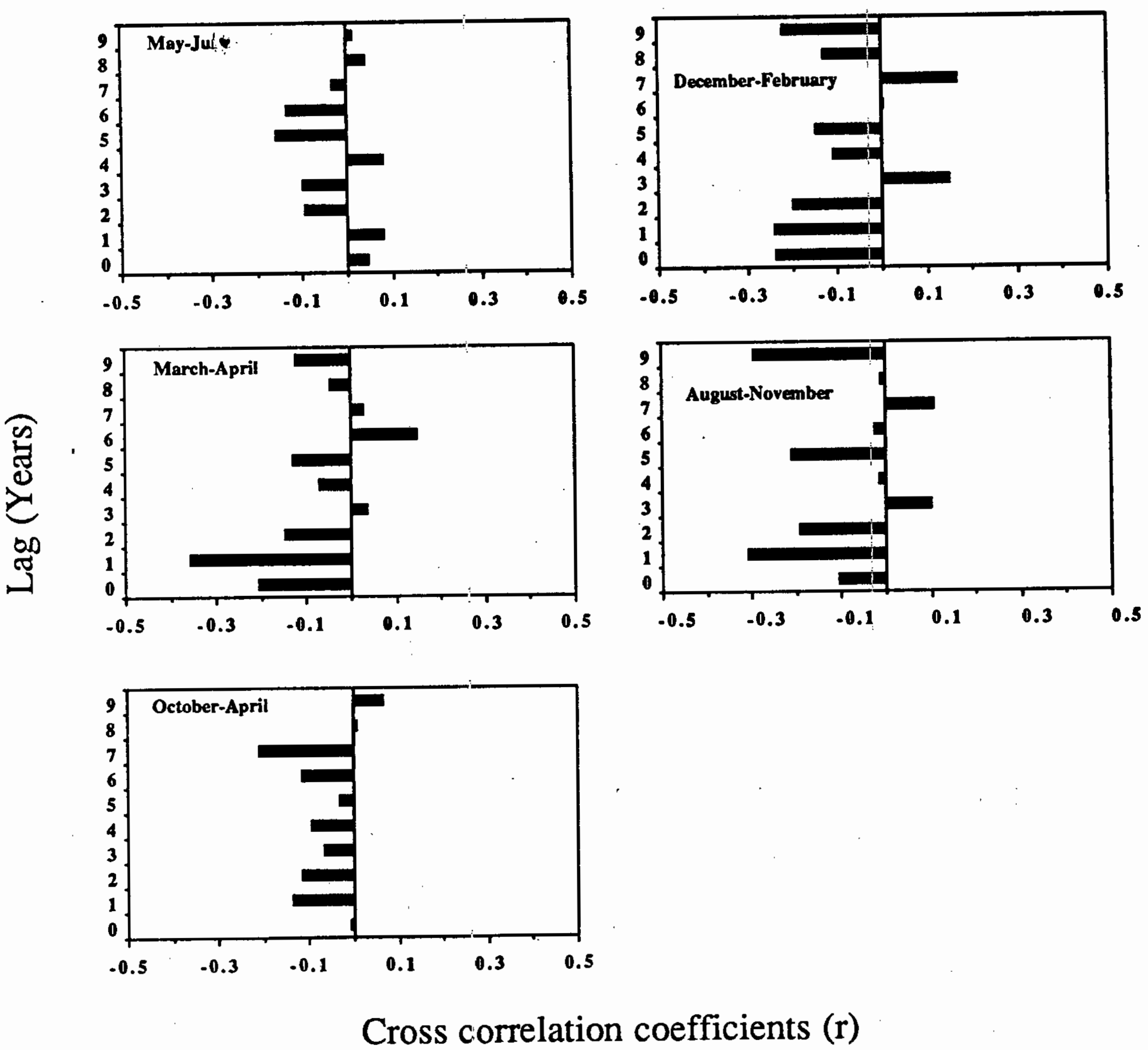


FIGURE 9.4.3 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.0708	-0.1023	-0.1498	-0.0803	-0.1796	-0.1286	-0.0382	0.0598	-0.1470	0.0717	-0.2016	-0.0306
1	-0.3175	-0.2406	0.0231	-0.2520	-0.3560	0.0493	0.0233	-0.0417	0.1316	-0.1079	-0.0991	0.1297
2	-0.2894	-0.2065	-0.1870	0.1983	-0.0480	0.2114	-0.1320	0.1719	-0.2355	-0.0275	0.0195	-0.1721
3	-0.3014	-0.3662	-0.2038	-0.0734	-0.3000	0.3436	-0.1577	-0.0158	0.2550	-0.1556	-0.1818	-0.0001
4	-0.2159	-0.1615	0.0668	-0.3011	-0.2168	0.3024	-0.1252	-0.1007	0.0974	-0.2259	-0.0827	-0.1166
5	-0.0298	-0.2066	-0.2708	-0.0621	-0.0350	0.0709	-0.0474	-0.0993	-0.0467	-0.0813	-0.1526	-0.1817
6	-0.0477	-0.1119	-0.1900	-0.1576	0.0032	0.0562	-0.1569	-0.3635	0.0308	-0.1990	-0.0872	-0.1546
7	-0.0226	0.1828	-0.0133	-0.3158	0.0572	0.1681	-0.2286	-0.1391	-0.0204	-0.1000	-0.1868	0.1170
8	0.0014	-0.0714	0.0459	-0.2436	-0.1438	0.0990	-0.2216	-0.1009	0.0412	-0.1413	0.0007	-0.1628
9	-0.0312	-0.0254	-0.0111	0.0215	0.1908	-0.0609	0.0826	-0.1539	-0.0950	0.1290	-0.0305	0.0654

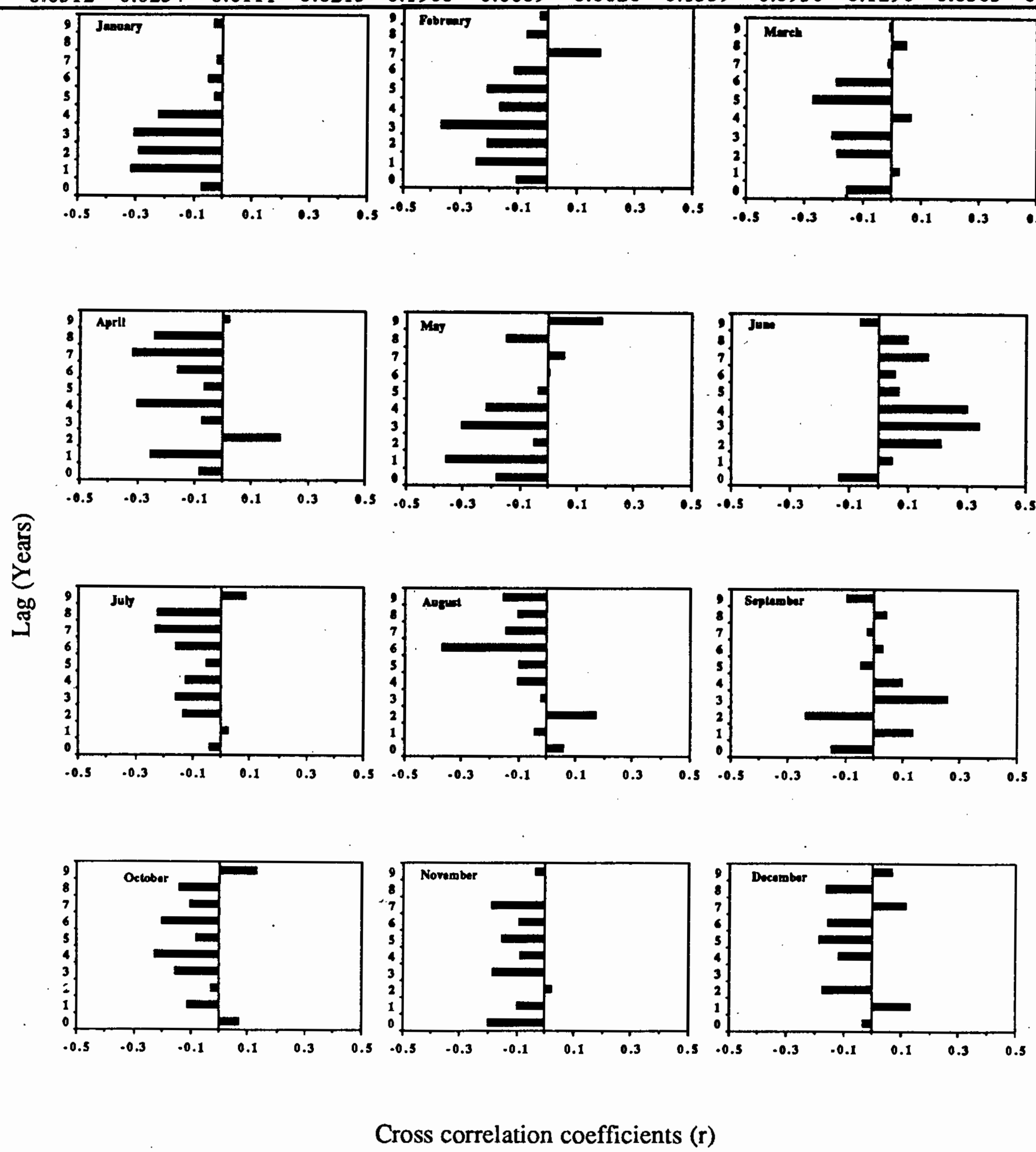


FIGURE 9.4.4 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.2205	0.1731	-0.1896	0.0810	-0.0783
1	-0.1223	-0.3453	0.0001	-0.2235	0.0010
2	-0.1858	-0.0592	0.0606	0.0281	0.0298
3	-0.1940	-0.1578	-0.1477	-0.1080	0.0120
4	-0.1785	-0.2936	-0.0598	-0.2213	0.0299
5	-0.2290	-0.0502	-0.1628	-0.0438	-0.0817
6	-0.1980	-0.0458	-0.1739	-0.0877	-0.2383
7	0.0099	-0.0838	-0.1812	-0.1515	0.0449
8	-0.0879	-0.0309	-0.0121	-0.0593	0.0612
9	0.1141	-0.1861	0.0450	-0.0922	-0.0493

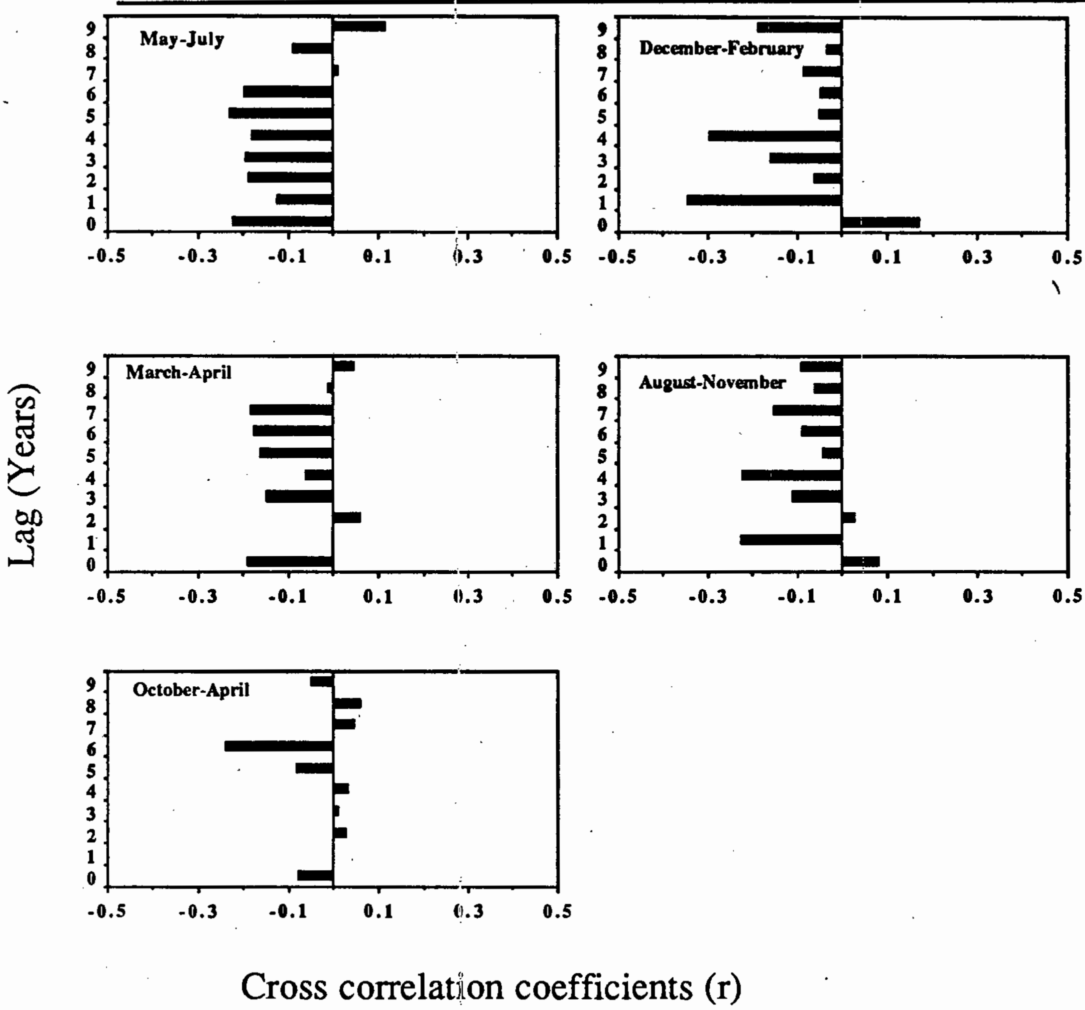


FIGURE 9.4.5 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all months and lags in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.3320	-0.0770	-0.1050	0.0175	-0.1767	0.0410	-0.0140	0.1189	0.1268	0.1106	-0.0620	0.2126
1	-0.0292	0.0580	0.0646	-0.0200	-0.4593	0.2190	0.0238	-0.1187	0.0235	-0.1309	-0.0360	0.2003
2	0.0575	-0.0283	-0.1226	0.1767	-0.1449	0.0718	0.0211	0.3586	-0.0501	0.1803	-0.0878	0.1626
3	-0.0383	-0.0063	-0.1187	-0.1842	-0.2915	0.3319	-0.1608	0.0321	0.2925	0.0315	0.0764	0.0381
4	-0.0215	-0.0583	0.0122	-0.3322	-0.2035	0.3135	-0.1072	0.0475	0.2512	-0.0641	-0.1125	0.0358
5	0.0031	0.1002	-0.0896	-0.0040	-0.0044	0.1148	-0.0347	-0.1636	0.0720	0.0561	-0.0459	0.1052
6	-0.1633	0.0777	-0.1338	-0.1557	-0.0434	0.0363	-0.1254	-0.1897	0.0988	0.1223	-0.0697	0.1256
7	0.2539	0.0373	0.0504	-0.0520	0.1549	0.1943	-0.0702	-0.2070	0.3118	0.0790	-0.0793	0.2809
8	0.0810	-0.0858	-0.0872	-0.0472	-0.0447	0.1658	-0.1130	-0.1030	0.2054	-0.1016	-0.0176	-0.0902
9	-0.0040	0.1908	0.0073	-0.1437	0.1966	-0.1723	0.0547	0.0906	-0.0222	0.0193	-0.1555	0.1803

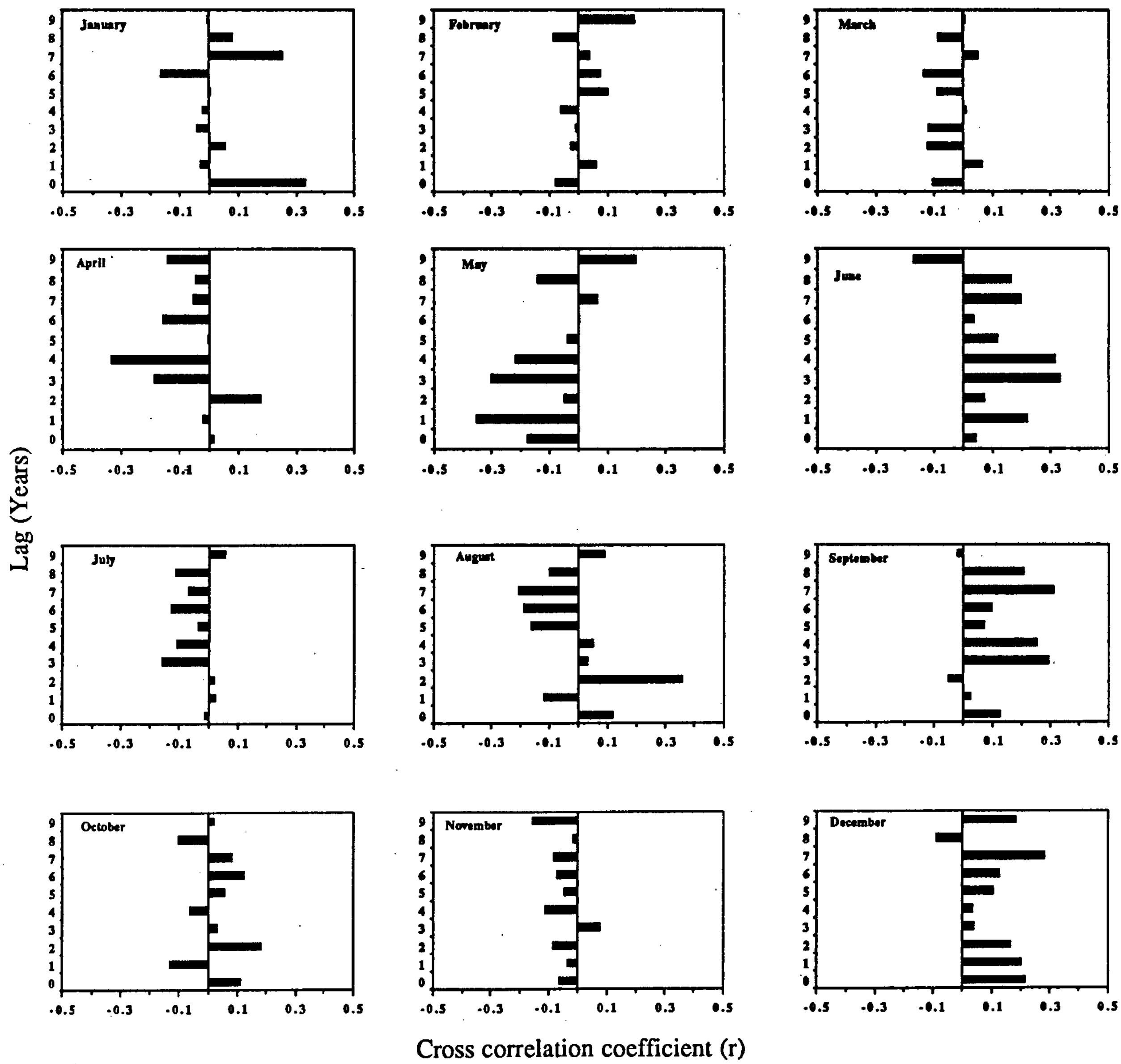


FIGURE 9.4.6 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.1198	0.2236	-0.0510	-0.0118	0.2226
1	-0.2413	0.0535	0.0240	-0.0095	-0.1988
2	-0.1122	0.0697	0.0659	0.2914	0.1654
3	-0.1453	-0.0418	-0.2214	-0.1536	0.2149
4	-0.0420	-0.0698	-0.2590	-0.2115	0.0902
5	-0.0057	0.1155	-0.0587	0.1294	-0.0517
6	-0.1218	0.1000	-0.2078	-0.0633	-0.0604
7	0.2053	0.0464	-0.0106	0.0588	0.0138
8	-0.0125	0.1357	-0.0919	-0.0574	0.0136
9	0.0860	0.0372	-0.1108	-0.0327	-0.0788

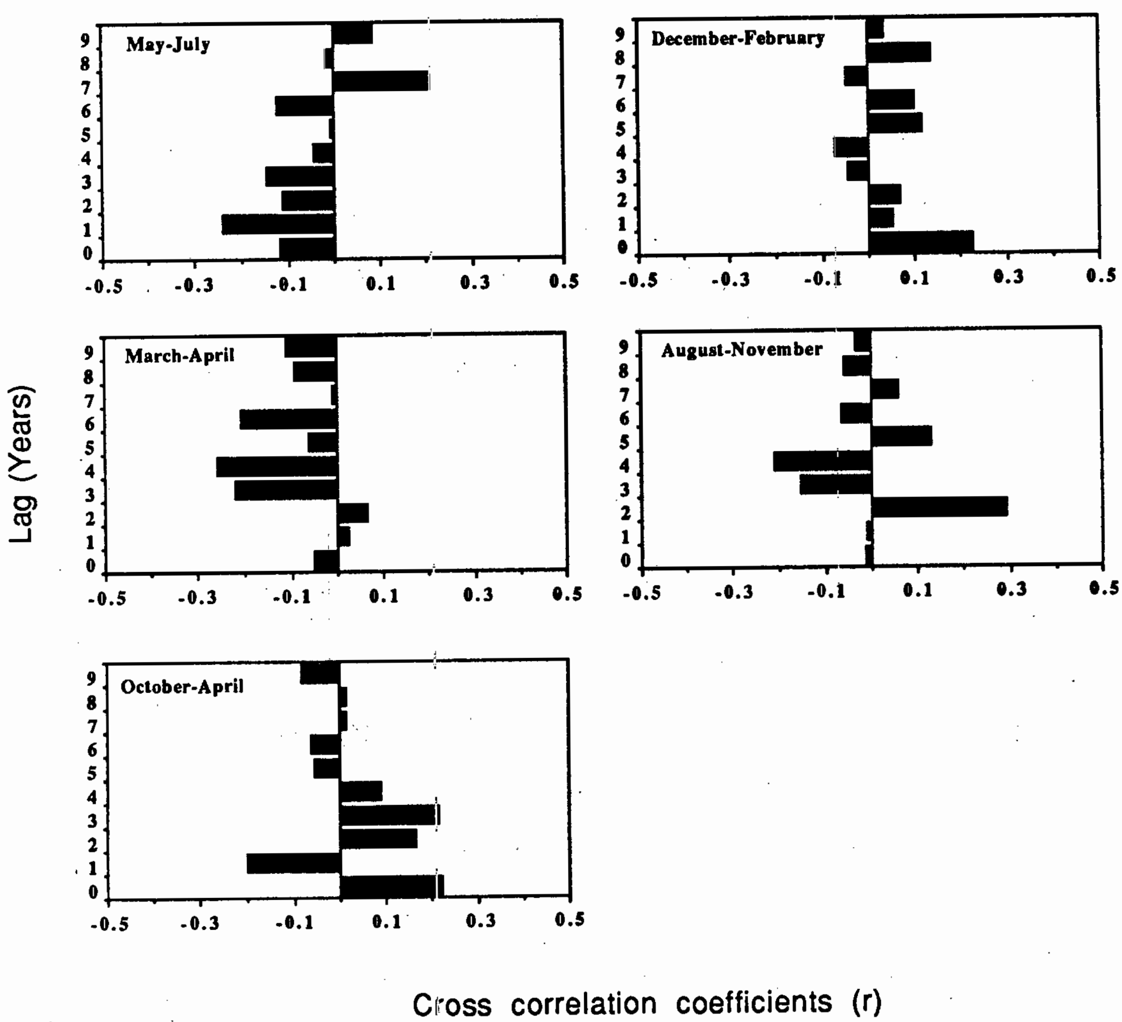
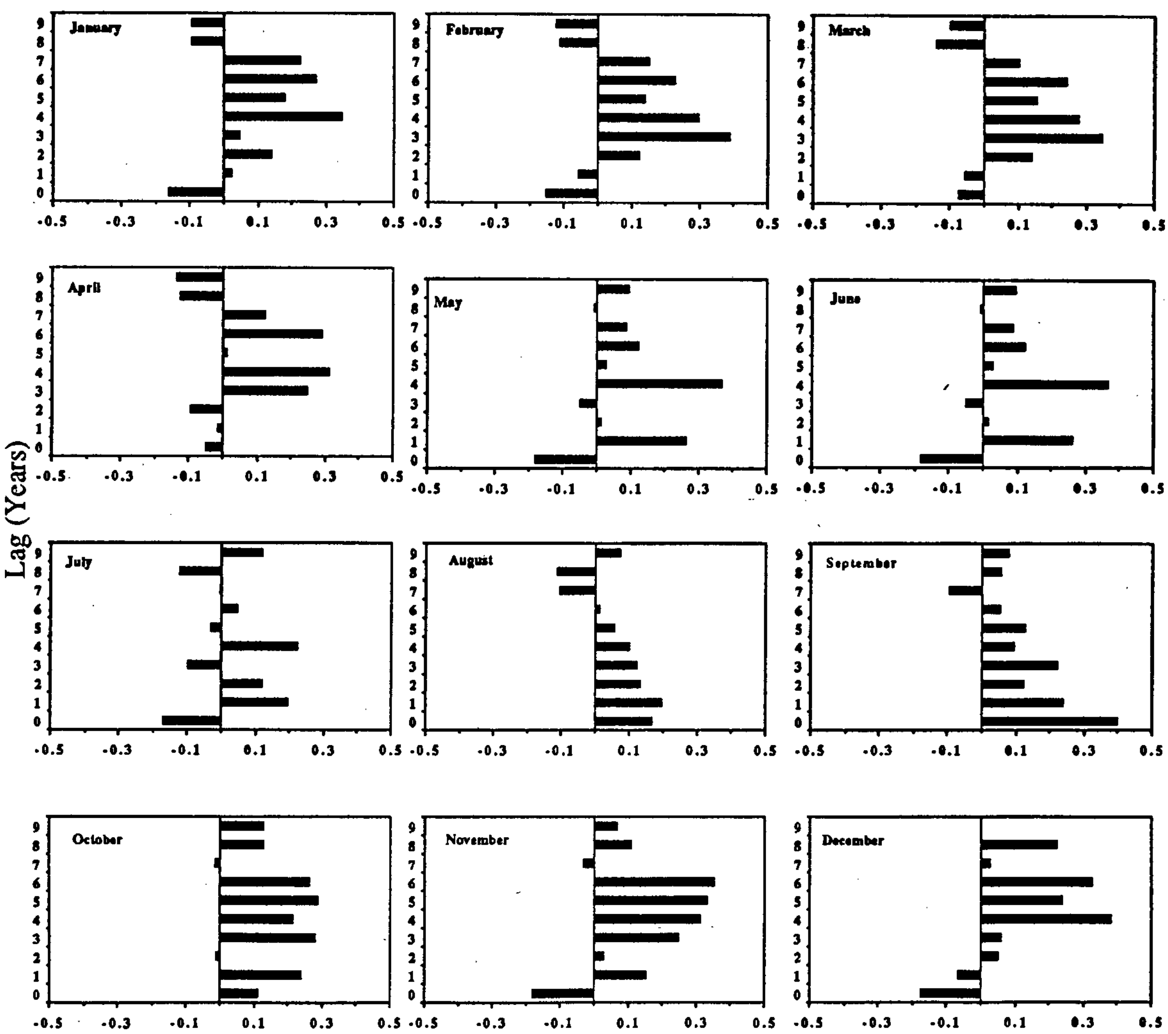


FIGURE 9.4.7 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1622	-0.1490	-0.0721	-0.0497	-0.1246	-0.1805	-0.1721	0.1695	0.3984	0.1108	-0.1835	-0.1736
1	0.0200	-0.0570	-0.0553	-0.0128	0.1636	0.2607	0.1972	0.1951	0.2379	0.2394	0.1539	-0.0680
2	0.1415	0.1218	0.1391	-0.0958	-0.1706	0.0136	0.1175	0.1317	0.1226	-0.0104	0.0271	0.0496
3	0.4593	0.3879	0.3460	0.2472	0.1153	-0.0480	-0.0970	0.1214	0.2216	0.2801	0.2478	0.0579
4	0.3447	0.2960	0.2758	0.3125	0.4010	0.3676	0.2222	0.1022	0.0945	0.2143	0.3129	0.3821
5	0.1777	0.1399	0.1546	0.0122	0.0224	0.0263	-0.0308	0.0555	0.1263	0.2853	0.3322	0.2378
6	0.2697	0.2284	0.2414	0.2918	0.2193	0.1213	0.0462	0.0127	0.0529	0.2631	0.3538	0.3260
7	0.2226	0.1495	0.0997	0.1217	0.1287	0.0881	-0.0034	-0.1058	-0.0932	-0.0150	-0.0313	0.0245
8	-0.0938	-0.1128	-0.1400	-0.1251	-0.0211	-0.0086	-0.1210	-0.1106	0.0543	0.1252	0.1079	0.2215
9	-0.0951	-0.1232	-0.0975	-0.1370	-0.0496	0.0927	0.1185	0.0738	0.0758	0.1263	0.0675	-0.0016



Cross correlation coefficients (r)

FIGURE 9.4.8 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.1565	-0.1421	-0.0542	0.0706	-0.0557
1	0.2566	-0.0121	-0.0699	0.2592	-0.0266
2	-0.0237	0.0132	-0.0062	0.0244	0.0185
3	-0.0024	0.3684	0.2914	0.2425	0.3359
4	0.3630	0.3034	0.2847	0.1644	0.3202
5	0.0073	0.1676	0.0724	0.1745	0.1843
6	0.1459	0.1488	0.2634	0.2464	0.1594
7	0.0742	0.2400	0.1320	-0.1138	0.1959
8	-0.0440	-0.0550	-0.1314	-0.0028	-0.0244
9	0.0562	-0.1387	-0.1292	0.1183	-0.1595

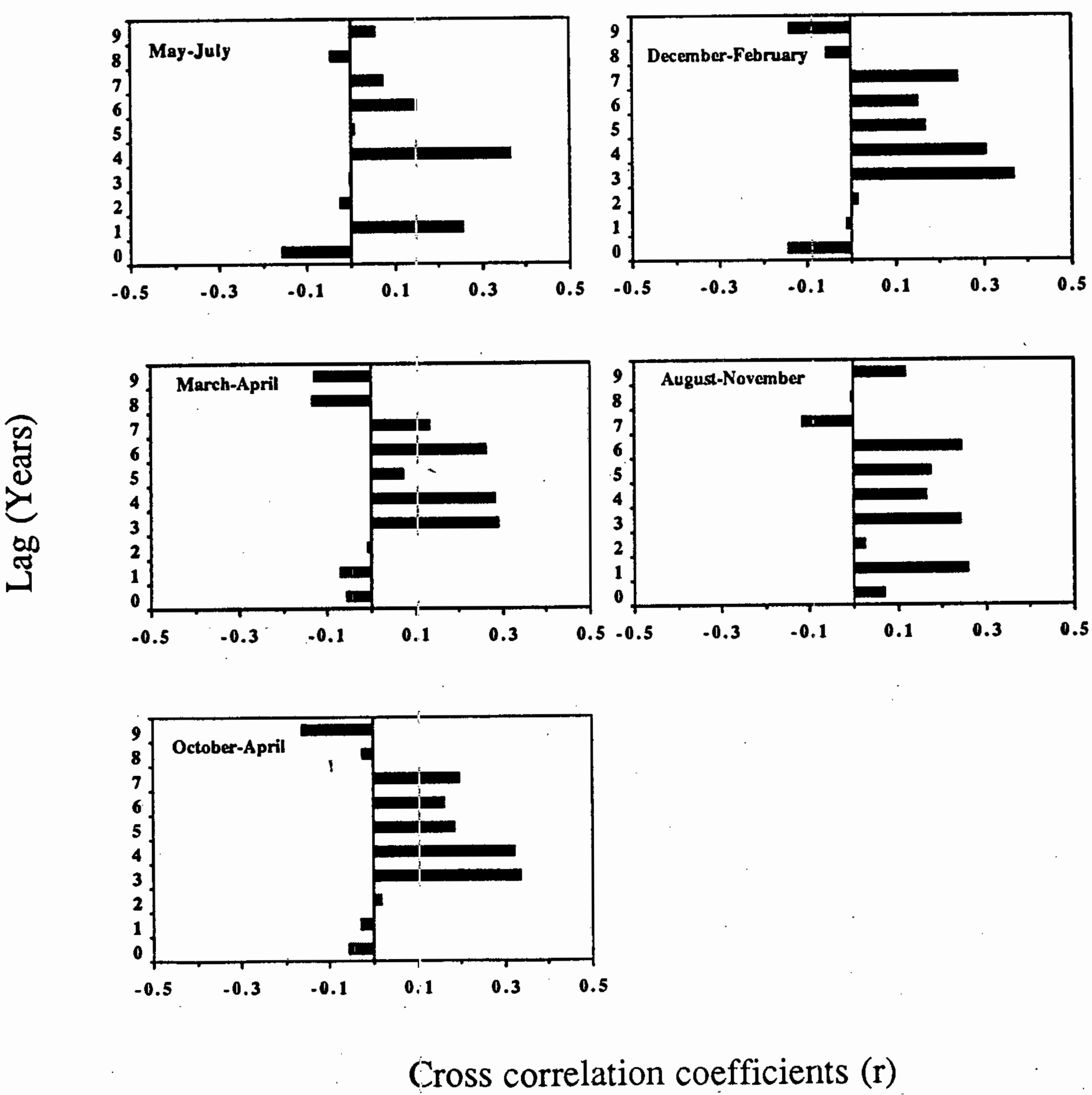


FIGURE 9.4.9 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.0106	-0.1053	-0.1654	-0.3091	-0.1232	0.1049	0.0962	-0.0313	-0.1450	-0.1784	-0.2904	-0.0163
1	-0.0934	-0.0851	-0.1364	-0.0348	-0.2751	-0.4109	-0.0859	-0.0022	0.1868	-0.1836	-0.0105	0.0001
2	-0.0223	-0.0735	-0.0617	0.0764	0.2506	0.0492	-0.0935	-0.0118	-0.3011	0.1221	-0.0117	-0.1351
3	-0.1661	-0.0544	-0.1333	-0.1170	0.1275	0.1741	-0.2234	-0.1051	0.2449	-0.1215	-0.0118	-0.2052
4	-0.1535	-0.0055	-0.1283	-0.2476	-0.1463	0.2496	-0.1565	-0.1110	-0.1625	-0.0331	-0.0498	-0.0303
5	-0.0579	0.0894	-0.0714	-0.0045	0.1164	0.1453	-0.1723	0.0119	-0.0389	0.1533	-0.0672	-0.1046
6	-0.1292	-0.0844	-0.2616	-0.0620	0.0764	0.1476	0.0048	-0.0203	-0.1343	0.0211	-0.0822	-0.1179
7	-0.2330	-0.0478	-0.0264	-0.3486	0.1649	0.0999	-0.0861	0.0003	-0.0046	-0.2790	-0.1921	-0.1155
8	-0.0551	-0.0846	-0.0292	-0.0971	-0.1898	0.1043	-0.0598	-0.1201	0.1065	-0.1369	0.1177	-0.2324
9	-0.0276	0.1107	-0.0962	0.0115	-0.0087	0.1118	0.1014	0.0957	-0.0632	0.0968	-0.2096	0.1464

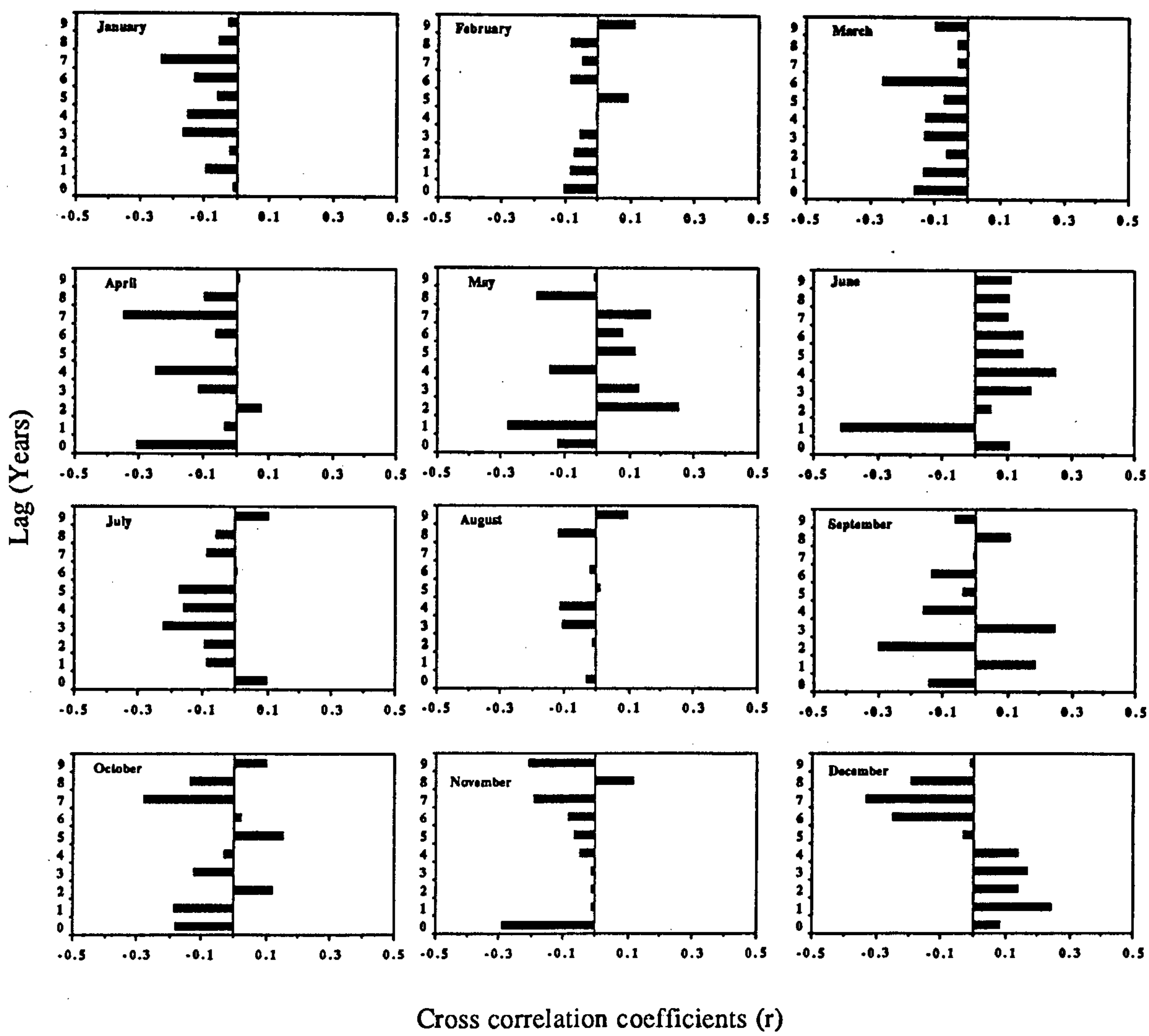


FIGURE 9.4.10 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.3327	0.1185	-0.2491	-0.2725	-0.0746
1	-0.3806	-0.3370	-0.0406	0.0701	0.0237
2	0.1437	-0.0540	0.0139	-0.0965	0.0047
3	-0.0267	0.0211	-0.1135	-0.0663	-0.0594
4	0.0947	-0.2158	-0.1419	-0.0987	-0.0104
5	0.2124	0.0942	-0.0214	0.0930	0.1157
6	0.1120	-0.2310	-0.1485	-0.0873	-0.3032
7	0.0432	-0.2572	-0.1511	-0.0459	-0.1680
8	-0.0529	0.0216	-0.0373	0.2477	0.0663
9	0.1459	-0.1601	-0.1291	0.0868	-0.1304

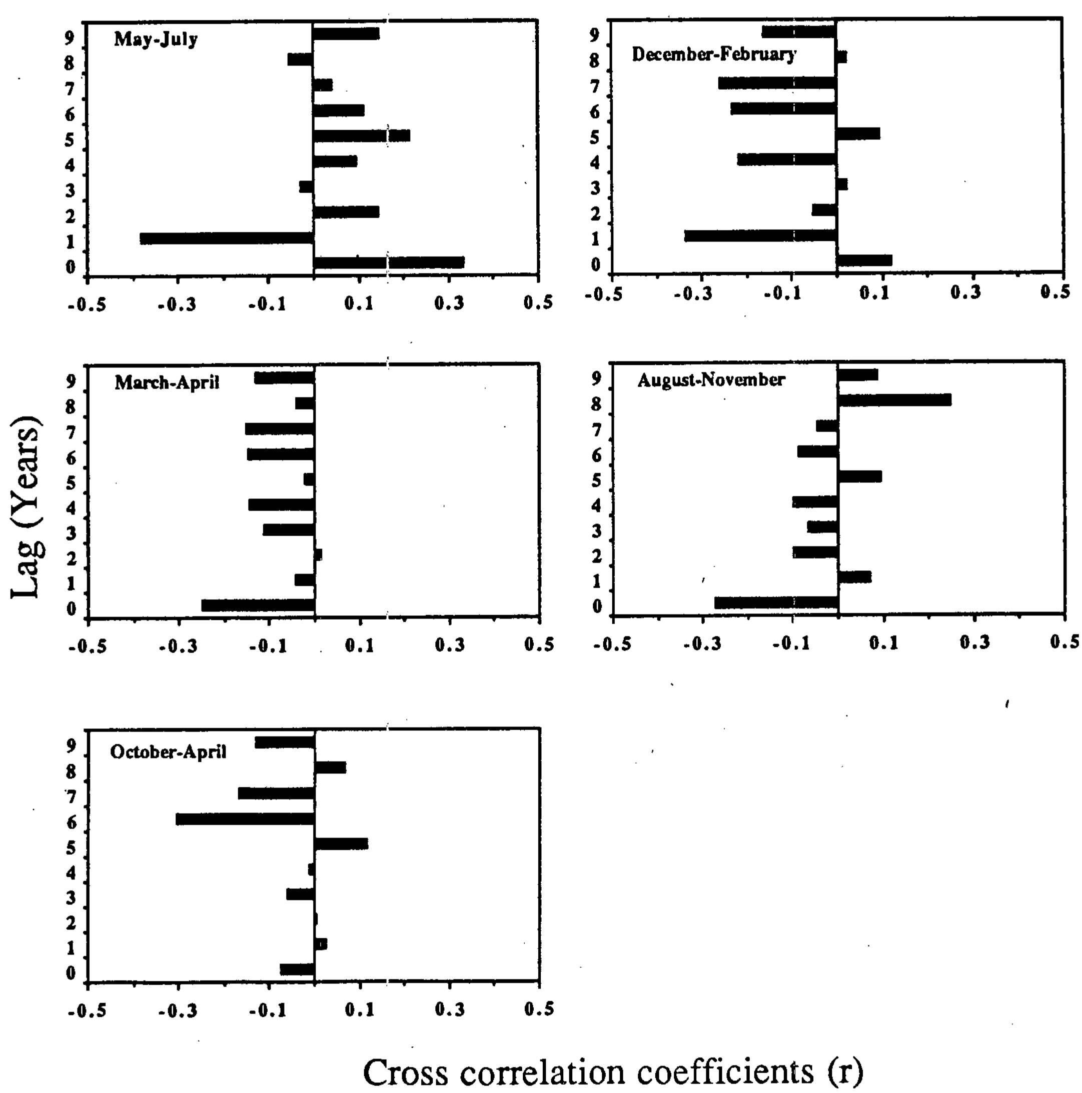


FIGURE 9.4.11 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all months and lags in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.1538	0.1003	-0.0371	-0.0321	-0.0582	0.1208	0.2489	-0.0661	0.0353	-0.0403	-0.2571	0.0823
1	-0.1035	0.0898	-0.0074	-0.1181	-0.4325	-0.2335	-0.0785	0.0180	0.1481	0.0354	-0.2591	0.2408
2	0.1418	0.0293	0.0887	-0.0039	0.0397	-0.0789	-0.0085	-0.0728	-0.1825	-0.1695	-0.1287	0.1348
3	0.1637	-0.0375	0.1344	-0.1752	-0.3885	0.1941	-0.0241	-0.0988	-0.0662	0.2993	-0.0041	0.1629
4	0.2040	0.0650	0.1548	-0.2505	-0.2996	-0.2977	-0.0953	-0.1450	-0.0895	-0.2689	-0.0811	0.1348
5	0.3183	0.1648	0.2147	0.1455	-0.0900	0.0055	-0.0812	-0.0741	-0.0446	0.2125	0.0136	-0.0317
6	-0.0146	0.2436	-0.0959	-0.0055	0.0056	0.0409	-0.2238	0.0613	-0.1537	0.1638	0.1243	-0.2466
7	-0.0322	0.2119	0.0748	0.1016	0.3059	-0.0245	0.0200	0.0368	0.1911	-0.1367	0.1155	-0.3333
8	-0.1337	0.3694	0.0361	0.0842	-0.0246	-0.0130	-0.1600	0.1738	0.3044	0.1462	0.0697	-0.1907
9	-0.2990	0.2417	-0.1402	-0.0428	0.1083	0.0148	-0.0279	0.2315	0.2974	0.2121	-0.0792	-0.0106

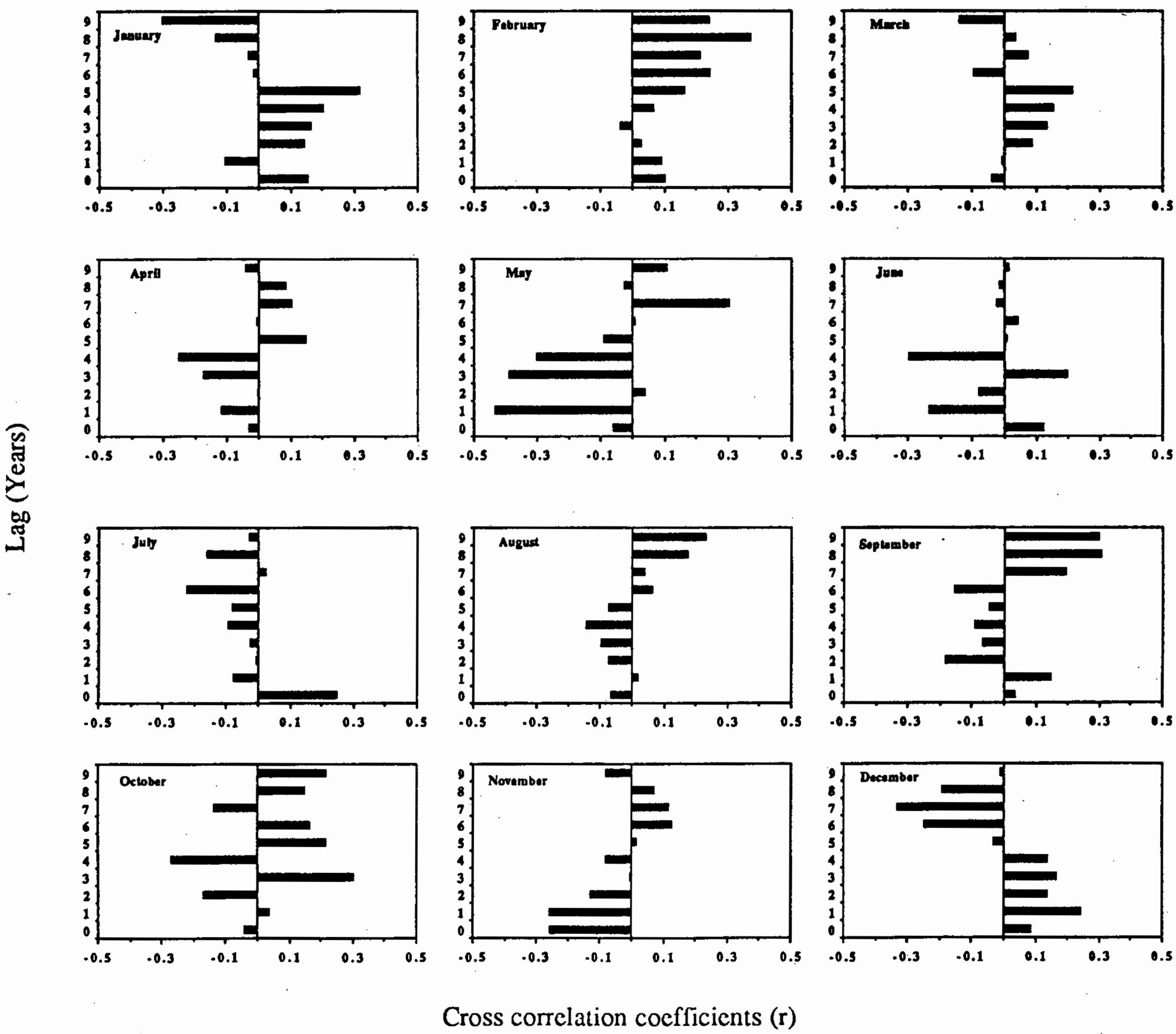


FIGURE 9.4.12 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1477	0.2809	-0.0587	-0.1022	0.0291
1	-0.3837	0.0298	-0.0704	-0.0855	-0.0396
2	-0.0243	0.1428	0.0777	-0.1676	0.1556
3	-0.1050	0.1422	0.0235	-0.0329	-0.0221
4	-0.3585	0.1466	-0.0010	-0.2513	0.1377
5	-0.0813	0.1947	0.2678	-0.0087	0.2850
6	-0.0829	0.0133	-0.0872	0.0357	-0.0305
7	0.1532	-0.0193	0.1211	0.0904	0.1336
8	-0.0940	0.1713	0.0804	0.2864	0.1666
9	0.0540	-0.0467	-0.1407	0.2280	-0.1340

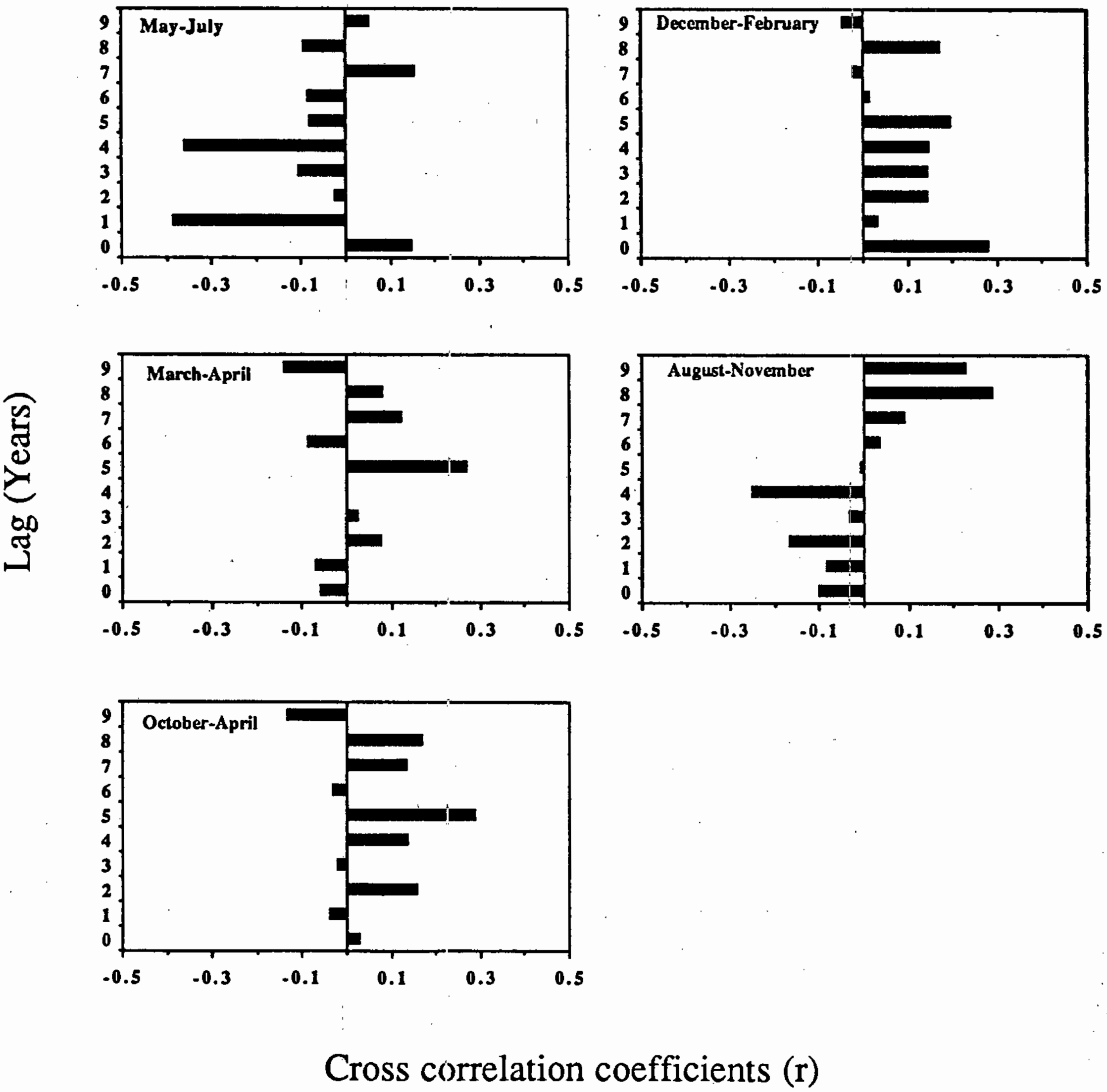


FIGURE 9.4.13 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the Agulhas Bank area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.2775	-0.3077	-0.2491	-0.1417	-0.0902	0.0259	0.2067	0.3268	0.2203	-0.1239	-0.2778	-0.1718
1	-0.0787	-0.2157	-0.0866	-0.0281	-0.0718	0.0579	0.2528	0.2678	0.1448	0.0540	0.0882	0.0151
2	-0.3222	-0.2452	-0.1514	-0.1366	-0.1380	-0.0222	0.0801	0.1321	0.0560	-0.1095	-0.0890	-0.0356
3	0.0229	0.1362	0.0650	0.0626	0.1115	0.1097	0.0951	0.1213	0.0574	-0.1176	-0.2045	-0.2417
4	-0.0236	-0.0642	-0.0386	0.0988	0.3077	0.3232	0.0471	-0.1713	-0.2167	-0.2106	-0.2228	-0.1451
5	-0.2080	-0.0734	-0.0984	-0.1203	-0.0341	0.0086	-0.1058	-0.1146	-0.0822	-0.0412	-0.1220	-0.1944
6	0.0086	0.0071	0.0431	0.1334	0.1273	0.0088	-0.0938	-0.1700	-0.1495	-0.0686	-0.1389	-0.2174
7	-0.0671	-0.0153	-0.0140	0.0381	0.1479	0.1356	-0.0477	-0.2377	-0.2784	-0.1744	-0.2101	-0.1999
8	0.1325	-0.0819	-0.1597	-0.1074	-0.0462	-0.0218	-0.0570	-0.0980	-0.0272	0.0581	-0.0005	-0.0142
9	-0.0825	-0.0481	0.1110	0.2117	0.1242	-0.0093	0.0488	0.0339	0.0443	0.1700	0.2023	0.1818

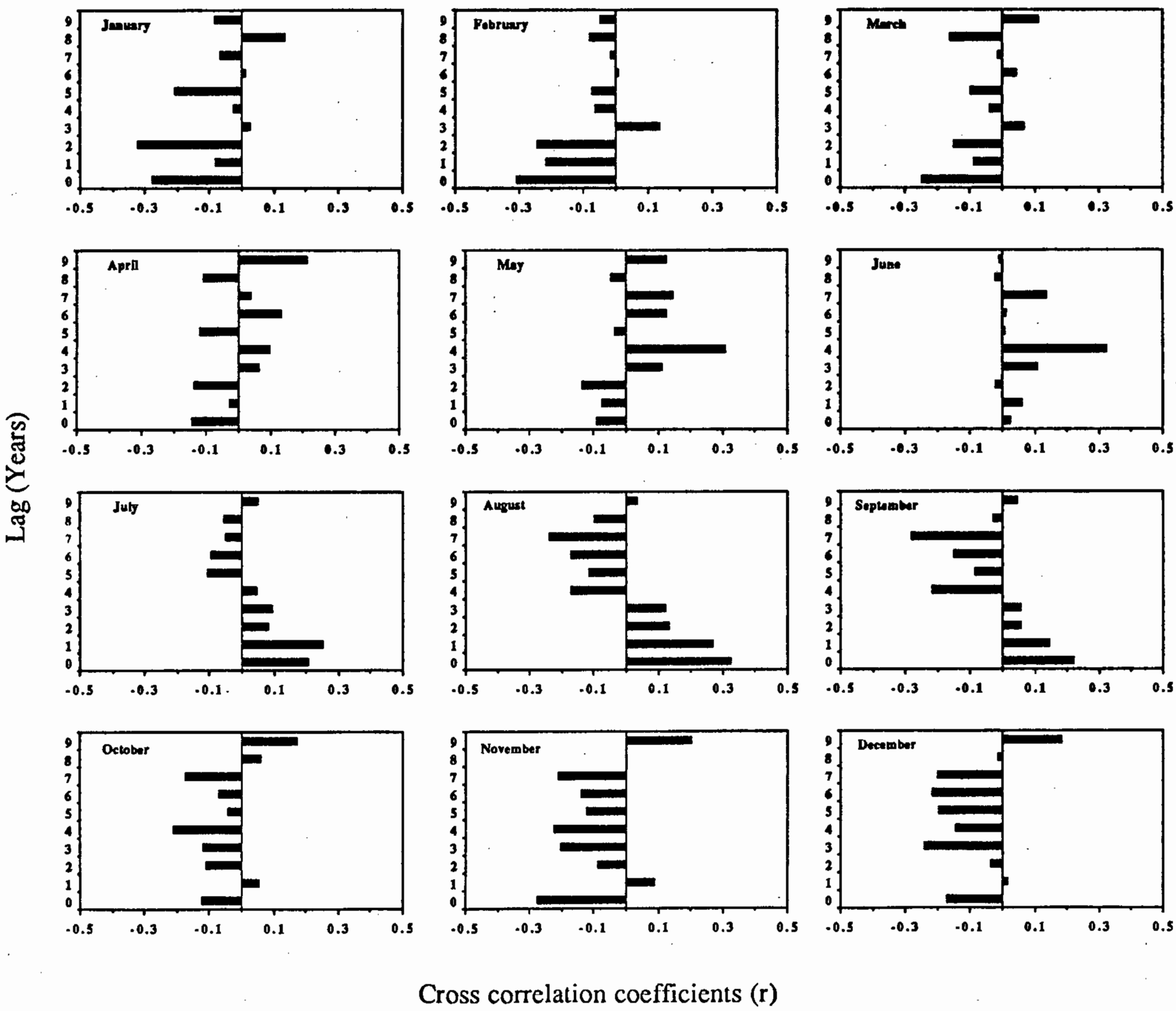


FIGURE 9.4.14 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Agulhas Bank area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.0203	-0.2048	-0.2019	0.0599	-0.2451
1	0.0945	-0.0687	-0.0591	0.1654	-0.0412
2	-0.0762	-0.3647	-0.1493	0.0056	-0.3229
3	0.0413	0.0974	0.0662	-0.0315	-0.0026
4	0.2838	-0.1051	0.0323	-0.2344	-0.0371
5	-0.0582	-0.1422	-0.1137	-0.1050	-0.1579
6	-0.0070	-0.0613	0.0923	-0.1543	-0.0835
7	0.1084	-0.0801	0.0129	-0.2612	-0.0334
8	-0.0736	0.0758	-0.1382	-0.0242	-0.0394
9	0.0217	-0.0871	0.1683	0.1233	0.0279

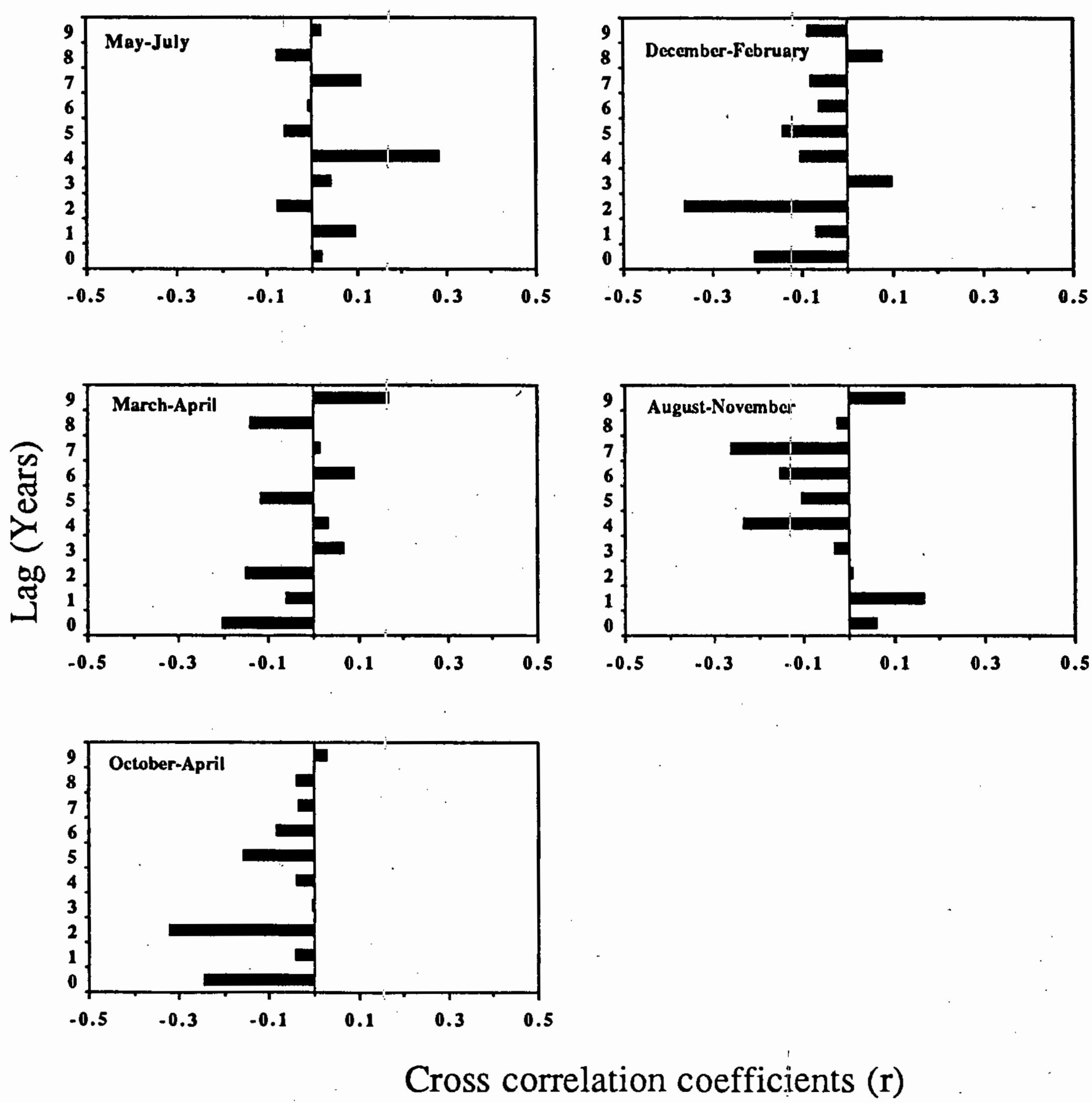


FIGURE 9.4.15 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Agulhas Bank area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.2023	-0.1558	-0.1628	0.0344	0.0350	0.3100	0.2735	-0.0101	0.1872	0.1543	-0.2511	-0.1624
1	0.1516	-0.1601	0.2555	-0.0582	-0.3382	-0.0091	-0.0086	0.0603	0.0358	-0.0623	0.1048	0.0951
2	0.3628	0.2882	0.2007	0.2369	0.1623	0.2248	0.1771	0.0291	-0.1385	0.3838	0.0975	0.2520
3	0.1782	0.1013	0.2822	0.2094	0.0586	0.2064	0.0417	0.0296	0.3088	0.2868	0.2592	0.1026
4	0.2887	0.3549	0.3770	0.0133	-0.1056	0.3368	-0.0649	-0.0560	0.1043	0.3131	0.2306	0.4614
5	0.1302	0.4719	0.1151	0.1731	0.1158	0.1402	-0.0156	-0.0316	0.2267	0.3293	0.2388	0.3607
6	0.2482	0.2244	-0.0738	0.0405	0.1098	0.0070	-0.0964	-0.1247	0.1234	0.3592	0.2712	0.0592
7	0.0224	0.2743	0.0861	-0.1445	0.2825	0.2411	-0.0369	-0.0410	0.2118	0.0602	-0.0311	0.1359
8	0.0739	0.0253	-0.1528	0.0316	-0.1192	0.1430	-0.1228	-0.0172	0.1989	-0.1344	0.0333	-0.1895
9	0.1336	0.0371	-0.0936	0.0884	-0.0147	-0.0768	-0.0655	0.0181	0.1456	0.0764	-0.1403	0.1123

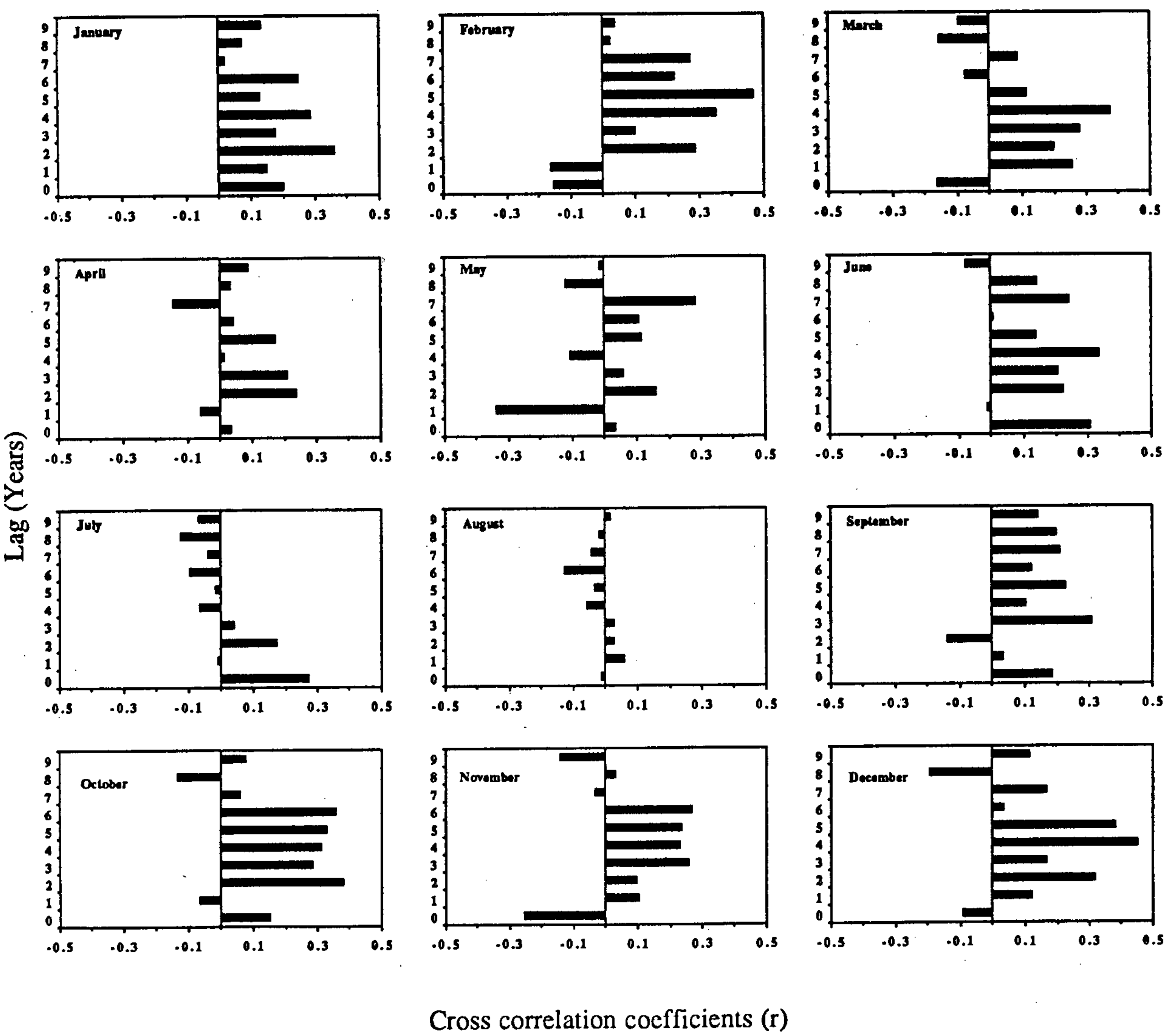


FIGURE 9.4.16 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Agulhas Bank area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.3249	0.1271	0.0271	-0.0823	-0.1171
1	-0.1794	0.0580	0.0263	0.1263	0.0986
2	0.2936	0.3693	0.0386	0.2927	0.2773
3	0.1628	0.1281	0.1113	0.3268	0.2362
4	0.0970	0.4232	0.0673	0.2543	0.3832
5	0.1265	0.0889	0.0902	0.1934	0.3368
6	0.0102	0.1983	0.0623	-0.0203	0.1327
7	0.2543	-0.0399	0.0199	-0.0429	-0.0233
8	-0.0446	0.0562	0.0055	-0.0778	0.0907
9	-0.0824	0.0306	0.0033	-0.0004	0.0039

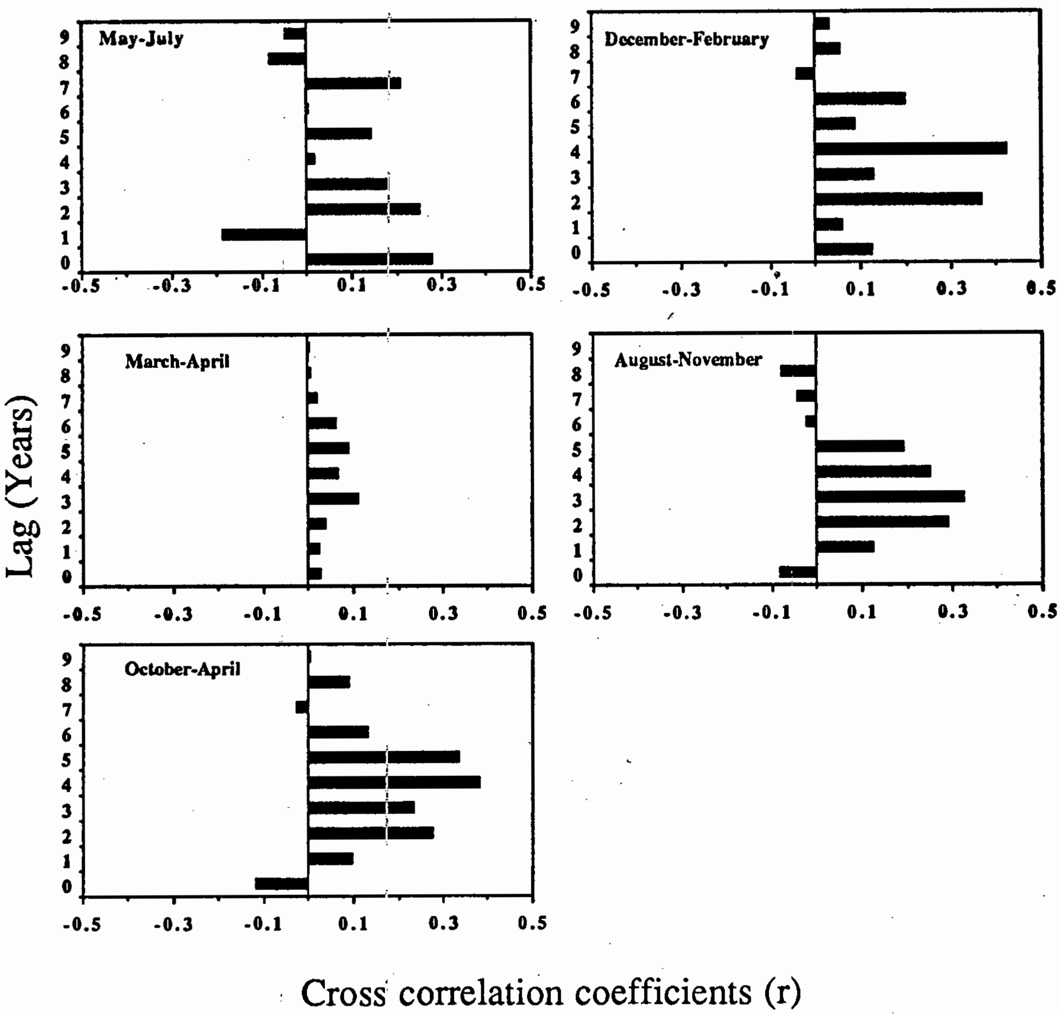


FIGURE 9.4.17 Tabular and graphical representation of the cross-correlation coefficients between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all months and lags in the Agulhas Bank area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.2635	-0.0775	-0.1944	-0.0199	0.0056	0.1811	0.4094	-0.0343	0.2012	0.0770	-0.0286	0.0985
1	-0.2471	-0.0754	0.2319	-0.1423	-0.4507	-0.1553	0.1212	-0.1039	0.2246	-0.3362	0.0251	0.4416
2	0.1519	0.0388	0.1184	0.1544	0.1854	0.0564	0.2195	0.1531	-0.0797	-0.0470	-0.1111	0.1809
3	-0.1056	-0.1322	0.1100	-0.0833	-0.1773	0.3400	0.2072	0.1149	0.2391	0.1990	0.0778	0.1169
4	-0.1278	0.0619	0.1803	-0.2512	-0.1341	0.2204	0.0314	0.0430	0.0071	-0.1526	0.1024	0.2456
5	0.1017	0.1360	0.0566	0.1558	0.0544	0.1208	0.0602	-0.0416	0.0923	0.2035	-0.2117	0.1831
6	-0.0151	0.1383	-0.1872	-0.0286	0.1410	0.2428	-0.1559	0.0241	0.0081	0.2662	-0.3015	-0.2087
7	-0.0691	0.0977	0.0661	0.0285	0.3502	0.3206	0.1753	0.2185	0.1771	-0.1168	-0.1903	-0.1458
8	-0.1373	0.1397	-0.0057	0.0005	-0.1381	-0.0269	-0.1092	0.1014	0.0896	-0.0284	0.0135	-0.0586
9	-0.0245	0.1984	-0.0774	-0.0798	0.0646	-0.0120	-0.0303	0.1974	0.0128	-0.0747	-0.1536	0.1709

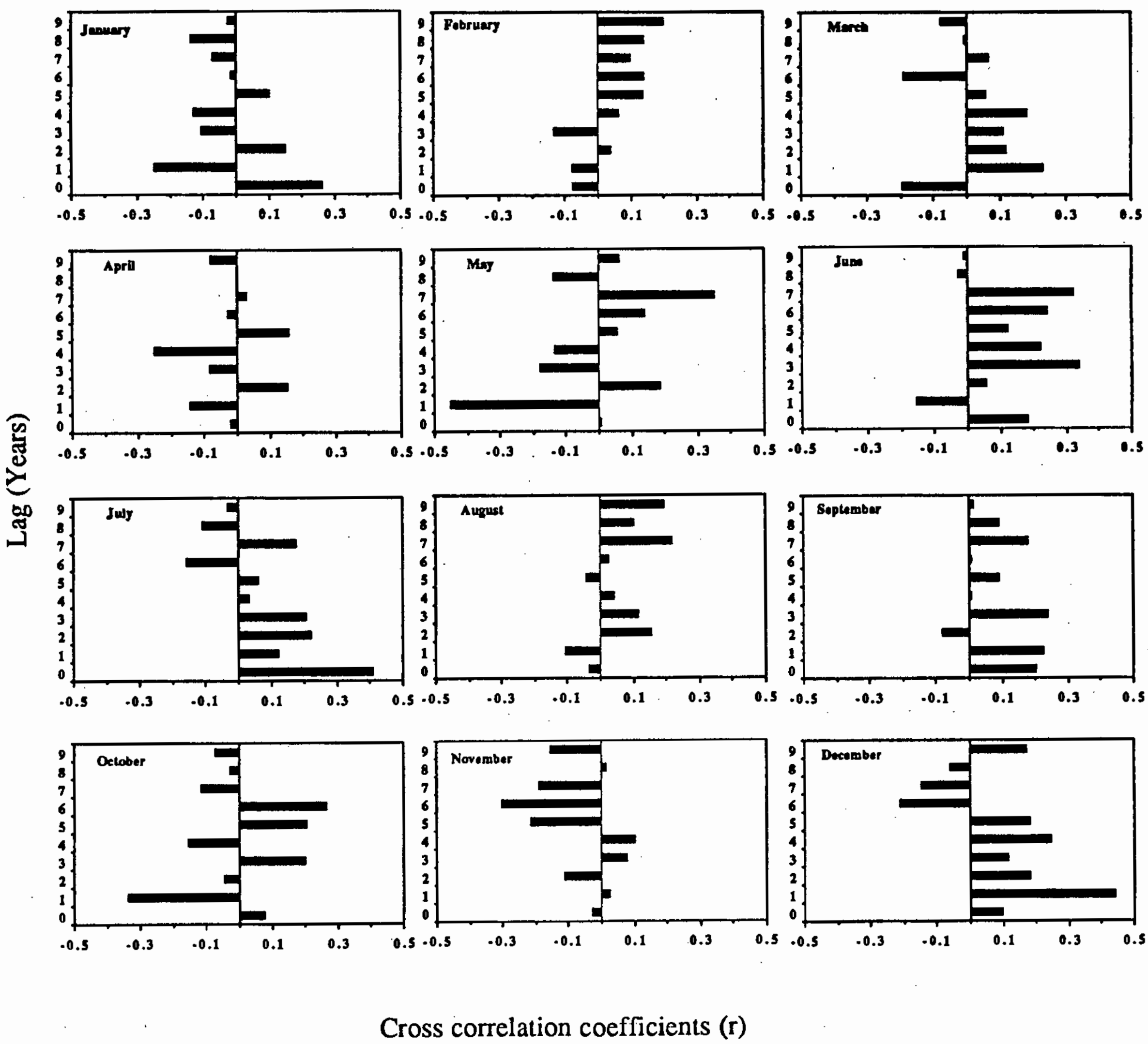


FIGURE 9.4.18 Tabular and graphical representation of the cross-correlation between pilchard (*Sardinops ocellatus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Agulhas Bank area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.3278	0.2165	0.0019	-0.1393	-0.0303
1	-0.2339	-0.0832	-0.0896	0.0571	-0.0497
2	0.1843	0.1121	-0.0033	0.1784	0.2581
3	0.0885	-0.1044	0.1851	0.0167	-0.0979
4	0.0855	0.1181	-0.0270	-0.0480	0.0811
5	0.0930	0.0572	0.0416	0.1392	0.1583
6	0.0652	0.0368	0.0481	-0.1404	-0.1078
7	0.4124	-0.0831	0.0677	0.0617	0.0092
8	-0.1047	0.1189	0.1340	-0.0033	0.0631
9	0.0575	0.0444	0.1250	-0.1028	0.0131

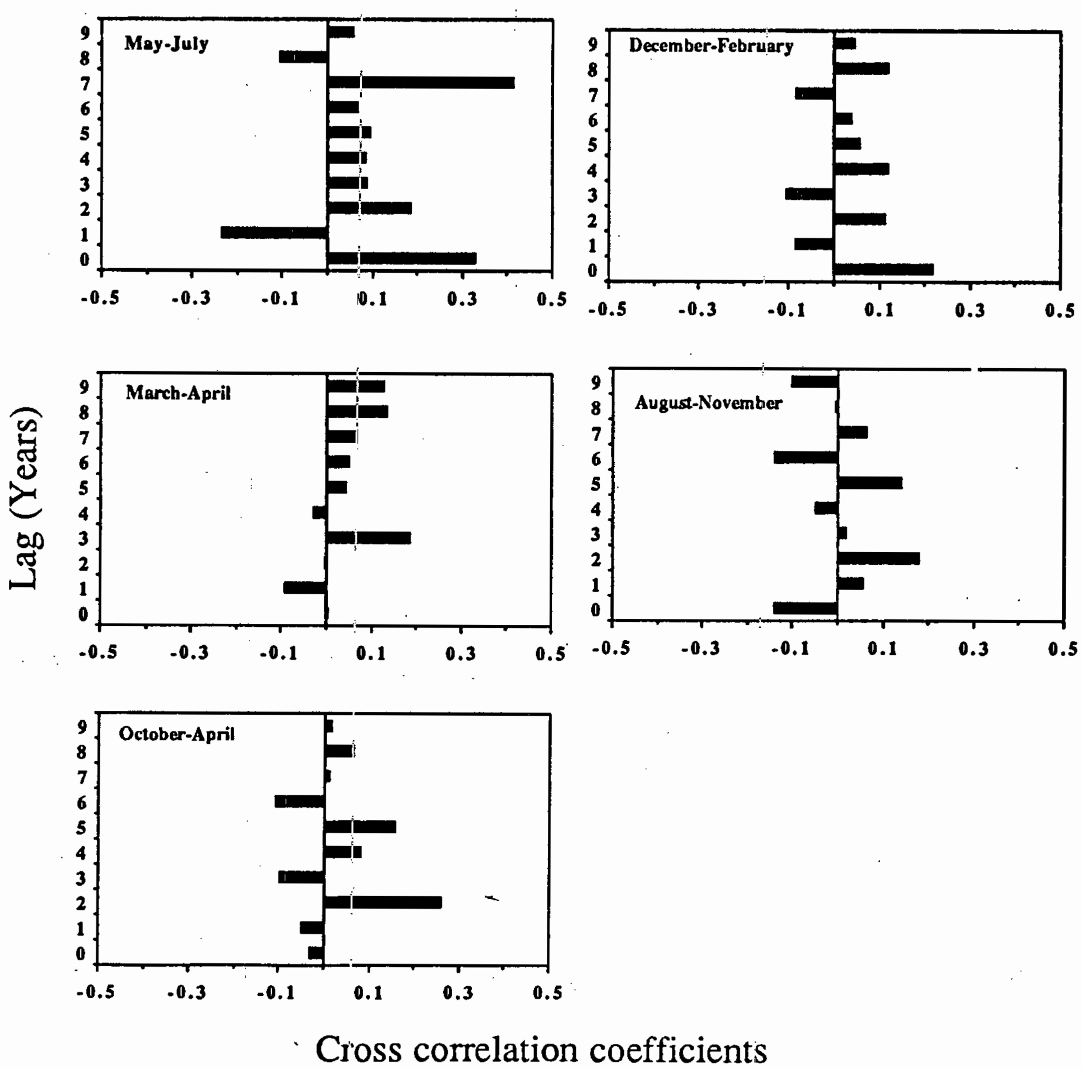


FIGURE 9.4.19 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.2499	-0.1625	-0.0659	0.0395	-0.1364	-0.3159	-0.3099	-0.3374	-0.3254	-0.1862	-0.0573	-0.1778
1	0.3223	0.3953	0.3784	0.1714	0.0354	-0.0944	-0.1021	-0.1443	-0.1604	-0.1629	-0.1386	0.2009
2	-0.1501	-0.1564	-0.1996	-0.0875	0.0591	0.0120	-0.0233	0.0080	0.0016	-0.0208	0.0586	0.2253
3	-0.3545	-0.3153	-0.1582	0.0572	0.1205	0.0653	0.1637	0.1455	0.1199	0.0206	-0.1029	-0.0687
4	-0.0197	0.1572	0.0258	0.1314	0.2246	0.2259	0.1208	0.1955	0.0605	-0.0518	-0.0882	-0.2616
5	0.1172	0.2182	0.2725	0.2430	0.0686	-0.1120	-0.0345	-0.1754	-0.2187	-0.0648	-0.0342	-0.1338
6	0.1538	0.1743	0.0935	0.0658	0.1765	0.2268	0.2125	0.1458	0.1173	0.1234	0.0245	0.0578
7	-0.1954	-0.1450	-0.0658	0.1248	0.2053	0.2038	0.2129	0.2749	0.3018	0.2678	0.2776	0.3588
8	0.1489	0.2587	0.1793	0.1616	0.1686	0.1522	0.1606	0.0527	0.0469	0.0721	-0.0086	-0.2188
9	0.1734	0.2680	0.2144	0.1931	0.1494	0.2287	0.2083	0.0683	0.0389	0.1095	0.1366	0.1026

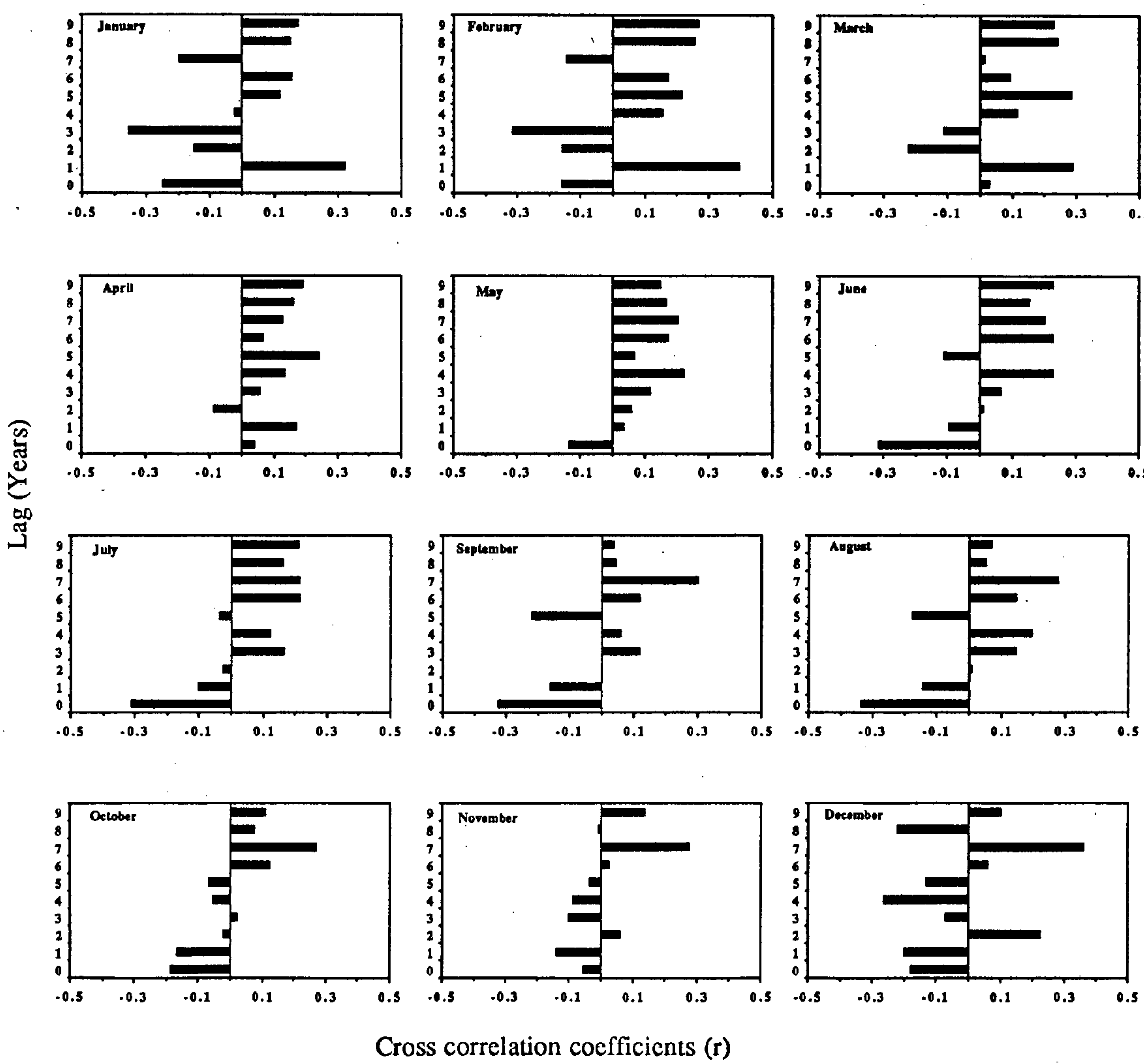


FIGURE 9.4.20 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.2771	-0.0910	-0.0714	-0.2277	-0.1981
1	-0.0583	0.2104	0.3101	0.3441	-0.1787
2	-0.0014	-0.0271	-0.1580	-0.1113	-0.0171
3	0.0800	-0.4917	-0.0522	-0.2870	0.0188
4	0.2345	0.1955	0.0422	-0.0473	0.0523
5	-0.0614	0.0931	0.2649	0.1842	-0.1546
6	0.1839	0.2305	0.0810	0.2385	0.0236
7	0.2113	-0.2243	0.0180	-0.1655	0.3066
8	0.1369	0.2161	0.1556	0.1601	0.0332
9	0.2329	0.2430	0.2027	0.2097	0.1027

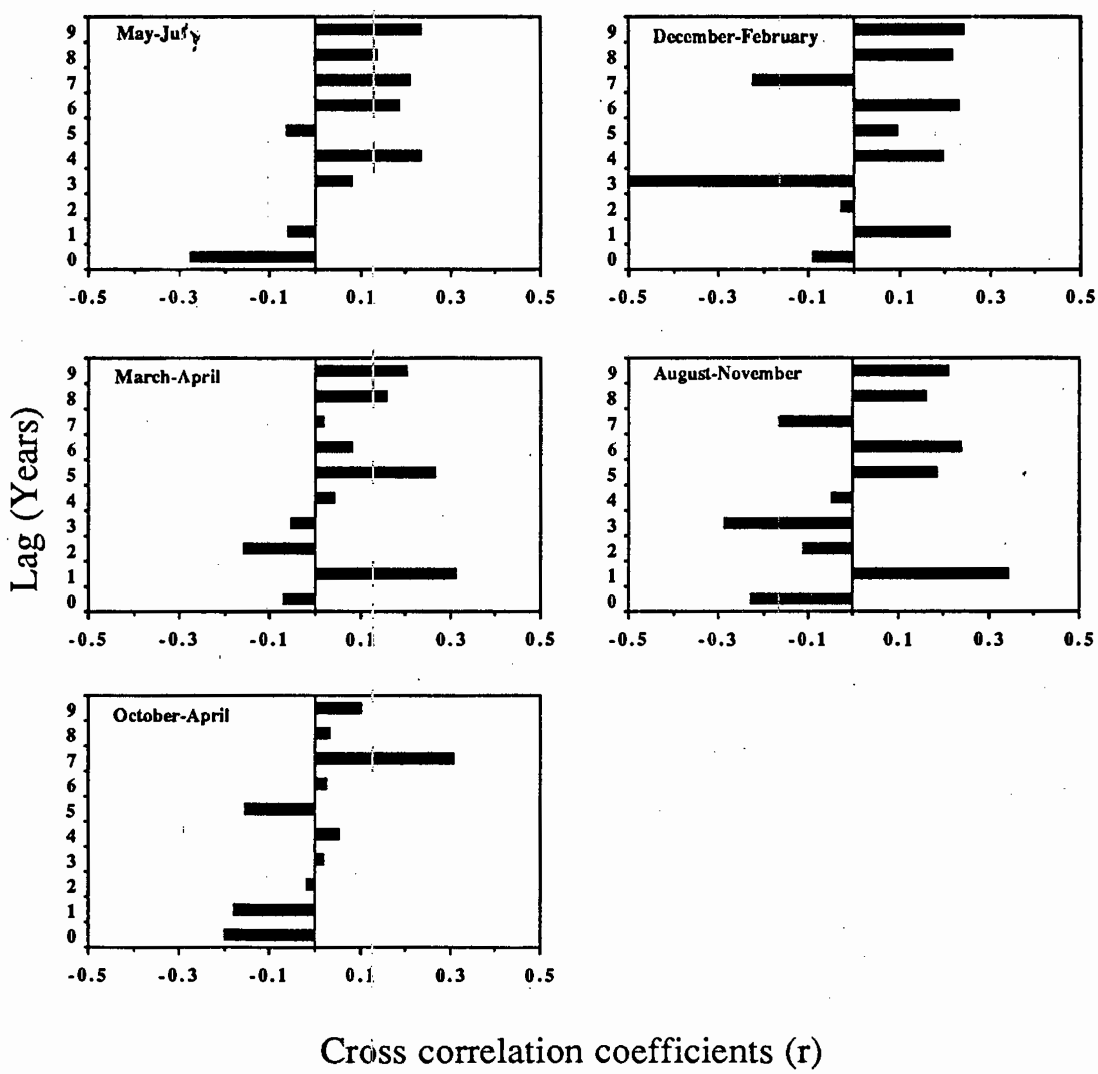


FIGURE 9.4.21 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.0937	-0.1506	-0.0301	-0.0092	0.1612	-0.0898	0.1254	-0.2459	-0.1767	-0.4264	-0.3127	0.0941
1	-0.1706	0.1905	-0.1459	-0.1901	-0.1035	0.0247	-0.0732	-0.2696	-0.1574	0.1754	0.1487	-0.1430
2	-0.0174	-0.1105	0.2698	-0.0562	-0.2130	-0.1181	-0.2811	0.1753	-0.1717	0.0133	-0.3006	0.1472
3	0.1116	-0.0272	0.0074	0.0493	-0.0745	-0.1839	0.2136	-0.0883	0.1195	0.0344	-0.0681	-0.0185
4	0.0196	-0.1188	-0.0883	-0.1827	-0.0010	-0.1542	0.0911	-0.0920	-0.0594	0.1000	-0.1330	0.1977
5	-0.0743	-0.1286	0.0507	0.1484	0.3095	0.2328	-0.1791	0.1565	-0.0034	0.1859	0.0592	0.1082
6	-0.0854	0.1497	0.1278	-0.0970	-0.1662	0.0730	-0.0919	0.2152	0.0597	0.0928	-0.1202	-0.0224
7	0.1762	0.0952	0.0529	0.1610	-0.1918	-0.0155	0.1241	-0.0947	0.0512	0.0522	0.0137	-0.0928
8	0.1616	-0.1338	0.0770	0.1770	0.2958	-0.0445	0.0171	0.1804	-0.1935	0.2077	0.0767	0.2744
9	0.0506	0.2887	0.0579	-0.0459	0.0822	0.1932	-0.0364	0.1414	0.0541	0.0117	-0.0680	0.1122

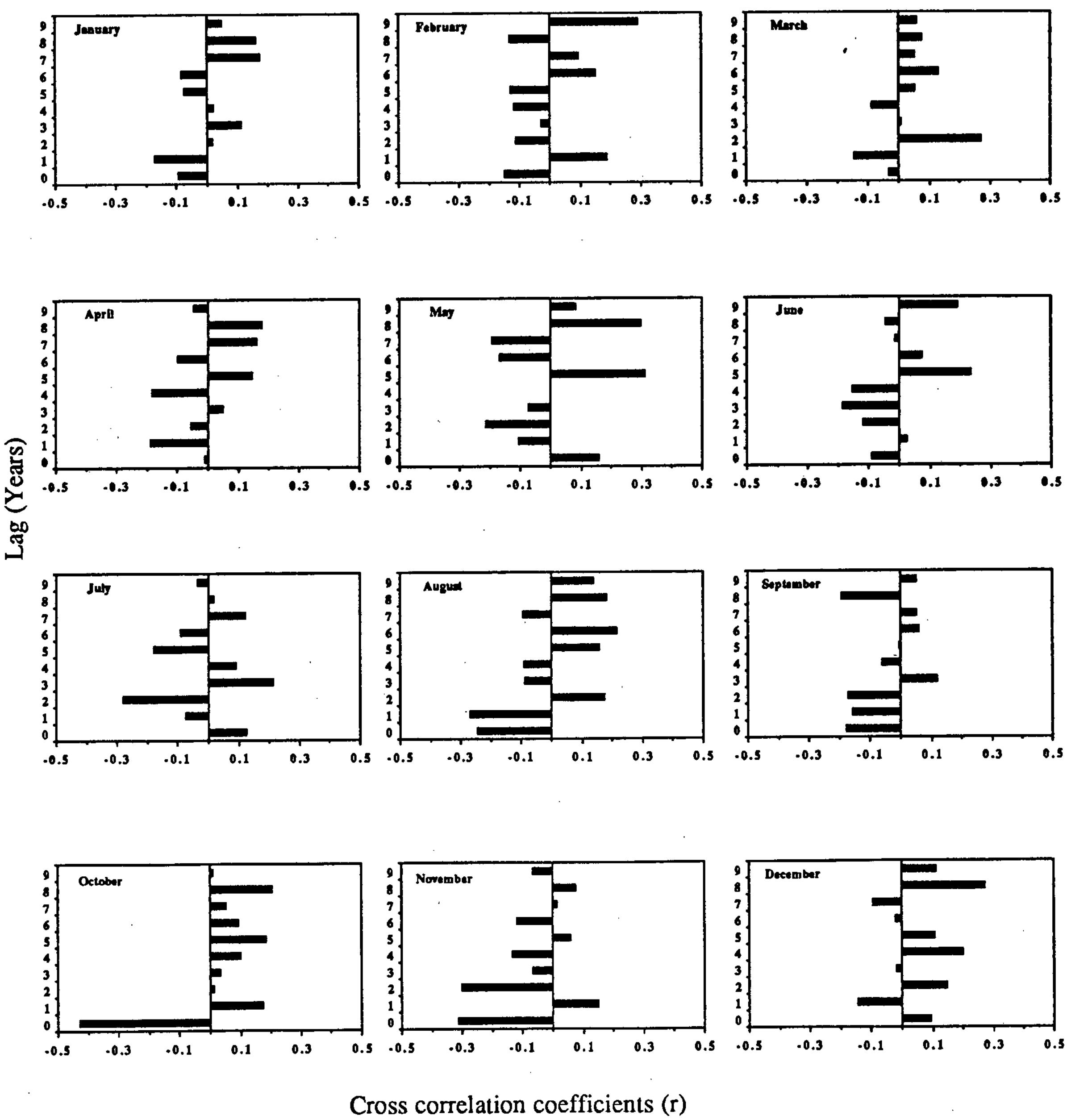


FIGURE 9.4.22 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1929	-0.2467	-0.1146	0.0332	-0.4367
1	0.0904	0.0896	-0.1736	-0.1775	-0.0975
2	0.3790	-0.1283	0.2395	-0.0299	-0.0546
3	0.0459	0.0956	-0.0682	0.0299	-0.0446
4	0.1262	0.0178	-0.1610	-0.0401	-0.1875
5	0.1032	-0.0686	0.0481	-0.0272	0.1354
6	0.0988	-0.1724	0.0024	-0.1850	0.1078
7	0.1142	0.1884	0.1982	0.1563	-0.0832
8	0.0637	0.1042	0.1362	0.0946	0.0080
9	0.0489	0.0624	-0.1158	0.0320	-0.0511

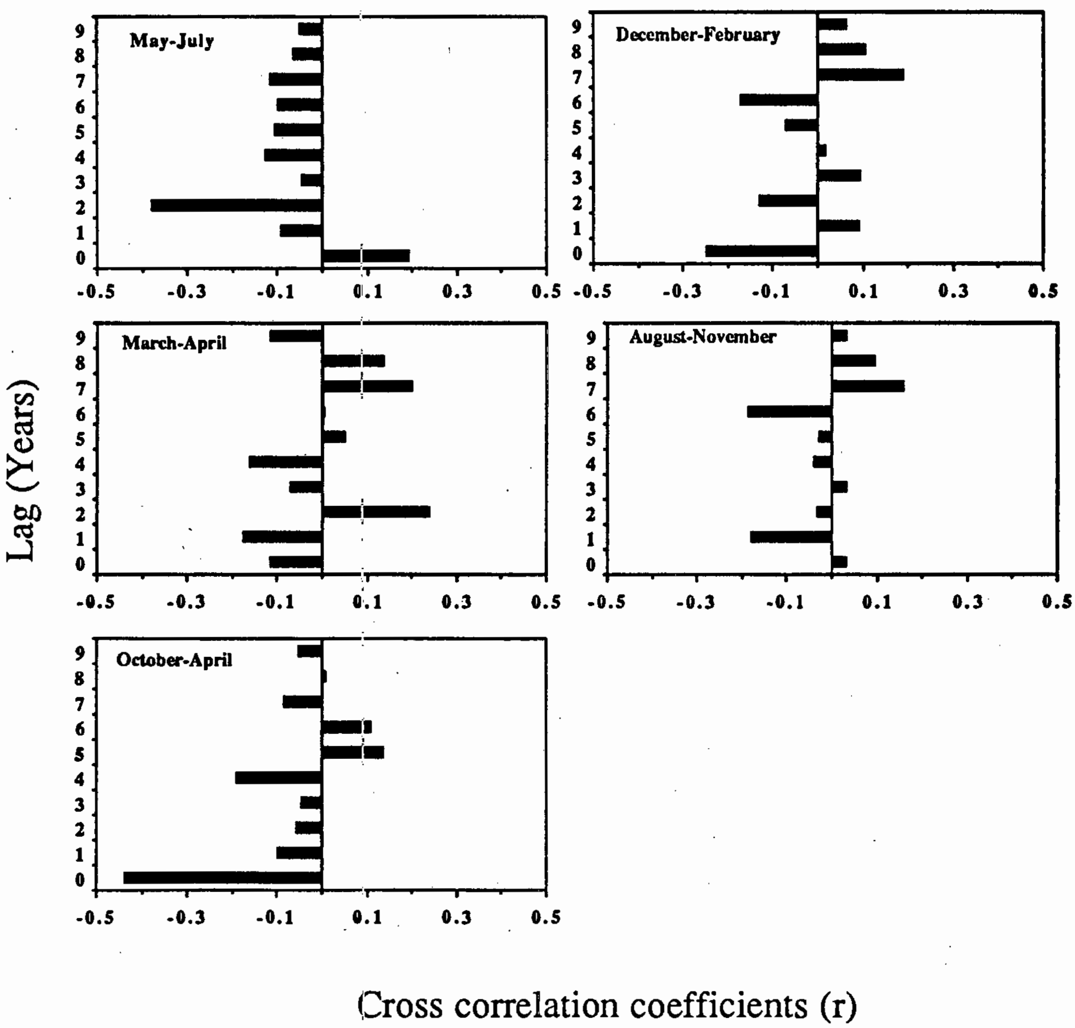


FIGURE 9.4.23 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-east wind component residuals, for all months and lag in the Namaqualand area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1201	-0.3222	-0.0090	-0.0708	0.0456	0.0798	-0.0184	-0.2770	-0.1037	-0.1470	-0.1576	0.1474
1	0.0321	0.0714	-0.2537	0.1532	0.0180	-0.0632	0.1464	-0.1402	0.0426	0.2105	-0.1987	-0.1373
2	0.2433	0.2257	0.3499	-0.0628	0.1914	-0.1172	0.1323	0.0181	0.0702	-0.1755	-0.3783	0.0093
3	0.3658	-0.1436	-0.0099	-0.1561	-0.0511	0.0541	0.2217	0.0724	0.0228	-0.0963	-0.3622	0.1640
4	0.0343	0.1795	0.1864	0.0988	0.0092	0.0241	0.1114	-0.2044	-0.0390	0.1586	-0.1108	-0.0735
5	0.1721	0.1697	-0.0724	0.1394	0.3104	0.0285	0.0866	0.3155	0.0412	0.3761	-0.1416	0.0390
6	0.3360	0.1270	0.3543	-0.0773	-0.2274	0.3058	-0.1705	0.0125	0.2213	-0.1878	-0.0503	0.1355
7	0.0936	0.2843	0.1958	-0.0627	-0.0525	0.0521	-0.0239	-0.0612	0.0222	-0.1162	-0.1276	-0.1856
8	-0.0441	0.2299	0.0433	0.1202	0.2131	-0.1637	0.0030	0.0767	-0.0098	0.2436	0.0211	0.2903
9	-0.0026	0.0844	0.1886	0.0698	-0.0469	0.2016	-0.1526	0.0902	0.1908	0.1564	0.0230	0.1131

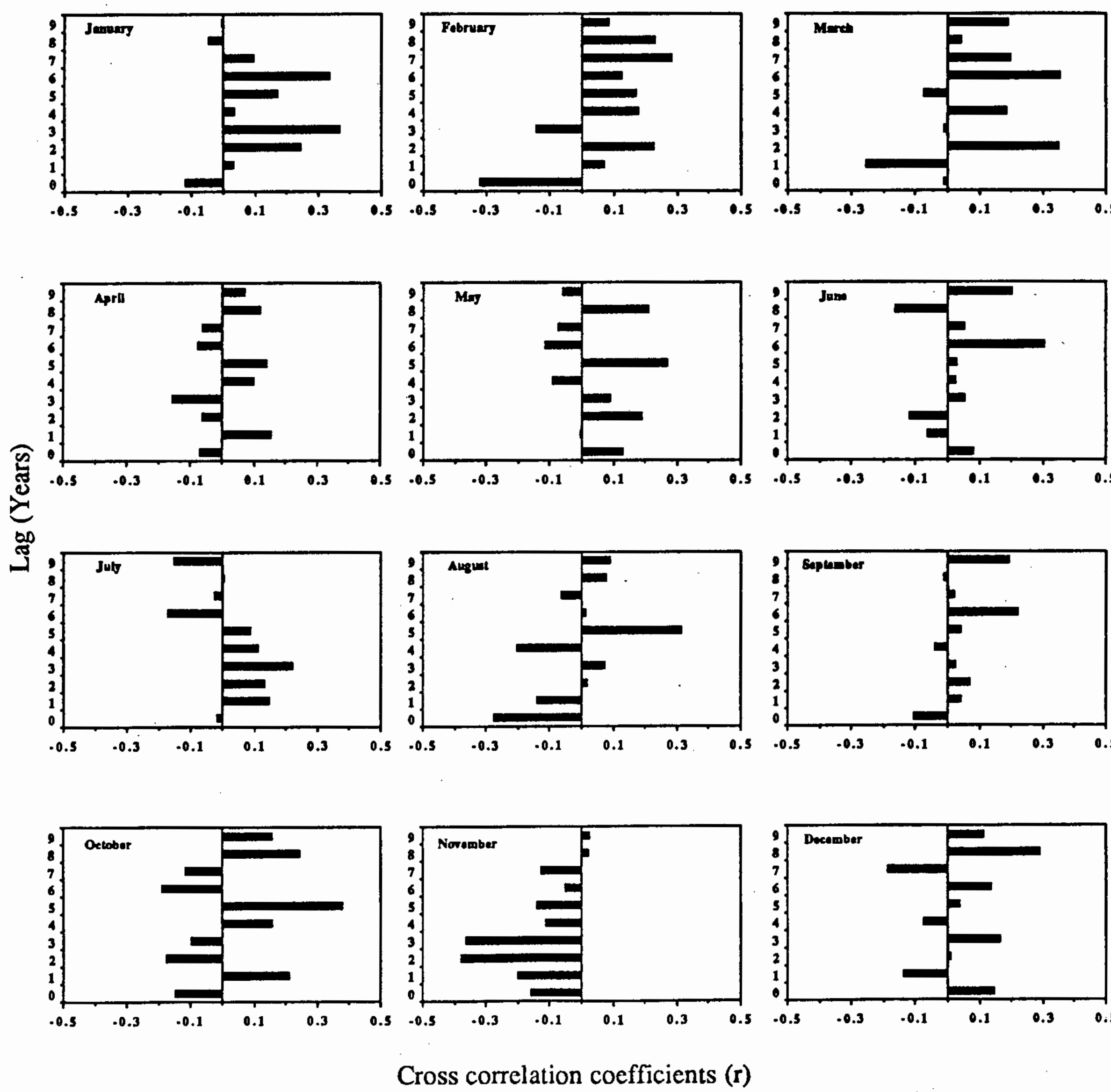


FIGURE 9.4.24 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Namaqualand area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1431	-0.4398	-0.0624	-0.1690	-0.3706
1	0.0470	0.0007	-0.0342	-0.2635	-0.0342
2	0.1429	0.2343	0.1663	0.0367	-0.2124
3	0.2271	-0.0235	-0.1315	-0.2420	-0.1004
4	-0.0397	0.0181	0.1948	0.2291	-0.2384
5	0.2411	0.1522	0.0670	0.0286	0.2833
6	0.0154	-0.0297	0.1574	-0.1727	0.0762
7	-0.0788	0.3356	0.0710	0.2531	-0.1782
8	0.0416	0.1257	0.1233	0.1279	0.1047
9	-0.0325	0.0211	0.1728	0.1644	0.2049

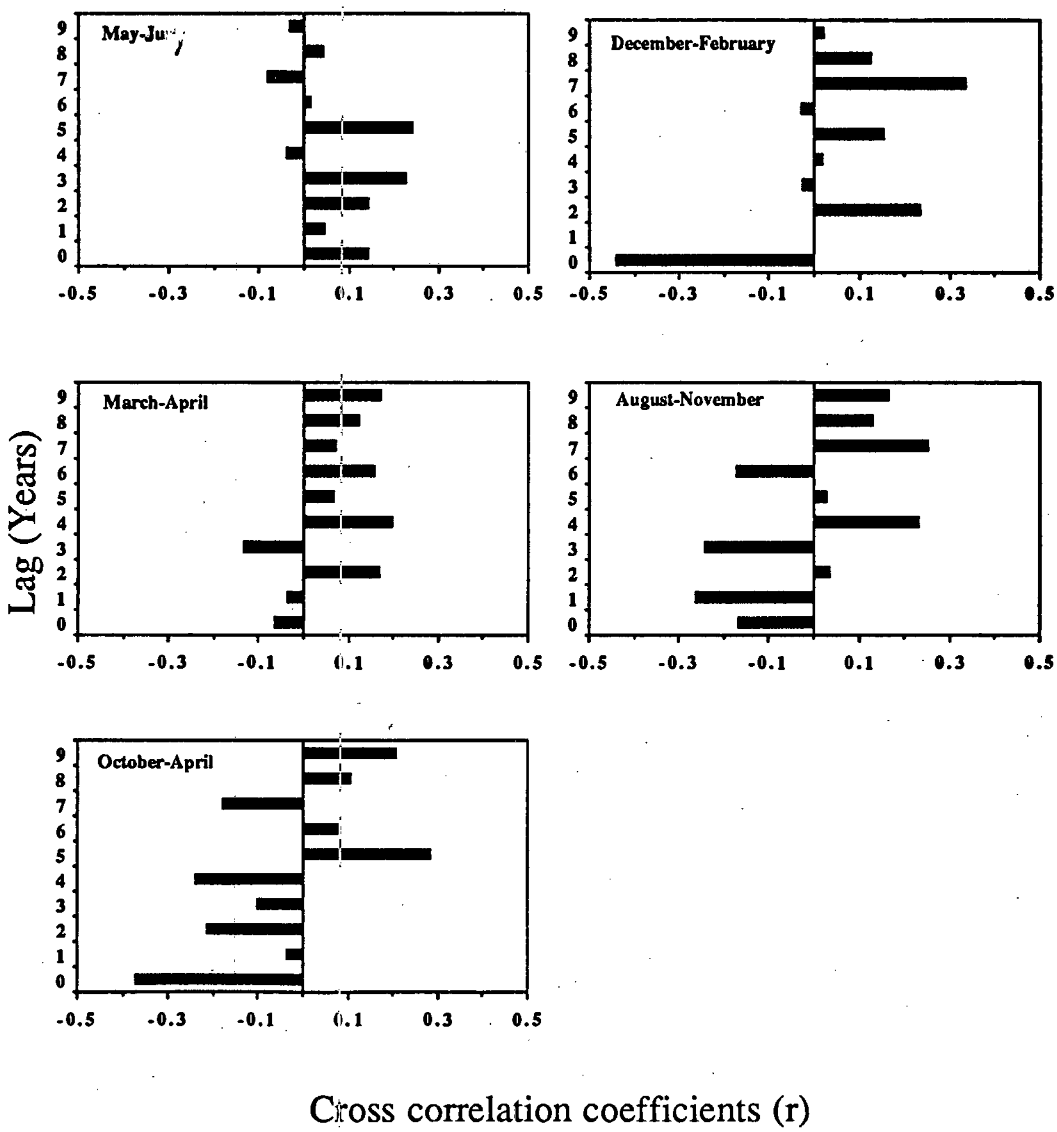


FIGURE 9.4.25 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.0028	0.0095	0.1049	0.0439	0.0995	0.0203	-0.0650	-0.0730	-0.0731	0.0121	0.0835	-0.0415
1	0.2525	0.3181	0.3765	0.3800	0.0874	-0.0005	0.0210	0.0279	0.1097	-0.0165	-0.0706	-0.0738
2	0.0104	-0.0334	-0.1080	-0.1028	0.0386	0.0651	-0.0557	0.0654	0.2073	0.2367	0.1852	0.2352
3	-0.2520	-0.1637	-0.0674	0.0405	0.0169	-0.0050	0.0210	0.1109	0.1074	0.0152	-0.0771	-0.0780
4	0.1186	-0.0211	0.0096	-0.0478	0.1538	0.2207	0.1896	0.2523	0.1543	0.0740	0.0351	-0.2042
5	0.0555	0.2334	0.3386	0.3268	0.0853	0.0179	0.0088	-0.0917	-0.1778	-0.1000	0.0537	0.2102
6	0.1884	0.0266	-0.0138	0.0048	-0.0133	0.0170	-0.0587	-0.0324	0.0818	0.1430	0.0544	-0.1175
7	-0.1023	-0.1014	-0.0841	-0.0038	0.1415	0.1342	0.0597	0.1590	0.2153	0.2963	0.3003	0.3197
8	0.2060	0.1334	0.0881	0.0778	0.1373	0.2226	0.1846	0.1419	0.0031	0.0493	0.1146	-0.0437
9	0.1845	0.1202	0.0211	0.0799	0.0683	0.0739	0.0479	-0.0919	-0.1339	0.0062	0.0951	0.2580

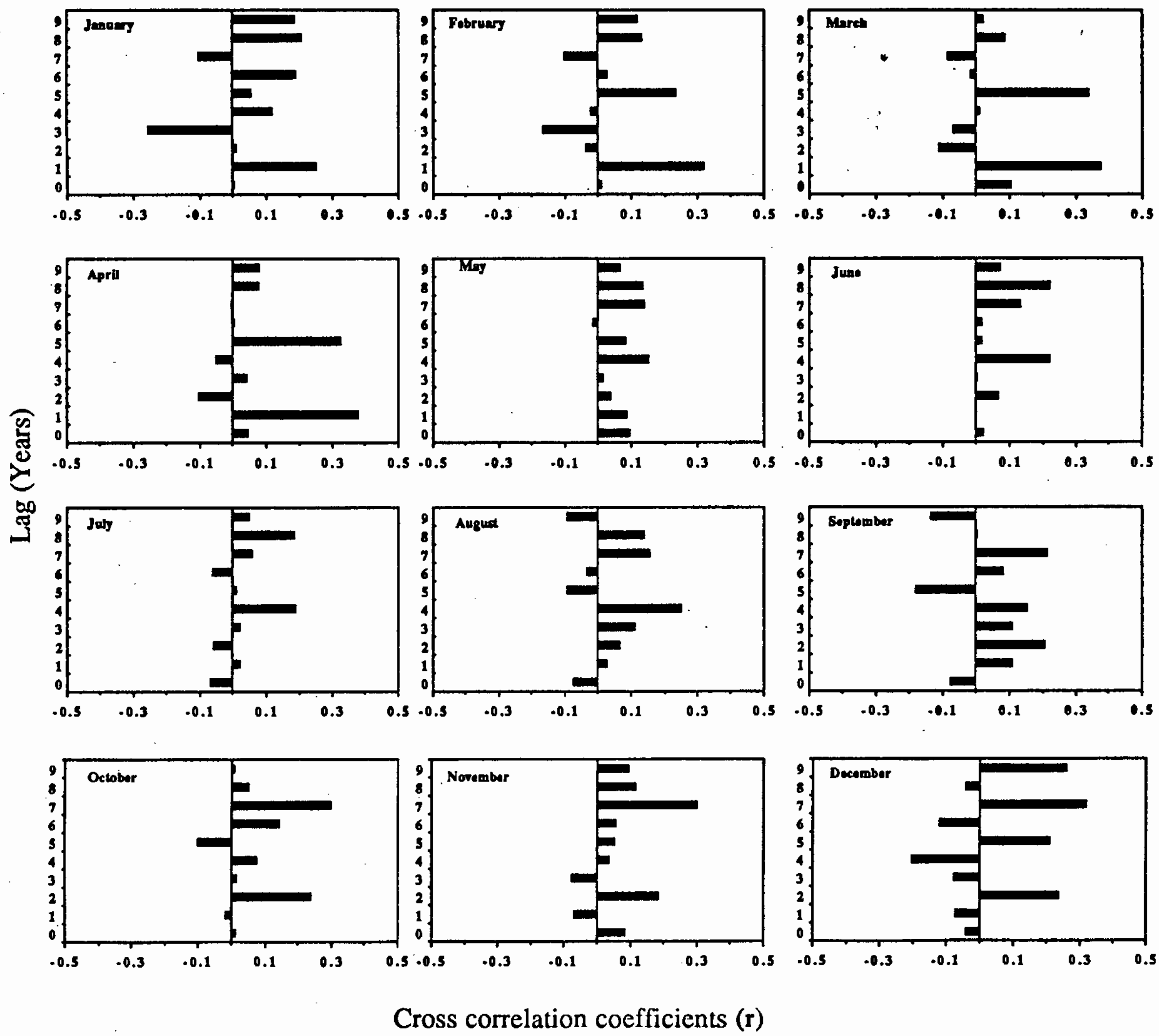


FIGURE 9.4.26 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.0314	-0.0343	0.0246	0.0218	-0.0437
1	0.0440	0.3024	0.4209	-0.0663	0.4138
2	0.0284	-0.0270	-0.0951	0.2414	-0.0838
3	0.0205	-0.2097	-0.0223	-0.0068	-0.1310
4	0.2063	0.0707	-0.0688	0.1774	-0.0266
5	0.0435	0.0977	0.3618	-0.0745	0.2125
6	-0.0163	0.1782	0.0097	-0.0259	0.1370
7	0.1291	-0.1011	-0.0683	0.2780	-0.0806
8	0.1927	0.1953	0.0905	0.1001	0.1729
9	0.0610	0.1381	0.0652	0.0076	0.0947

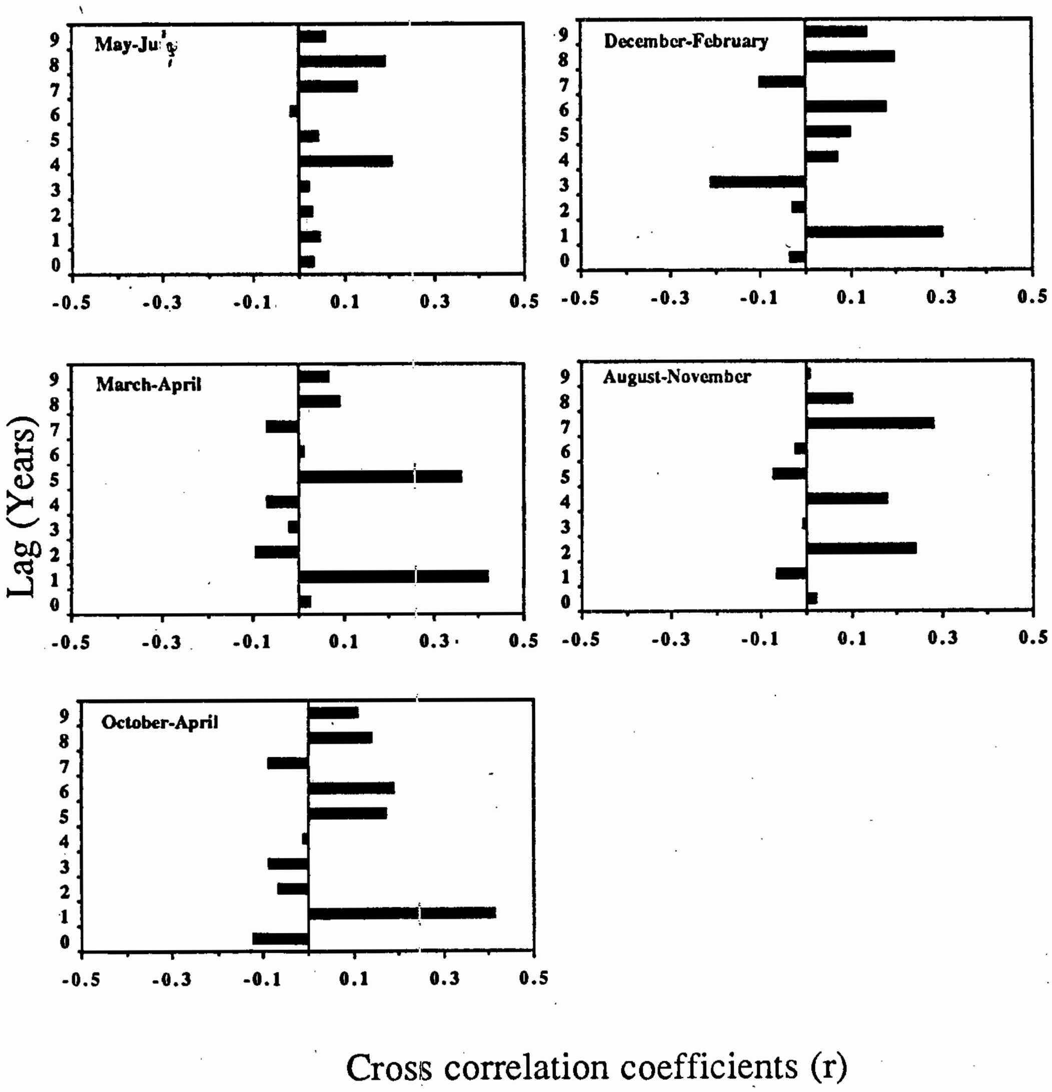


FIGURE 9.4.27 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1375	-0.2301	0.1370	0.1773	0.1386	-0.0136	0.0098	-0.1486	-0.1634	-0.1862	-0.0385	0.1126
1	-0.1497	-0.2219	0.1041	-0.1247	0.0115	0.2737	-0.0859	-0.3037	-0.0996	-0.0511	0.1576	-0.1904
2	-0.0339	0.0851	0.0317	-0.1768	-0.0849	-0.2002	-0.1729	0.1773	0.1555	-0.0583	-0.0257	-0.1060
3	0.3104	0.1543	0.0450	-0.1937	-0.1591	0.3168	0.0176	0.0183	-0.2183	0.1380	-0.0965	0.3109
4	-0.0689	-0.1296	0.0034	0.0437	0.0517	-0.2105	0.1093	0.1866	0.1889	0.1694	-0.0511	0.0911
5	0.1108	-0.2002	-0.0431	0.2893	0.3175	-0.1460	-0.3238	-0.0442	0.1188	0.0334	0.1750	-0.1037
6	0.0984	0.2104	0.1618	-0.2207	0.0058	0.1398	-0.2913	0.0258	0.2132	0.1705	0.2123	-0.2226
7	0.2012	0.3838	-0.0667	0.1148	-0.1727	0.0617	0.1575	-0.1063	-0.0069	0.2888	0.0987	0.1044
8	0.0544	-0.0227	-0.0313	0.1260	0.2292	0.0035	-0.1518	0.3825	0.0158	0.3474	-0.0860	0.2333
9	-0.0701	0.0452	0.0105	0.1413	0.2704	-0.0806	-0.0587	0.0534	0.1809	0.0059	0.1953	-0.1359

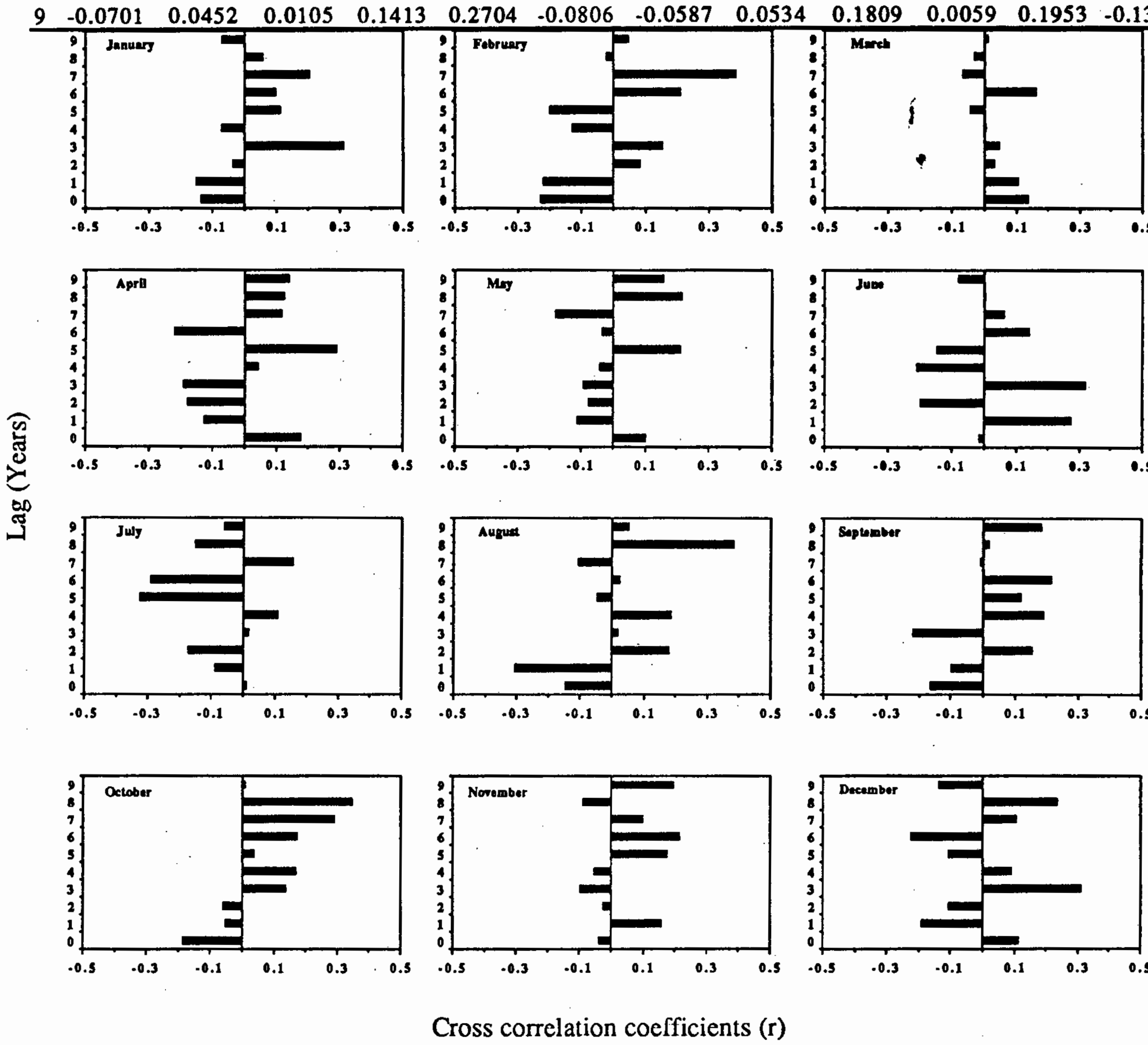


FIGURE 9.4.28 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.1019	-0.2993	0.2287	-0.2928	-0.1046
1	-0.0395	-0.1624	0.0349	-0.0551	-0.3834
2	-0.2601	0.0842	-0.1362	0.0778	0.0857
3	0.2404	0.1180	-0.0308	-0.1334	0.0549
4	-0.1658	-0.1484	-0.0017	0.0971	-0.1365
5	-0.1588	-0.2466	0.1491	0.0465	-0.1475
6	-0.1348	0.2714	-0.0597	0.3212	0.2508
7	0.1075	0.3191	0.0813	0.0166	0.2742
8	0.1476	-0.1043	-0.0458	0.0345	-0.0422
9	-0.0806	-0.0436	0.1251	0.1914	-0.0249

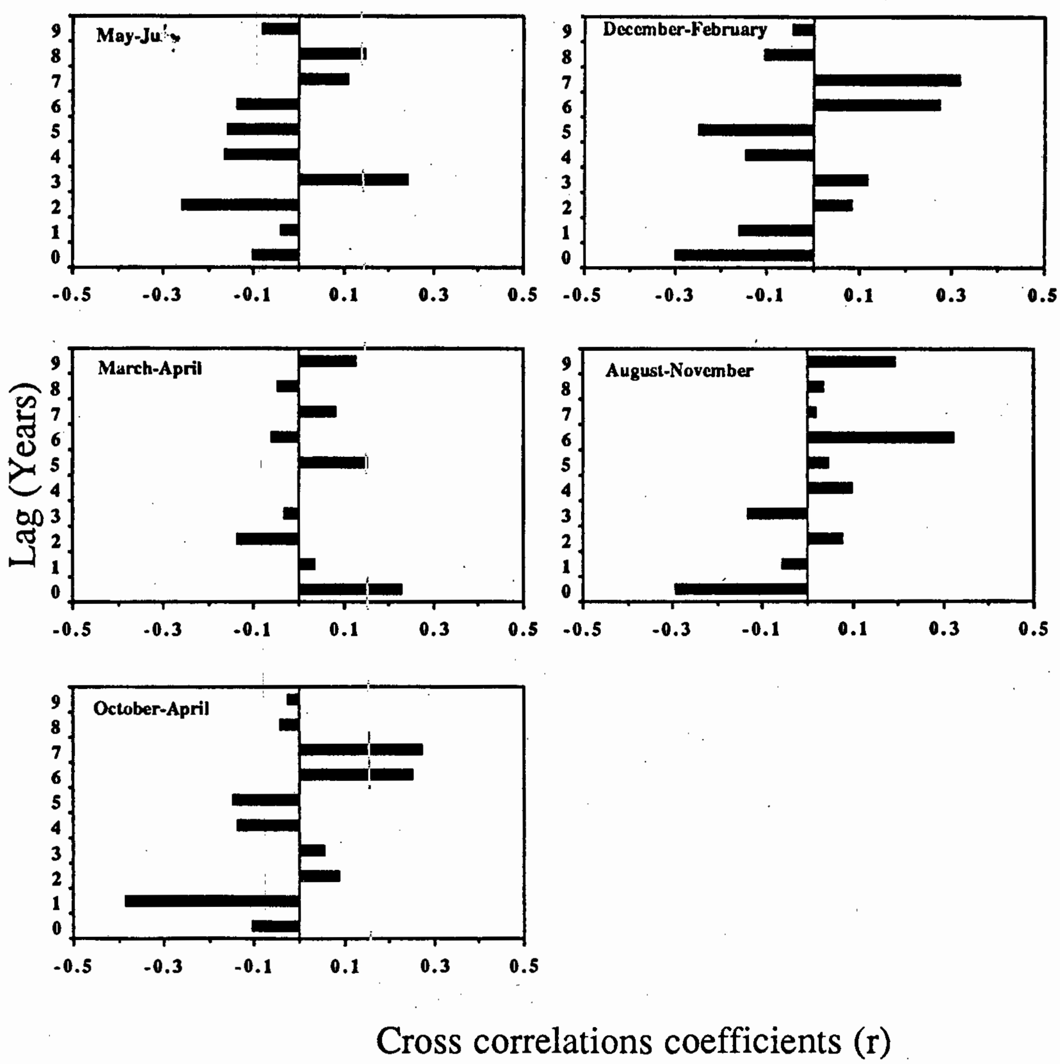


FIGURE 9.4.29 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-east wind component residuals, for all months and lag in the south western Cape area. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.0182	0.0711	0.0693	0.0332	0.1265	-0.0734	-0.1570	0.0039	-0.2986	0.2689	-0.1403	0.0677
1	-0.2311	-0.3210	0.0206	-0.0588	0.0629	-0.0012	0.0278	-0.1260	0.1947	0.0063	-0.0387	-0.0498
2	-0.0056	0.1966	0.1206	-0.1503	-0.1048	-0.2825	0.1684	0.3376	0.2853	0.1534	-0.1502	-0.0368
3	0.1978	0.2222	0.0607	-0.0345	-0.0441	0.0136	-0.0176	0.0674	0.0145	0.1486	-0.3638	0.0940
4	-0.0649	-0.1691	-0.0190	-0.0527	-0.1556	-0.1313	-0.1292	0.2327	0.0907	0.3849	-0.1720	0.0423
5	0.0048	0.0170	-0.1427	-0.1020	0.2166	-0.0874	0.0937	0.0573	-0.1494	-0.0933	-0.1154	-0.0412
6	0.0640	0.1309	0.3092	-0.1655	-0.0935	0.1027	-0.0630	0.0215	0.3296	0.0955	0.1365	-0.0651
7	0.1884	0.2171	0.1044	0.0284	-0.2276	-0.1978	-0.0972	0.1697	-0.1214	0.0402	-0.1301	0.0489
8	0.0282	0.0405	-0.1069	-0.0828	0.0578	-0.0109	-0.1659	0.0875	-0.1849	0.0970	-0.1287	-0.1367
9	-0.2317	-0.0422	0.1087	-0.0191	0.1878	-0.0359	-0.1245	0.0845	0.0446	-0.0520	0.1113	-0.3090

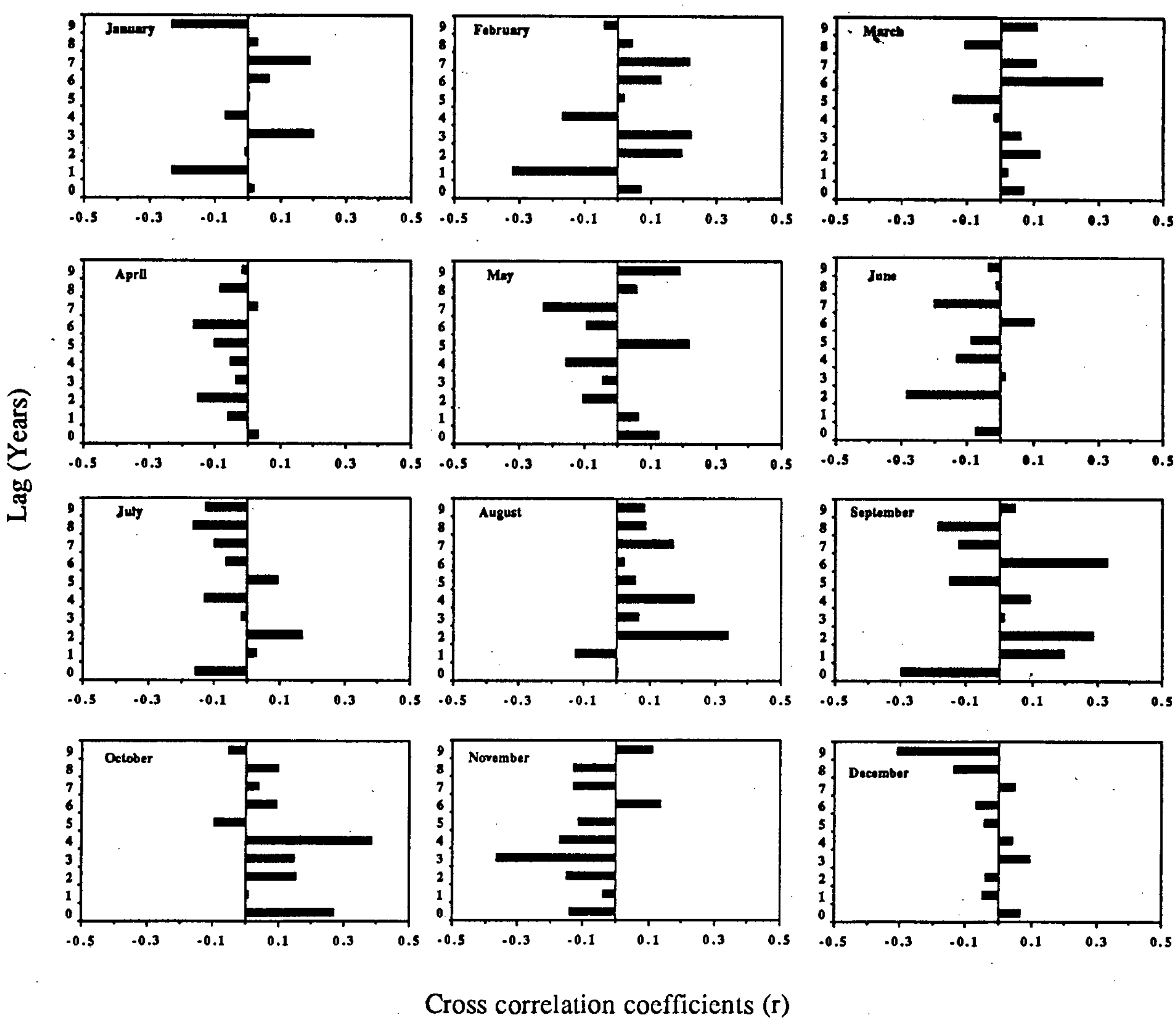


FIGURE 9.4.30 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the south western Cape area. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.0591	-0.0221	0.0671	-0.0856	0.0441
1	0.0452	-0.3196	-0.0136	0.0460	-0.2346
2	-0.1233	0.2147	0.0247	0.2338	0.0627
3	-0.0225	0.2147	0.0358	-0.0693	0.1394
4	-0.2100	-0.1386	-0.0427	0.1249	-0.1478
5	0.1112	-0.0061	-0.1773	-0.0997	-0.0162
6	-0.0210	0.2199	0.1826	0.2282	0.1797
7	-0.2664	0.2243	0.1101	-0.0259	0.1390
8	-0.0532	-0.0646	-0.1349	-0.1088	-0.1381
9	0.0185	-0.2172	0.0865	0.0310	0.0137

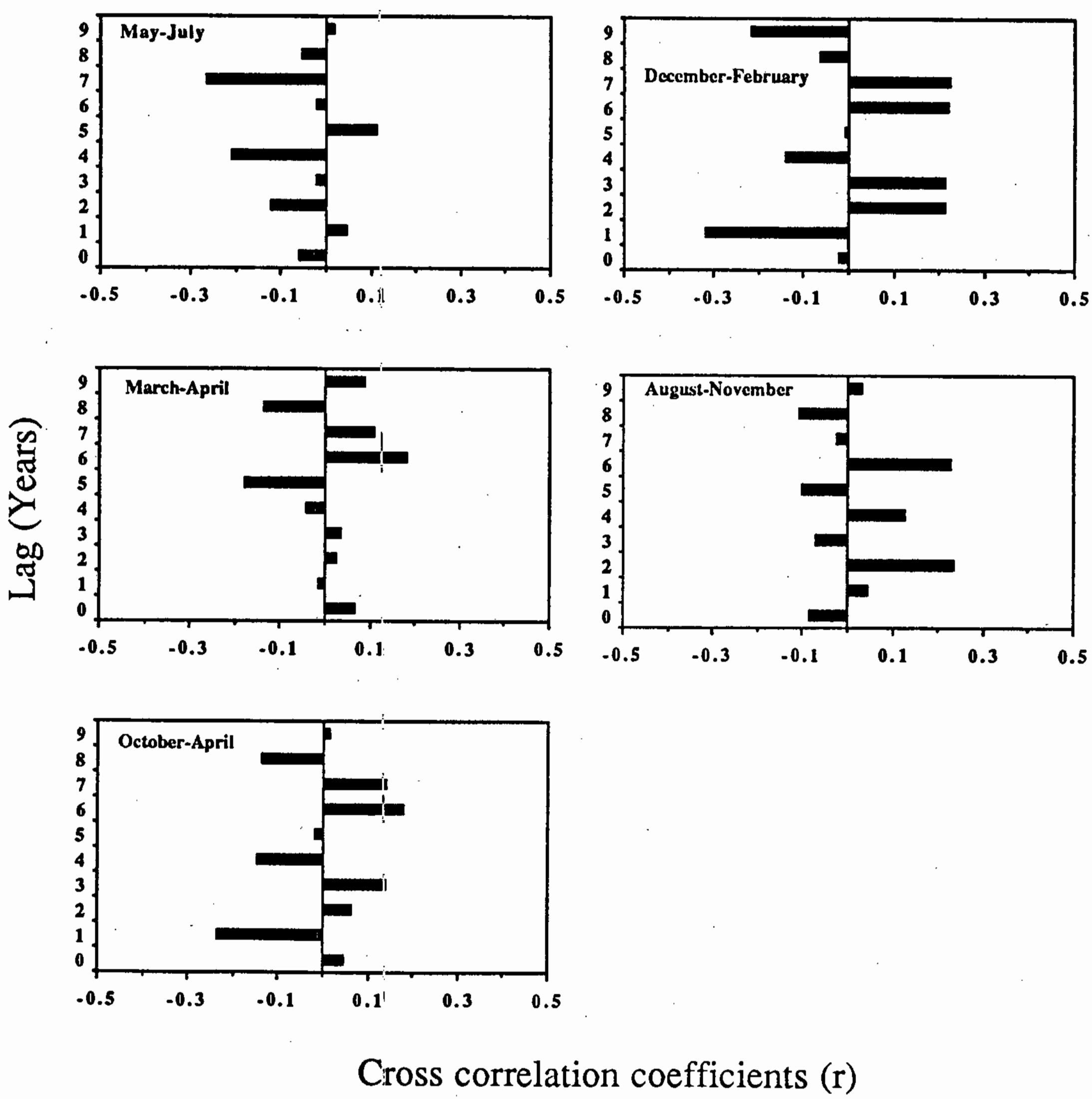


FIGURE 9.4.31 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags ir the Agulhas Bank. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.2184	0.3360	0.4182	0.3571	0.1765	-0.0146	-0.0991	0.0363	0.0345	0.2078	0.4067	0.2542
1	0.0754	0.1995	0.2366	0.1847	0.1463	0.2642	0.3229	0.2741	0.2492	0.1529	0.0166	0.0484
2	0.0753	-0.1081	-0.1330	0.0045	0.0650	-0.0462	-0.0070	0.1214	0.1976	0.2339	0.1330	0.0501
3	-0.2001	-0.1908	-0.0378	0.0980	0.1146	0.0683	-0.0181	0.1160	0.0732	0.0066	0.0517	0.1013
4	-0.0533	0.0303	0.1302	0.1644	0.1478	0.2197	0.3884	0.3363	0.2165	0.2156	0.1998	-0.0036
5	-0.0071	0.1023	0.2239	0.2181	0.1481	0.0523	-0.0572	-0.0888	-0.0923	-0.0823	-0.0535	-0.0433
6	-0.0710	-0.1423	-0.2374	-0.1697	-0.0578	0.0684	0.0344	-0.0690	-0.0487	0.0083	-0.0703	-0.1379
7	0.0490	-0.0975	-0.1992	-0.1291	0.0190	0.0269	-0.0032	0.0085	0.0457	0.0526	0.0220	0.0491
8	-0.1841	0.0036	0.0732	0.0829	0.1201	0.1013	-0.0428	-0.1706	-0.2396	-0.2006	-0.1412	-0.1619
9	0.3046	0.1989	0.0882	-0.0265	-0.0897	-0.0790	-0.0513	-0.1461	-0.0711	0.0609	0.0195	-0.0165

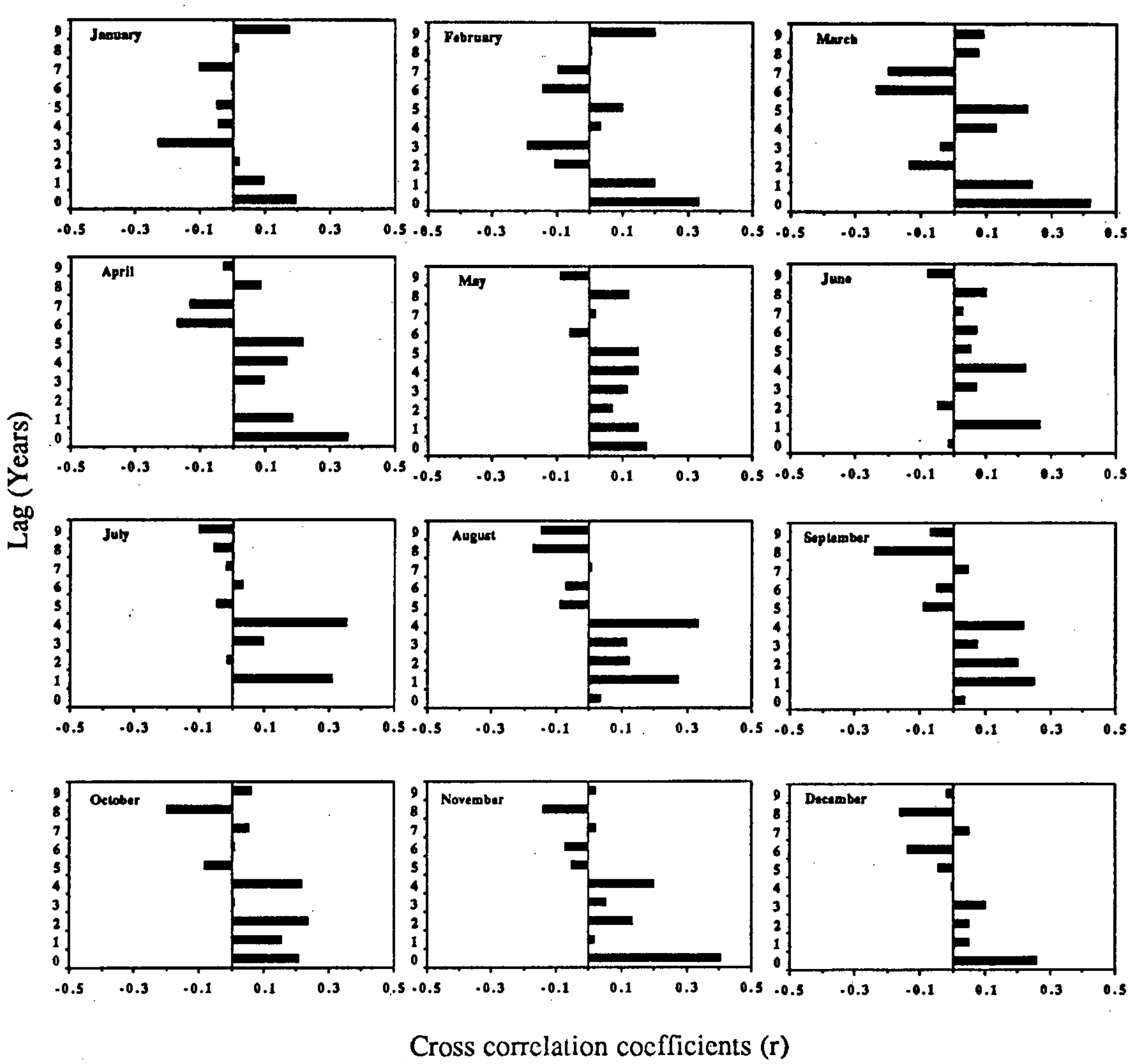


FIGURE 9.4.32 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Agulhas Bank. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.0132	0.2340	0.4018	0.1876	0.2343
1	0.2712	0.1321	0.2182	0.2042	0.2657
2	-0.0274	-0.0083	-0.0656	0.1940	-0.0340
3	0.0238	-0.1281	0.0323	0.0744	-0.0177
4	0.2567	-0.0212	0.1531	0.2804	-0.0188
5	0.0658	-0.0202	0.2293	-0.0914	0.0927
6	0.0062	-0.0578	-0.2107	-0.0537	-0.0224
7	-0.0089	-0.1440	-0.1698	0.0360	-0.2344
8	0.1046	0.0180	0.0811	-0.2159	-0.0148
9	-0.0936	0.1337	0.0311	-0.0462	0.1393

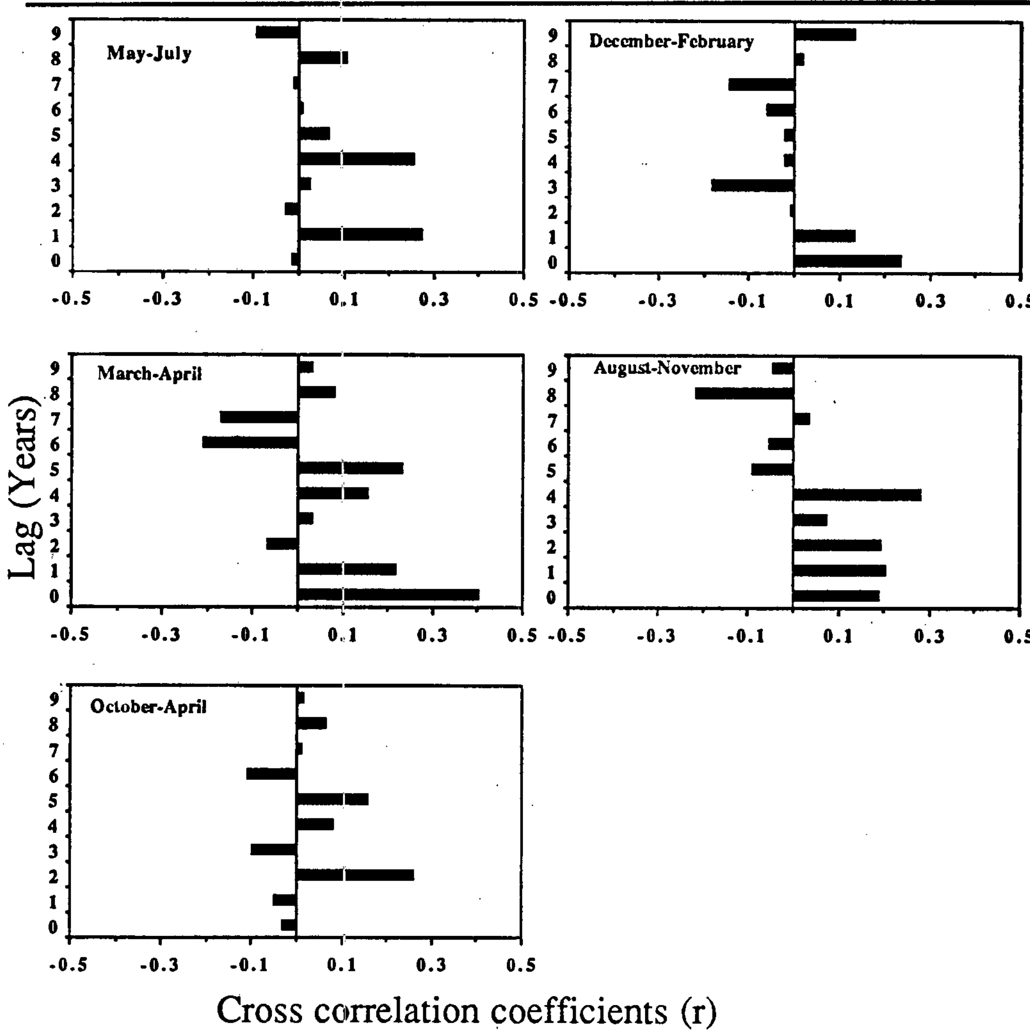
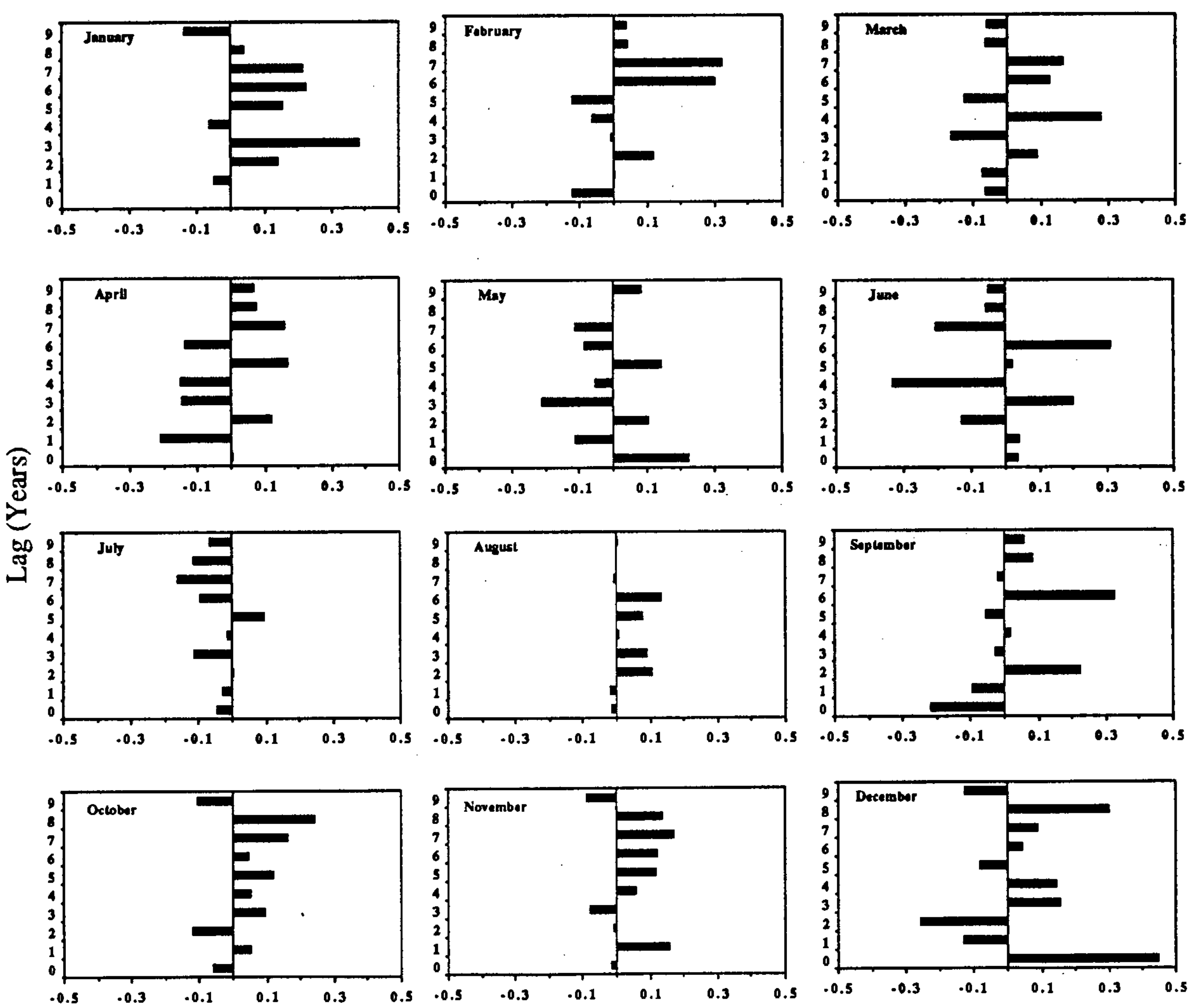


FIGURE 9.4.33 **Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Agulhas Bank. 1951-1985.**

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.0003	-0.1231	-0.0640	0.0023	0.2223	0.0349	-0.0443	-0.0148	-0.2177	-0.0588	-0.0138	0.4464
1	-0.0498	0.0050	-0.0722	-0.2108	-0.1132	0.0387	-0.0269	-0.0175	-0.0956	0.0522	0.1571	-0.1281
2	0.1403	0.1194	0.0863	0.1196	0.1038	-0.1286	0.0028	0.1045	0.2255	-0.1195	-0.0063	-0.2561
3	0.3813	-0.0083	-0.1644	-0.1460	-0.2095	0.1992	-0.1123	0.0895	-0.0244	0.0957	-0.0755	0.1544
4	-0.0638	-0.0644	0.2777	-0.1509	-0.0519	-0.3311	-0.0156	0.0054	0.0189	0.0522	0.0584	0.1448
5	0.1531	-0.1220	-0.1260	0.1683	0.1421	0.0199	0.0958	0.0764	-0.0525	0.1202	0.1186	-0.0808
6	0.2221	0.3015	0.1268	-0.1355	-0.0846	0.3104	-0.0939	0.1316	0.3256	0.0469	0.1211	0.0407
7	0.2118	0.3229	0.1636	0.1583	-0.1105	-0.2069	-0.1609	-0.0068	-0.0180	0.1620	0.1696	0.0882
8	0.0381	0.0418	-0.0615	0.0719	0.0002	-0.0574	-0.1154	-0.0009	0.0843	0.2417	0.1364	0.3007
9	-0.1373	0.0374	-0.0593	0.0655	0.0838	-0.0493	-0.0669	0.0033	0.0604	-0.1045	-0.0874	-0.1258



Cross correlation coefficients (r)

FIGURE 9.4.34 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Agulhas Bank. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1472	-0.1410	-0.0159	-0.0400	0.0252
1	-0.0255	-0.0855	0.0078	-0.1912	-0.2987
2	-0.0673	0.2285	0.0403	0.1379	0.1530
3	-0.0966	0.2638	0.0151	-0.2068	0.1196
4	-0.1013	-0.0943	0.0147	0.0774	-0.0011
5	0.1165	0.0048	0.0365	0.0332	-0.0942
6	0.1069	0.3203	0.0948	-0.0103	0.1112
7	-0.3567	0.3137	0.0284	0.2147	0.5112
8	0.0492	-0.1230	0.0482	0.0092	-0.1756
9	-0.0284	-0.0646	-0.0179	0.0063	0.0328

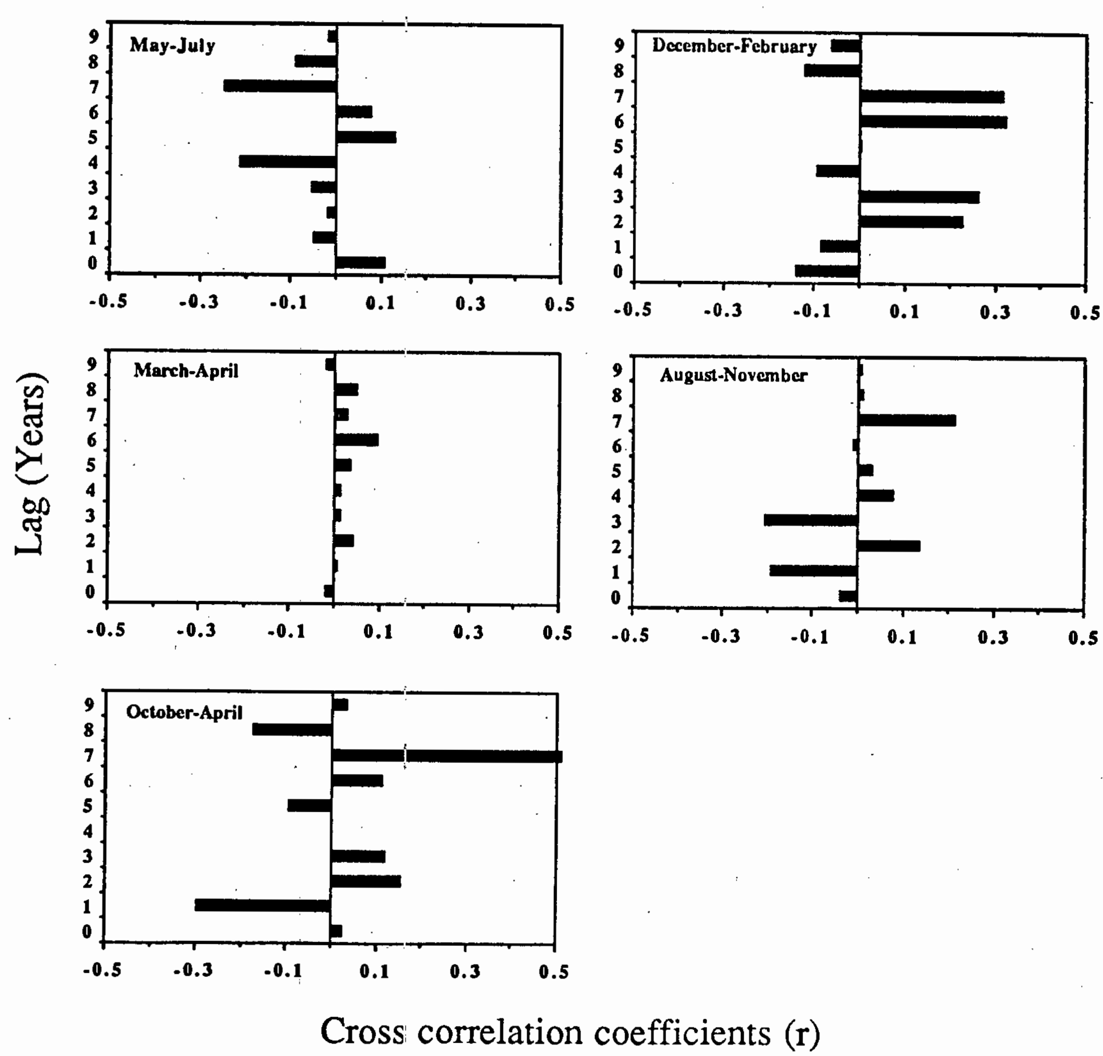


FIGURE 9.4.35 Tabular and graphical representation of the cross-correlation coefficients between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-eastwind component residuals, for all months and lags in the Agulhas Bank. 1951-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.1981	-0.0733	-0.1777	0.1420	0.0535	0.0069	-0.0437	-0.0305	-0.2945	0.1369	-0.2367	0.1490
1	-0.0637	-0.2391	-0.0927	-0.0138	-0.0326	-0.0114	0.1296	0.1782	0.1035	0.0420	-0.1579	-0.3428
2	-0.0775	0.1195	0.1545	-0.0572	-0.2273	-0.1736	0.2795	0.3020	0.1806	-0.1548	0.0070	0.0532
3	0.3500	0.0890	-0.0956	-0.0934	-0.1941	-0.0573	-0.0198	0.0290	-0.0598	-0.0092	-0.0725	0.3896
4	0.0439	-0.1424	0.0501	0.1994	-0.2901	-0.1478	-0.0476	0.0648	0.1590	-0.0790	-0.1243	0.0864
5	0.1824	0.0702	-0.1255	0.1212	0.1955	-0.0100	0.3411	0.2321	-0.0060	0.0109	-0.3042	-0.2092
6	-0.0802	0.2456	0.3813	-0.0542	-0.1697	0.2406	0.0807	0.0696	0.1754	-0.1203	0.2118	0.2041
7	0.1003	0.0924	0.1272	-0.0105	-0.4625	-0.2152	-0.0623	-0.0478	-0.2687	-0.1614	0.2177	0.0502
8	0.2070	0.3372	-0.0368	0.0188	0.1305	0.0676	-0.0343	0.0048	0.0165	0.0985	-0.2360	0.0307
9	-0.2045	-0.0403	0.1619	0.0178	0.0213	-0.0092	-0.0879	-0.0198	0.1718	0.1353	-0.0507	-0.2680

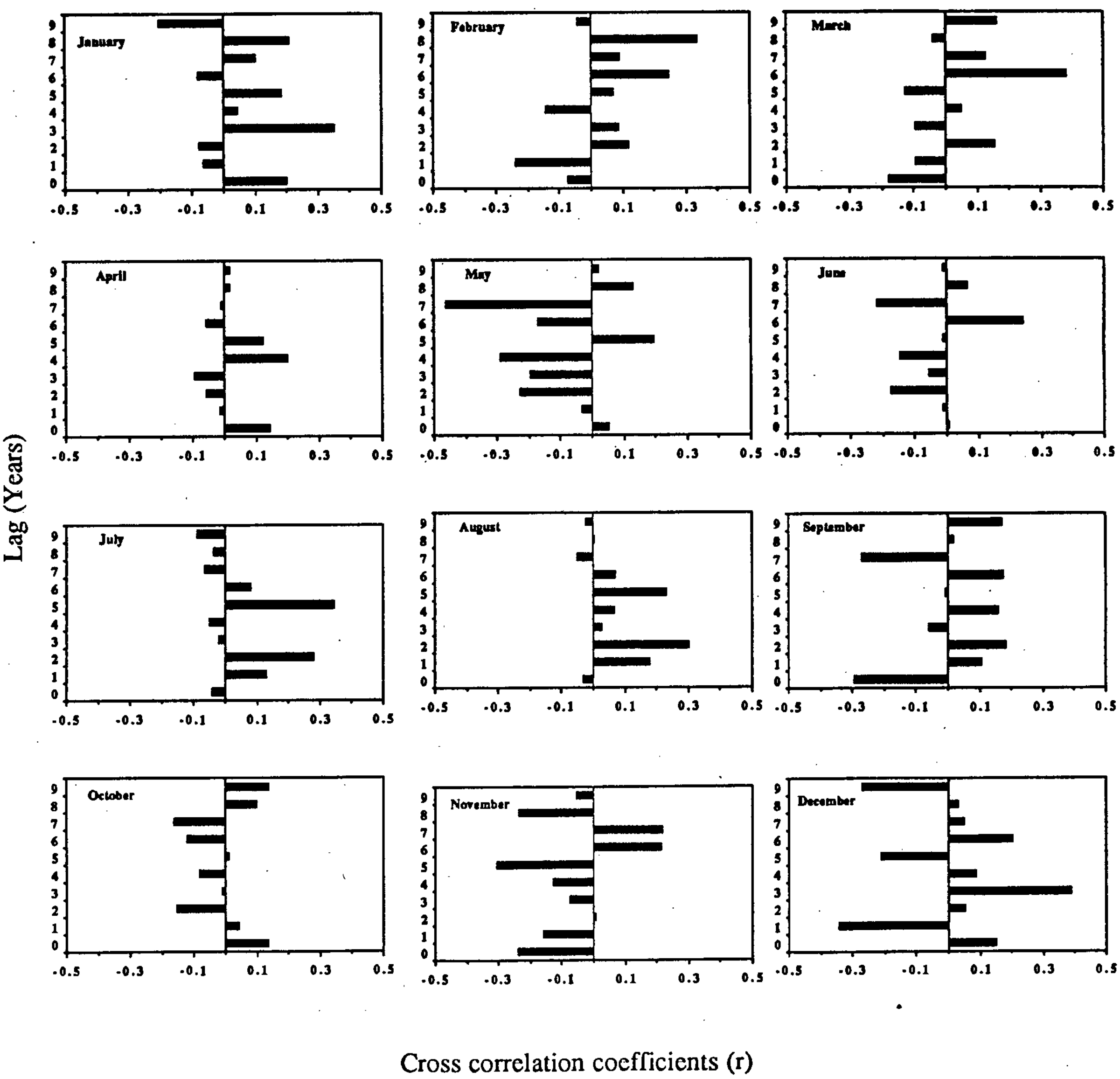


FIGURE 9.4.36 Tabular and graphical representation of the cross-correlation between horse mackerel (*Trachurus trachurus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Agulhas Bank. 1951-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1214	-0.0963	-0.1147	-0.0221	-0.0914
1	-0.0050	-0.2428	0.0970	-0.0693	-0.2961
2	-0.0121	0.2348	0.0516	0.0628	0.0860
3	0.0387	0.3483	-0.0747	-0.1235	0.1111
4	-0.2447	-0.1806	0.0121	0.1636	-0.1298
5	0.2378	0.2239	-0.0356	-0.0018	0.1973
6	0.0333	0.1229	0.1279	0.2120	0.1551
7	-0.3116	0.2103	-0.1207	0.0757	0.1025
8	0.0960	0.1870	-0.0586	-0.0115	0.1126
9	-0.0922	-0.2022	0.0169	0.1168	-0.0627

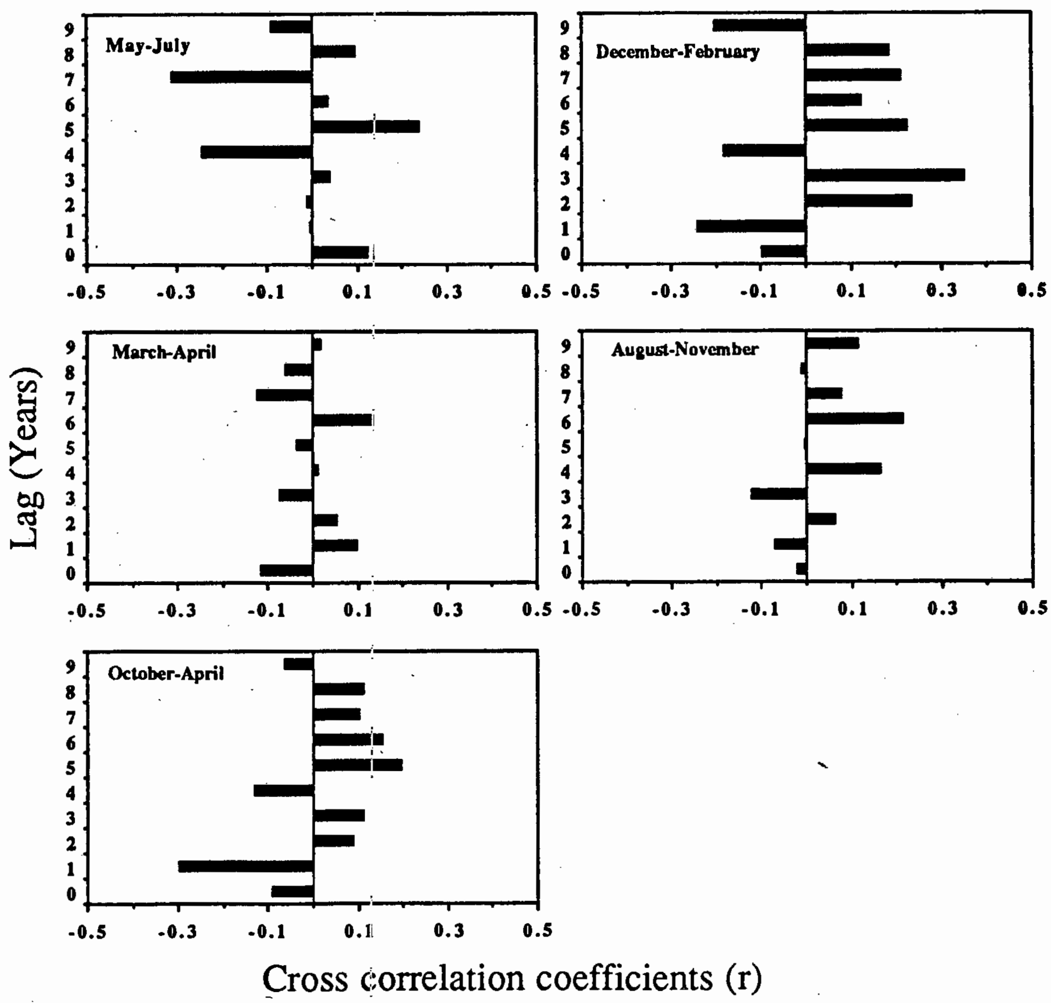


FIGURE 9.4.37 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scpmber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the Namaqualand area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1094	-0.2104	-0.4498	-0.5162	-0.4188	-0.2603	-0.3255	-0.1616	-0.4032	-0.5517	-0.3474	-0.1482
1	-0.2525	-0.3252	-0.2251	-0.3486	-0.4889	-0.4994	-0.4413	-0.4630	-0.3109	-0.2204	-0.0978	0.0283
2	-0.0298	-0.0267	-0.0658	0.0467	0.0793	-0.1280	-0.1366	-0.1215	-0.1446	-0.1578	-0.1931	-0.2546
3	-0.0111	-0.1825	-0.1104	0.0356	0.0605	0.0735	-0.0653	-0.0140	-0.1197	-0.0865	-0.0637	-0.0710
4	0.0863	-0.1443	-0.1487	-0.2399	-0.3047	-0.2718	-0.4263	-0.3916	-0.3532	-0.2267	-0.1787	-0.2925
5	-0.2325	-0.1512	-0.1490	-0.1970	-0.3113	-0.3545	-0.3385	-0.1393	-0.0394	-0.1566	0.0439	0.1116
6	-0.0196	-0.1421	-0.2762	-0.2479	-0.1586	-0.2579	-0.2035	-0.1728	-0.1837	-0.2632	-0.1869	-0.0983
7	-0.3126	-0.2858	-0.2729	-0.0485	0.1347	0.1345	-0.0175	0.0854	0.0654	-0.1453	-0.2058	-0.0867
8	-0.3714	-0.4005	-0.3246	-0.3211	-0.2925	-0.1573	-0.0711	-0.0614	-0.2417	-0.2501	-0.1684	-0.2368
9	0.1353	0.1546	0.1374	0.0842	-0.0232	-0.1615	-0.0659	0.0153	-0.0900	-0.1725	-0.2279	-0.3728

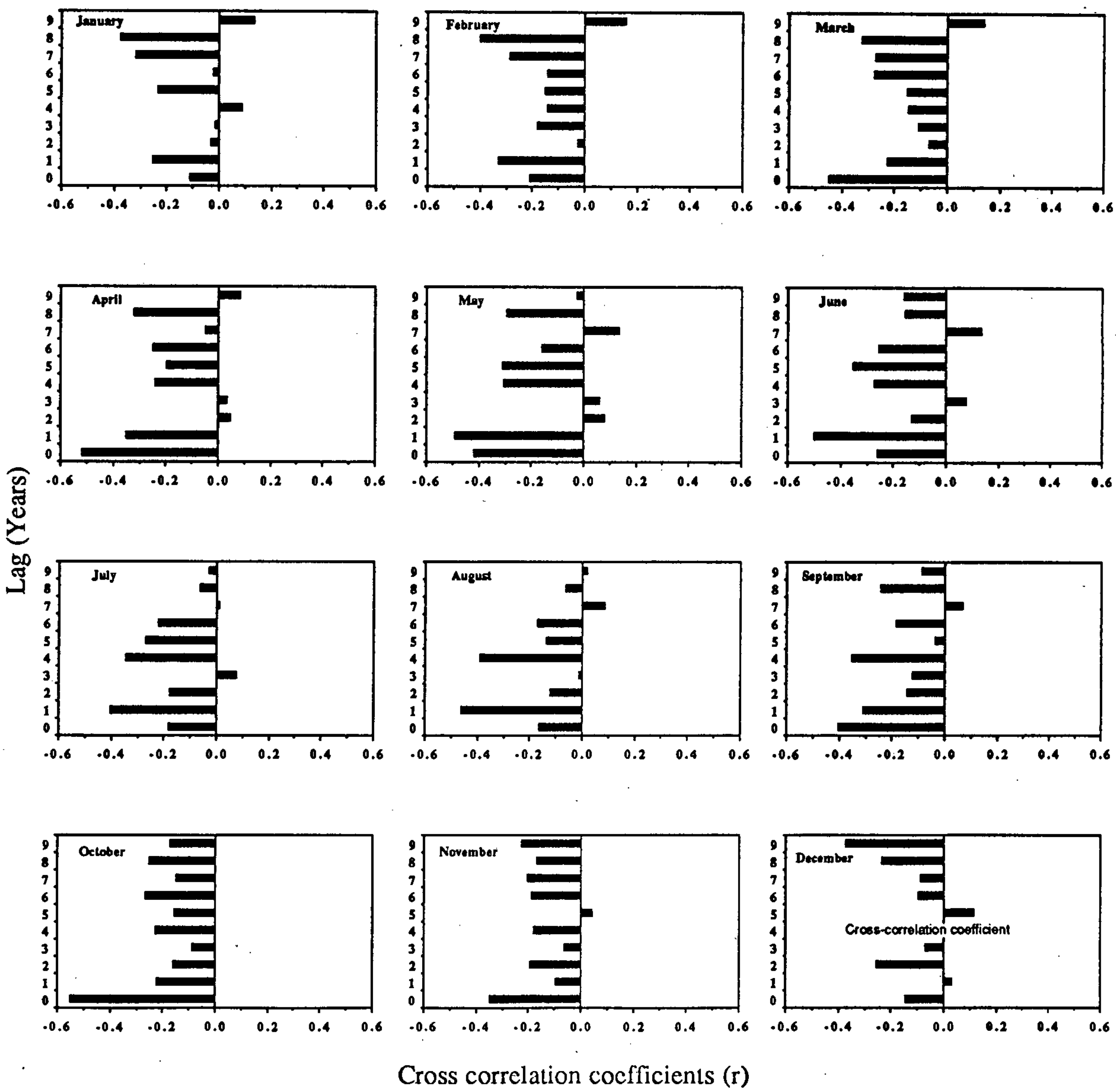
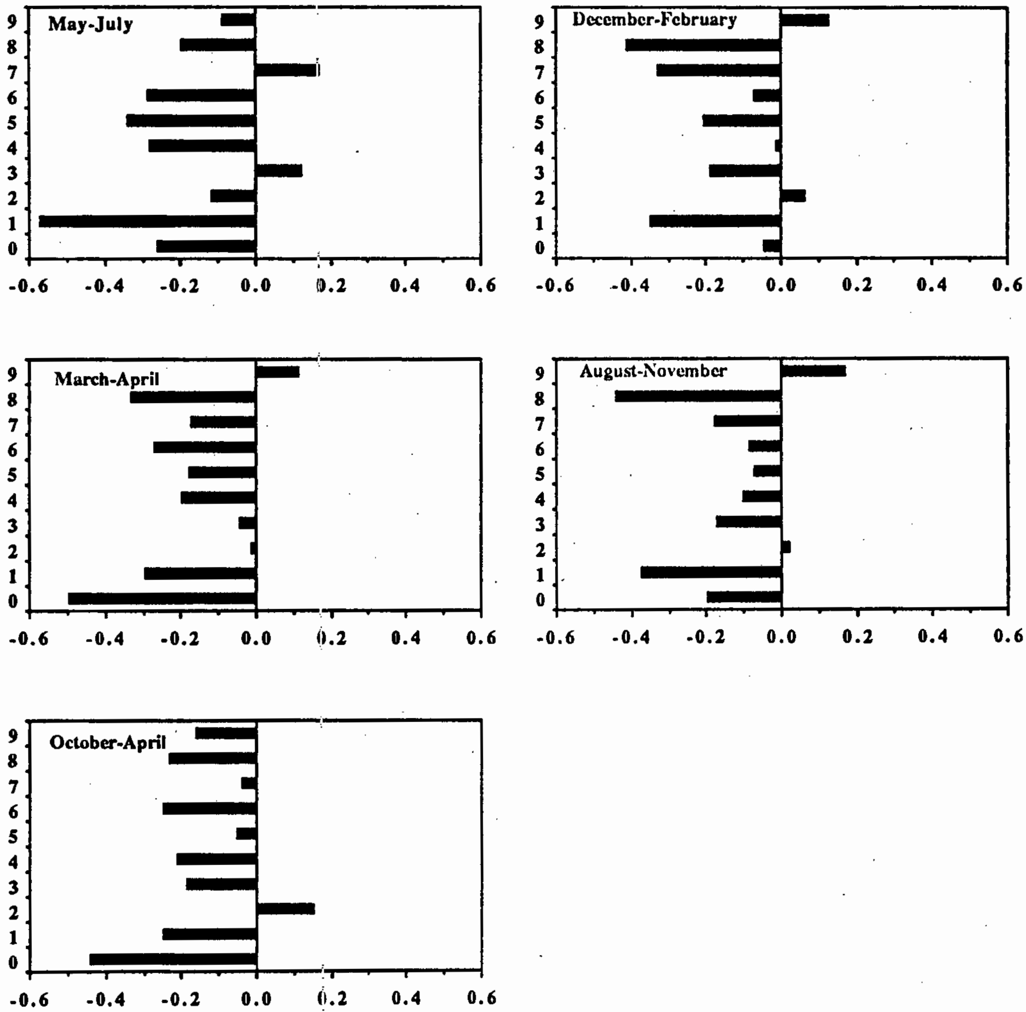


FIGURE 9.4.38 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Namaqualand area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.2594	-0.0441	-0.4947	-0.1962	-0.4425
1	-0.5721	-0.3485	-0.2920	-0.3748	-0.2489
2	-0.1174	0.0642	-0.0124	0.0219	-0.1830
3	0.1234	-0.1900	-0.0418	-0.1731	0.1514
4	-0.2797	-0.0131	-0.1976	-0.1003	-0.2088
5	-0.3410	-0.2070	-0.1767	-0.0722	-0.0490
6	-0.2848	-0.0718	-0.2699	-0.0847	-0.2459
7	0.1670	-0.3280	-0.1702	-0.1781	-0.0362
8	-0.1967	-0.4128	-0.3318	-0.4400	-0.2315
9	-0.0866	0.1258	0.1150	0.1685	-0.1614

Lag (Years)



Cross correlation coefficient (r)

FIGURE 9.4.39 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scpmber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Namaqualand area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.6398	-0.3728	-0.1604	-0.3907	-0.2948	-0.1091	-0.0392	-0.2359	-0.0692	-0.3669	-0.0594	-0.2273
1	-0.3444	-0.0018	-0.3856	0.2600	-0.0423	0.1991	-0.1220	-0.1432	-0.1040	-0.2481	-0.0549	-0.4169
2	0.0302	-0.0386	-0.2235	-0.1839	-0.2515	0.0643	-0.3072	0.0013	0.1350	-0.2326	-0.1923	-0.0070
3	0.0853	-0.0684	0.0323	-0.3062	-0.1469	0.0164	-0.0524	-0.0576	0.1004	-0.0978	-0.2135	0.0101
4	-0.1403	-0.3141	-0.1488	-0.1725	0.1183	-0.1036	0.1481	-0.2400	-0.1582	-0.3592	-0.0681	-0.0096
5	-0.4310	-0.1669	-0.1864	0.0325	-0.1172	-0.0226	0.1111	-0.4332	-0.2639	-0.1607	0.2096	-0.3475
6	-0.1541	0.0328	-0.0387	-0.1482	0.0029	-0.0019	-0.0128	-0.1502	-0.2362	0.0339	-0.1983	0.1779
7	0.0558	-0.2360	-0.0253	-0.1646	-0.4868	-0.2001	-0.1111	0.0773	0.1361	0.0056	-0.0585	-0.3213
8	-0.1286	-0.2263	-0.0302	-0.2320	-0.0227	-0.2217	0.0691	-0.1373	0.0299	0.0552	-0.3930	0.2389
9	-0.1658	-0.1646	-0.1481	0.1183	-0.0774	-0.0042	-0.2551	-0.0352	-0.0653	-0.1707	0.0081	-0.3374

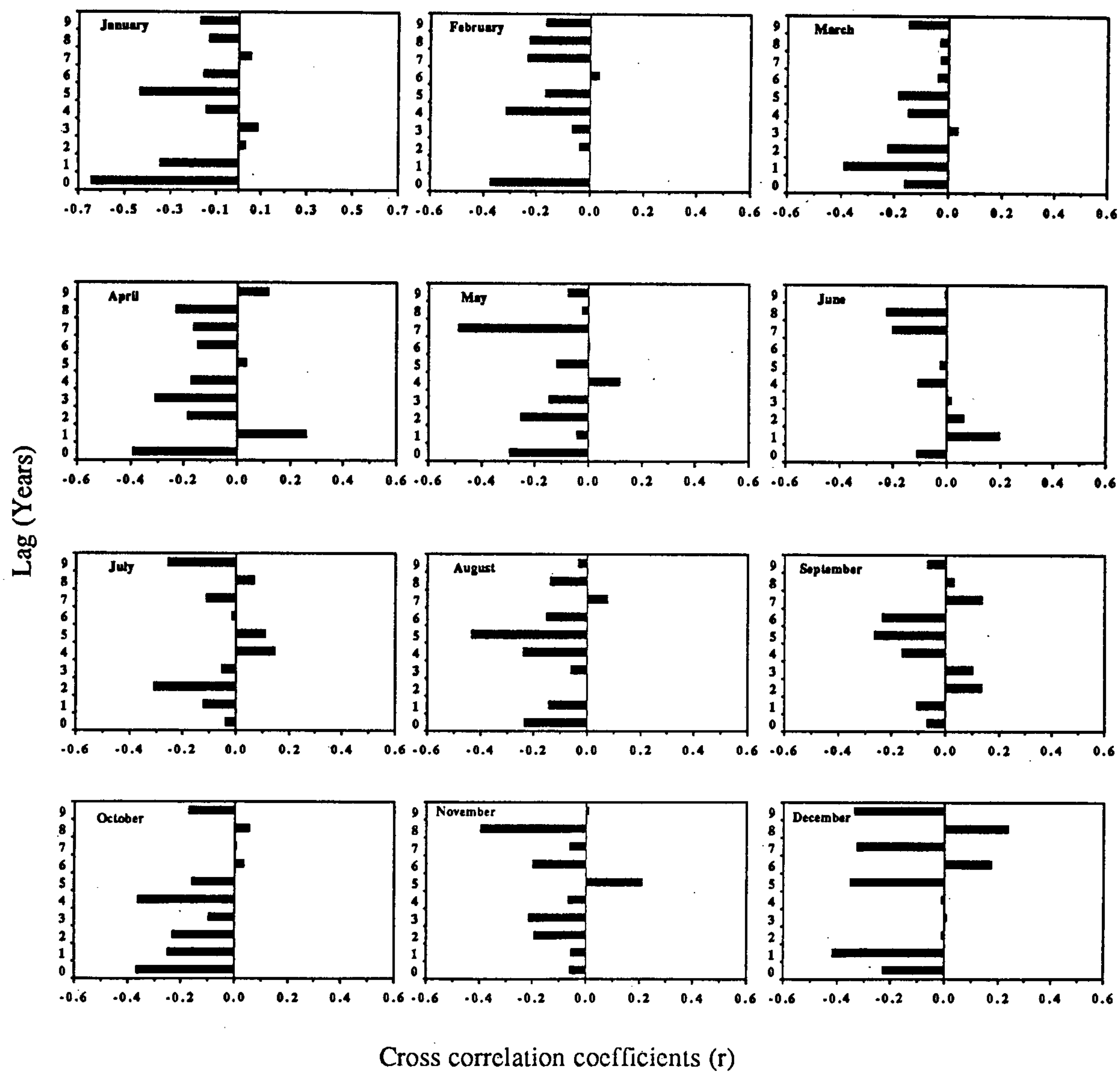


FIGURE 9.4.40 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Namaqualand area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.0372	-0.5388	-0.0905	-0.4913	-0.2378
1	0.0633	-0.1478	-0.1530	-0.1032	-0.2793
2	-0.0748	-0.0167	-0.1771	-0.1133	0.0615
3	-0.1320	0.1626	-0.1517	-0.0317	0.1055
4	0.1442	-0.2441	-0.0644	-0.0647	-0.0274
5	-0.0414	-0.2618	-0.0014	-0.0968	-0.3164
6	0.0753	-0.2560	-0.1316	-0.0890	-0.2379
7	-0.5193	0.1809	-0.1103	-0.0011	0.1236
8	-0.0796	-0.2672	-0.1561	-0.2426	-0.0837
9	-0.1414	0.0280	-0.0925	-0.0349	-0.1375

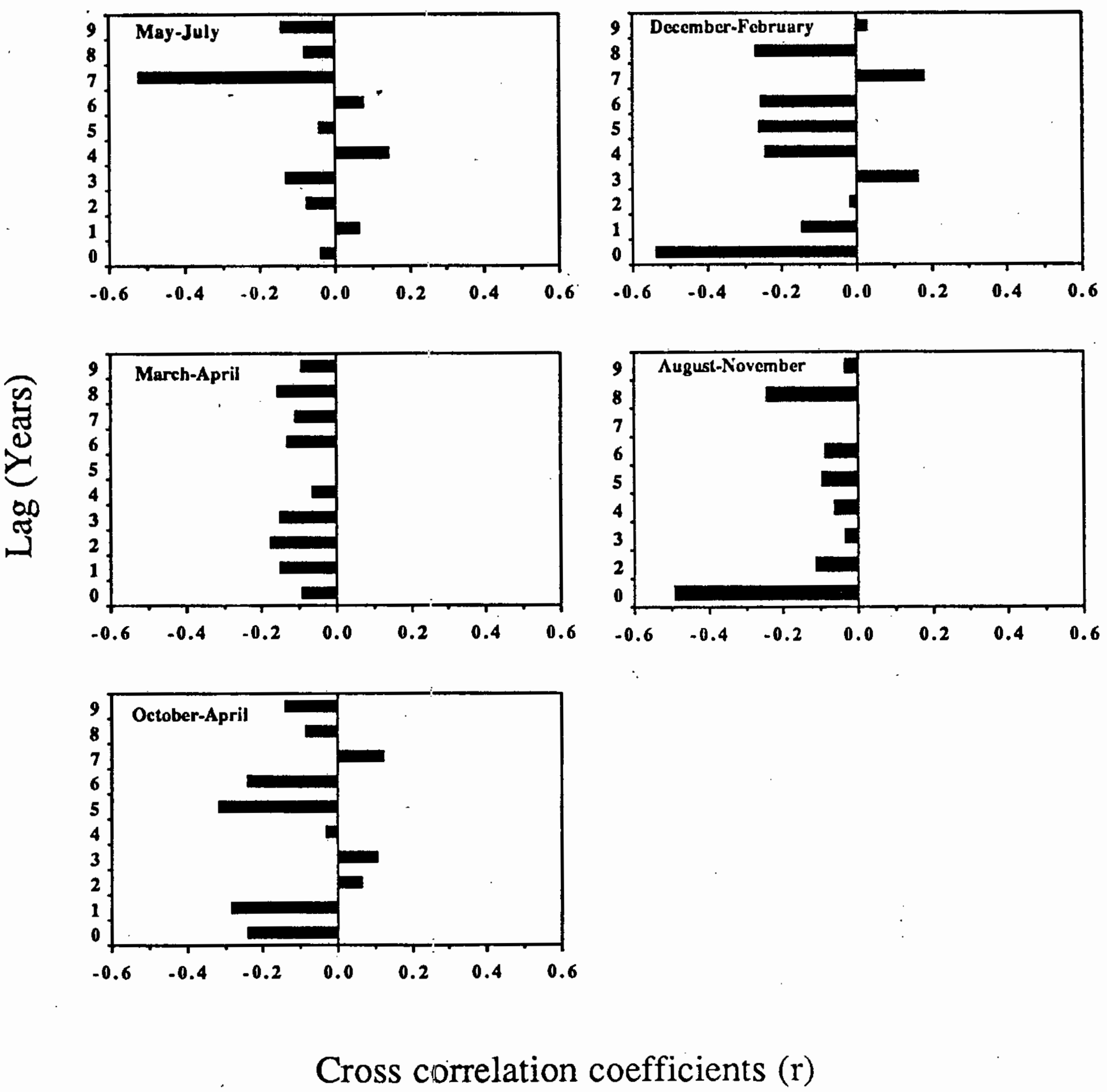


FIGURE 9.4.41 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scpmber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all months and lag: in the Namaqualand area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.3779	-0.2504	-0.0831	0.1329	-0.3399	0.0587	-0.4749	-0.2157	-0.0820	-0.3894	0.4605	-0.1519
1	-0.3274	-0.0460	-0.5577	0.2401	0.0761	-0.1026	-0.1179	0.1590	0.0785	0.0432	-0.1705	-0.0123
2	-0.1725	-0.0663	-0.0841	-0.1753	-0.1734	0.1627	0.0311	0.0118	0.2258	0.1004	-0.1879	0.1671
3	0.2616	-0.1852	-0.0365	-0.2611	-0.1062	0.1231	0.3395	0.1331	-0.2210	0.0063	-0.1991	-0.0680
4	0.1731	-0.4095	-0.1943	0.0848	0.0445	0.1101	0.0133	-0.4199	-0.3442	-0.2495	0.1551	0.0854
5	-0.3739	-0.2160	-0.2160	-0.0092	-0.1414	-0.1156	-0.1817	-0.1732	-0.2524	-0.0600	0.0185	-0.2519
6	-0.0598	0.0801	-0.1669	-0.1130	0.0521	-0.2269	0.1060	-0.0826	0.0999	0.0558	-0.3131	0.2341
7	0.0983	-0.1028	0.0447	-0.1777	-0.2647	-0.0034	0.1151	0.0590	0.1590	0.0275	-0.2408	-0.2503
8	0.1899	-0.0274	-0.0101	-0.1446	-0.0783	0.0087	0.3636	-0.0639	-0.1728	-0.0452	-0.3355	0.2391
9	0.1683	-0.3115	-0.0742	0.1954	-0.1400	0.3162	-0.1898	0.0273	-0.0544	0.0510	-0.1155	-0.0031

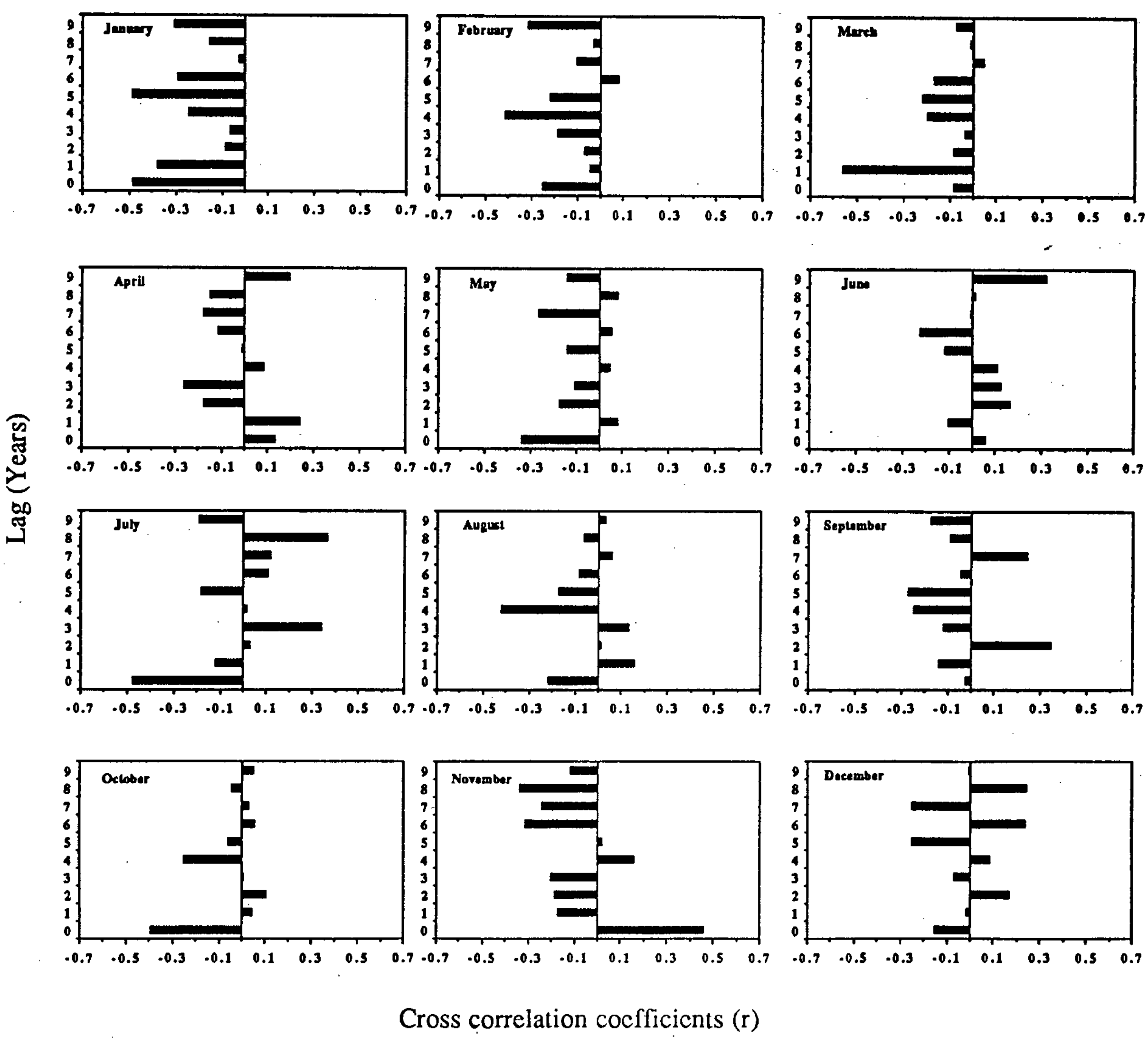


FIGURE 9.4.42 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Namaqualand area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.5225	-0.3586	0.0562	-0.1773	-0.0342
1	-0.0940	0.0305	-0.1509	-0.0932	0.0242
2	-0.0405	-0.0658	-0.1941	-0.2222	-0.0260
3	0.2007	0.1203	-0.2341	-0.0845	0.0996
4	0.1239	-0.2776	-0.0516	-0.0820	-0.3592
5	-0.2704	-0.1148	-0.1412	-0.1470	-0.2012
6	-0.0212	-0.1742	-0.1949	-0.1461	-0.1175
7	-0.1642	0.2068	-0.1162	-0.1593	0.1051
8	0.1387	-0.0207	-0.1234	-0.1038	-0.2055
9	-0.0860	-0.1282	0.1123	0.0710	-0.1086

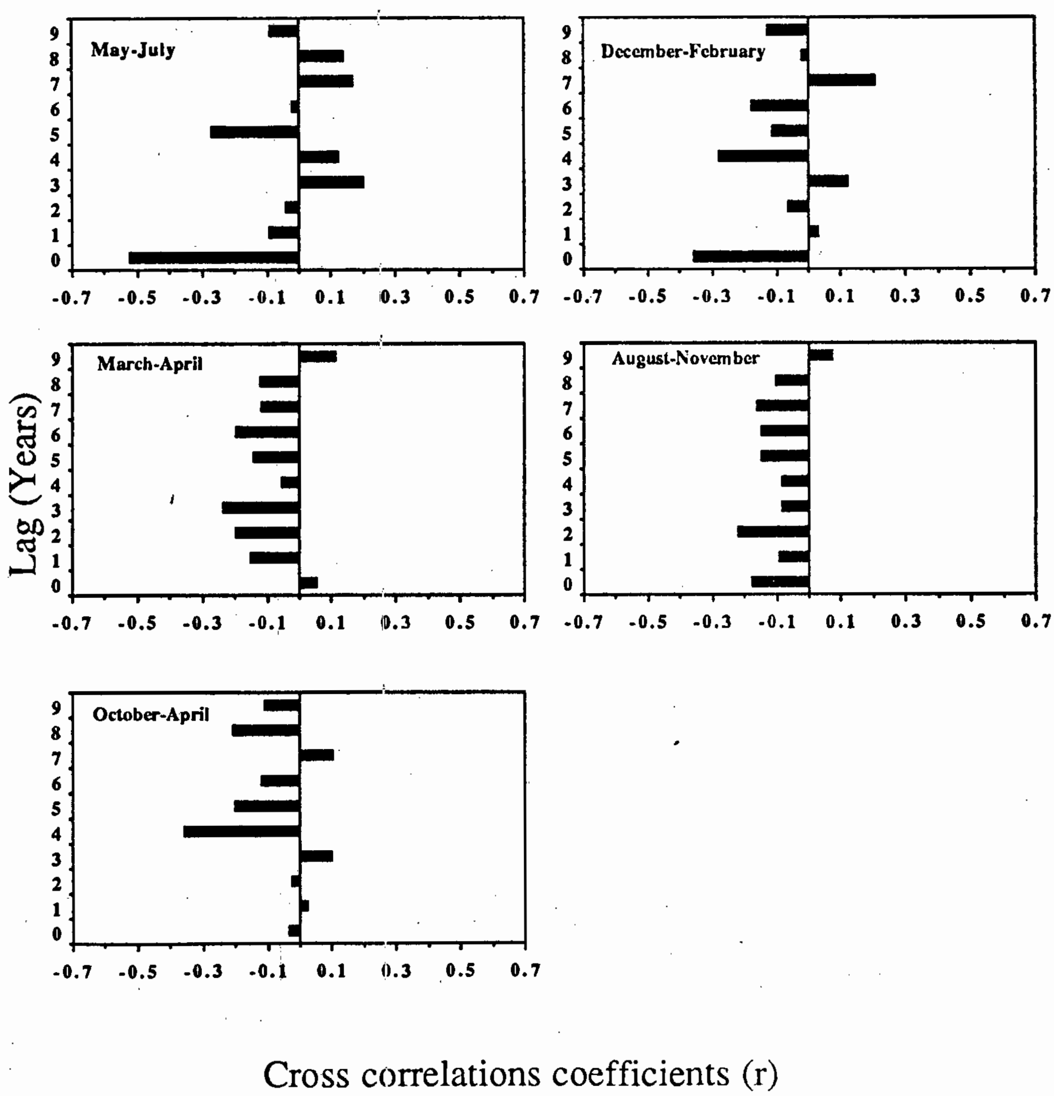


FIGURE 9.4.43 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scpmber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the south western Cape area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	0.1185	-0.0546	-0.1056	-0.2066	-0.1138	-0.0501	-0.0632	0.0796	0.3019	0.1730	0.0372	-0.0892
1	-0.0946	0.0557	0.1308	-0.1882	-0.4616	-0.4567	-0.3038	-0.2194	-0.1355	-0.2121	0.1025	0.3050
2	0.1418	0.0408	0.0991	0.1757	0.1554	-0.0427	-0.0951	-0.0384	0.0441	0.2732	0.2855	0.1146
3	-0.0924	0.1032	0.2004	0.3138	0.3212	0.1756	0.1476	0.0735	0.0987	0.0849	0.0034	0.0637
4	-0.0158	0.1141	0.1414	-0.0253	-0.1223	-0.1460	-0.0899	-0.0171	-0.0890	-0.0370	-0.2094	-0.2635
5	0.0277	0.0877	0.0991	-0.0160	-0.1758	-0.1330	-0.0354	0.1037	0.2519	0.0796	-0.0270	0.0002
6	0.0074	-0.0760	-0.0167	0.0118	-0.0176	-0.0552	-0.0560	0.0788	0.0215	-0.0147	-0.0780	-0.0802
7	-0.1614	-0.1651	-0.0701	0.0448	0.1501	0.1269	0.1393	0.2841	0.2966	0.0414	-0.0404	-0.0367
8	-0.1854	-0.0139	0.0912	0.1009	0.1514	0.1187	0.0670	0.0373	0.0042	0.1708	0.1697	-0.1531
9	0.3224	0.3148	0.3032	0.1590	-0.0676	-0.0999	0.1055	0.2603	0.2109	0.0237	0.0279	0.0474

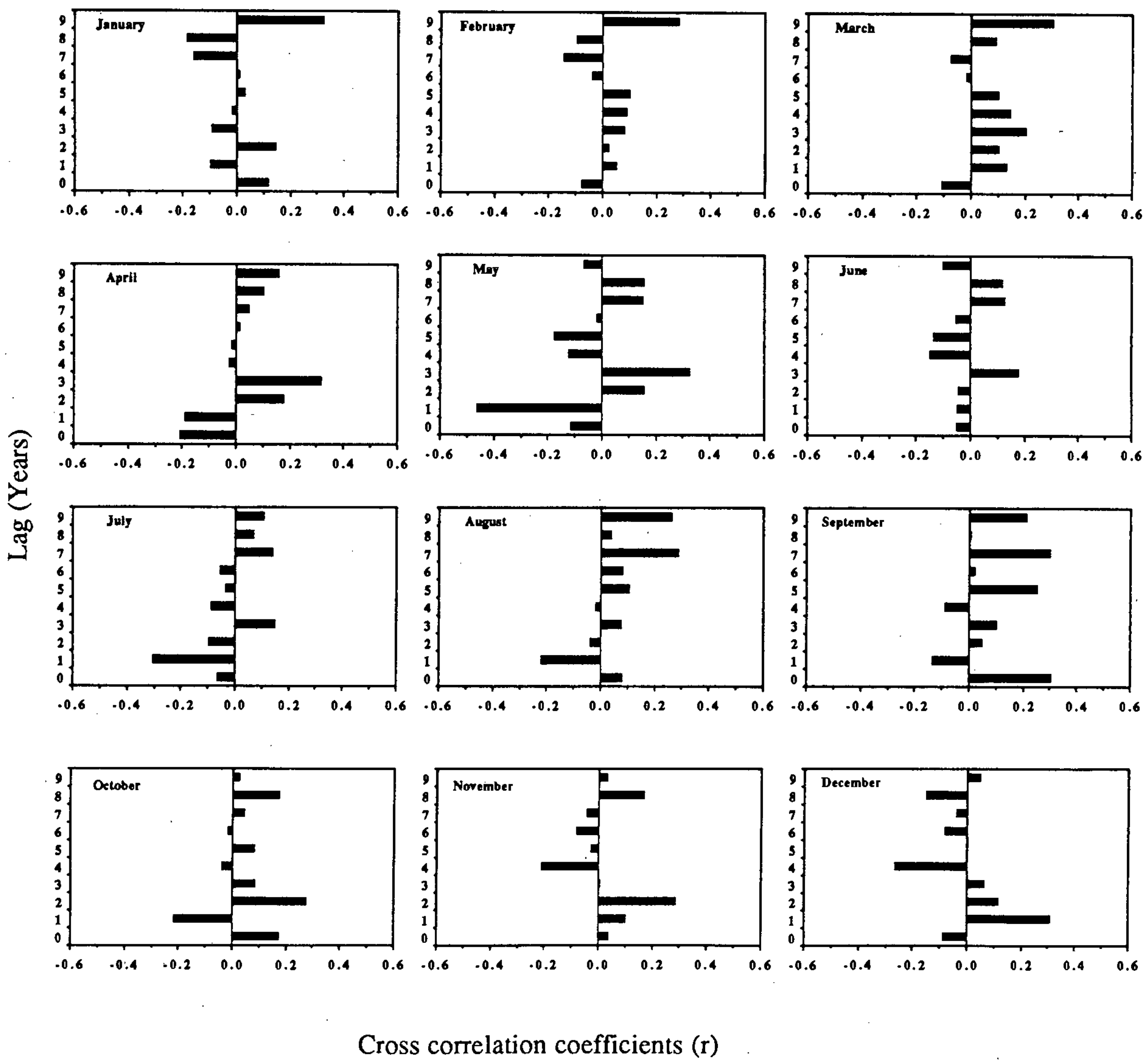


FIGURE 9.4.44 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the south western Cape area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.0659	0.0702	-0.1880	0.2263	-0.0822
1	-0.4622	0.0517	-0.0129	-0.1348	0.0353
2	0.0154	0.0558	0.1170	0.1482	0.1219
3	0.2436	-0.0661	0.2357	0.1636	0.0079
4	-0.1290	0.0549	0.0541	-0.1916	0.0383
5	-0.1274	0.0523	0.0595	0.1482	0.0539
6	-0.0374	-0.0307	0.0164	-0.0036	0.0476
7	0.1578	-0.2049	-0.0279	0.1498	-0.1191
8	0.1321	-0.0169	0.0552	0.1476	-0.0955
9	-0.0341	0.3640	0.2349	0.1576	0.2943

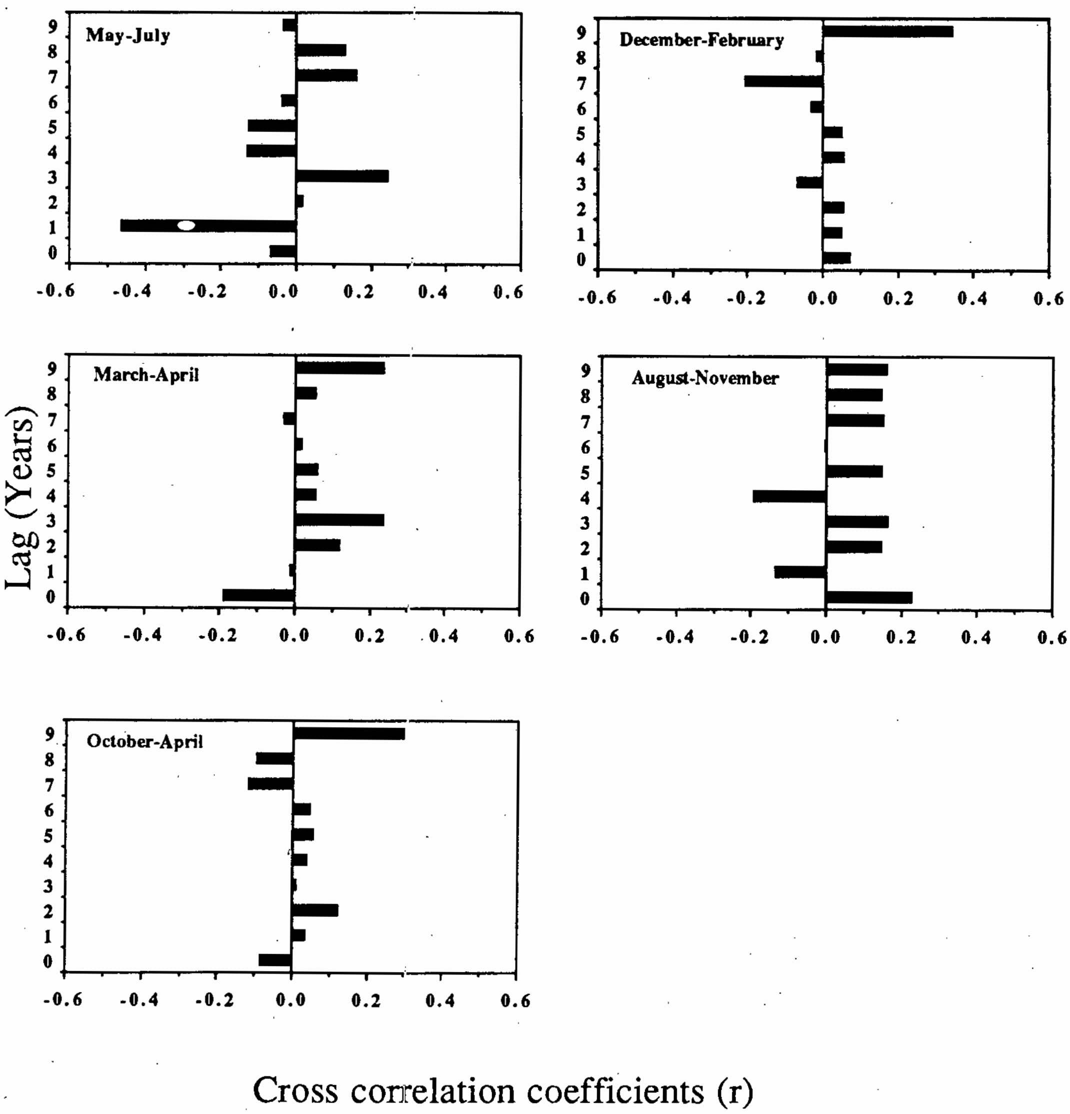
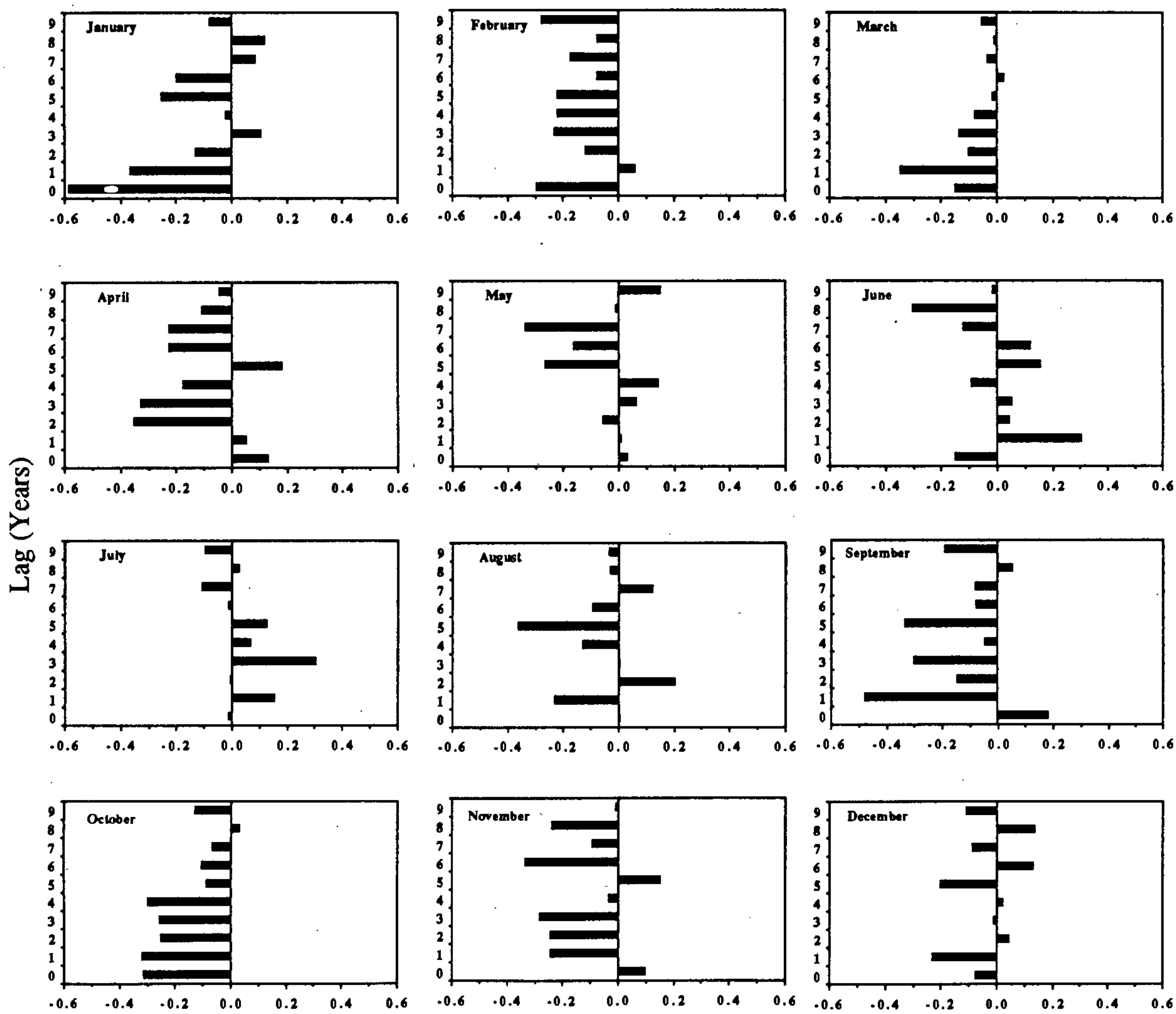


FIGURE 9.4.45 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the south western Cape area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.5861	-0.2951	-0.1514	0.1304	0.0286	-0.1504	-0.0121	0.0025	0.1815	-0.3153	0.0985	-0.0746
1	-0.3665	0.0592	-0.3423	0.0519	0.0090	0.3062	0.1510	-0.2318	-0.4739	-0.3178	-0.2429	-0.2302
2	-0.1301	-0.1189	-0.1015	-0.3507	-0.0536	0.0422	-0.0046	0.2007	-0.1417	-0.2502	-0.2452	0.0428
3	0.1049	-0.2314	-0.1362	-0.3262	0.0649	0.0513	0.3007	0.0030	-0.2988	-0.2554	-0.2806	-0.0108
4	-0.0208	-0.2200	-0.0801	-0.1781	0.1417	-0.0938	0.0667	-0.1280	-0.0443	-0.2998	-0.0315	0.0206
5	-0.2497	-0.2181	-0.0158	0.1821	-0.2656	0.1541	0.1255	-0.3610	-0.3346	-0.0862	0.1517	-0.2016
6	-0.1970	-0.0746	0.0247	-0.2247	-0.1579	0.1164	-0.0127	-0.0906	-0.0773	-0.1065	-0.3348	0.1294
7	0.0860	-0.1707	-0.0332	-0.2255	-0.3372	-0.1220	-0.1082	0.1205	-0.0803	-0.0687	-0.0933	-0.0876
8	0.1161	-0.0757	-0.0096	-0.1099	-0.0068	-0.3029	0.0251	-0.0293	0.0524	0.0290	-0.2373	0.1348
9	-0.0813	-0.2776	-0.0556	-0.0473	0.1516	-0.0149	-0.0962	-0.0347	-0.1902	-0.1283	-0.0066	-0.1072



Cross correlation coefficients (r)

FIGURE 9.4.46 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the south western Cape area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.1860	-0.4818	0.0685	0.1456	-0.2513
1	0.3265	-0.0378	-0.1654	-0.5112	-0.1398
2	0.0026	0.0661	-0.3144	-0.1037	-0.0982
3	0.2479	-0.1800	-0.1972	-0.3462	-0.1735
4	-0.0177	-0.1772	-0.0960	-0.0846	-0.0281
5	-0.0604	-0.1264	0.1080	-0.2504	-0.1672
6	0.0569	-0.1874	-0.1013	-0.1981	-0.1372
7	-0.0522	0.0525	-0.0511	-0.0474	-0.2016
8	-0.1381	-0.2013	-0.0100	-0.0476	0.0344
9	-0.1117	-0.1987	0.0530	-0.2275	-0.4070

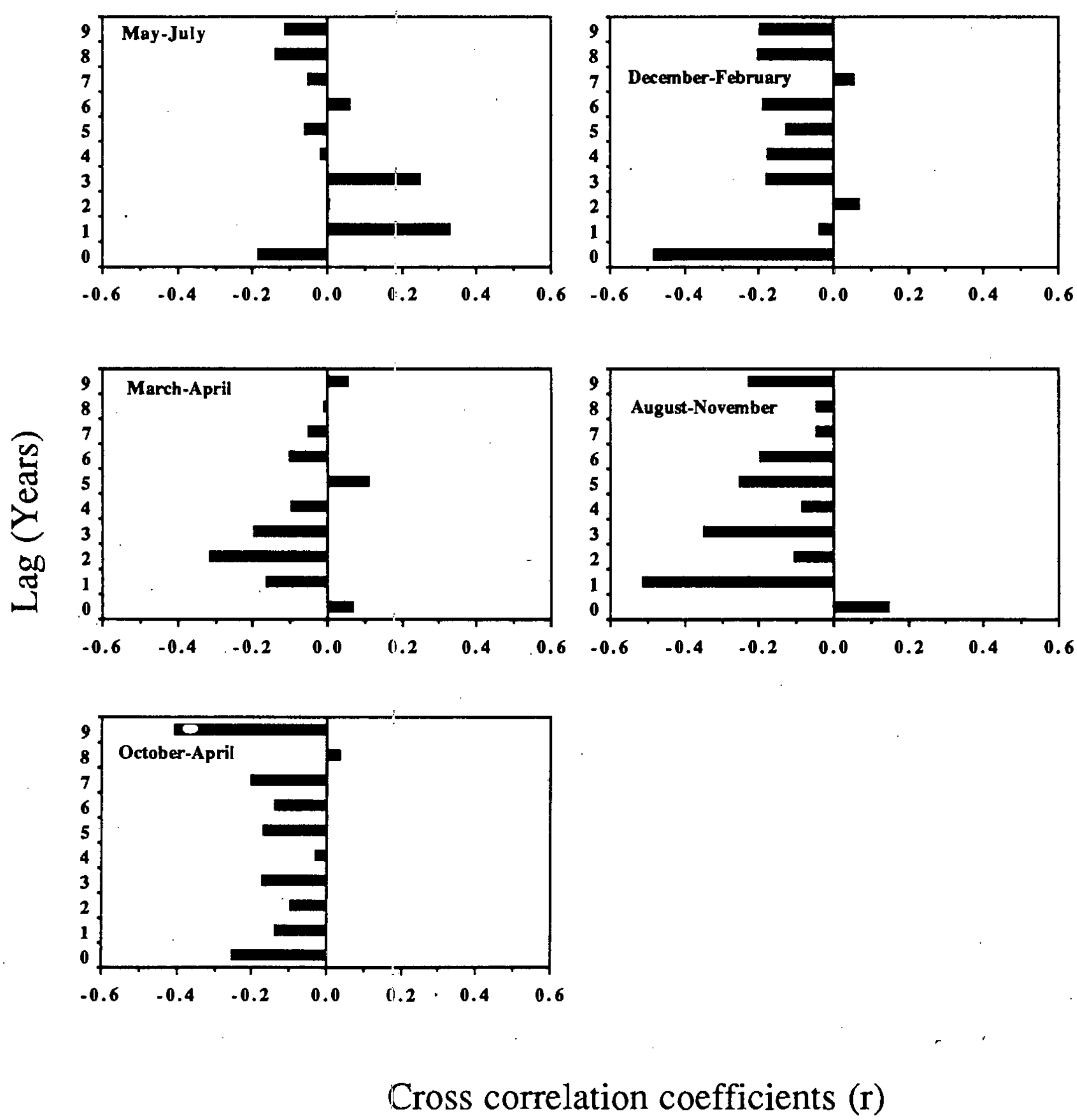


FIGURE 9.4.47 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scpmber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all months and lag: in the south western Cape area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.2130	-0.0591	0.0294	0.1886	-0.2346	-0.1148	0.0820	-0.2013	-0.0626	-0.0150	0.2740	0.4137
1	0.0760	0.0804	-0.1962	0.0723	0.1939	0.0056	0.1223	-0.1482	-0.2543	-0.3403	0.0072	-0.0419
2	-0.0115	-0.0613	0.0721	-0.2745	-0.1976	0.3764	-0.1284	0.1576	0.3139	0.1846	-0.0691	0.1297
3	0.2648	-0.1914	-0.0136	0.0136	-0.0516	-0.0533	0.3762	-0.0334	-0.1172	-0.2954	-0.1437	0.0399
4	0.2568	0.0148	0.0128	0.2603	0.0578	0.0566	0.1438	-0.2044	-0.1139	0.0889	0.0518	0.1935
5	-0.1493	-0.0205	-0.1000	0.1799	-0.1776	-0.0674	-0.0491	-0.2347	-0.3080	0.2129	0.2536	0.0725
6	0.0523	-0.0187	0.0428	-0.1014	0.0033	-0.0861	0.0414	0.0039	0.1239	0.0894	-0.2146	0.0531
7	0.1607	-0.0575	0.0529	-0.1958	-0.3028	-0.1650	-0.0561	0.0491	0.1269	0.1801	-0.1669	0.0580
8	0.2854	0.1372	0.0552	-0.0008	-0.1442	-0.0923	0.2021	-0.0335	0.1601	0.1438	-0.2731	0.2930
9	0.1347	-0.0508	0.0498	0.1592	0.0908	0.1736	-0.1128	-0.1468	-0.1887	-0.0148	-0.0603	0.0983

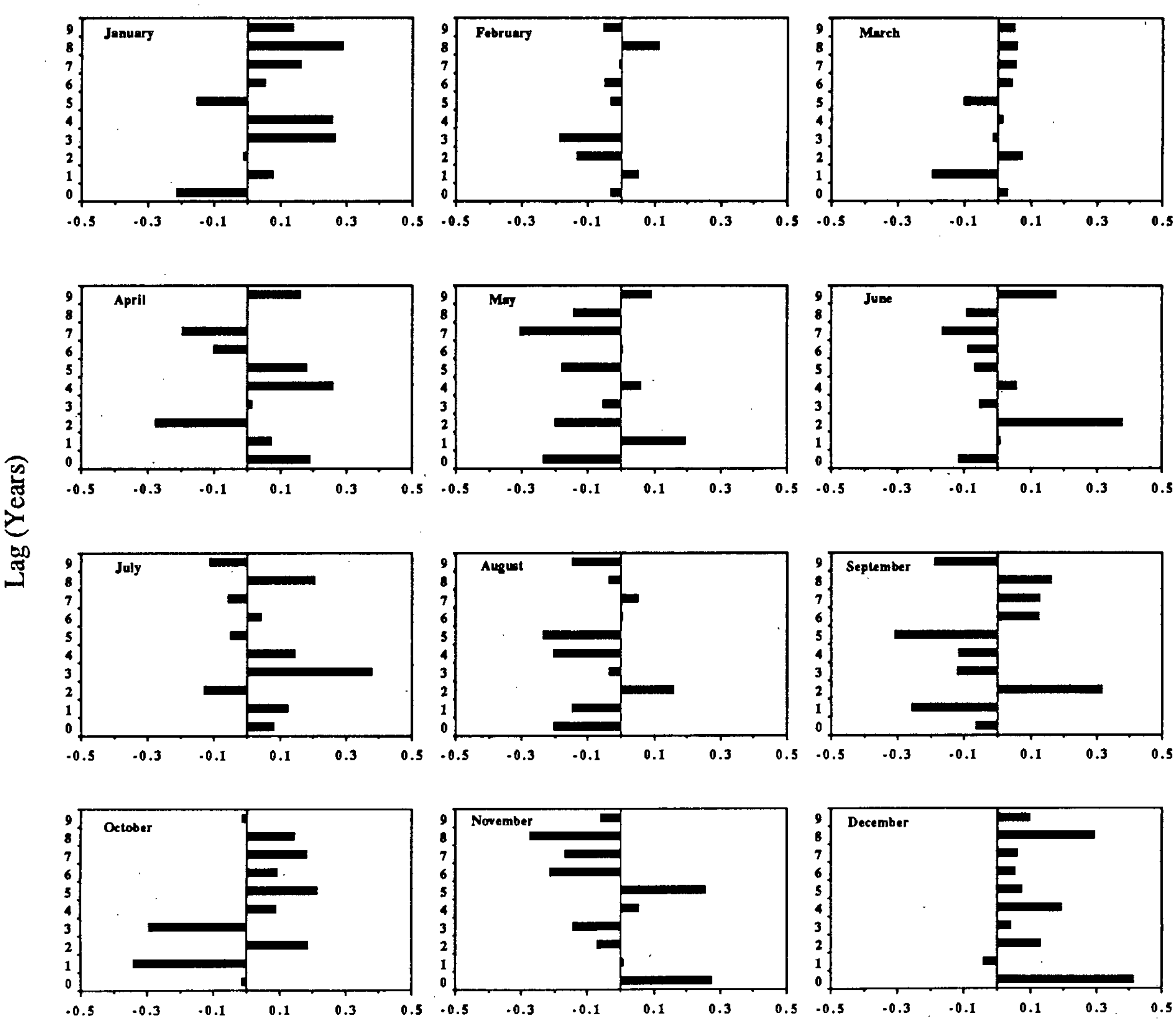


FIGURE 9.4.48 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the south western Cape area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.2312	0.0283	0.0272	0.0349	-0.0183
1	0.1743	0.0200	-0.1283	-0.4188	-0.0348
2	0.0081	-0.0900	-0.0895	0.1887	-0.2112
3	0.1435	0.0779	-0.0019	-0.4044	0.0810
4	0.1367	0.1714	0.1623	-0.0956	0.3224
5	-0.1514	-0.0674	0.0199	-0.0425	-0.0861
6	-0.0129	-0.0964	-0.0142	0.0071	-0.1127
7	-0.2688	0.1929	-0.0575	-0.0254	0.0017
8	-0.0127	0.2683	0.0547	-0.0592	0.1960
9	0.0802	0.0399	0.1400	-0.1668	0.0864

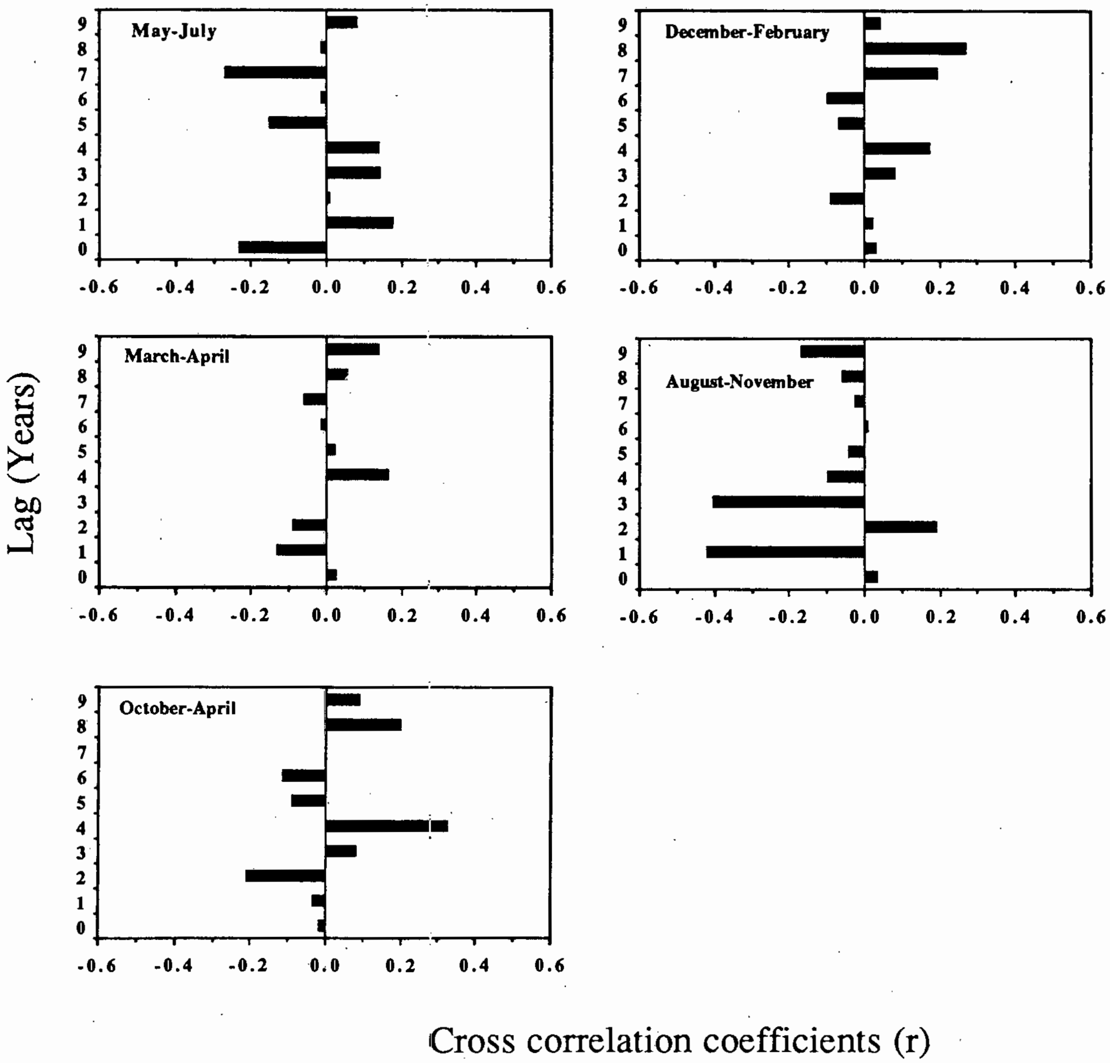


FIGURE 9.4.49 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all months and lags in the Agulhas Bank area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.0860	-0.1038	-0.1317	-0.1861	-0.1799	-0.1017	-0.0356	0.2527	0.1977	0.1582	0.0925	-0.0406
1	-0.1925	-0.0214	-0.1007	-0.2650	-0.3453	-0.3514	-0.3293	-0.1933	-0.1741	-0.3063	-0.2564	-0.0740
2	0.1083	0.0285	0.0777	0.1566	0.0484	-0.1153	-0.0491	0.0609	0.1462	0.0285	-0.1579	-0.1786
3	-0.0299	-0.0635	0.0508	0.1954	0.2303	0.1848	0.1912	0.1736	0.0366	-0.0461	-0.0317	0.0409
4	-0.0564	-0.0150	-0.0074	-0.0939	-0.0497	0.1096	0.1206	-0.0696	-0.0430	-0.0191	0.1765	0.1670
5	0.1210	0.1317	0.0740	0.0079	-0.1130	-0.0847	0.0990	0.2200	0.2708	0.2104	0.1863	0.1428
6	-0.2028	-0.0626	0.0225	0.0743	0.1449	0.1477	0.1484	0.1038	0.1924	0.0821	0.0300	0.0894
7	-0.1941	-0.2748	-0.1568	0.0343	0.0458	0.0473	0.2306	0.3231	0.3744	0.1862	-0.0290	-0.1257
8	-0.2418	-0.2112	0.0296	0.1510	0.0998	0.0885	0.1861	0.2214	0.1904	0.1526	0.1673	0.0374
9	0.0534	0.0240	-0.0640	-0.1281	-0.1392	0.0241	0.2043	0.2415	0.0996	-0.0508	-0.0514	-0.0920

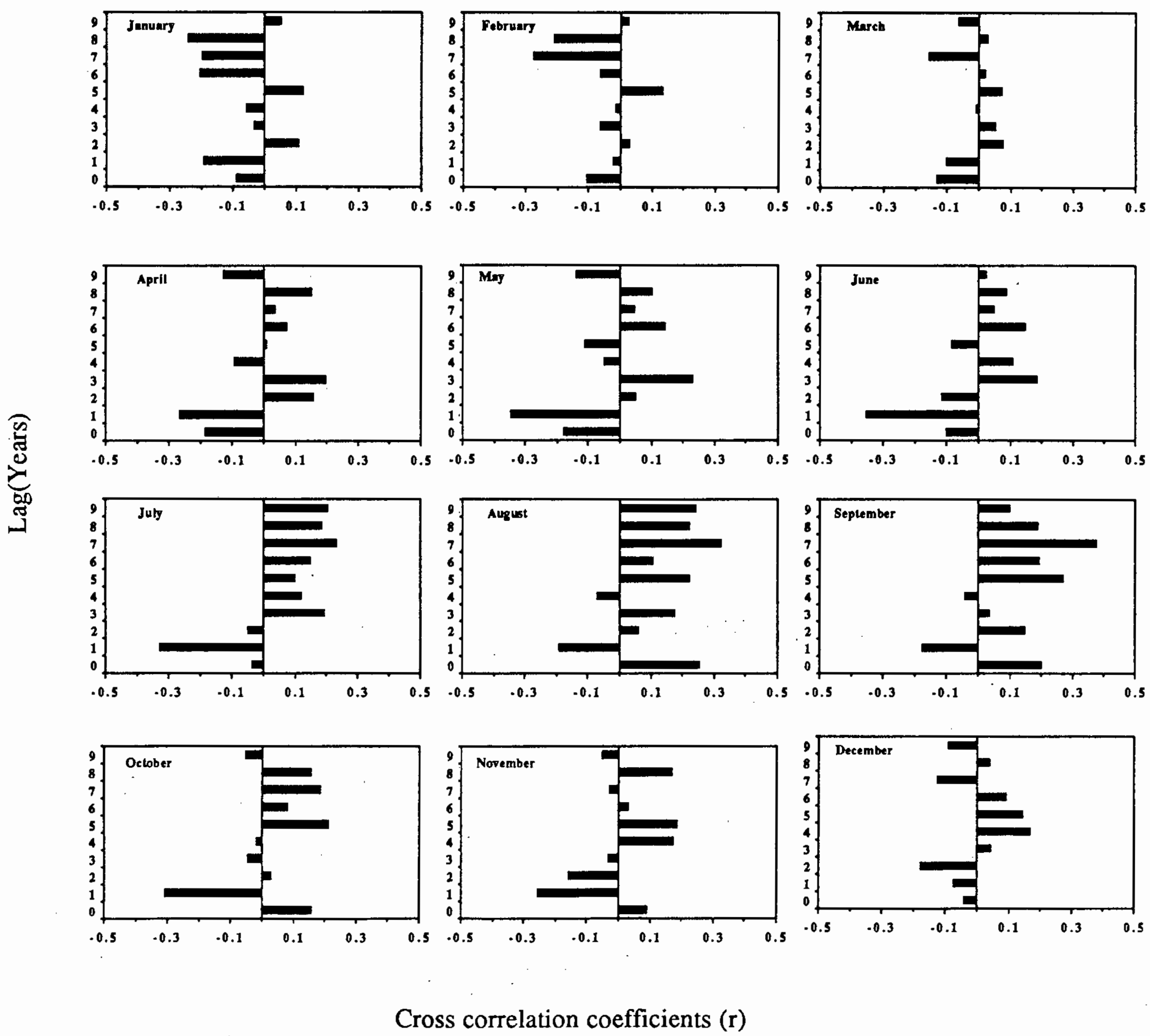


FIGURE 9.4.50 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly sea surface temperature residuals, for all combination of months and lags in the Agulhas Bank area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.0003	-0.0299	-0.1218	0.1822	-0.1028
1	-0.3873	-0.2333	-0.2091	-0.2519	-0.3185
2	-0.1134	0.0714	0.0925	0.0412	0.0517
3	0.2228	0.0263	0.1445	0.0391	0.0916
4	0.0793	-0.0525	-0.0568	0.0326	0.0089
5	-0.0928	0.1556	0.0303	0.2684	0.0393
6	0.1377	-0.1185	0.0727	0.1504	0.0232
7	0.0819	-0.1390	-0.0882	0.2719	-0.1476
8	0.1410	-0.2207	0.1172	0.2281	-0.0124
9	-0.0027	-0.0313	-0.1069	0.0685	-0.1105

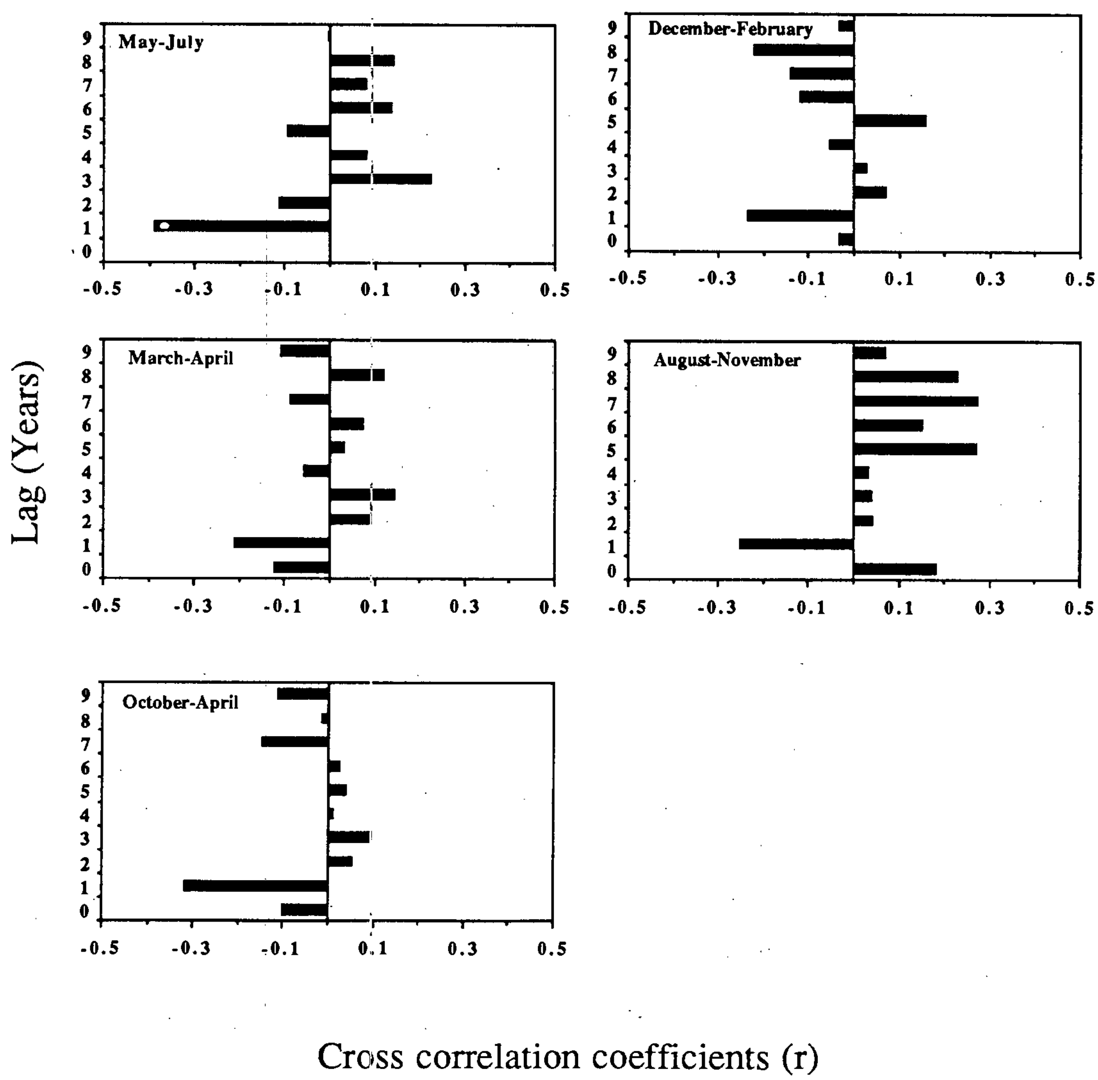


FIGURE 9.4.51 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all months and lags in the Agulhas Bank area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.1976	-0.0477	0.3077	0.2530	0.1296	-0.0529	0.1278	0.1588	0.3786	0.0330	0.2660	0.1494
1	0.0382	0.2979	-0.1112	0.3771	0.0610	0.2592	0.0096	-0.0610	-0.2344	0.2520	-0.2515	0.0366
2	0.1296	-0.0197	0.0535	-0.2433	0.0221	0.2428	-0.0264	0.0789	-0.1104	-0.0233	0.0017	0.0137
3	0.1504	-0.0493	0.1101	-0.1739	0.1313	0.0889	0.2149	-0.0767	-0.1586	0.0414	-0.1497	0.0237
4	-0.1065	-0.0525	0.0116	-0.2538	0.2316	0.0641	0.2870	-0.1452	-0.0499	-0.1950	0.1273	0.2753
5	-0.0434	0.0641	0.0358	0.2021	-0.0101	-0.0311	-0.0509	-0.0945	-0.2600	-0.0871	0.1563	-0.1874
6	-0.0543	-0.0208	-0.0055	-0.1242	0.0222	0.1275	0.1207	-0.0176	-0.0145	-0.0048	-0.1038	0.0786
7	0.2250	-0.1922	0.0040	-0.0818	-0.2705	0.0637	0.0481	0.0269	0.0986	0.0459	-0.0794	-0.2239
8	0.2811	-0.0576	0.0662	-0.0723	0.0129	0.0091	0.2705	-0.0273	0.0578	0.2056	0.0308	0.3697
9	0.1339	0.0904	0.1522	-0.1806	0.1989	0.0744	-0.0706	0.0326	-0.0752	0.0888	0.1118	-0.0081

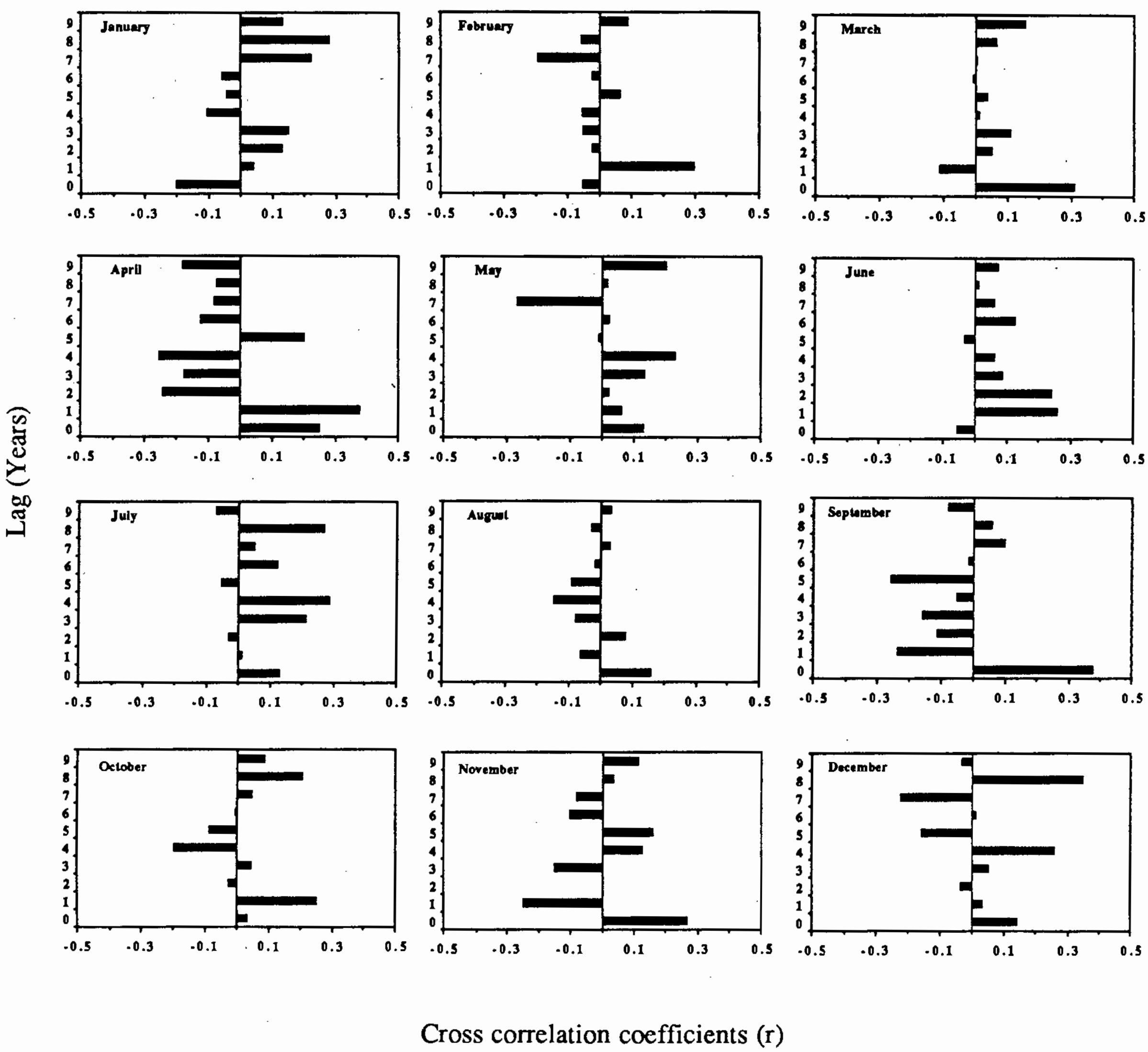


FIGURE 9.4.52 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly north-south wind component residuals, for all combination of months and lags in the Agulhas Bank area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	0.1008	-0.2074	0.3411	0.3455	-0.0605
1	0.1774	0.1409	-0.0497	0.1713	0.1843
2	0.1307	0.0143	-0.0079	-0.1215	-0.0528
3	0.2241	0.2326	-0.0727	-0.0435	0.0899
4	0.2973	-0.1574	-0.0305	-0.1534	0.0899
5	-0.0482	0.1033	-0.0247	0.1493	0.0702
6	0.1427	-0.1955	-0.0238	-0.0819	-0.2134
7	-0.0752	0.2272	-0.0065	-0.0493	0.1206
8	0.1497	0.0561	0.0054	-0.0058	0.0723
9	0.1038	0.1973	0.0086	-0.0224	0.0301

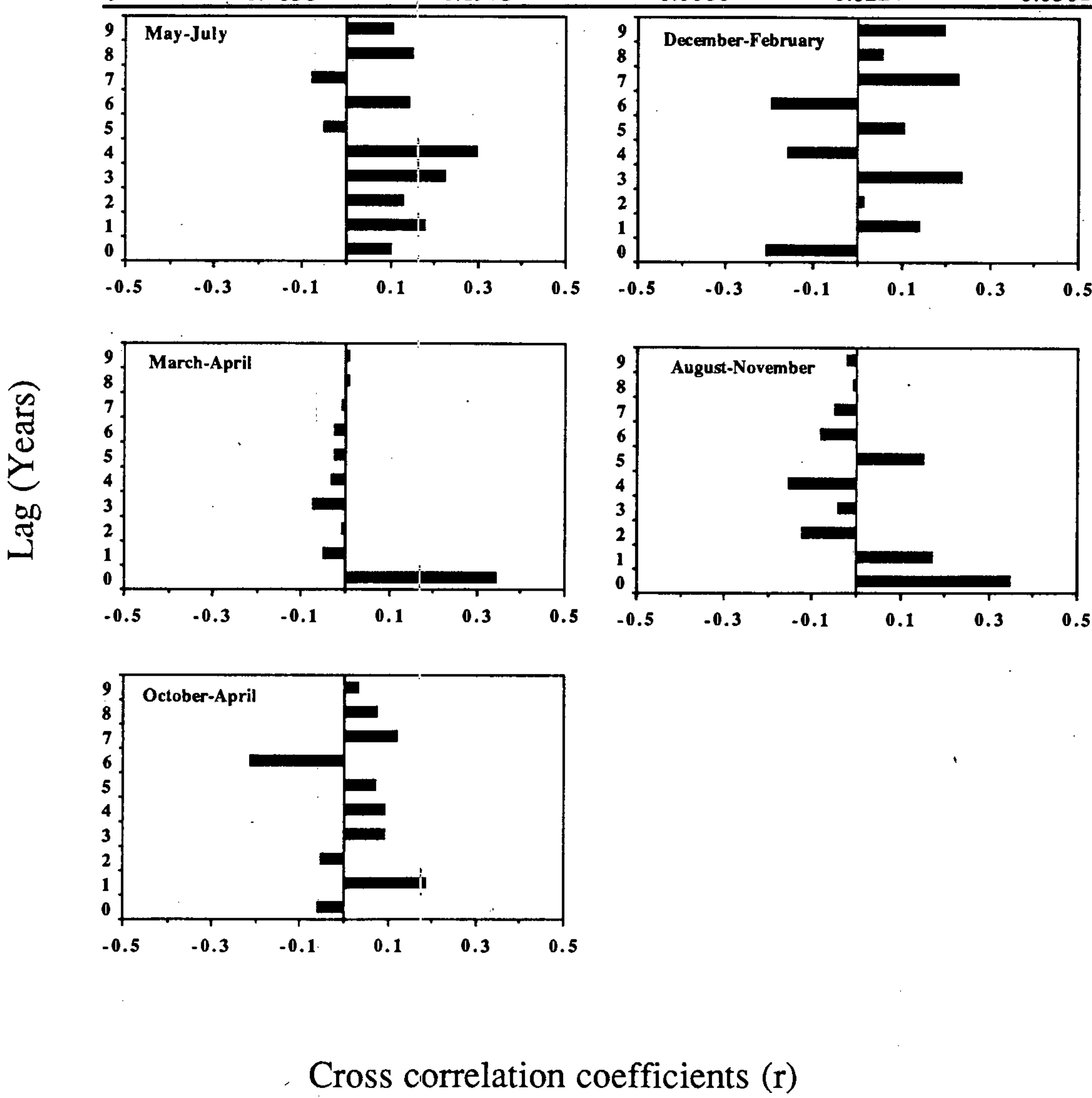


FIGURE 9.4.53 Tabular and graphical representation of the cross-correlation coefficients between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all months and lags in the Agulhas Bank area. 1954-1985.

Lag	January	February	March	April	May	June	July	August	September	October	November	December
0	-0.6114	-0.1445	0.2025	0.1725	-0.1611	0.1174	-0.1325	-0.3594	0.0693	-0.0442	0.2624	0.2996
1	-0.0772	0.0282	-0.1303	0.2321	0.4355	-0.0365	0.0014	0.0558	-0.2211	0.2791	-0.1993	-0.1654
2	-0.2174	-0.0591	-0.0148	-0.3585	0.1373	0.2342	-0.0602	0.1959	0.3789	0.3588	0.0128	0.0912
3	0.2470	-0.2399	-0.1907	-0.2773	0.1031	0.2796	0.2673	0.0036	-0.0110	-0.0369	-0.0633	0.0243
4	0.1398	-0.1302	0.0044	0.1658	0.0671	0.1016	0.3231	-0.1415	-0.1074	-0.0601	-0.1427	0.2823
5	-0.0521	-0.0817	-0.0985	0.2351	-0.0684	-0.1148	-0.0607	-0.1178	-0.3470	0.1283	0.1122	-0.2142
6	-0.0571	-0.1723	-0.0738	-0.1319	0.1796	-0.1374	0.2069	0.2628	0.1784	-0.1687	-0.0844	0.0373
7	0.0731	-0.1884	-0.3022	-0.1364	-0.2564	-0.0979	-0.0731	0.0256	0.2661	0.2049	-0.0924	0.0817
8	0.3613	-0.0248	-0.0624	0.0292	0.0345	0.1703	0.3484	-0.0462	0.1394	-0.1602	-0.3852	0.5134
9	0.0353	-0.0910	0.0447	0.2451	-0.0151	0.1836	0.0520	0.1017	-0.0863	0.0739	-0.1920	-0.0785

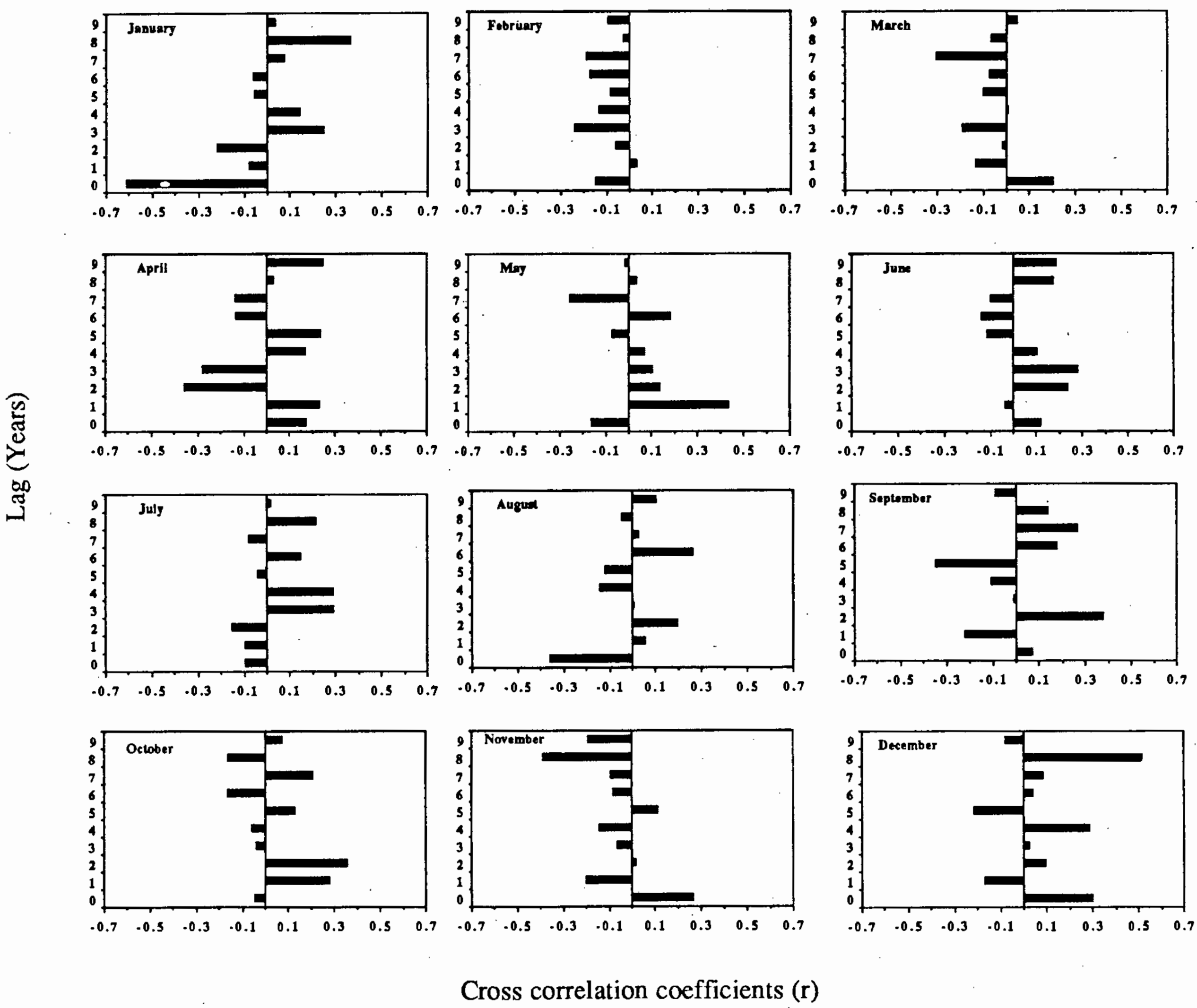


FIGURE 9.4.54 Tabular and graphical representation of the cross-correlation between chub mackerel (*Scomber japonicus*) annual catch residuals and monthly west-east wind component residuals, for all combination of months and lags in the Agulhas Bank area. 1954-1985.

Lag	May-July	December-February	March-April	August-November	October-April
0	-0.1161	-0.4784	-0.0351	0.2437	-0.1209
1	0.2120	-0.0140	0.0961	0.0733	0.0957
2	0.0893	-0.1469	0.2069	-0.2498	-0.3653
3	0.3714	0.1517	-0.2417	-0.3065	-0.0659
4	0.2254	-0.1135	-0.1214	0.1140	0.1738
5	-0.1238	-0.0333	0.0370	0.0954	-0.0063
6	0.1415	-0.2249	0.1415	-0.1351	-0.2459
7	-0.1539	0.2214	0.1108	-0.2824	-0.1459
8	0.2960	0.2040	-0.1186	-0.0198	0.1770
9	0.0998	-0.0804	0.0159	0.1926	0.0662