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AC Cockcroft , D van Zyl & L Hutchings
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Large-scale changes in the spatial distribution of South African West Coast rock lobsters: an overview

AC Cockcroft*, D van Zyl and L Hutchings

Marine and Coastal Management, Department of Environmental Affairs and Tourism, Private Bag X2, Rogge Bay 8012, South Africa
** Corresponding author, e-mail: cockcrof@deat.gov.za*

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A major shift in resource availability in the West Coast rock lobster *Jasus lalandii* from the traditional fishing grounds on the West Coast to the more southern fishing grounds was observed between the late 1980s/early 1990s and the turn of the century. The contribution of the West Coast region to total lobster landings declined from about 60% to <10%, whereas in the southern region it increased from around 18% to 60% during that period. The early 1990s was also the start of a major influx of lobsters into the area east of Cape Hangklip, an area not previously associated with high lobster abundance. Whereas the 1990s was a period of change, the period 2000 to present has been one of relative stability in lobster catches. The ecological, fisheries and resource management implications of these shifts have been severe and are likely to cause challenges in the future management of both the rock lobster and abalone *Haliotes midae* resources. The temporal coincidence of the shifts in lobster distribution with events such as the onset of reduced somatic growth and increased lobster walkouts suggests environmental forcing factors, as do congruent changes in other components of South Africa's Western Cape marine ecosystems. However, despite a number of studies on the variability of the physical environment, the causes of these events remain poorly understood.

Keywords: environmental change, *Jasus lalandii*, southward distributional shift, West Coast rock lobster

Introduction

West Coast rock lobsters *Jasus lalandii* are distributed generally close to the shore from about 23° S, just north of Walvis Bay in Namibia to about 28° E, near East London in South Africa (Cockcroft and Payne 1999). The South African commercial lobster fishery commenced in the early 1800s, and is currently managed using various strategies: a total allowable catch (TAC), minimum size limit, closed seasons, and defined fishing zones and areas. The fishery is valued in excess of R260 million (c. US$40 million) per annum and provides employment for some 4 000 people. Traditionally, it was of particular importance to communities on the South African west coast which relied heavily on the seasonal employment it provided.

The development of the *J. lalandii* fishery and the trends in commercial landings are well documented (e.g. Pollock 1986, Cockcroft and Payne 1999, Pollock *et al*. 2000, Melville-Smith and van Sittert 2005). The West Coast rock lobster fishing grounds were divided into fishing zones and areas in the early 1980s (Figure 1) and the tail mass production quota was replaced by a whole landed mass TAC for each zone/area at about that period (Pollock 1986). Prior to 1997, TACs were set for each zone/area and then summed to provide an overall TAC for the fishery. An Operational Management Procedure (OMP), which set a global TAC for the lobster resource that was then subdivided on a zonal/area basis, was introduced in 1997 (Johnston and Butterworth 2005). A revised OMP is currently in use.

Two important milestones relevant to commercial fishing in South Africa were achieved with the advent of democracy in that country in 1994. These were the promulgation of the Marine Living Resources Act in 1998 (Anon. 1998) and the equitable redistribution of fishing rights via the medium-term rights allocation (2001/2002) and the long-term rights in 2006. The long-term rights allocation process for West Coast rock lobsters was based on an accepted fishing policy, and resulted in the commercial fishery being divided into distinct nearshore and offshore components. The split in TAC between these components was based on resource availability (Table 1). The offshore component (allocated approximately 80% of the TAC with some 245 rights-holders) consists of individuals or companies (juristic persons) who use traps deployed from large vessels in deep water. Offshore rights-holders are not restricted to a particular fishing zone or area but are allowed to fish according to an agreed inter-area schedule. The nearshore component (allocated approximately 20% of the TAC with

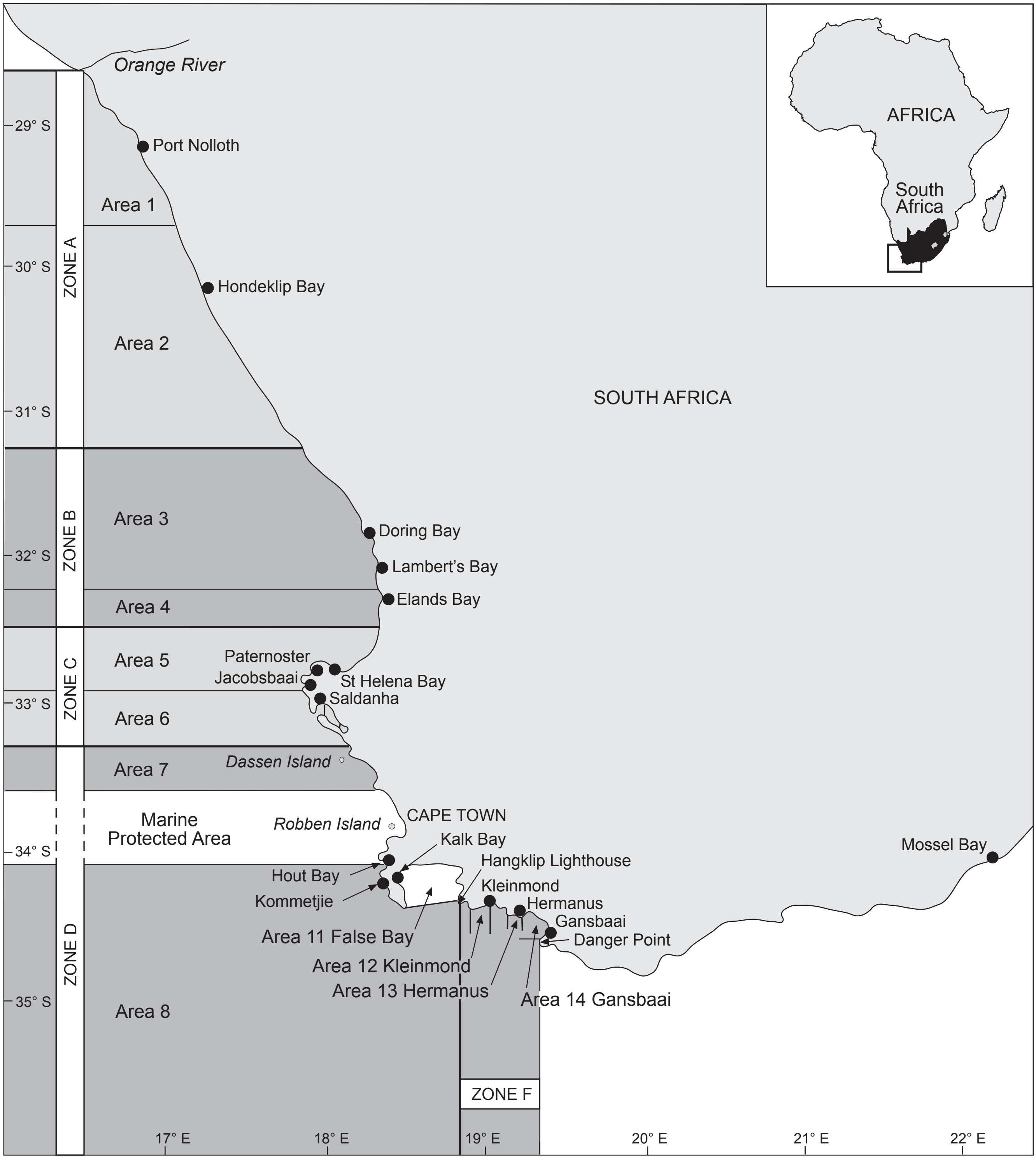

Figure 1: Map of the South African coast showing the fishing zones and areas of the West Coast rock lobster fishery

812 rights-holders) consists of individual rights-holders (natural persons) who are restricted to the zone or area of their residence and to the use of ringnets from small vessels. The numbers of rights within each nearshore area/zone were based on resource status or strength, resulting in an uneven spread of nearshore rights-holders around the coast (Table 2).

South Africa is committed to an ecosystems approach to fisheries (EAF) and has been actively engaged in implementing this approach in recent years (Shannon *et al*. 2006).

Table 1: Number of medium-term rights-holders, long-term rights applications and rights awarded in the nearshore and offshore sectors in the West Coast lobster fishery

Sector	Number of medium-term rights-holders	Number of long-term rights applicants	Number of long-term rights awarded	Successful long-term rights applications (%)
Nearshore	785	4 070	812	20
Offshore	234	733	245	33

Table 2: Number of long-term rights applications and those awarded to the nearshore sector for each fishing zone

Zone	Number of long-term rights applications	Number of successful long-term rights-holders	Successful long-term rights applications (%)
A	184	39	21
B	775	131	17
C	318	63	20
D	960	207	22
Area 11	484	57	12
F	1 349	315	23

Following the EAF framework, a workshop on ecological risk assessment on key South African fisheries was held in Cape Town in 2007 (Nel *et al.* 2007). A major risk identified at the workshop was the general southward shift in the spatial distribution of lobsters and a specific influx of them into an area previously not associated with high lobster abundance. The social, economic, ecological and management implications of this shift in lobster distribution, particularly to the nearshore component of the fishery, were considered to be far-reaching (Nel *et al.* 2007).

This paper addresses the following questions pertinent to understanding the mechanisms involved in this distributional shift and its possible causes:

- Has there been a shift in the spatial distribution of West Coast rock lobsters in recent times?
- What are its implications?
- Is the shift still occurring?
- What are the mechanisms involved?
- What are the causes?

Has There Been a Shift in Lobster Distribution Since the 1980s?

Regional overview

One of the most significant factors affecting the fishery for *J. lalandii* in the past two decades was the sharp decline in lobster somatic growth rates at the end of the 1980s/early 1990s, which resulted in decreased recruitment to lobsters above the minimum size limit for catches (Pollock 1994, Melville-Smith *et al.* 1995, Cockcroft and Goosen 1995, Cockcroft 1997). As a result of poor catches of lobsters of legal size and concerns regarding increased discard mortality due to increased handling of undersized lobsters, the minimum size limit was reduced from 89 mm to 75 mm carapace length (CL) between the 1991/1992 and 1993/1994 fishing seasons (Cockcroft and Payne 1999, Pollock *et al.* 2000), and has remained unchanged since then. During that period of low productivity, the TAC decreased from 3 790 t in 1990/1991 to 1 500 t in 1995/1996, and remained depressed until a modest recovery in 2000/2001 (Figure 2).

The period was also characterised by a clear shift in regional resource availability of lobsters. The resource, based on biological considerations such as the timing of the moult and reproductive cycles (Newman and Pollock 1971, Pollock 1986), can be divided into two broad regions. Fishing zones A–C are considered typical of the West Coast environment, whereas Area 8 together with Area 11 and Zone F constitute the more southern component of the fishery (Figure 1). Area 7 (Dassen Island) separates these regions. The relative contribution of these regions to the overall annual commercial landings (Figure 2) clearly illustrates a major shift in spatial resource availability between the late 1980s/early 1990s and the turn of the century, the start of a period of relative stability of catches. The contribution of the West Coast region to total lobster landings declined from about 60% to <10%, whereas in the southern region it increased from around 18% to around 60% during that period. The relative contribution of Area 7 declined slightly during the 1990s, but increased to around 30% and has remained stable at that level since 2000.

The decline in somatic growth rates, which was considered to be a coast-wide phenomenon and not restricted to a particular area/zone, sex or size class (Cockcroft and Goosen 1995, Goosen and Cockcroft 1995, Melville-Smith *et al*. 1995, Pollock *et al*. 1997, Hazell *et al*. 2001), markedly affected the overall productivity of the resource, and hence the TAC. However, its impact on the changes in resource distribution observed during the 1990s is uncertain. The lobster fisheries in the West Coast fishing Zones B and C were also severely impacted by a dramatic increase in the number and severity of lobster mass strandings (walkouts) during the 1990s (Cockcroft 2001; Figure 3). Subsequent recovery of the resource in those zones has been slow, with current landings in Zones B and C at around 7% and 2% respectively of their average catch during the 1980s. The decline in the contribution of the West Coast region to total lobster landings during the 1990s is most likely a

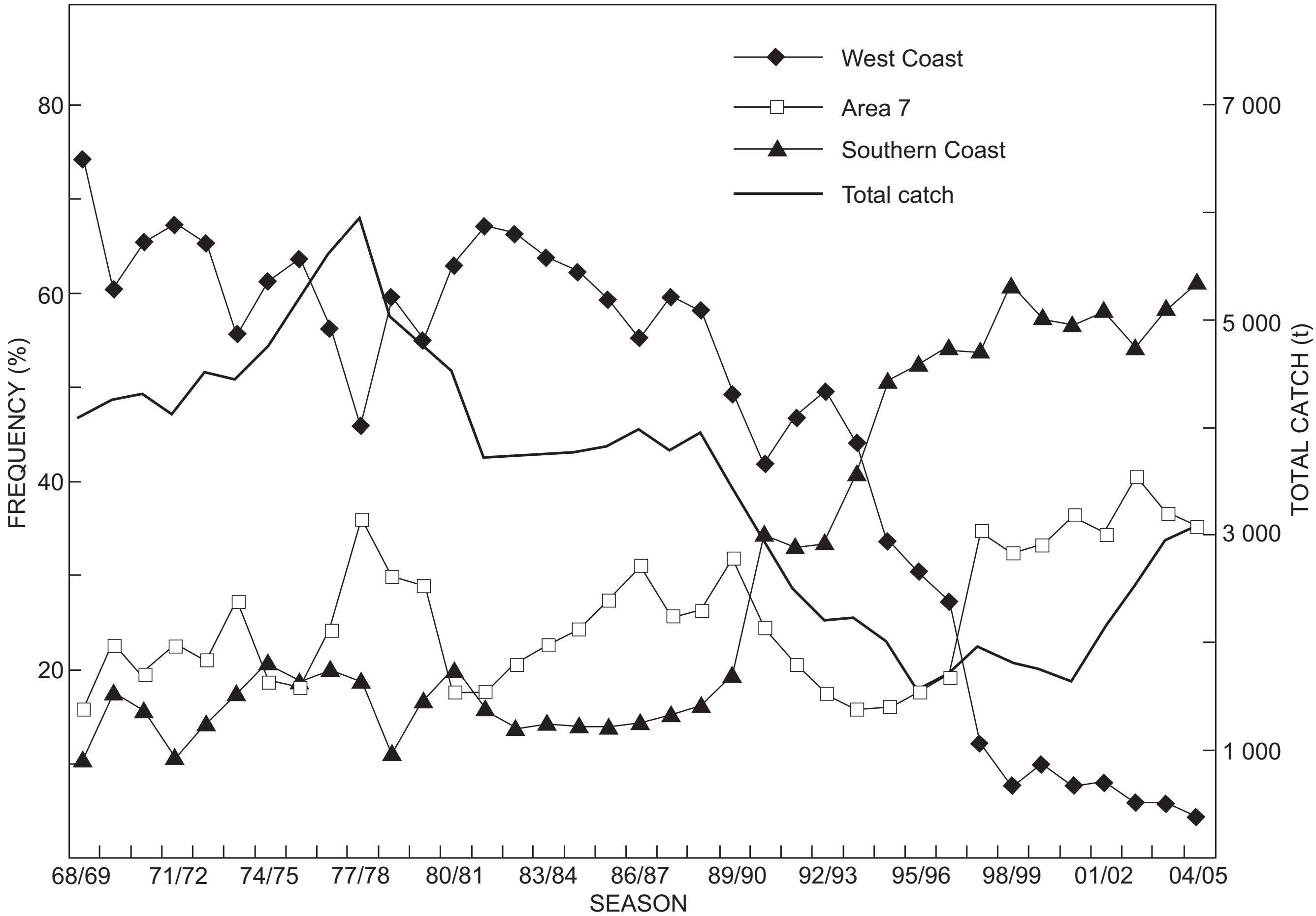

Figure 2: Percentage contribution of the West Coast, Area 7 and the southern coast to the total West Coast rock lobster landings. The total landed catch of the fishery is also provided

combination of reduced somatic growth rates, the loss of a considerable biomass (2 263 t) during lobster walkouts and the slow rate of resource recovery in those areas since then (Cockcroft 2001). It is unlikely that the observed changes in the distribution of landed catches were a result of a major migration of adult lobsters from the West Coast region to the more southern grounds. Based on tag-recapture data during the period 1968–2000, Atkinson and Branch (2003) found no evidence to support any longshore migrations of adult *J. lalandii*.

Results from the trap-based Fisheries Independent Monitoring Surveys (FIMS; Marine and Coastal Management, unpublished data), initiated in 1993 to examine the possible effects of the changes in size limit on the lobster resource, emphasise the relative importance of the southern fishing grounds during the past two decades (Figure 4). Those surveys were designed to monitor the West Coast rock lobster resource by providing annual relative abundance indices, in terms of catch per unit effort (cpue), in four areas (Zones B and C on the West Coast, Dassen Island and Area 8). The importance of Area 8 to the fishery is clearly evident in the cpue (number of lobsters >60 mm CL per trap) values (Figure 4), constituting 70–92% of total FIMS catches per year throughout the study period. Dassen Island is the second most important area (5–62%), whereas Zone B and Zone C combined (West Coast component) only contribute from <1% to 15% of total FIMS catches per year.

This change in resource distribution has had major implications for the lobster fishery as well the fishing community. The lobster fishery on the West Coast is now almost exclusively (>99%) a nearshore hoopnet fishery. The loss of jobs in lobster processing facilities, coupled with the reduced numbers of long-term rights that could be allocated in that region to ensure resource sustainability (Table 2), has resulted in substantial economic hardship for the West Coast communities. This has been exacerbated by the job losses associated with an eastward shift in the pelagic fish resources (van der Lingen *et al*. 2005, Fairweather *et al.* 2006, Roy *et al*. 2007). The highly dynamic nature of the West Coast environment makes the assessment of any ecosystem effects of this resource shift difficult to identify. Although the decrease in abundance of a key predator such as lobster has been shown to influence benthic community structure elsewhere (Breen and Mann 1976, Tegner and Levin 1983), there is little evidence to indicate that this has occurred off the west coast of South Africa (Cockcroft 2001). The concern that whelks could achieve and maintain dominance in the inshore benthic communities of the areas

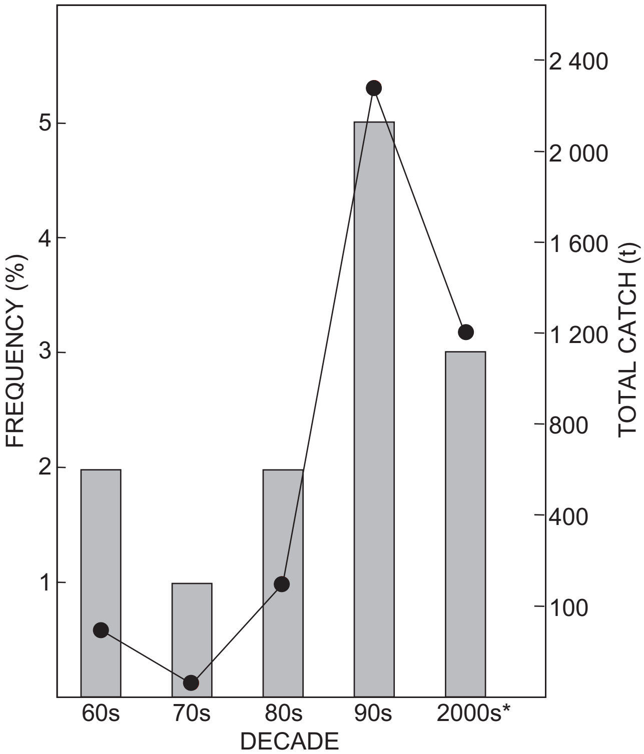

Figure 3: Number of lobster walkout events on the West Coast and the amounts stranded on a decadal scale. *The 2000s includes data up until March 2008

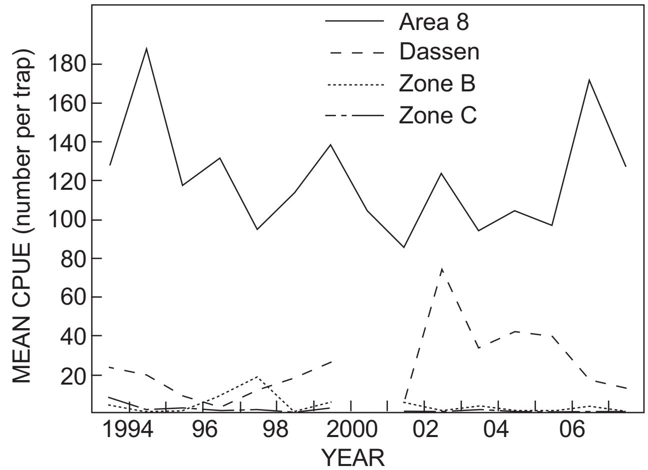

Figure 4: Mean cpue per zone/area derived from the trap-based Fisheries Independent Monitoring Survey (FIMS) for the West Coast rock lobsters

affected by lobster walkouts, thereby effectively excluding lobsters (Barkai and McQuaid 1988), has been shown to to be unfounded (Cockcroft *et al*. 1999). However, the decrease in lobsters along the West Coast has had a significant impact on the number of breeding pairs of bank cormorants *Phalacrocorax neglectus*, a major predator of lobsters (Rand 1960), on islands along the West Coast (Crawford *et al*. 2008a).

Movement of lobster into the area east of Cape Hangklip

The large-scale shift in lobster commercial catch distribution was accompanied by a marked influx of lobsters into an area not previously associated with lobster harvesting. A line due south from the Cape Hangklip lighthouse (18°50′00″ S, 34°23′09″ W) marks the eastern boundary of Area 8 (Figure 1), the easternmost extent of traditional lobster fishing grounds. The area east of this boundary up to Danger Point (Figure 1) is referred to hereafter as the area east of Cape Hangklip (EOCH).

The numbers of West Coast rock lobsters in the nearshore (<30 m) regions EOCH prior to the 1990s were negligible (Field *et al*. 1980, Tarr *et al*. 1992). An increase in the abundance of lobsters in that area was first observed during abalone recruitment surveys conducted in the early 1990s (Tarr *et al*. 1992). Those observations were corroborated by catch data for the recreational lobster fishery obtained during telephone surveys over that period (Cockcroft and MacKenzie 1997, Cockcroft and Payne 1999). The relative contribution of the area EOCH to the total recreational catch increased from 19% in 1991/1992 to 44% in 1994/1995, and remained at around 40% thereafter. Because recreational lobster fishers have no restriction on where they fish (the exception being marine protected areas), the marked increase in the fishing activity and landings in the area EOCH implied an increased abundance of lobsters in that region in the early 1990s (Cockcroft and MacKenzie 1997).

The increased abundance of lobsters between Cape Hangklip and Danger Point was confirmed and quantified by field surveys (mostly hoopnet and diving) during the period 1996–1999 (Schoeman and van Zyl 1999, Mayfield and Branch 2000, Mayfield *et al*. 2005). Estimates of lobster abundance, based on the calorific value for *J. lalandii* within 200 m of the shoreline (Field *et al*. 1980), showed an increase from zero to 652 kJ m^{-2} between 1980 and 1997 (Mayfield and Branch 2000). Schoeman and van Zyl (1999) found clear gradients in the inshore (<30 m) rock lobster population structure, with abundance decreasing and average size increasing from west (Cape Hangklip) to east (Danger Point). Highest concentrations of lobsters were found between Cape Hangklip and Hermanus, one of the most important commercial fishing grounds for the South African abalone *Haliots midae* (Tarr 2000).

Implications of the Shift

Ecological implications

Since 1949, the South-East coast has traditionally been the region that supports the lucrative South African abalone fishery (Tarr 1996). There is a strong and mutually beneficial relationship between juvenile abalone and sea urchins *Parechinus angulosus,* as demonstrated in field experiments conducted in False Bay (Day and Branch 2000a) and surveys conducted in the area EOCH (Mayfield and Branch 2000). Juvenile abalone derive protection from predation by sheltering under sea urchin spines (Tarr 2000). In addition, grazing by sea urchins on the benthos may be an important factor in maintaining the coverage of healthy crustose coralline algae, a key element in abalone larval settlement (Day and Branch 2000b). The presence of sea urchins is therefore considered important to the successful recruitment of juvenile abalone to the commercial fishery.

The influx of lobsters had a profound effect on the benthic ecology of the area between Cape Hangklip and Danger Point, the most evident being the virtual disappearance of sea urchins and the winkle *Turbo cidaris*, which resulted in a major increase in foliar algal abundance (Mayfield and Branch 2000, Tarr 2000). Working in the area EOCH, Mayfield and Branch (2000) showed that densities of sea urchins were negatively correlated with those of large lobsters (>68 mm CL); at density of around 0.25 large rock lobster m^{-2} very few sea urchins survived. Those authors linked the increase in lobster abundance to the decline in urchin numbers in the area EOCH. They also found that at urchin densities below about 25 m^{-2}, densities of juvenile abalone and those of sea urchins were correlated.

Fishery implications

The decrease in abalone recruitment, together with rampant illegal harvesting (Plagányi 2007), had severe impact on the commercial and recreational abalone fisheries. As a result, the commercial abalone TAC has decreased by 80% since 1996, and the recreational fishery was suspended in 2003 and two formally productive abalone harvesting zones between Cape Hangklip and Hermanus were closed in 2006.

The increased lobster abundance in the area EOCH prompted an investigation into the possibility of introducing a commercial lobster fishery in that area. To this end, an experimental nearshore fishery for lobsters, using hoopnets from small boats, was introduced in 1999/2000 in three fishing grounds: Kleinmond, Hermanus and Gansbaai — lobster fishing areas 12, 13 and 14 respectively — which contribute to Zone F (Figure 1). Based on those findings, a TAC of 100 t (40 t each in Areas 12 and 13 and 20 t in Area 14) was recommended as a sustainable harvesting level for the lobster fishery EOCH. However, 230 t (90 t each for Areas 12 and 13 and 50 t in Area 14) were allocated to rights-holders during the medium-term rights allocation process in 2001/2002 and 215 t (Area 14 reduced from 50 t to 35 t) during the 2005/2006 long-term rights allocation process.

Not unexpectedly, the trends in fishery performance indicators mirrored the west-to-east lobster abundance trends reported by Schoeman and van Zyl (1999). Whereas lobster landings and cpue in Area 12 remained relatively consistent over the 2003/2004–2006/2007 fishing seasons, they declined markedly in Areas 13 and 14 over that period (Figure 5). The fishery in Area 14 has been the most impacted with less than one-third of the 35 t TAC landed in the past two seasons. The decrease in resource availability had a severe impact on nearshore rights-holders in Area 14 (and, to lesser extent, Area 13), and relief in the form of boundary changes of some areas have been requested by affected rights-holders (Marine and Coastal Management [MCM] unpublished data).

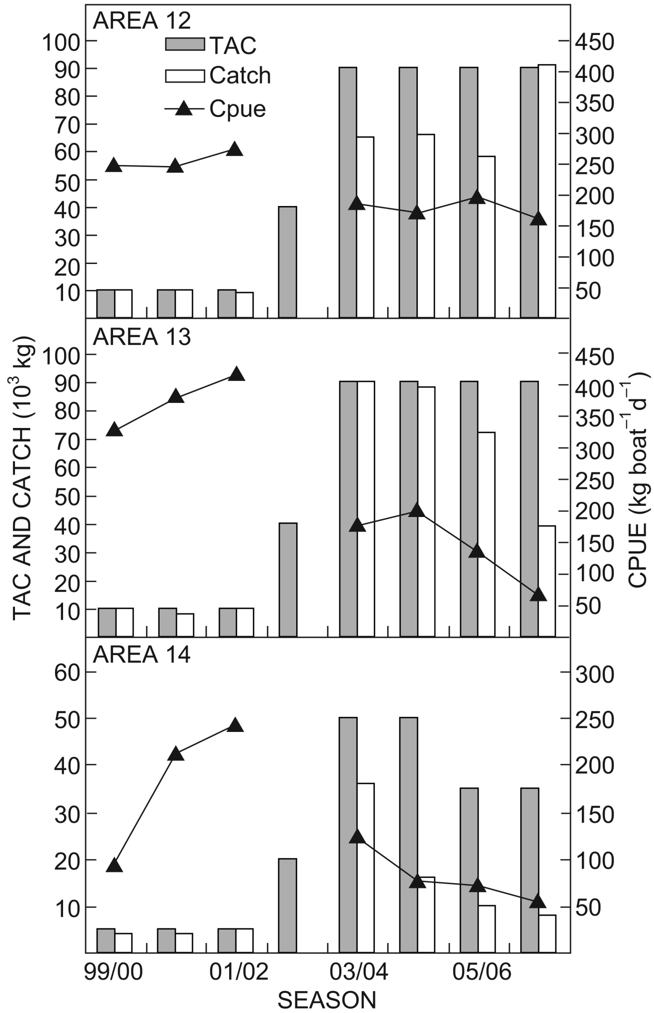

Figure 5: Total allowable catch (TAC), total landings and cpue for Areas 12, 13 and 14

Is the Shift Continuing Eastwards?

A continuation of the eastward movement of lobsters into the area east of Danger Point is not supported by the commercial lobster fishery data in Areas 13 and 14 or the results of directed inshore FIMS conducted throughout the South African lobster fishing grounds (including the area EOCH) for the period 2002–2005 (Brouwer and van Zyl 2004). A continuing movement of lobsters into Areas 12, 13 and 14 (Zone F) would be expected to result in increased abundance, which would manifest itself in increasing, or at least stable, fishery performance indicators. The decline in the commercial catch and catch rates in Areas 13 and 14 indicates that the removal of lobsters exceeds any recruitment to the fishery via somatic growth or the movement or influx of adult lobsters into these areas. An overall decline in the cpue measured during the inshore FIMS in Zone F between 2002 and 2004 (Table 3) reinforces the trend in the commercial fishery data. The most compelling evidence that lobsters have not moved farther eastwards in any appreciable numbers is the very low cpue values in the area east

Table 3: Mean cpue per zone/area derived from a hoopnet-based Fisheries Independent Monitoring Survey in shallow water (<30 m). F+ is the area immediately east of Zone F

	Cpue (lobsters hoopnet^{-1})			
Zone	2002	2003	2004	2007
B	0.04	0.01	0.01	
C	0.00	0.17	0.31	
Dassen Island	–	5.68	7.17	
Area 8	7.95	15.68	13.75	
E	2.18	9.83	4.88	
F	6.61	5.10	3.38	
F+	0.33	0.02	0.02	0.05

of Danger Point (Zone F), estimated from the inshore FIMS surveys between 2002 and 2004, and in 2007 (Table 3).

Whereas the commercial fishery and inshore FIMS data reflect the changes in lobster resource abundance in shallow water (<30 m) since the turn of the century, it is not known whether such changes occurred in the deep water lobsters EOCH. It is noteworthy, however, that the offshore trap surveys in Areas 12, 13 and 14 at depths between 30 m and 100 m in 1997 (Schoeman and van Zyl 1999) showed similar spatial trends to those of the inshore hoopnet survey, with abundance decreasing from west to east.

Mechanisms of Lobster Movement

The intuitive assumption that the lobsters EOCH are an extension of the population in the adjacent Area 8 is supported by the similarity in their size composition and sex ratio characteristics (Schoeman and van Zyl 1999), and from genetic evidence (Matthee *et al*. 2007). Whereas adult lobsters do not undertake distinct longshore migrations (Atkinson and Branch 2003), they undergo a well-defined seasonal migration towards and away from shore (Newman and Pollock 1971, Pollock 1982, Goosen and Cockcroft 1995). The hypothesis that an onshore movement from deeper waters was the most likely source of the lobsters moving into EOCH is supported by the size composition (mainly adults) of lobsters in these two regions observed during the early phase of the influx (Tarr *et al*. 1992, Schoeman and van Zyl 1999). Settlement of post-larval lobsters into EOCH only became a regular event after a substantial adult population had been established there (Schoeman and van Zyl 1999).

The mechanism of the lobster influx appears to be fairly clear, but the underlying reason why this has happened is not. The hypothesis that the habitat EOCH became favourable to lobster occupation in the early 1990s is difficult to quantify given the paucity of long-term environmental data in that region. There is evidence to suggest that there was an increase in seaweed biomass in the area at around the same period (R Anderson, MCM, unpublished data), which could support the improved habitat hypothesis, but other factors such as reduced grazing by urchins should also be considered. Anecdotal evidence of a reduction in temperature in the area remains untested. The benefits for lobsters of moving into the area EOCH, indicated by good somatic growth, enhanced reproduction and successful post-larval recruitment (Schoeman and van Zyl 1999, Mayfield and Branch 2000), negate the theory that the lobsters were forced into a suboptimal habitat by intraspecific competition.

Possible Causes

Reduced somatic growth, increased lobster walkouts, a southward shift in lobster catch distribution and an influx of lobsters into the area EOCH appear to have had a profound affect on the West Coast rock lobster resource during the past two decades. The temporal coincidence of these events between the late 1980s/early 1990s and early 2000s strongly suggests a linkage in the underlying environmental causes or forcing factors. Whereas the 1990s was a period of transition, the most recent period (2000–current) appears to be one of relative stability for the resource. This is evident by enhanced somatic growth rates, the moderate recovery in the TACs, the reduced number and severity of walkouts, and the stabilising of the southward shift in resource availability and influx of lobsters into the area EOCH. The fundamental question is whether these events can be explained by an underlying environmental change that occurred during the transition period and whether they are temporary or part of a long-term ecosystem change. The possibility that the observed changes in lobster productivity and resource distribution were exacerbated by fishing pressure (especially the overfishing during 1960s and 1970s) appears unlikely, because lobster landings during the 1980s indicate a period of relative stability in the fishery with catch rates increasing (Cockcroft and Payne 1999).

The reasons for the increase in numbers and intensity of lobster walkouts during the 1990s are reasonably well understood. Walkouts have been the result of low-oxygen events associated with the accumulation and subsequent decay of dense dinoflagellate blooms during late summer/early autumn (Cockcroft *et al*. 1999, Cockcroft 2001). Upwelling pulses followed by quiescent periods during the relaxation of southerly winds allow the shoreward transport of blooms that are formed at the upwelling front by weak across-shore currents and the formation of dense inshore red tides (Pitcher *et al*. 1995, Pitcher and Boyd 1996). The underlying cause of the coast-wide decrease in somatic growth, however, remains poorly understood. Shannon *et al.* (1992) ascribed the low growth rate phenomenon to a large-scale change in the environment, and Pollock *et al.* (1997) linked it to possible productivity changes in the southern Benguela associated with the anomalous *El Niño* event during the period 1990–1993. Reduced resource productivity as a result of an increased frequency of oxygen-depleted bottom waters, influenced by the poleward undercurrent (De Decker 1970, Nelson 1989), has also been suggested as a possible cause for the decrease in the somatic growth of West Coast rock lobsters (Pollock *et al*. 2000). Further, the quiescent conditions that facilitate the shoreward transport of phytoplankton blooms also favour the incursion of low-oxygen bottom water into shallow water (Newman and Pollock 1971).

Upwelling winds generally increased over the period 1950–1985 (Taunton-Clark and Shannon 1988), superimposed on

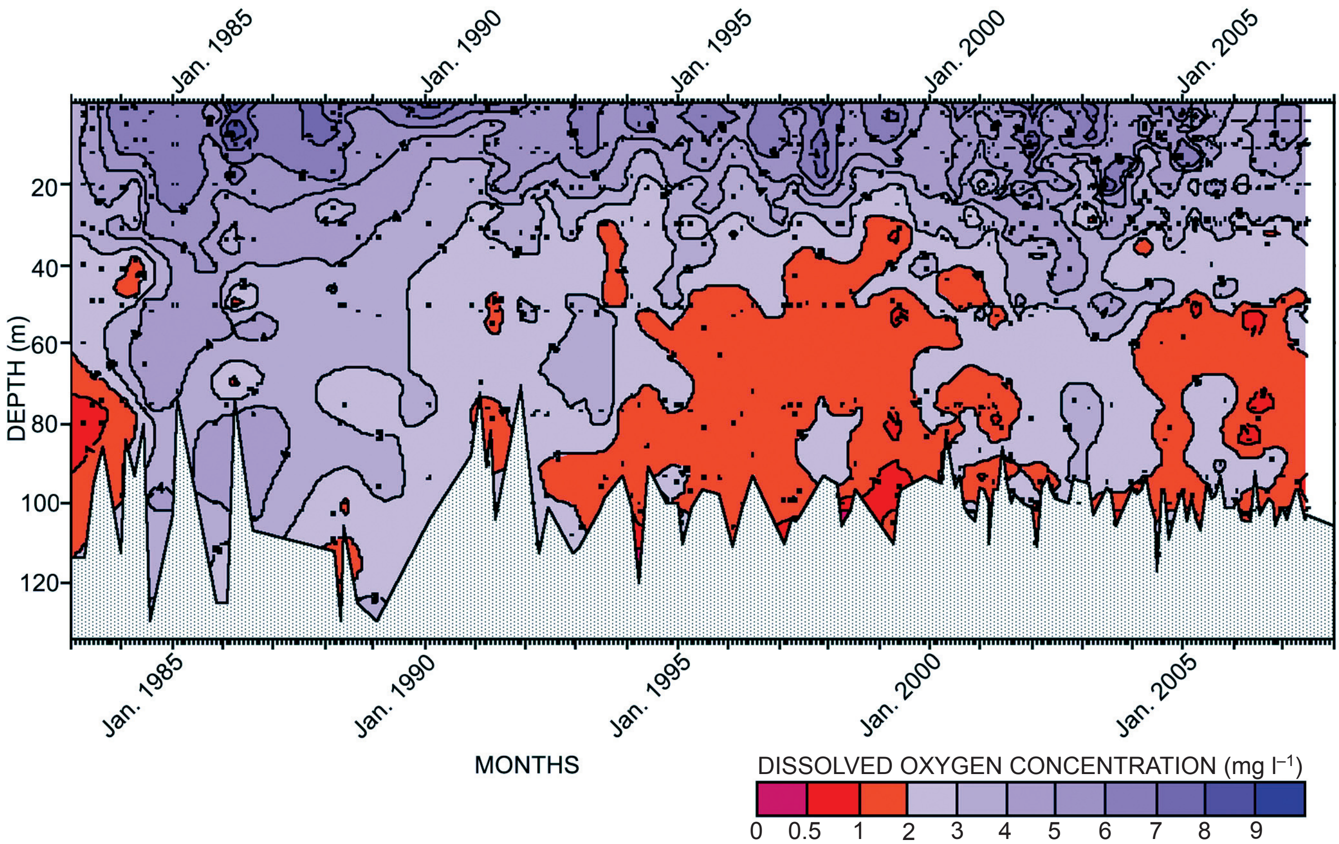

Figure 6: A time-depth section at a station GWB-2 in approximately 100 m depth off Cape Columbine from 1983 to 2007, showing the distinct increase in the volume of low-oxygen water during the period 1994–2007 (updated from van der Lingen 2006a)

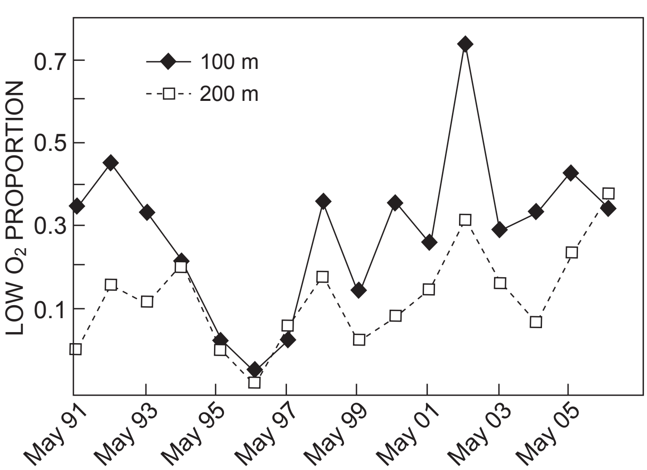

Figure 7: Incidence of low-oxygen water in the coastal area of the Orange River to Cape Columbine in May each year, expressed as the area where dissolved-oxygen values were <2 ml l^{-1} as a proportion of the total geographical areas between the coast and the 100 m and 200 m depth contours

strong decadal cycles. Upwelling-favourable winds on the West Coast were lower than normal during the period 1982–1993, but increased in intensity during 1998–2001. The low-oxygen water mass, lying in a belt inshore along the West Coast and peaking in late summer and autumn, is thought to be linked to the accumulated decay of phytoplankton blooms induced by upwelling (Monteiro and van der Plas, 2006). Data collected at a station off Cape Columbine in approximately 100 m depth between 1983 and 2007 (Figure 6) indicate an increased occurrence of low-oxygen water (<2 ml l^{-1}) during the past two decades compared with the mid-1980s. The low-oxygen water as a proportion of the area of the shelf <100 m declined from 1991 to 1996 but increased in subsequent years (Figure 7). Phytoplankton biomass estimates derived from satellite imagery or ship-board measurements during the period 1997–2007 are too variable to distinguish any trends. The environmental changes that would result in the habitat EOCH becoming more favourable to lobster occupation in the early 1990s thus remains unclear.

The period of observed changes in the lobster resource appears to coincide with an eastward shift in the distribution of sardine *Sardinops sagax* biomass and anchovy *Engraulis encrasicolus* spawner biomass (van der Lingen *et al*. 2005, Roy *et al*. 2007). There was a steady shift in sardine biomass from west to east of Cape Agulhas during the late 1990s; a situation that has persisted since then (van der Lingen *et al*. 2005). Differential growth and exploitation of the West and East coasts' substocks of sardine has been suggested as a plausible explanation for their eastward shift, but environmentally mediated changes should not be discarded as a possible cause (Coetzee *et al.* 2006). The eastward shift in anchovy spawner biomass was attributed by Roy *et al*. (2007) to improved conditions for spawning to the east of Cape Agulhas. The eastward shift in the sardine resource has had a considerable impact on the distribution and abundance of seabirds including African penguins *Spheniscus demersus*, Cape gannets *Morus capensis*, Cape cormorants *Phalacrocorax capensis* and swift terns *Sterna bergii* (Crawford *et al*. 2008b, 2008c).

Howard *et al.* (2007) used a new method known as the sequential *t*-test algorithm for analysing regime shifts (STARS) to identify regime shifts in the southern Benguela. They applied a set of biological state variables as well as environmental and anthropogenic forcing variables and identified two major long-term ecosystem changes since the 1950. The first was during the 1960s, which appeared to be caused mainly by heavy fishing pressure, but with some environmental forcing. The second shift occurred in the early 2000s, caused mainly by environmental forcing. West Coast rock lobster data (both as biological state and anthropogenic variables) were not included in the analysis, so it is uncertain if such data would have had an influence on the periods of change detected by the STARS analysis. The long-term ecosystem change identified in the early 2000s by Howard *et al.* (2007) does, however, coincide with the start of the period of relative stability identified for rock lobsters.

Despite a number of recent studies on the variability of the physical environment and its impacts on the resources in the Benguela Current Large Marine Ecosystem (BCLME) (Shillington *et al*. 2006, Monteiro and van der Plas 2006, van der Lingen *et al*. 2006a, 2006b), it has not been possible to identify environmental signals that could explain a deterioration in conditions for lobsters on the West Coast and improved conditions for lobsters EOCH during the 1990s (BCLME 2007). The lack of relevant long-term environmental data, especially bottom temperature and oxygen levels at depths <50 m around the west and southwest coasts of South Africa, limits understanding of the likely causes of the southward shift in the distribution of the West Coast rock lobsters.

Conclusion

Available evidence shows that during the 1990s there was a major shift in lobster availability from the West Coast region to more southerly grounds, as well as an influx of lobsters into the area EOCH, an area not previously associated with high lobster abundance. The period since the turn of the century has been one of relative stability. The temporal coincidence of these shifts with a coast-wide decrease in lobster somatic growth rates and a major increase in the number and severity of low oxygen-induced lobster walkouts, suggests some underlying environmental cause. Whereas these events have not occurred in isolation (the 1990s being a period of an eastward shift in pelagic resources), the linkage between the changes in the pelagic and benthic systems, if any, remains unknown. Whether these shifts are permanent or part of a cycle remains conjecture. The ecological, fisheries and resource management implications of these shifts in the distribution of the West Coast lobster resource have been severe and are likely to cause challenges in the future management of both the rock lobster and abalone resources.

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