International Council for the
Exploration of the Sea

Theme Session on Impacts of Cephalopods
In the Food Chain and their Interaction
with the Environment
C.M. 1998/M:16

MANAGEMENT OF THE SOUTH AFRICAN CHOKKA SQUID JIG FISHERY UNDER UNCERTAINTY REGARDING TRENDS IN RESOURCE ABUNDANCE

Beatriz A. Roel and Andrew I. L. Payne

Sea Fisheries Research Institute, Private Bag X2, Rogge Bay 8012, Cape Town, South Africa

ABSTRACT

The fishery for chokka squid *Loligo vulgaris reynaudii* in South Africa is managed by means of effort limitation. In practice it takes the form of a licensing system and a closed season implemented at the peak of the spawning season. With the onset of a democratic era for the country in 1994, demands to broaden access to this fishery by previously disadvantaged fishermen increased. An assessment of the current levels of effort was undertaken on the basis of four resource abundance indices. First examination showed contradictory trends, particularly between the commercial catch rate data, which suggested that the stock has been declining, and the biomass estimates from scientific surveys, which suggested a recent increase in resource abundance. Despite the uncertainty in relation to the status of the resource management decisions had to be made. Application of the precautionary principle in this context is examined.

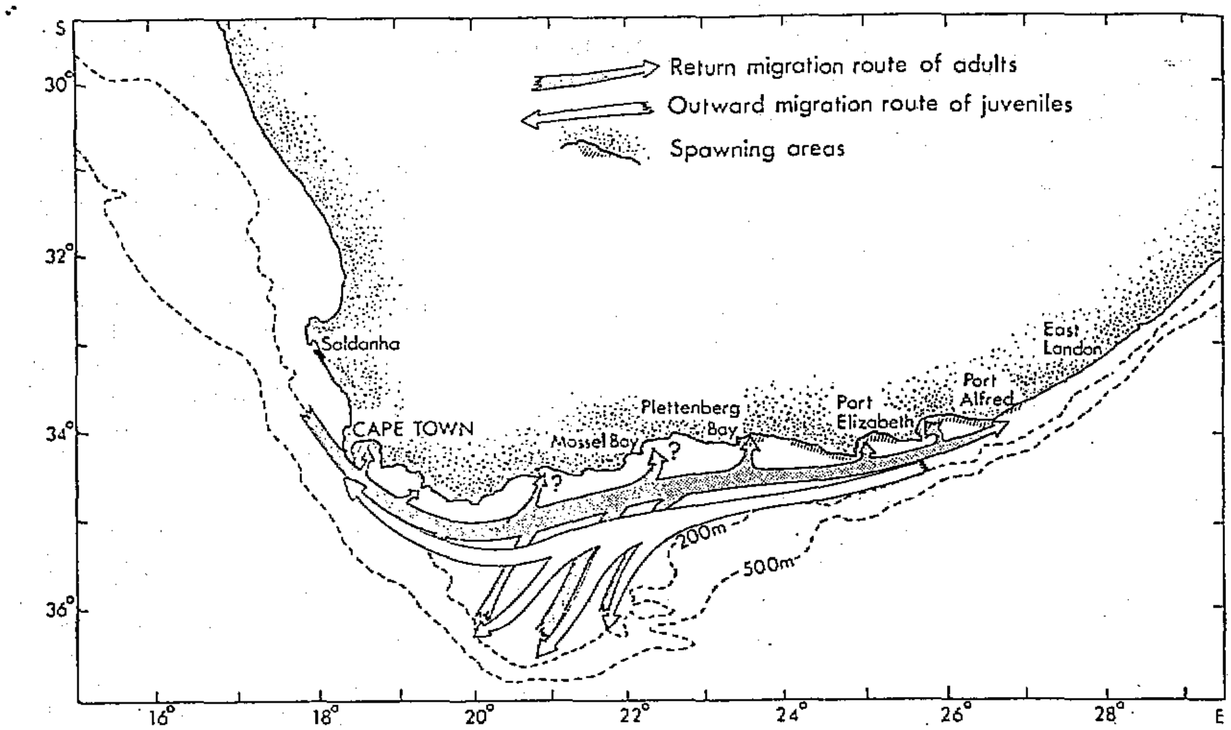

Fig. 1: Diagrammatic representation of the postulated migration cycle of chokka squid

Introduction

The South African jig fishery for chokka squid *Loligo vulgaris reynaudii* is comparatively new, having only been initiated in the early 1980s (Augustyn 1989, Augustyn *et al.* 1993), although trawl bycatches of the species have been made for many years (Augustyn and Smale 1995, Roel 1998). Like most fisheries worldwide that target short-lived species, the local squid jig fishery is highly dynamic, with a high inter-annual variability of the catches. The fishery targets on spawning aggregations, appearing inshore in areas off South Africa's south coast. Augustyn and Smale (1995) present a clear graphic account of the life history migrations of the species and, as exemplification, it is reproduced here as Figure 1.

Many theories have been advanced about the environmental and biological stimuli that affect the intensity of spawning, and the manifold works of Augustyn, Sauer, Smale, Lipiński, Roberts and others are testimony to this (Lipiński 1987, Sauer and Smale 1991, Sauer *et al.* 1991, 1992, Sauer 1993, Smale *et al.* 1995, Augustyn *et al.* 1994, Roberts 1998). Physical factors such as wave action, turbidity, temperature, currents and winds, and biological factors such as the presence of predators, have all been mentioned as contributing to the variability. Without a doubt, however, the fishery itself, especially during the earlier years when fishermen were learning how to make the most of the resource without damaging it physically (e.g. by allowing the anchor chains of the boats to drag through the egg beds - Sauer 1995) has played a key role in what now appears to be an erosion of the resource base, concomitant with what may well be simply overexploitation.

Management of the squid fishery has only been by control of effort, ever since the fishery initially increased rapidly (Augustyn and Smale 1995, Augustyn *et al.* 1993). However, it has become clear that, instead of effort (up to now measured in terms of man-days fishing by boats owned by licensed operators) having been capped at a level concomitant with that scientifically advanced as desirable, it has actually been creeping upwards for several years (Roel *et al.* 1998). That was one of the reasons why the closed season, which protects the squid for 3 - 4 weeks, deduced on the basis of a clear procedure (Augustyn *et al.* 1993), was initiated originally. As of 1998, therefore, only those two limits are in place to control the level of exploitation.

South Africa has recently adopted a new fishing policy (Anon. 1997) and development of that, especially in terms of the democratic process of debate, has been outlined in several papers (Payne and Cochrane 1994, 1995, Payne *et al.* 1996, Cockcroft and Payne 1997). The three pillars of the new policy are sustainability, stability and equity, and the Act, which will be promulgated as from 1 September 1998, is written to give credence to those three. It is a difficult marriage (Badenhorst and Payne 1998), and administrators will struggle to achieve harmony. Sustainability is a clear objective, especially to scientists, and it can probably be achieved provided that stability (of industry) is attained. However, stability has also been defined as political stability, and that definition is clearly orientated to the other pillar of the policy, namely equity, whereby those not able to gain access to resources through the inequities of the past are granted "equal" opportunity in future. This is an absolutely crucial aim of the policy, but put simply, it means that some of those who have (access) must give up some of their rights to those that do not have that access, because the fisheries are fully subscribed, with no room for extra without compromising sustainability.

In the squid jig fishery, pressures for access are just as great as elsewhere in the fishing industry, and given that the technology needed to access the resource is not as great as in, for instance, the trawl fishery, the numbers involved in pressuring for entrance to the fishery would be expected to be large. However, clearly mentioned in South Africa's new fishing policy is the Precautionary Principle and, as shown by Cockcroft and Payne (1997), some of South Africa's fisheries already take cognizance of the precautionary approach, as defined by Garcia (1994). The squid fishery is no different, and it is a challenge to fisheries managers and scientists to ensure that development of the squid jig fishery takes place within the constraints of resource sustainability.

With this aim in mind, it becomes abundantly clear that an evaluation needs to be made of the trends in abundance in the squid resource. Only armed with that evaluation can rational management measures be applied, so that the objectives of the new policy can all be met.

Analysis

Some measure of abundance or, at the least, of changes in abundance, is vital for any stock assessment. A variety of such measures have been used in squid assessments worldwide. For example, assessment of the two cephalopod stocks caught off the Falkland Islands, *Loligo gahi* (Agnew *et al.* 1998) and *Illex argentinus*, based on Delury depletion models (Beddington *et al.* 1990, Rosenberg *et al.* 1990, Basson *et al.* 1996), made use of indices of stock abundance derived from *cpue* data. Such a measure has, indeed, already been considered for the South African chokka squid fishery (Augustyn *et al.* 1993). In the northwest Atlantic, Brodziak and Rosenberg (1993) also used *cpue* as an index of abundance to assess the squid stock. Lange (1991) investigated the use of spatial dispersion indices as an alternative to mean catch-per-tow indices of abundance provided by research vessels to predict stock availability in the fishery for longfin squid *Loligo pealei*, also a short-lived, migratory and schooling squid species, and Montevecchi (1993) attempted to provide a short-term index of inshore availability of the short-finned squid *Illex illecebrosus* based on the proportion of squid eaten by gannets.

Catch per unit effort (*cpue*) is generally used as an index of stock abundance because it is difficult or costly to obtain direct measures of stock abundance by means of research surveys. Obtaining reliable estimates of *cpue* from the commercial fishery is usually therefore one of the first steps taken in a fishery study as a prerequisite to resource assessment. There are cases, however, where *cpue* does not provide a reliable estimate of abundance. An example is the jig fishery for chokka, which concentrates effort where the animals aggregate. Even were the stock to be depleted, the number of aggregations would decrease, while local abundance would remain high. As a result, the *cpue* could stay high while the biomass drops. Such a type of non-linear relationship between *cpue* and biomass was termed hyperstability by Hilborn and Walters (1992). Nevertheless, unless a better estimate of resource abundance is available, *cpue* can still be used provided the errors that may be introduced by the manner in which *cpue* may misrepresent abundance are taken into account in an appropriate manner (Gulland 1983).

Table I: Features of the time-series used in the analysis

Jig *cpue*	Trawl *cpue*	Autumn/Spring surveys
	Positive features	
Large data set, can be related to spawner abundance. Data resolution daily.	Longest time-series. Obtained from bycatch fishery, and therefore sampling should be more random in relation to distribution than in a directed fishery. Corresponds to most of the animals' distribution.	Random stratified surveys. After 1986 there was at least one survey every year in either spring or autumn. The methodology used was kept consistent throughout the years.
	Negative features	
Effort under reported. No information on sounding or distance from the coast. No information on vessel attributes before 1995.	Possible changes in fishing patterns and efficiency over time.	Incomplete coverage of resource distribution area. Possible increase in efficiency over time as a result of "learning from experience".

The South African chokka squid resource has the use of four indices of abundance that may be used to assess its status. The time-series are jig *cpue*, trawl *cpue* and the two research surveys, in spring and summer. Their relative merits vary, and Table I lists the positive and negative features of each time-series.

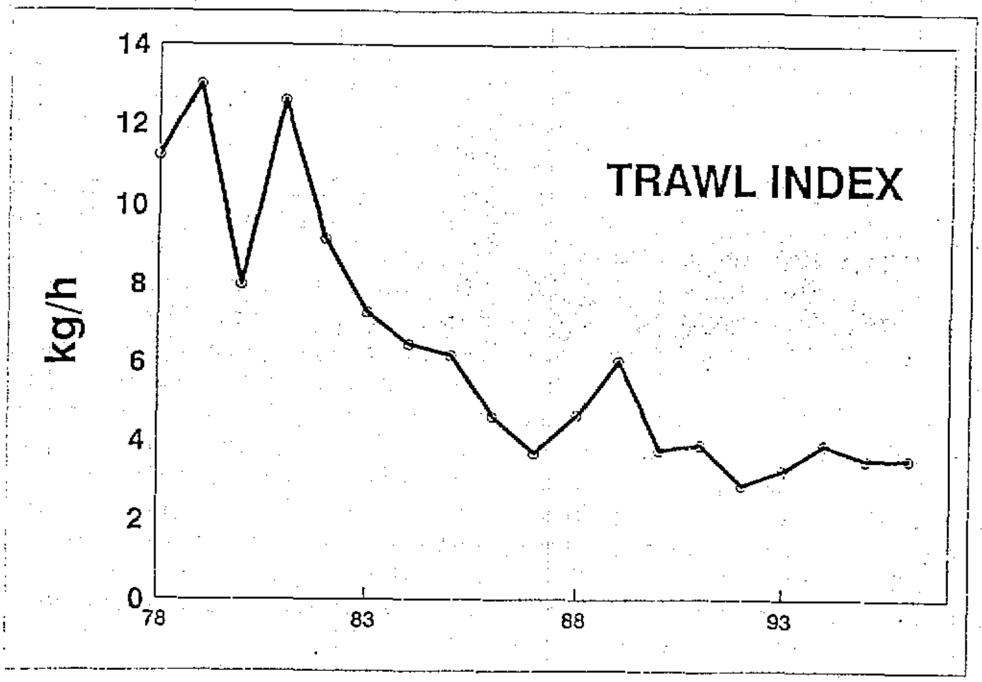

Fig. 2: Time-series of an index of abundance of chokka squid derived from the South African trawl catch and effort data, 1978-1996

Some of the negatives, such as changes in fishing patterns, i.e. the spatial distribution of the fleet, can be overcome by means of a General Linear Modelling (GLM) analysis so long as data on, for instance, catch position, are available. Other potential problems, such as possible increases in efficiency in the scientific surveys through learning, cannot be quantified and, although they may not invalidate the use of these data, they must be taken into account at the time that results based on them are being interpreted.

Trawl bycatch fishery

GLM techniques were applied to *cpue* data from the hake fleet working in the squid distribution area between 1978 and 1996. The intention was to obtain an index of relative abundance independent of changes in fishing patterns and composition of the fishing fleet. The resultant trend is shown in Figure 2.

Although highly variable, as would be expected given the dynamic nature of the resource, a decrease in trawl catch rate started in the early 1980s and, apart from a slight upturn in 1989, levelled out at a catch rate about one-third of what it was before the decrease. The year 1989 was the year of record chokka squid landings in South African waters (Augustyn and Smale 1995), so the brief recovery is not surprising. Trawl catches during the same period declined from a mean of just over 2 000 tons annually to a figure less than a quarter of that. To the trawl fishery, particularly one so dependent on mixed catches as inshore one on the South Coast (Payne and Badenhorst 1995), a decrease of 75% in annual catches of such a valuable bycatch species has a huge impact on the economics of the fishery.

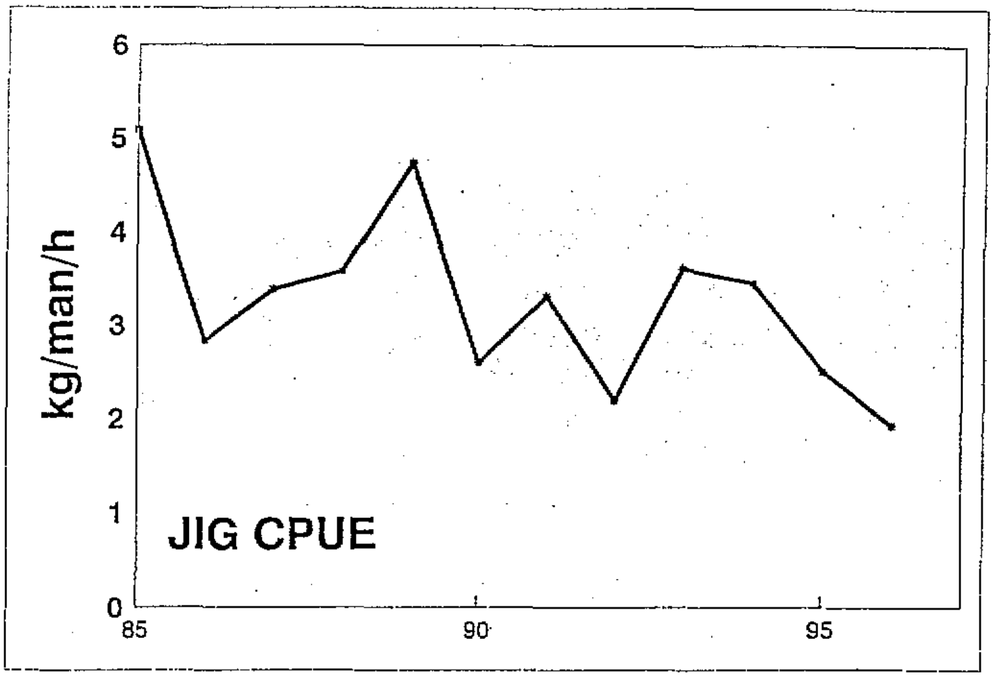

Fig. 3: Time-series of catch-rates (man-hours) in the jig fishery for chokka squid, 1985-1996

Jig fishery

An index of abundance based on monthly *cpue* data from the jig fishery can also be used to assess the chokka squid resource. The index is expressed as kg per man per hour, i.e. the average catch per hour taken by a jig fisher. Although it could be argued that factors such as vessel attribute and area of operation could be influencing the *cpue* and should be taken into account, such information is not readily available. Some of the information was obtained from questionnaires sent to the fishers, as well as from data on catches available from officially submitted statistics.

Although there is a lot of noise in the resultant analysis, the general trend of the series is downwards (Fig. 3). Again the peak in catches was in 1989, associated with an apparent recovery in catch rate, and the minor peaks in catch rate in 1991 and 1993/94 are also associated with relatively high catches. The concern with the jig *cpue* series is not so much the downward trend, but the fact that, unlike the trawl series, the trend by 1996 was still downwards. Subsequent catches give little cause for optimism either, although a rigorous analysis of catch rate such as that reported here has not been made of the 1997 or early 1998 data. The jig catch is 1989 was almost 10 000 tons, the highest recorded in the short history of the fishery (Augustyn and Smale 1995).

Research-survey determined abundance

The fishing grounds are surveyed by means of a semi-random stratified bottom trawl survey (swept area method) with the purpose of estimating hake biomass (Badenhorst and Smale 1991). Estimates of stock size of species such as

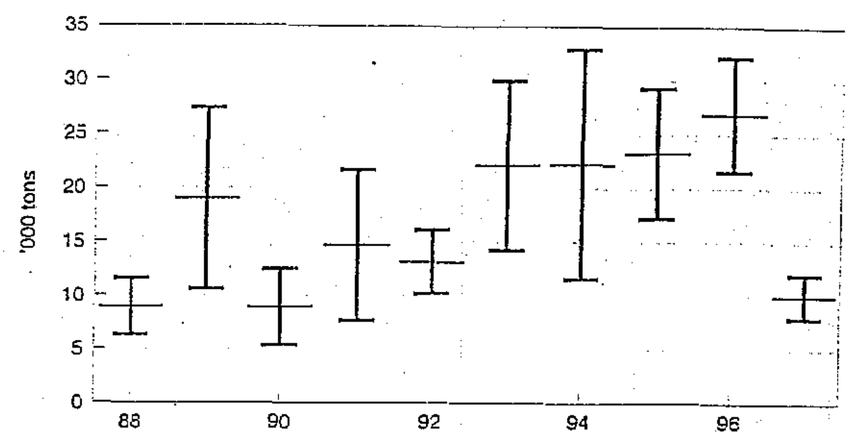

Fig. : Time-series from the South Coast autumn demersal surveys (error bars correspond to 2 std. errors)

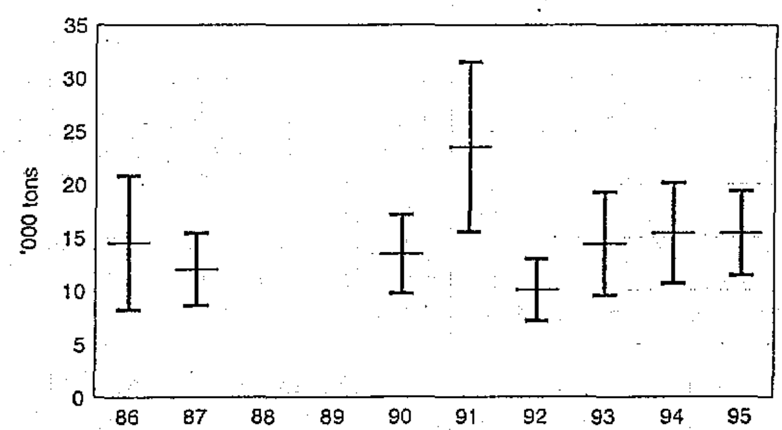

Fig. : Biomass estimates from the South Coast spring surveys (error bars correspond to 2 std errors).

Fig. 4: Time-series of biomass estimates from the South African south coast demersal research surveys in (a) authumn and (b) spring, 1986-1997 (error bars correspond to 2 standard errors)

Loligo, which are caught in the trawl, are also produced. The survey programme started in September 1985 (Payne *et al.* 1989) and, from 1988, the surveys took place twice a year, in autumn and spring. The results in terms of chokka are shown in Figure 4.

Neither research-survey time-series show a decrease in biomass from the time the surveys started, although the last data point in the autumn time-series (May 1997) is clearly well below its predecessors. Unfortunately, no swept area demersal research surveys of the South Coast have been made since May 1997, so it is not possible to say whether the May 1997 value is an outlier or not. The general trend in autumn survey results is, however, upwards, so giving a different indicator of stock status from the trawl and jig fisheries. The spring surveys, which tend to just precede the main jig-fishing season for chokka, do not show an increase over time, but rather stability except for the single high value obtained in spring 1991. Again, however, the trend is different from that obtained in the two fisheries.

Discussion

Chokka squid has been, in some years, a very significant contributor to the overall earnings of the South African fishing industry. No wonder then that there have been two powerful lobbies active during the fishery's brief history. The first lobby, the economic one, pushes for as much catch as possible annually, especially as a large proportion of the South African catch is exported at an extremely competitive price, so maximizing value to the fisher and the fish marketer. The second lobby is for sustainability, to keep the resource in a healthy state so that it can continue to contribute to the overall wellbeing of the South African fishing industry for many years to come. It is the latter lobby in particular that has been the driving force behind the large amount of effort put into chokka squid research in South Africa over the past 15 years. Indeed, a not insignificant part of the funding for that research has been derived from the very industry that also lists among its members active protagonists of the first lobby! At face value, at least, it seems to be the second lobby which has won for now, as the new marine fisheries policy (Anon. 1997) has had the objective of sustainability enshrined powerfully within its pages.

To determine sustainable levels, it is crucial that all data are accorded weight in rigorous modelling exercises. Therefore, when it became evident that jig catch rates were continuing to decline and anecdotal evidence indicated possible creeping increases in effort, allied to a significant reduction in trawl catch rates, rigorous modelling exercises such as those of Augustyn *et al.*(1993) and particularly those of the first author (Roel 1998) were commenced. One of the first findings was that the four series of data on which squid resource status can be modelled showed different trends. A first attempt to reconcile the four time-series was done by means of a biomass-based modelling approach with Bayesian estimation (Roel and Cochrane 1996). Those authors reached the somewhat obvious conclusion that there was a need to clarify the reasons for the contradictory trends in the series, and that two related management aims needed to be met:

- a cautious management regime needed to be implemented;
- there should be no increase in effort beyond that then in the fishery at least until the reasons for the contradiction had been found.

The work of the first author (Roel 1998) has been addressing the second of these aims, and every attempt has been made by the authorities, at the insistence of the scientists, to preclude any increase in effort. The first aim is, of course, addressed by this last approach, and it has been aided by one of the primary objectives of the marine fisheries policy.

It is the opinion of the current authors that, in terms of Table I, the seriousness of the "negative" features shown for the four time-series (three, if the two research survey time-series are treated as one, which for simplicity they are from now on) dictates that the trends of the two fishery-based series be taken as most closely displaying the true trend in the resource. In terms of jig *cpue*, the downward trend would be even more marked were effort actually under-reported, the likely scenario given that more men (disguised as "packers") are actually being carried in recent years (such a problem may well be overcome if the unit of effort is changed from man-hours to boat-days). For the trawl series, there is no doubt that fishing patterns and capture efficiency did change over time, but in general the changes were probably modest only, and if they were indeed more pronounced, then the decline would again have been more obvious than it actually was. For both those two indices, it must be remembered that they cover different parts of the squid distributional area, and that together they cover most of it. The research surveys, which cover the whole area of squid distribution but in an extremely patchy fashion (Badenhorst and Smale 1991), and the inshore squid jigging area least of all, without a doubt showed some increase in efficiency over time, if only because knowledge gained on each survey contributed to better utilization of survey time and more efficient surveying during later surveys. Even the trawling officers probably learned significantly from experience gained using the non-standard gear employed on the surveys. Therefore, the trend shown in Figure 4 is probably an overoptimistic appraisal of stock status, though there is no factual evidence to indicate that the trend should actually be downwards. More rigorous modelling, such as that carried out by Roel (1998) does indeed cast some light on the possibility that the survey data may be rather optimistic.

The likely trend in terms of resource status is therefore downwards from the mid 1980s at least, and even if the general tendency in new fisheries to "mine out" a resource was followed for chokka squid (as seems likely from the trawl index in Fig. 2), the continuing decline shown by the jig *cpue* itself is cause for concern. Indeed, the findings re-emphasize the wisdom of the recommendations by Roel and Cochrane (1996) for cautious management and no increase in current levels of fishing effort.

Given this situation and the need to "marry" the three pillars of new marine fisheries policy in South Africa (sustainability, stability and equity, Anon. 1997), how then does South African compliance with the management tools proposed to support the objectives of the Precautionary Principle measure up? Using Garcia's (1994) tools:

- in terms of *sustainable development*, the chokka fishery is well past the need for development - it is already mature;
- *precautionary management* is being undertaken, at least for the present, and there is a clear understanding in the industry that room can only be made for newcomers by conceding some of the rights already active;
- the *"best scientific evidence available"* is not only being used, but is actively being improved;
- scientists at least are looking to having a *broad range of management benchmarks and reference points adopted* by decision-makers - at present the challenge is to actually find those values for, e.g., survey-based

biomass, environmental conditions on the spawning grounds, catches early in the season;

- the same applies to the development of *a set of criteria for use when assessing the impact of development;*
- over several years of management, scientists have been advocating a *risk-averse stand* - and it is encouraging that many entrepreneurs in the industry and fisheries decision-makers support such a stand;
- without knowing with some degree of confidence what are and what are not *acceptable levels of impacts or risk* for the squid resource, it is impossible to comply with the implementation of such an objective - however, the aim certainly falls within the range of scientifically determined management tools planned once knowledge of the resource is bettered;
- the marine fisheries policy stresses the need for a *holistic view of the resources within their environment* and the basic systems research currently being undertaken (e.g. by Roberts 1998) advances the likelihood that it will be a part of the overall process of chokka squid management;
- *speeding up management response time* is an aim of all South African fisheries administration - it is just the extent of the implementation of new policies that is slowing the system down currently;
- *"non-fishery users" are well entrenched in fisheries management bodies* on a global scale in South Africa - that situation is likely to be improved further when the bodies associated with the new Policy are convened.
- *improving decision-making procedures* is an aim of the new marine fisheries policy and will, for the sake of good reason, be aimed for by all;
- the chokka squid industry has long been interested in improving *prior consulting procedures* - even greater efforts have been made to consult more widely by all involved in the chokka industry and its management recently;
- South Africa is introducing *stronger MCS (Monitoring, Control and Surveillance) and deterrent-level penalties* in terms of its new Act.

Overall, therefore, cautious management of the chokka squid fishery seems to be either already in place or most certainly achievable in the short term. All that is needed for the current situation to change for the worse, however, is for rational scientific advice aimed at ensuring sustainable exploitation of the resource to be overlooked for reasons other than those most obvious, e.g. for political or social reasons. A review of the recent history of fisheries management in South Africa does give one some confidence that the future should be bright. However, all are supremely aware that the challenges facing the country in its move towards democracy and equality of opportunity for all can bring to nothing the best meant management advice if political expediency should triumph.

The current authors believe that this will not happen.

References

AGNEW, D. J., BARANOWSKI, R., BEDDINGTON, J. R., DES CLERS, S. and C. P. NOLAN 1998 - Approaches to assessing stocks of *Loligo gahi* around the Falkland Islands.

Fish. Res. **35**: 155-169.

ANON. 1997 - *White Paper. A Marine Fisheries Policy for South Africa.* [Cape Town; Department of Environmental Affairs & Tourism]: 46 pp.

AUGUSTYN, C. J. 1989 - Systematics, life cycle and resource potential of the chokker squid *Loligo vulgaris reynaudii*. Ph.D. thesis, University of Port Elizabeth: xi + 378 pp.

AUGUSTYN, C. J., LIPIŃSKI, M. R., SAUER, W. H. H., ROBERTS, M. J. and B. A. MITCHELL-INNES 1994 - Chokka squid on the Agulhas Bank: life history and ecology. *S. Afr. J. Sci.* **90**(3): 143-154.

AUGUSTYN, C. J., ROEL, B. A. and K. L. COCHRANE 1993 - Stock assessment in the chokka squid *Loligo vulgaris reynaudii* fishery off the coast of South Africa. In *Recent Advances in Cephalopod Fisheries Biology*. Okutani, T., O'Dor, R. K. and T. Kubodera (Eds). Tokyo; Tokai University Press: 3-14.

AUGUSTYN, C. J. and M. J. SMALE 1995 - Cephalopods. In *Oceans of Life off Southern Africa*, 2nd ed. Payne, A. I. L. and R. J. M. Crawford (Eds). Cape Town; Vlaeberg: 91-104.

BADENHORST, A. and A. I. L. PAYNE 1998 - A South African marriage of politically derived expectations and scientifically determined sustainable utilization - will it succeed? *Abstracts of the Meeting - Challenges for the New Millenium: Shaping the Future of Fisheries Science and the Fisheries Profession. The 128th Annual Meeting of the American Fisheries Society, Hartford, Connecticut, August 1998*

BADENHORST, A. and M. J. SMALE 1991 - The distribution and abundance of seven commercial trawlfish from the Cape south coast of South Africa, 1986-1990. *S. Afr. J. mar. Sci.* **11**: 377-393.

BASSON, M., BEDDINGTON, J. R., CROMBIE, J. A., HOLDEN, S. J., PURCHASE, L. V. and G. A. TINGLEY 1996 - Assessment and management techniques for migratory annual squid stocks: the *Illex argentinus* fishery in the Southwest Atlantic as an example. *Fish. Res.* **28**: 3-27.

BEDDINGTON, J. R., ROSENBERG, A. A., CROMBIE, J. A. and G. P. KIRKWOOD 1990 - Stock assessment and the provision of management advice for the short fin squid fishery in Falkland Islands waters. *Fish. Res.* **8**: 351-365.

BRODZIAK, J. K. T. and A. A. ROSENBERG 1993 - A method to assess squid fisheries in the north-west Atlantic. *ICES J. mar. Sci.* **50**: 187-194.

COCKCROFT, A. C. and A. I. L. PAYNE 1997 - Cautious fisheries management in South Africa: the fisheries for rock lobster. *ICES Doc.* **C.M. 1997/V:3**: 14 pp. (mimeo).

GARCIA, S. M. 1994 - The precautionary principle: its implications in capture fisheries management. *Ocean coast. Mgmt* **22**: 99-125.

GULLAND, J. A. 1983 - *Fish Stock Assessment: a Manual of Basic Methods.* New York; Wiley: 223 pp.

HILBORN, R. and C. J. WALTERS 1992 - *Quantitative Fisheries Stock Assessment. Choice, Dynamics & Uncertainty.* New York; Chapman & Hall: xv + 570 pp.

LANGE, A. M. 1991 - Alternative survey indices for predicting availability of longfin squid to seasonal Northwest Atlantic fisheries. *N. Am. J. Fish. Mgmt* 11: 443-450.

LIPIŃSKI, M. R. 1987 - Food and feeding of *Loligo vulgaris reynaudii* from St Francis Bay, South Africa. In *The Benguela and Comparable Ecosystems*. Payne, A. I. L., Gulland, J. A. and K. H. Brink (Eds). *S. Afr. J. mar. Sci.* **5**: 557-564.

MONTEVECCHI, W. A. 1993 - Seabird indication of squid stock conditions. *J. Cephalopod Biol.* **2**(2): 57-63.

PAYNE, A. I. L. and A. BADENHORST 1995 - Other groundfish resources. In Cephalopods. In *Oceans of Life off Southern Africa*, 2nd ed. Payne, A. I. L. and R. J. M. Crawford (Eds). Cape Town; Vlaeberg: 148-156.

PAYNE, A. I. L., BADENHORST, A., AUGUSTYN, C. J. and R. W. LESLIE 1989 - Biomass indices for Cape hake and other demersal species in south African waters in 1988 and earlier. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 16(2): 25-62.

PAYNE, A. I. L., BADENHORST, A. and D. W. JAPP 1996 - Managing fisheries following political transition in South Africa, faced with multiple objectives and aspirations. *ICES Doc.* **C.M. 1996/P:5**: 16 pp. (mimeo).

PAYNE, A. I. L. and K. L. COCHRANE 1994 - Managing fisheries in a changing society with a well developed science base. *ICES Doc.* **C.M. 1994/T:26**: 15 pp. (mimeo).

PAYNE, A. I. L. and K. L. COCHRANE 1995 - How management and science are trying to develop fisheries policy in South Africa. *ICES Doc.* **C.M. 1995/S:8**: 13 pp. (mimeo).

ROBERTS, M. J. 1998 - The influence of the environment on chokka squid *Loligo vulgaris reynaudii* spawning aggregations: steps towards a quantified model. In *Cephalopod Biodiversity, Ecology and Evolution*. Payne, A. I. L., Lipiński, M. R., Clarke, M. R. and M. A. C. Roeleveld (Eds). *S. Afr. J. mar. Sci.* **20**: in press.

ROEL, B. A. 1998 - Stock assessment of the chokka squid. *Loligo vulgaris reynaudii*. Ph.D. thesis, University of Cape Town.

ROEL, B. A. and K. L. COCHRANE 1996 - a biomass based assessment of the South Africa n chokka squid. In *Abstracts of the Benguela Dynamics Symposium - Impacts of Variability on Shelf-Sea Environments and their Living Resources, Cape Town, November 1996*: p. 63

ROEL, B. A., COCHRANE, K. L. and D. S. BUTTERWORTH 1998 - Investigation on the effects of different levels of effort and of the closed season in the jig fishery for chokka squid *Loligo vulgaris reynaudii* . In *Impacts of Variability on Shelf-Sea Environments and their Living Resources*. Pillar, S. C., Moloney, C. L., Payne, A. I. L. And F. A. Shillington (Eds). *S. Afr. J. mar. Sci.* 19: in press.

ROSENBERG, A. A., KIRKWOOD, G. P., CROMBIE, J. A. and J. R. BEDDINGTON 1990 - The assessment of stocks of annual squid species. *Fish. Res.* **8**: 335-350.

SAUER, W. H. H. 1993 - The ecology of spawning squid, *Loligo vulgaris reynaudii*, in the inshore areas of the Eastern Cape, South Africa. Ph.D. thesis, University of Port Elizabeth: 122 pp.

SAUER, W. H. H. 1995 - The impact of fishing on chokka squid *Loligo vulgaris reynaudii* concentrations on inshore fishing grounds in the SouthEastern Cape, South Africa. *S. Afr. J. mar. Sci.* **16**: 185-193.

SAUER, W. H. H., GOSCHEN, W. S. and A. S. KOORTS 1991 - A preliminary investigation of the effect of sea temperature fluctuations and wind direction on catches of chokka squid *Loligo vulgaris reynaudii* off the Eastern Cape, South Africa. *S. Afr. J. mar. Sci.* **11**: 467-473.

SAUER, W. H. H. and M. J. SMALE 1991 - Predation patterns on the inshore spawning grounds of the squid *Loligo vulgaris reynaudii* (Cephalopoda: Loliginidae) off the south-eastern Cape, South Africa. *S. Afr. J. mar. Sci.* **11**: 513-523.

SAUER, W. H. H., SMALE, M. J. and M. R. LIPIŃSKI 1992 - The location of spawning grounds, spawning and schooling behaviour of the squid *Loligo vulgaris reynaudii* (Cephalopoda: Myopsida) off the Eastern Cape coast, South Africa. *Mar. Biol.* **114**(1): 97-107.

SMALE, M. J., SAUER, W. H. H. and R. T. HANLON 1995 - Attempted ambush predation on spawning squids *Loligo vulgaris reynaudii* by benthic pyjama sharks, *Poroderma africanum* off South Africa. *J. mar. biol. Ass. U.K.* **75**(3): 739-742.