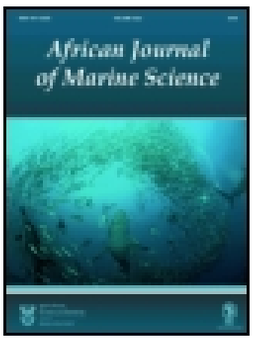

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HANDLINE CATCHES AND STOCK IDENTITY OF SNOEK *THYRSITES ATUN* OFF SOUTH AFRICA AND NAMIBIA

R. J. M. CRAWFORD, L. G. UNDERHILL† and J. D. VENTER**

Handline catches of snoek *Thyrsites atun* off southern Africa tend to be of sexually mature fish, and to be either good off South Africa or off Namibia but not in both localities simultaneously. When catches are low off Namibia they are made mostly in the south, suggesting a southward displacement of the stock, and vice versa. Handline catches made off South Africa, mainly in winter, are significantly negatively correlated with those made off Namibia the preceding summer, in agreement with this hypothesis. That the converse does not apply is attributed to recruitment of maturing fish to the spawning shoals as the latter leave South African waters. Although some immature snoek are probably resident in South African waters throughout the year, snoek in the South-East Atlantic are thought to belong to a single stock.

Die tendensie by handlynvangste van snoek *Thyrsites atun* teenoor suidelike Afrika is dat hul uit geslagsryp vis bestaan en goed òf teenoor Suid-Afrika òf Namibië is maar nie teenoor albei gelyktydig nie. Wanneer die vangs teenoor Namibië laag is, word dit meestal in die suide gedoen, wat dui op 'n suidwaartse verplasing van die stapel; die omgekeerde geld ook. Die handlynvangs teenoor Suid-Afrika, hoofsaaklik in die winter gedoen, is op beduidende wyse negatief gekorreleerd met dié teenoor Namibië in die voorafgaande somer, wat klop met hierdie hipotese. Dat die omgekeerde nie geld nie word toegeskryf aan die rekrutering van rypende vis na die kuitskietskole soos lg. die Suid-Afrikaanse waters verlaat. Ofskoon van die onvolwasse snoek stellig die hele jaar in Suid-Afrikaanse waters hou, word die snoek in die Suidoos-Atlantiese Oseaan as 'n enkele stapel beskou.

In contrast to what is believed to be the case for most of the abundant fish species of the Benguela system (Crawford *et al.* 1988), a number of authors (Van Wyk 1944, Davies 1954, De Jager 1955, Nepgen 1979, Crawford and De Villiers 1985) have argued that snoek *Thyrsites atun* in the South-East Atlantic belong to a single stock which undertakes extensive migrations. This understanding has been based on all 19 recoveries of snoek tagged off Namibia showing southward movement (14 movement into South African waters — De Jager op. cit.) and on more substantive observations that snoek have for many years been available to linefishermen operating in different areas during different seasons. In particular, the historical tendency has been for snoek to be caught by handline off Namibia from November to March (Venter 1988), off Port Nolloth (29°15′S, 16°52′E) in April and May, off St Helena Bay (*c.* 32°40′S, 18°05′E) from May to July, and east of Cape Point (34°21′S, 18°30′E) from June to October (Crawford and De Villiers op. cit.). Trawl catches along different sectors of the coast have shown similar seasonality (Crawford and De Villiers op. cit.).

In recent years, this traditional pattern has changed somewhat, and summer months have provided large handline catches off South Africa's Cape Province, mostly made by skiboats operating out of Yzerfontein (33°20′S, 18°09′E), a harbour for which few records of catches exist prior to the mid 1970s (Dudley 1987). As good winter catches of snoek have continued to be made off South Africa, it seems likely that some snoek are resident in South African waters throughout the year. It is therefore possible to argue that, in accord with most other commercially exploited teleosts, separate stocks of snoek may exist in waters off South Africa and off Namibia.

The identity of a stock is of considerable importance in its management, and this paper attempts to provide more light on the subject by examining the statistical relationship between trends in the handline catches of snoek off Namibia and off South Africa. Information on the geographic distribution and the size structure of the handline catch off Namibia is also presented to facilitate consideration of possible size-related patterns of migration.

DATA AND METHODS

Handline catches of snoek off Namibia were available for each month between November 1964 and February 1988 (Venter 1988). They were grouped into years extending from September to August inclusive

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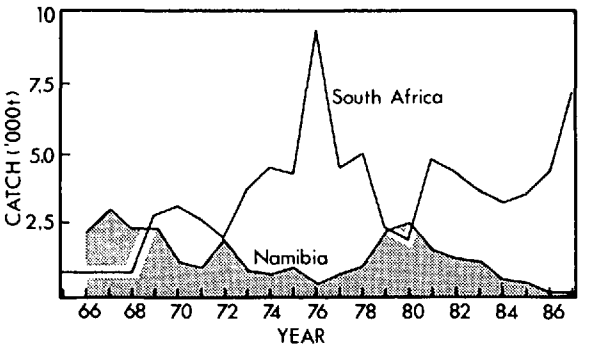

Fig. 1: Catches of snoek made by line off South Africa mostly in winter contrasted with those made off Namibia mostly in the preceding summer

because catches were only recorded between October and July, with most fishing being undertaken between November and March (Venter op. cit.). Handline catches off South Africa were available for the period 1969–1987 (Crawford *et al.* 1987) and were grouped by calendar year because of the historical tendency for snoek catches to be centred around mid year (Crawford and De Villiers 1985). For the years 1965–1968, handline catches off South Africa were estimated from an index of relative abundance suggested by a survey of fishermen (Crawford and Kriel 1985). However, although useful for a visual comparison of trends in line catches from the northern and southern Benguela (Fig. 1, Crawford and Macdonald 1988), these early approximations were not used in statistical analysis of the data.

The relationship between line catches off Namibia and South Africa was investigated by means of time-series analysis. Each data series was modelled by standard univariate Box–Jenkins techniques to remove systematic time-series effects (Box and Jenkins 1976). The subtraction of the fitted time-series model from the original time-series generates a series of "prewhitened" residuals, which has no autocorrelation structure as measured by the Q-statistic:

$$Q = n \sum_{r=1}^{n} r_k^2,$$

where $r_1, r_2, \ldots, r_n$ are the autocorrelations at lags 1, 2, . . ., n. Large values of Q indicate substantial autocorrelation at one or more of the first n lags. The Q-statistic has approximately a χ^2 distribution with n degrees of freedom. For the present study, n was taken as 10 lags.

The prewhitened residuals represent that part of the original time-series which cannot be predicted from previous observations, and may loosely be interpreted as the "anomalies" in the time-series. If the prewhitened residuals from two time-series have anomalies which at some lag tend to coincide, there is evidence of a relationship between the series, either a causal relationship or an underlying cause affecting both series. Cross-correlation of the prewhitened residuals from the two series measures the strength of this relationship.

Table I: Correlation coefficients between prewhitened residuals of time-series of handline catches of snoek made off Namibia and off South Africa

i	South African v. Namibian of ith previous season	Namibian v. South African of ith previous season
1	−0,51*	−0,09
2	−0,02	0,15
3	0,04	0,33
4	−0,25	0,33
5	0,34	−0,01

* Significant at 5-per-cent level

Catch returns submitted by fishermen for the period 1978/79 to 1986/87 permitted allocation of the line catch of snoek off Namibia to Divisions of the International Commission for the Southeast Atlantic Fisheries (ICSEAF) — see Fig. 3 — and also a breakdown of the numbers of snoek caught into three size categories — large (>90 cm total length), medium (80–90 cm) and small (<80 cm). These sizes represent fish aged about four years or older, three to four, and less than three respectively (Venidiktova 1988).

RESULTS

Both Namibian and South African line catches showed some degree of autocorrelation. An AR(1) (autoregressive of order one) model was fitted to each series. Computation of the Q-statistics (Box and Pierce 1970) over 10 lags showed there was no significant autocorrelation in the calculated residuals from the above model (Namibia, $Q = 3{,}87$, $p > 0{,}5$; South Africa, $Q = 3{,}64$, $p > 0{,}5$). Cross-correlation of the prewhitened residuals (Table I) showed that the Namibian time-series was significantly negatively correlated with the South African time-series of the immediately succeeding season (Fig. 2; $r = -0{,}51$; $p < 0{,}05$), although the converse did not apply. There were no other significant correlations with lags either way of up to five years.

The Namibian line boats operate from Walvis Bay (22°53′S, 14°32′E) at the centre of ICSEAF Division

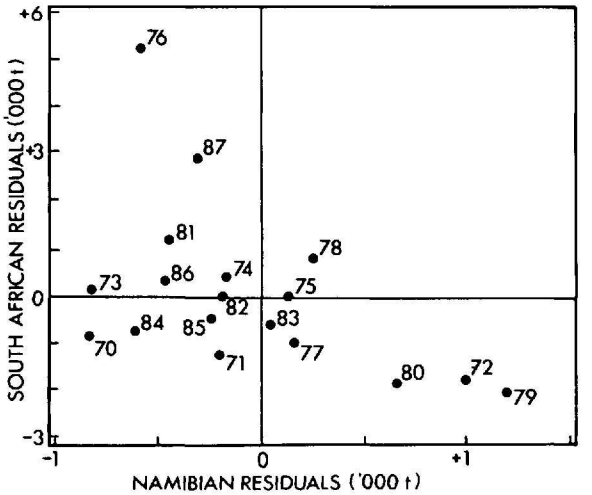

Fig. 2: The relationship between prewhitened residuals obtained for catches made by line off South Africa mainly in winter and off Namibia mainly the previous summer. Years of the South African winter are indicated

1.4, and in all seasons between 1978/79 and 1984/85 this Division contributed more than half the snoek catch (Fig. 3). Division 1.3 off northern Namibia contributed more than 20 per cent of the catch in some years, but no catches were made in Division 1.5 off southern Namibia until the 1981/82 season. The proportional contribution of that Division then increased, and it provided the entire Namibian line catch of snoek in 1986/87. However, the Namibian line catch of snoek decreased substantially after the 1982/83 season and the actual catch in 1986/87 was small (Fig.1).

The largest size category of snoek dominated the line catches of this species off Namibia in all seasons for which information was available, except for 1985/86 when medium-sized fish were most important (Fig. 4). In other seasons medium-sized fish contributed about 10% of the catch. Small snoek were absent from or contributed very little to the catch in most seasons, with 1980/81 a notable exception.

DISCUSSION

Handline catches of snoek tend either to be high off Namibia or off South Africa, but not off both countries in the same year (see Fig. 1). This observation is borne out by the negative correlation between residuals of catches made off Namibia (mainly from November to March) and off South Africa slightly later (mainly from April to October). A possible explanation for this

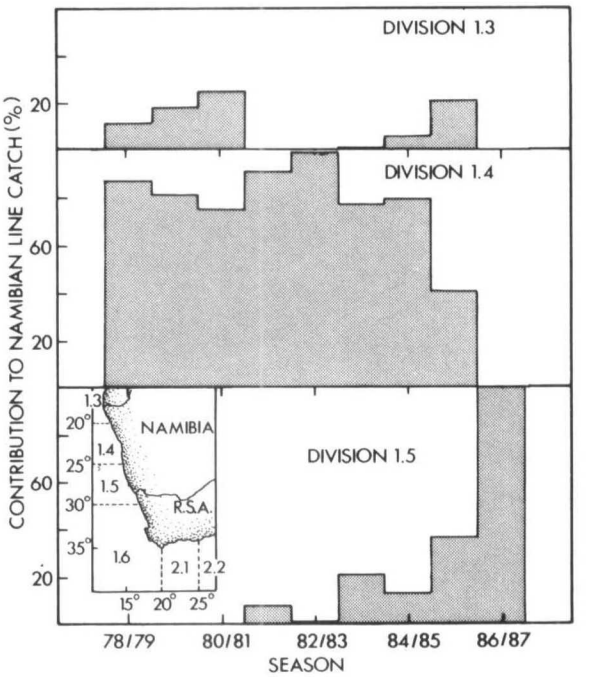

Fig. 3: The proportional contribution of different ICSEAF Divisions to line catches of snoek made off Namibia, 1978/79-1986/87 (ICSEAF Divisions shown in inset)

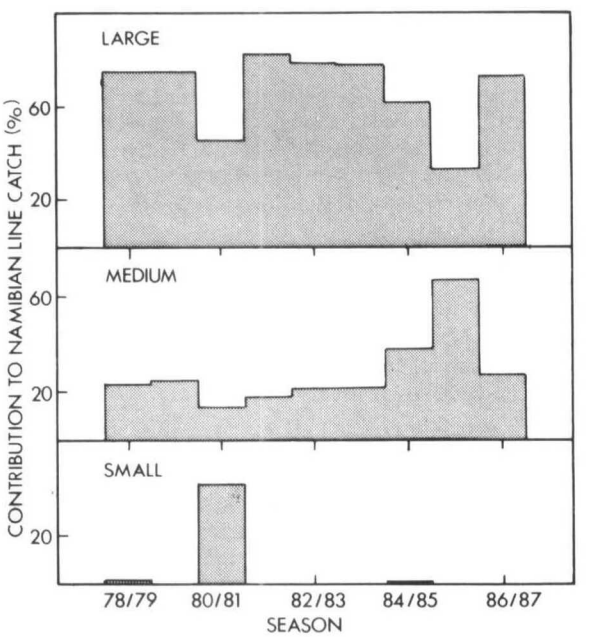

Fig. 4: The proportional contribution of snoek of different sizes to line catches made off Namibia, 1978/79-1986/87

phenomenon is that high Namibian line catches deplete the stock, and few fish remain to be caught off South Africa. However, such an explanation is considered unlikely because line catches contribute only a small fraction of the total snoek harvest in the Benguela system. Catches made with trawl nets are much higher (Crawford *et al.* 1987).

A more plausible explanation is that snoek belong to a single stock, which in some years is displaced to the north and in others to the south, leading to changes in the availability of snoek to linefishermen in the two areas. If snoek were displaced to the north their availability to linefishermen off Namibia might be expected to increase, but if to the south they would probably be more susceptible to capture off South Africa. For example, since 1979/80 the line catches of snoek off Namibia have shown a progressive decline, but simultaneously there has been a tendency for waters off southern Namibia (Division 1.5) to provide an increasing proportion of the catches (Fig. 3) and for line catches off South Africa to increase (Fig. 1).

The size composition of line catches off South Africa and Namibia is similar. Off Namibia most snoek are longer than 90 cm (Fig. 4), whereas between 1958 and 1975 the mean fork lengths of snoek taken off South Africa ranged from 80,7 to 91,3 cm (Nepgen 1979) corresponding to total lengths of 89–101 cm (Dudley 1987). This similarity supports the hypothesis that the same segment of the snoek population is exploited by linefishermen off Namibia and off South Africa, with seasonal migration between the two localities.

The lack of any significant relationship between residuals of catches off South Africa and those of catches off Namibia in the following season is of interest, but in keeping with the observation that there is less evidence for a northward than for a southward migration of snoek off south-western Africa (Dudley 1987). Most evidence for the southbound migration derives from the catches of inshore linefishermen, that sector of the fishery considered in this paper and seemingly based mostly on fish aged four and older. Information in Dudley (op. cit.) suggests that these larger snoek contribute to catches made by bottom trawlers off South Africa in winter (July), but rarely to catches made in summer (January). By summer they have presumably moved farther north to Namibian waters, perhaps offshore (Crawford and De Villiers 1985). Younger fish, however, continue to be caught by bottom trawlers off South Africa throughout the summer (Dudley op. cit.). The summer catch by linefishermen at Yzerfontein is also of relatively small snoek, about 84 cm total length or three years of age (C. G. Wilke, Sea Fisheries Research Institute, pers. comm.).

Snoek become sexually active when aged three or four years (Venidiktova 1988). At the end of winter it is likely that such maturing fish join adults that have migrated from Namibia to South Africa on their return northward migration to Namibia. South of Walvis Bay, spawning aggregations of snoek have been recorded at water depths of 30–115 m (Venidiktova 1987). Young fish from northern Namibia also join the spawning groups (Venidiktova 1987), and it is quite possible that this extensive recruitment to the shoals normally exploited by linefishermen is sufficient to mask any possible relationship between catches made off Namibia in summer and those made off South Africa the previous winter.

If the observed trends in handline catches of snoek off Namibia and South Africa are due to latitudinal displacements of the population, they appear to persist for a number of years. Long-term shifts in the locations of catches have been recorded for several other fish species in the Benguela system and attributed to environmental influences (Crawford and Shannon 1988). Shifts in the distribution of snoek could similarly be influenced by the physical environment, by the relative abundance of forage organisms in different regions, or by both factors.

In 1984 an intrusion of warm water off northern Namibia, a so-called Benguela Niño, led to greatly decreased catches of anchovy *Engraulis capensis* in the region (Boyd *et al.* 1985); there was also a large reduction in the snoek catch (Venter 1988). Although the anchovy fishery has since recovered, Namibian line catches of snoek stayed low until the conclusion of the 1986/87 season. From 1985/86 they were considerably less than any previously recorded (Fig. 1). Line catches of snoek were also poor from 1973/74 to 1976/77, after the Benguela Niño of 1974 (Shannon 1989).

Venidiktova (1987) suggests that the migration of large predatory fish such as snoek is frequently related to food availability. In keeping with this concept, line catches of snoek off Namibia were high in the mid 1960s and in the late 1970s, when pilchard *Sardinops ocellatus* and horse mackerel *Trachurus capensis* respectively were abundant in the northern Benguela (Crawford *et al.* 1987). Off South Africa line catches were high in the mid 1970s and mid 1980s, both periods of increased abundance of anchovy in the southern Benguela (Crawford *et al.* 1988).

Whatever the cause of the probable long-term displacements of the snoek resource — or at least the sexually mature component of it, that part seemingly most available to linefishermen — the displacements are likely to continue to exert a considerable impact on the performances of linefishermen in different regions. This is especially so because snoek provide the bulk of the line catch off south-western Africa (Crawford *et al.*

1987, Venter 1988). Although the large-scale introduction of skiboats has greatly improved the mobility of many linefishermen by permitting rapid travel overland (Van der Elst 1989), the distances over which displacements of snoek occur are large. Indeed, between Walvis Bay and Port Nolloth there are few places available for the launching of boats.

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