Benguela Dynamics
Pillar, S. C., Moloney, C. L., Payne, A. I. L. and F. A. Shillington (Eds). *S. Afr. J. mar. Sci. 19: 197–210*
1998

WEEKLY VARIABILITY OF CLUPEOID EGGS AND LARVAE IN THE BENGUELA JET CURRENT: IMPLICATIONS FOR RECRUITMENT

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Weekly sampling of ichthyoplankton, current vectors and surface temperature along a 34-mile transect crossing the jet current off the Cape Peninsula was conducted from August 1995 to July 1996 as part of the third phase of the South African Sardine and Anchovy Recruitment Programme, designed to investigate within-season variability in factors affecting sardine *Sardinops sagax* and anchovy *Engraulis capensis* recruitment. Anchovy eggs and larvae were found from October 1995 to February 1996, with most intense spawning from mid-October to early December. Peak abundances of anchovy eggs (717·m^{-2}) and larvae (342·m^{-2}) were encountered during mid-November. Sardine eggs and larvae were found throughout the year, but were most abundant from August 1995 to February 1996. Numbers were greatest during late September, reaching 630 eggs·m^{-2} and 142 larvae·m^{-2}, with secondary peaks of >200 eggs·m^{-2} during August, October and January. Spawning products were low from March onwards, but increased slightly during July 1996. Current vectors indicated that spawning prior to December was most favourable for transport of eggs and larvae to the West Coast nursery area. January and February were characterized by increasingly complex flow patterns, while the frontal jet current was positioned offshore of the transect for most of March and April as a result of prolonged periods of upwelling. Monthly length-frequency distributions of larvae indicated spawning by both species farther east on the western Agulhas Bank later in the season, or more complex transport from that region to the sampling area. Mean monthly (August–March) anchovy and sardine (September – February) egg abundances were significantly correlated ($p < 0.05$) with the estimated birthdate distribution of recruits, suggesting that frequent monitoring of egg abundance along the transect may be useful for forecasting recruitment strength.

Anchovy *Engraulis capensis* and sardine *Sardinops sagax* currently form the mainstay of the South African purse-seine fishery (Shannon *et al*. 1996). Anchovy dominated the landings from 1966 (Crawford *et al*. 1987), although the sardine stock is showing signs of recovery since its decline in the late 1960s and early 1970s, as indicated by both acoustic surveys (Hampton 1992) and seabird diet (Crawford and Dyer 1995). Clupeoid populations are prone to large natural variations in abundance and geographical range (Cochrane and Starfield 1992, Lluch-Belda *et al*. 1992), and catches of anchovy and sardine can fluctuate widely. This has been particularly evident in South African waters, with considerable interannual variability in anchovy spawner and recruit biomass estimates during the 1980s and 1990s, and little evidence of a spawner-recruit relationship (Hutchings and Boyd 1992). For example, the high estimate of anchovy recruitment for June 1997 (third highest on record) followed the in November 1996 lowest spawner biomass estimate on record since acoustic surveys were initiated in 1984 (M. Barange, Sea Fisheries, pers. comm.)

The variability of fish recruitment is considered to be the most important unsolved problem in fishery population dynamics (IOC/UNESCO 1990). The ability to forecast recruitment would therefore greatly benefit fisheries management. Simulation studies have indicated that the ability to differentiate between below-median and median or better recruitment could lead to a valuable increase in mean annual yield of the South African anchovy fishery (Cochrane and Starfield 1992, Cochrane and Hutchings 1995). Recruitment is thought to be determined largely by events during the early life-history stages, particularly the larval stage (Lasker 1981, Parrish *et al*. 1981, Alheit 1990). A number of environmental and biological variables are considered to influence recruitment success, including temperature, wind, food availability, transport, turbulence/stability, predation, competition, population density and gross egg production, as well as localised and widespread oceanographic events (Lasker 1985, Hutchings and Boyd 1992, Cochrane and Hutchings 1995). Different variables, or combinations of variables, may control recruitment from year to year, and a suite of hypotheses involving these factors has evolved over the past two decades (Cushing 1975, 1990, Lasker 1985, Cury and Roy 1989, Roy *et al*. 1992, Bakun 1993, 1996).

In the late 1980s, the international Sardine/Anchovy

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Manuscript received: February 1997

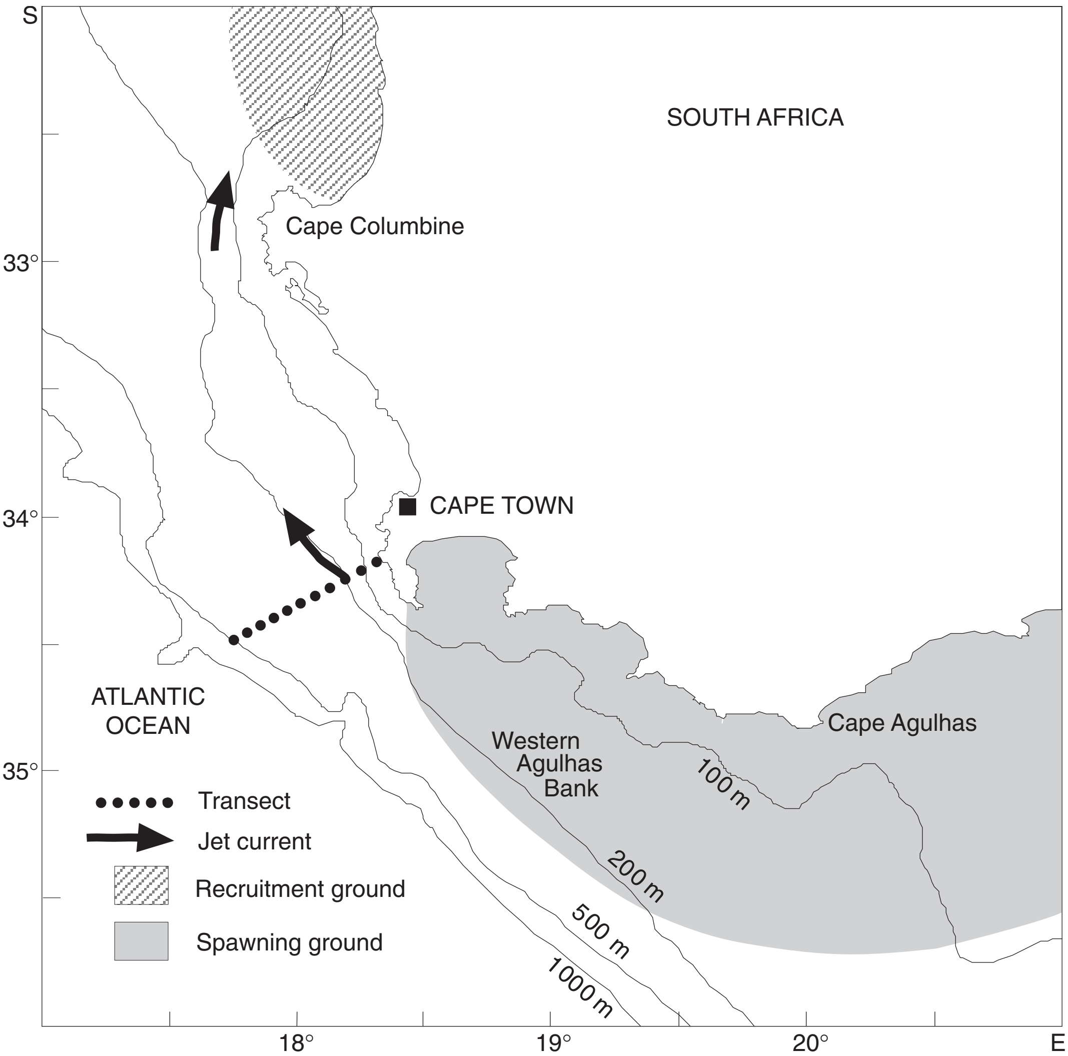

Fig. 1: Map showing station positions along the SARP III transect, crossing the jet current off the Cape Peninsula. The approximate locations of the spawning and recruitment grounds of anchovy and sardine are shown

Recruitment Project (SARP) was initiated to investigate the processes governing recruitment fluctuations in marine fish stocks (IOC/UNESCO 1990). A similar programme was launched in South Africa, consisting of monthly cruises during the summers of 1993/94 (SARP I) and 1994/95 (SARP II), which focused on within-season variations in factors affecting anchovy and sardine recruitment. Results from those cruises yielded interesting hypotheses regarding the distribution and spawning success (Richardson *et al*. 1998, Painting *et al.* in press b) and transport of eggs and larvae (Fowler and Boyd 1998) of anchovy and sardine, as well as forecasts of recruitment of anchovy (Painting and Korrûbel 1998). However, it was evident from those studies that an attempt to forecast recruitment would require more frequent sampling to investigate adequately the intra-annual variability in ichthyoplankton abundance and transport.

SARP III was initiated in August 1995, with the objective of monitoring the abundance of clupeoid eggs and larvae on a weekly basis along a transect crossing the jet current off the Cape Peninsula. The north-west flowing, shelf-edge, frontal jet current is instrumental in transporting spawning products of fish on the western Agulhas Bank to the nursery grounds on the West Coast (Shelton and Hutchings 1982). Hutchings (1992) suggested that regular monitoring of this critical gateway during the spawning season would be useful in predicting recruitment success. The objectives of this paper are to describe the variability in the abundance, distribution and transport of anchovy and sardine eggs and larvae along a transect crossing the jet current, and to determine whether frequent monitoring of egg and larval abundance could provide an index of recruitment.

MATERIAL AND METHODS

Sampling was conducted at 12 evenly-spaced stations along a 34-mile transect running west-south-west of Slangkop Point, Kommetjie, off the Cape Peninsula (Fig. 1). A number of vessels were used, including Sea Fisheries (SF) R.V. *Eck-lonia*, R.S. *Sardinops*, F.R.S. *Algoa* and F.R.S. *Africana*, a privately-owned tuna fishing vessel M.F.V. *Osprey*, and the Norwegian research ship R.V. *Dr Fridtjof Nansen*. Sampling took place in 38 out of 52 weeks between August 1995 and July 1996, with 11 or 12 stations sampled on 29 cruises. A strong swell sometimes prevented sampling at the inshore station. Bad weather was usually responsible for those weeks not sampled.

At each station, near-surface (2 m deep) currents were measured by tracking a tetrahedral drogue with drifter. The position and time of drogue deployment were noted on the vessel's Global Positioning System, as well as being stored on a hand-held unit, when available. The position and the time were again noted after completion of sampling, when the drogue was retrieved. Positions recorded by the hand-held unit were later corrected differentially using base station data. On the larger vessels (*Algoa*, *Africana* and *Dr Fridtjof Nansen*) an Acoustic Doppler Current Profiler (ADCP) was also used to measure current vectors 30–35 m deep.

Ichthyoplankton samples were collected by means of a mini-Bongo net sampler (0.0245 m^2 mouth area) with 200–300-μm mesh nets. The net was lowered to 70 m while the vessel was stationary, and then towed obliquely to the surface at a rate of 1-2 $m \cdot s^{-1}$ while underway at a speed of 2 knots. The net was fitted with a flowmeter to estimate the volume of water filtered. Samples were preserved in 5% buffered formaldehyde. A continuous series of hourly wind vectors was obtained from Cape Point Lighthouse. Daily summaries of the (equatorward) upwelling component during the SARP III sampling period (August 1995–July 1996) are given by Boyd and Nelson (1998).

In the laboratory, eggs and larvae of anchovy and sardine were identified and counted, and the body length (mm) of each larva was measured. Eggs were divided into three developmental stages: early (before gastrulation), intermediate (from the beginning of gastrulation to before tail separation) and late (from tail separation to just before hatching). Eggs of all stages were used to calculate weekly and monthly egg abundance, and abundance of both eggs and larvae was standardized to numbers per m^2 of sea surface. Three-dimensional representations of mean monthly abundances of eggs and larvae along the transect were determined using SURFER® for Windows v.6 (Golden Software Inc., USA) and Kriging with a linear variogram.

Anchovy eggs hatch after 2.5 days at 17°C (King *et al.* 1978), whereas sardine eggs hatch after 2.1 days at that temperature (King 1977). These data, together with larval growth rates of anchovy and sardine observed in the laboratory by Brownell (1979), were used to estimate age ranges and modal age for the length frequencies observed during each month. Possible spawning range (minimum to maximum distance) was calculated using vector-averaged current velocities of 10–15 $cm \cdot s^{-1}$ in a west-north-westerly direction across the inner western Agulhas Bank (Boyd and Oberholster 1994). However, these distances would be considerably reduced if spawning had occurred near the 200 m isobath or farther offshore, where current velocities average 20–30 $cm \cdot s^{-1}$.

Estimated birthdate distributions for anchovy and sardine from the 1995/96 season (S. F. Bloomer, formerly SF, unpublished data) were based on length frequencies of recruit-sized fish (anchovy, 3.5–10.0 cm; sardine, 3.5–15.0 cm) collected during an acoustic survey in June 1996. Growth rates of fish spawned during 1993/94 were used for these calculations (Bloomer, unpublished data), as data on ageing were not available for the 1995/96 season. Pearson product-moment correlation analysis (StatSoft 1996) was performed on the mean monthly abundances of anchovy and sardine eggs, larvae, and eggs and larvae combined (mean of all stations sampled during each month), and the corresponding birthdate distribution, i.e. the number of recruits born during each month. Data were considered significant at the 95% level. Mean monthly abundances of larvae were not adjusted to reflect month of birth, because it was not possible to do so quantitatively without bias from sampling frequency.

Austral spring is defined here as September–November, summer as December–February, autumn as March–May and winter as June–August.

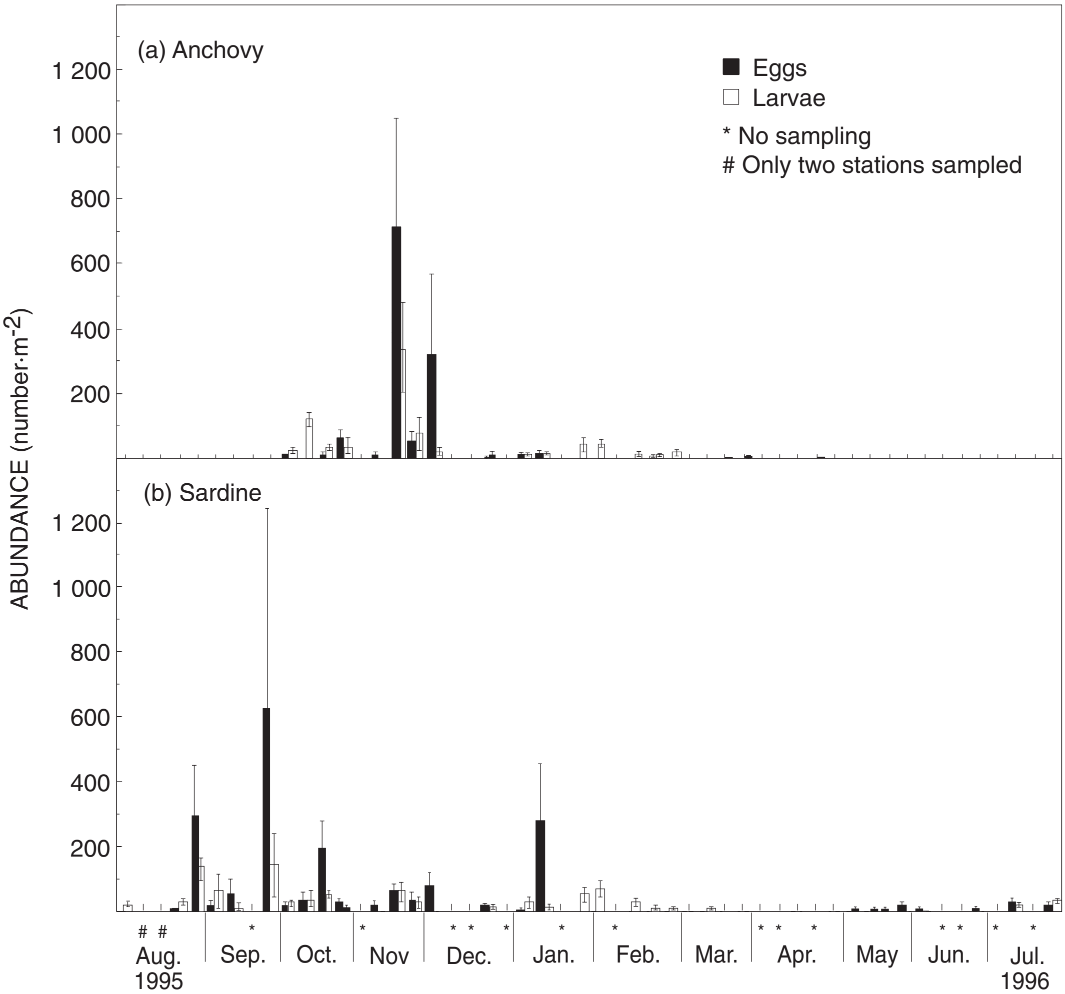

Fig. 2: Mean weekly abundance (± *SE*) of (a) anchovy eggs and larvae and (b) sardine eggs and larvae along the SARP III transect from August 1995 to July 1996

RESULTS

Seasonality

Mean weekly abundances of anchovy and sardine eggs and larvae collected along the transect are shown in Figure 2. Anchovy spawning products were first encountered during early October 1995, and subsequent sampling showed a period of intense spawning between mid-October and early December, whereas low numbers were present until the end of February 1996 (Fig. 2a). Peak abundances of anchovy eggs (717·m^{-2}) and larvae (342·m^{-2}) were observed during November. Weekly abundances of sardine eggs and larvae (Fig. 2b) revealed a protracted spawning period from August 1995 to February 1996, although spawning products were found throughout the year. Highest numbers (up to 630 eggs·m^{-2} and 142 larvae·m^{-2}) were encountered during late September, with secondary peaks of >200 eggs·m^{-2} in August, October and January. Sardine eggs and larvae were scarce from March onwards, but increased slightly during July 1996.

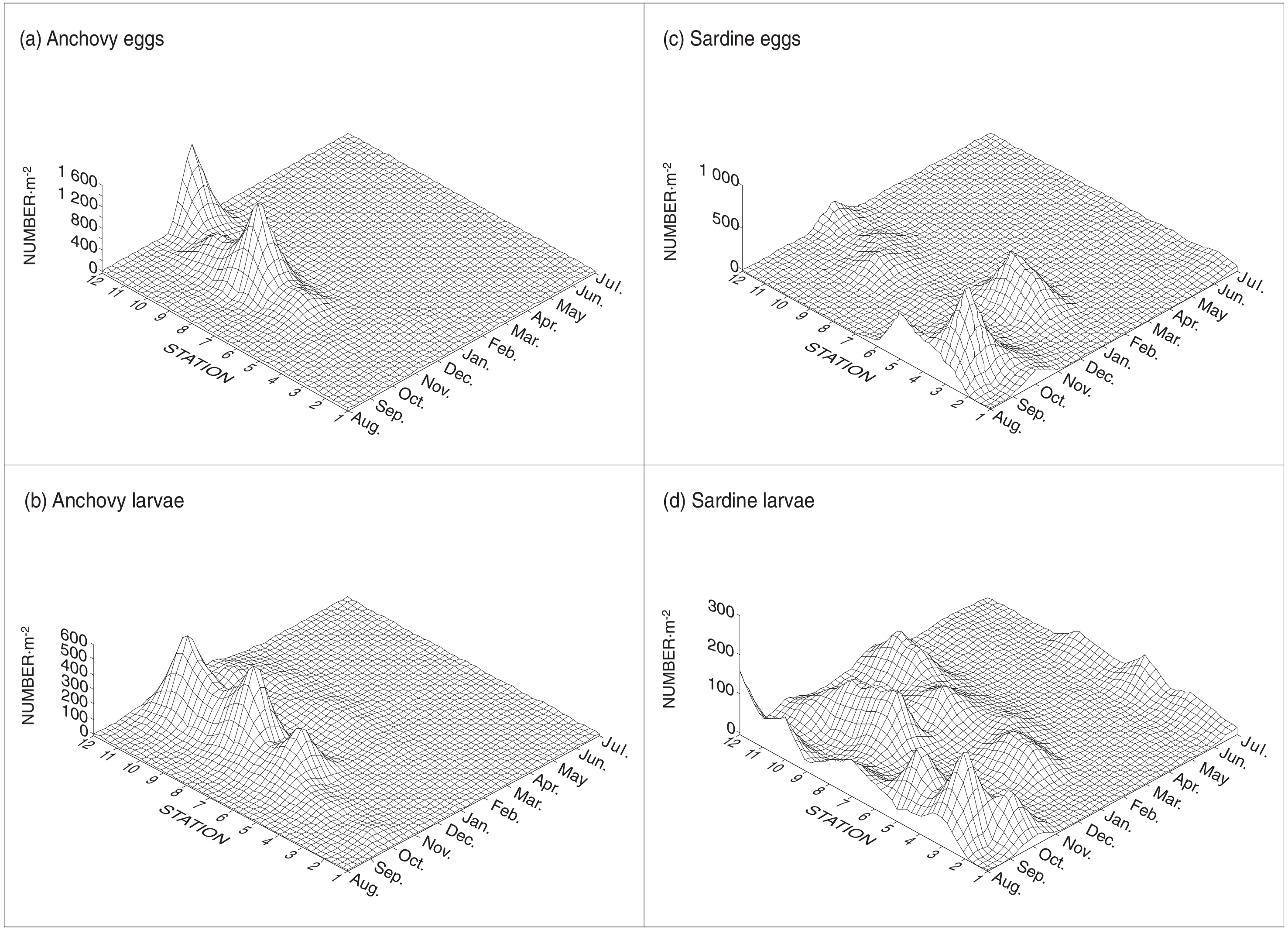

Fig. 3: Three-dimensional representation of mean monthly abundances and distribution of (a) anchovy eggs, (b) anchovy larvae, (c) sardine eggs and (d) sardine larvae along the SARP III transect from August 1995 to July 1996

Table I: Modal egg developmental stage, larval age, and estimated distance from spawning during each month of the main spawning period for anchovy and sardine. Modes are shown in parenthesis

Species	Month	Modal egg stage	Range of larval age (days)[1]	Range of distance from spawning (km)[2]
Anchovy	Oct. 1995	Early	2 – 32.9 (8)	17 – 426 (104)
	Nov. 1995	Early	2 – 22.4 (2.5)	17 – 290 (27)
	Dec. 1995	Intermediate	2.5 – 8 (2.5)	22 – 104 (27)
	Jan. 1996	Early	2.5 – 43.4 (12.5)	22 – 562 (135)
	Feb. 1996	Early	8 – 69.8 (32.9)	104 – 905 (355)
Sardine	Aug. 1995	Intermediate	2.1 – 23.9 (7.2)	18 – 310 (65)
	Sep. 1995	Late	1.5 – 18 (2.5)	13 – 233 (43)
	Oct. 1995	Intermediate	1.5 – 20.9 (4.6)	13 – 271 (54)
	Nov. 1995	Intermediate	1.5 – 12.5 (4.6)	13 – 162 (54)
	Dec. 1995	Early	1.5 – 2.1 (1.5)	13 – 18 (32)
	Jan. 1996	Early	1.5 – 26.8; 44.5 (7.2)	13 – 347; 577 (65)
	Feb. 1996	–	2.1 – 44.5; 53.3 (23.9)	18 – 577; 691 (310)
	Mar. 1996	–	4.6 – 12.5 (7.2)	54 – 162 (65)
	Jul. 1996	Early	1.5 – 26.8 (4.6)	13 – 347 (54)

[1] Assumes growth rates of 0.22 mm·day^{-1} from hatching to 5.9 mm, 0.19 mm·day^{-1} for lengths >5.9 mm for anchovy; 0.38 mm·day^{-1} from hatching to 9.3 mm, 0.34 mm·day^{-1} for lengths >9.3 mm for sardine (after Brownell 1979)
[2] Assumes average current velocities of 10–15 cm·s^{-1} in a west-north-westerly direction

Distribution of eggs and larvae along transect

Three-dimensional plots of mean monthly abundances of eggs and larvae of anchovy and sardine are shown in Figure 3. A strong pulse of anchovy eggs passed the Cape Peninsula in late spring/early summer (Fig 3a), with the November peak concentrated 22 miles offshore (Station 8) and the December peak 34 miles offshore (Station 12). Highest numbers of anchovy larvae were found in October and November, offshore from Station 6 (16 miles offshore), although very low numbers were found inshore at the beginning of the season (Fig. 3b).

The main peak of sardine eggs in late winter/spring was approximately 7–13 miles offshore, closer inshore than for anchovy eggs (Fig. 3c). There was a secondary peak of sardine eggs in January, at a position similar to that of the anchovy eggs. The offshore distributions of both sardine and anchovy eggs indicate that, in December, the eggs may have extended beyond the transect. Sardine larvae were more widely distributed along the transect than were eggs (Fig. 3d). They were more commonly found inshore from August to October, and farther offshore from November to February.

Seasonal trends in transport of eggs and larvae

The inshore distribution of sardine eggs and larvae during August and September coincided with strong north-westerly flow between Stations 2 and 5 (4–13 miles offshore), suggesting successful transport to the West Coast (e.g. 4 September 1995, Fig. 4a). In October, sardine eggs were still concentrated close to the coast, but larvae were also found farther offshore. Eggs and larvae of both anchovy and sardine were encountered over and beyond the midshelf during November, but still peaking before the end of the transect. October and November were characterized by consistent north-westerly flow over most of the transect (Boyd and Nelson 1998). During the two December cruises, most anchovy and sardine eggs were associated with north-westerly flow beyond the front, peaking at Station 12, and indicating additional eggs farther offshore (e.g. 3 December 1995, Fig. 4b).

In the first two weeks of January, ichthyoplankton was concentrated within the region of warm, north-flowing water near the coast (e.g. 10 January 1996, Fig. 4c), but may have circulated within an eddy. The currents appear to have returned larvae to the shelf on 22 January 1996 (Fig. 4d). Southward flow prevailed on the outer and midshelf regions in late January and early February respectively (see Boyd and Nelson 1998 and Nelson *et al.* 1998), and few sardine and anchovy eggs were caught during that period. Only towards the end of February were larvae abundant and moving towards the nursery grounds (e.g. 28 February 1996, Fig. 4e).

In March and April, sustained upwelling wind events (Boyd and Nelson 1998) would have influenced the thermal structure of the western Agulhas Bank, forcing the front offshore. No sardine or anchovy eggs were recorded in the six cruises during this period, but

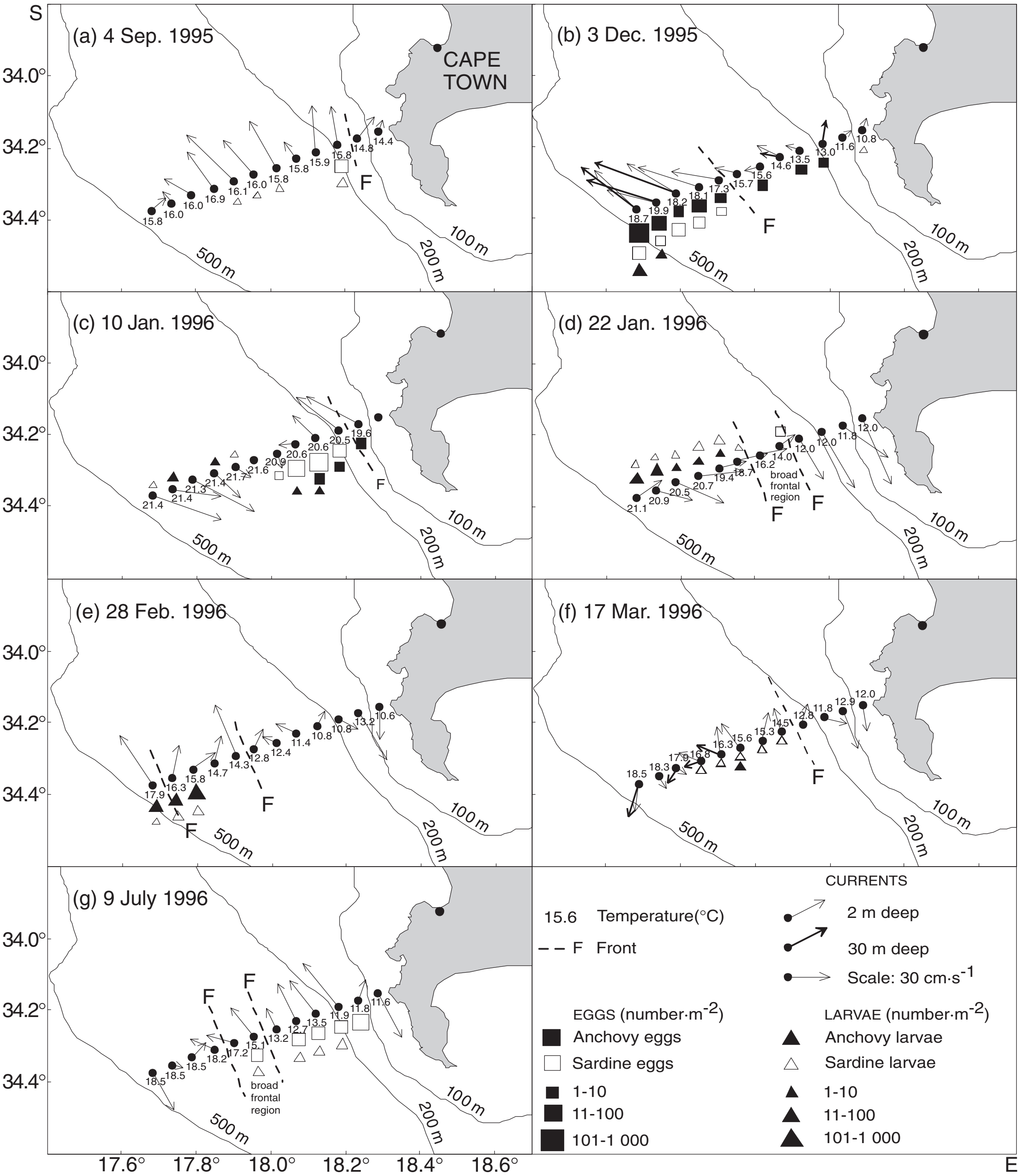

Fig. 4: Current vectors, surface temperature and associated distribution of sardine and anchovy eggs and larvae along the transect on (a) 4 September 1995, (b) 3 December 1995, (c) 10 January 1996, (d) 22 January 1996, (e) 28 February 1996, (f) 17 March 1996 and (g) 9 July 1996

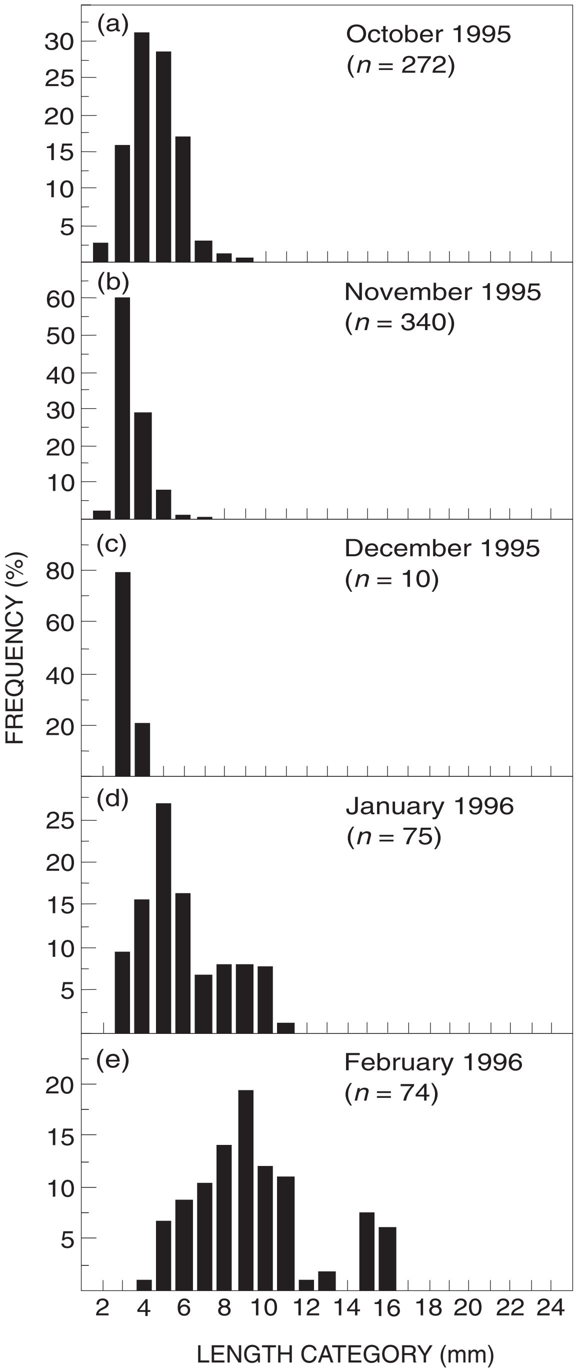

Fig. 5: Length frequencies of anchovy larvae (calculated from total monthly number·m^{-2}) during (a) October 1995, (b) November 1995, (c) December 1995, (d) January 1996 and (e) February 1996. Total numbers of larvae collected each month are indicated in parenthesis

some larvae were recorded over the midshelf following relaxations between upwelling events in March (e.g. 17 March, Fig. 4f). In May and June, northward transport resumed (Boyd and Nelson 1998), but eggs and larvae were generally absent. In July, sardine eggs and larvae were collected from inshore to midshelf, in the area of northward flow (e.g. 9 July 1996, Fig. 4g), and mostly inshore of the front.

Egg development and length frequency distributions of larvae

Anchovy eggs showed an early modal stage of development from October to February (Table I), except in December, although few eggs were collected in that month. Modal anchovy larval length was small (3–5 mm) from October to January (Figs 5a–d), whereas larger larvae were more abundant during January and February (Figs 5d, e), with a modal length of 9 mm observed during February. Larvae of that size would be approximately one month old, and would have travelled from some ~350 km further east, although some recirculation is likely, based on the current data in Figures 4 (c, d). The largest larvae of 15–16 mm collected during February would have been spawned two months earlier (Table I), and could have come from the eastern Agulhas Bank.

Modal sardine egg development from August to November was mostly intermediate, whereas the highest abundances during September were dominated by late-stage eggs (Table I). Modal larval length during that period was 4–6 mm (Figs 6a–d), corresponding to an age of up to one week (Table I). Low abundances of eggs and larvae in December (Figs 2b, 6e) were followed by a secondary peak of early-stage eggs during January 1996 (Table I). As with anchovy, increasingly larger sardine larvae were found in the January and February samples (Figs 6f, g). The largest larvae collected during February were nearly two months old, and may have been spawned up to 700 km east of the transect on the eastern Agulhas Bank (Table I). Low numbers of small larvae were collected during March (Fig. 6h), apparently marking the end of the main spawning season, although a few eggs and larvae were found in May and early June (Fig. 2b). An increase in the numbers of eggs and larvae (Figs 2b, 6i) in July 1996 suggests that the subsequent spawning season had begun.

Estimating recruitment

Estimated birthdate distributions for anchovy and sardine (Bloomer unpublished data) are shown in Figure 7. Anchovy births were low (0.39 billion) in

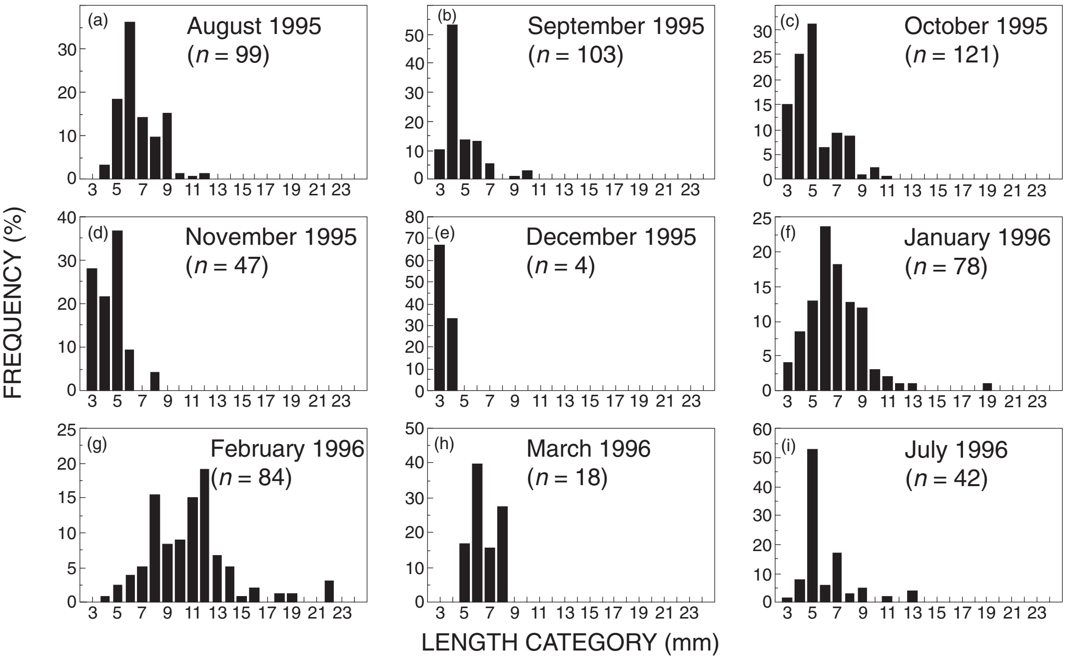

Fig. 6: Length frequencies of sardine larvae (calculated from total monthly number·m^{-2}) during (a) August 1995, (b) September 1995, (c) October 1995, (d) November 1995, (e) December 1995, (f) January 1996, (g) February 1996, (h) March 1996 and (i) July 1996. Total numbers of larvae collected each month are indicated in parenthesis

September, rising steadily to a maximum of 7.86 billion recruits born during December 1995, and declining thereafter. Sardine birthrates were more evenly distributed during the spawning season, with highest abundances of around 0.8 billion recruits born during September 1995, January 1996 and March 1996. Fewest sardines (0.09 billion) were born in February 1996. Corresponding monthly mean numbers of egg and larva abundances from this study are shown in Figures 7(a ,b). Monthly abundances of anchovy eggs were positively correlated with recruit birthdates from August 1995 to March 1996 ($p < 0.05$, Fig. 8a), but not with anchovy larvae nor eggs and larvae combined ($p > 0.05$). Monthly abundances of sardine eggs, larvae, and eggs and larvae combined showed no correlation with recruit birthdates when all data points (September 1995–March 1996) were used, but sardine eggs were significantly correlated with the birthdate distribution when the March 1996 data point was omitted (Fig. 8b). March 1996 showed the greatest discrepancy between spawning products collected on the transect and the numbers of recruits born, as indicated by the birthdate distribution.

DISCUSSION

Seasonality

The spawning seasons inferred for anchovy and sardine during this study are consistent with the findings of previous investigations. During surveys conducted between 1964 and 1969, anchovy spawning was largely confined to the period from October to January (Crawford 1981b). During the Cape Egg and Larva Programme (CELP) from August 1977 to August 1978, anchovy eggs peaked between October and February, and they were either absent or few during autumn and winter (March–August, Shelton 1986). Annual surveys by the SF to evaluate adult anchovy biomass have traditionally been undertaken during November, generally believed to be the month of peak anchovy spawning on the western Agulhas Bank (Hampton 1992). The present study supports this belief, but the month of peak spawning in anchovy may vary. From early surveys, Crawford (1981b) found greatest abundance of anchovy eggs in December, whereas during the CELP, spawning peaked in October

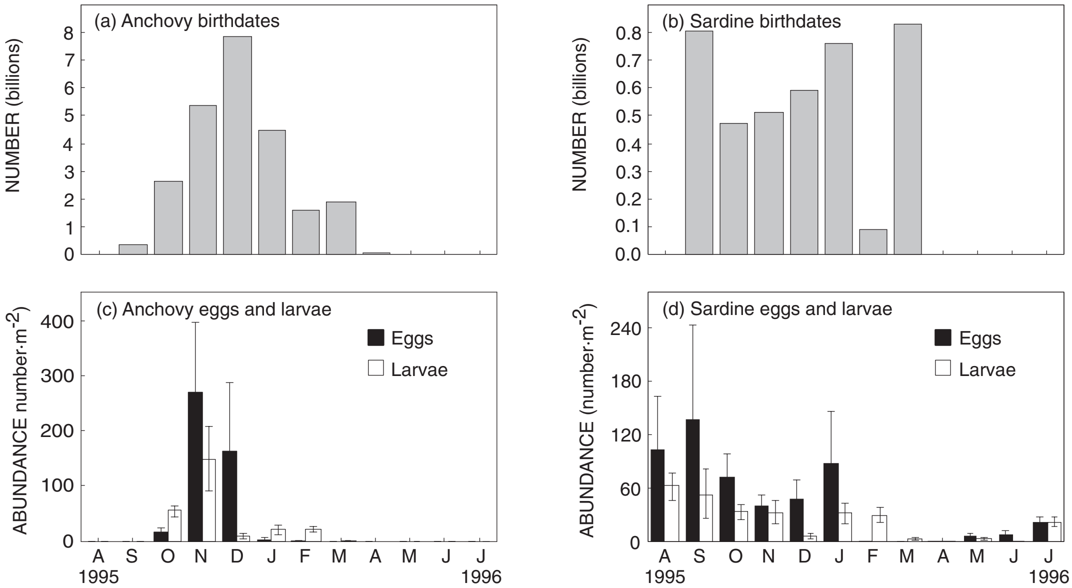

Fig. 7: Proposed birthdate distribution of (a) anchovy and (b) sardine recruits during the 1995/96 season based on length frequencies of recruits collected during the June 1996 acoustic survey and average growth rates from 1993/94. Corresponding mean monthly abundance of eggs and larvae collected along the SARP III transect for (c) anchovy and (d) sardine are shown

(Shelton 1986). Highest numbers of anchovy eggs on the western Agulhas Bank were also collected in October during SARP I (1993/94), but in November during SARP II (1994/95, Painting *et al*. in press b).

As with the present study, surveys conducted between 1951 and 1967, as well as those during the CELP, showed sardine eggs and larvae to be present throughout the year (Crawford 1981a, Shelton 1986). The main spawning season during those early surveys extended from September to February, with most intense spawning in January and a secondary peak in September (Crawford 1981a). During SARP I and II, most sardine eggs and larvae were collected during summer, in January and February 1994, and in February 1995 (Fowler *et al*. 1996). In contrast, sardine egg abundance during this study (SARP III) indicate more intense spawning during late winter and spring (August/September 1995), with a secondary peak in summer (January 1996). This discrepancy may not necessarily reflect a shift in the timing of peak sardine spawning, but may be a consequence of variable transport in summer, and offshore position of the front in autumn, compared to the first half of the season. Slow transport from the spawning grounds could increase egg mortality by prolonging exposure to possible predation by adult pelagic fish (Valdés-Szeinfeld and Cochrane 1992, Cochrane and Hutchings 1995).

Seasonal transport

From August to mid-November, the upwelling front and the jet current were usually encountered close inshore, within 10 miles of the coast. The inshore jet current reached high velocities of 60–100 cm·s^{-1} on several occasions, and often appeared to have two components (e.g. Fig. 4a). The distribution of sardine eggs (generally closer inshore) and larvae (both inshore and offshore) suggests transport from two sources, possibly the central and outer western Agulhas Bank.

Anchovy eggs and larvae were encountered mainly over the midshelf during October, moving farther offshore in November, but still peaking before the end of the transect. Those months were characterized by consistent north-westerly flow over most of the transect. South-easterly winds alternated with calm periods during the first half of November 1995, but thereafter sustained south-easterlies displaced the front offshore, along with many eggs and larvae situated beyond the front. Although high numbers of anchovy and sardine eggs at the offshore limit of the transect in December were associated with north-westerly flow (Fig. 4b), offshore losses may have occurred. During January and February, south-easterly winds alternated with increasingly complex advection patterns, often with a southward flow of cool water

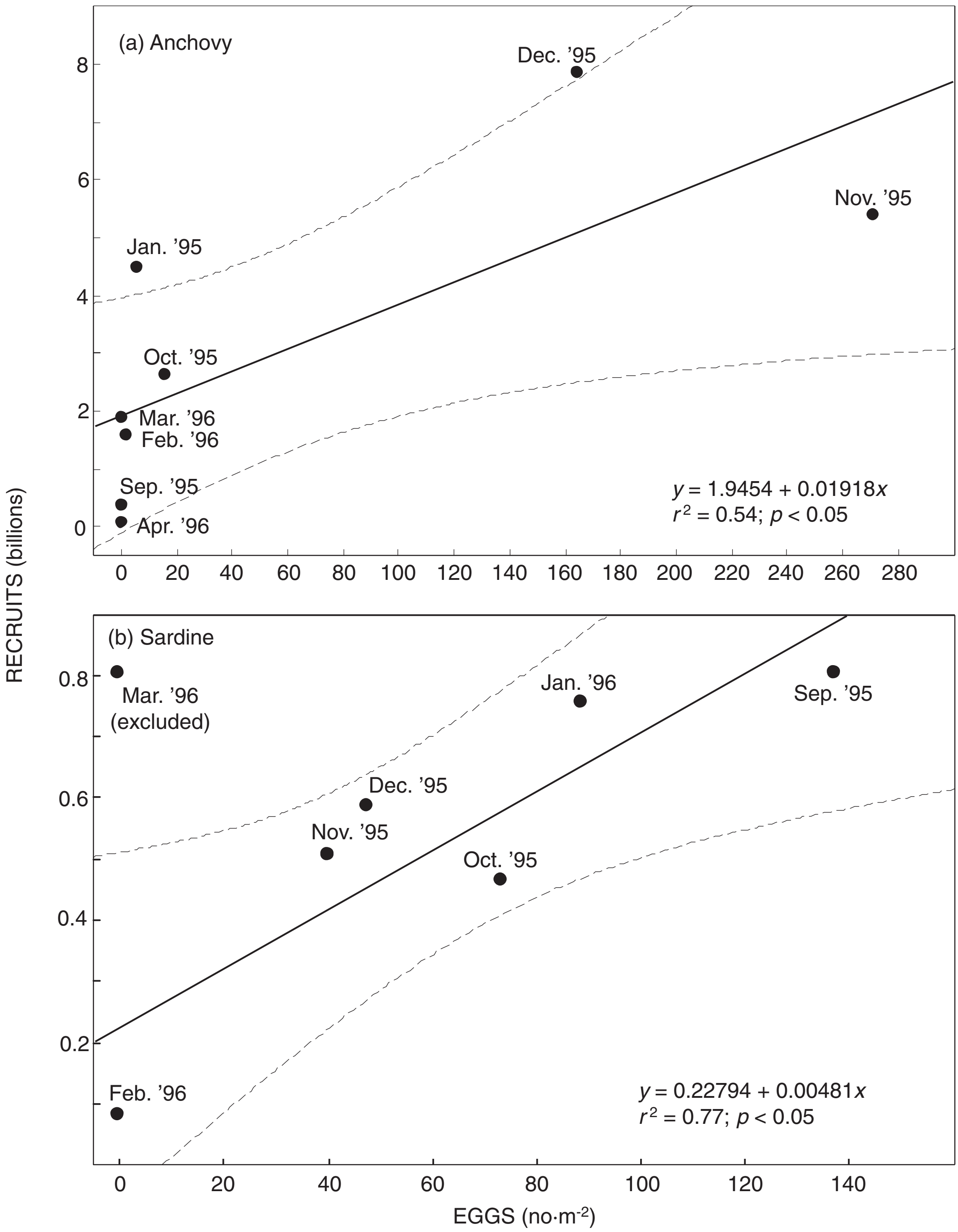

Fig. 8: Scatterplot showing regression and 95% confidence intervals for a Pearson product-moment correlation between mean monthly egg abundance along the SARP III transect and estimated number of recruits born each month for (a) anchovy and (b) sardine. Note that the March 1996 data point was excluded from the regression in (b)

following upwelling. This suggests that the first part of the season may have been the most efficient for transporting eggs and larvae to the West Coast. However, they may have been transported beyond the sampling grid in March, because sustained upwelling events kept the front offshore for most of autumn (Boyd and Nelson 1988).

The estimated distances from spawning (Table I) are based on averaged current data (at 30 m deep), and may underestimate the distance travelled by eggs and young larvae during periods of sharp fronts and associated swift currents on the western Agulhas Bank (e.g. December 1995). However, extensive southward flow in late January and early February 1996 (Boyd and Nelson 1998, Nelson *et al.* 1998) could mean that "straight line" distances are not appropriate. Furthermore, flow patterns may have caused bimodality in larval size distributions by delaying the transport of eggs and larvae to the sampling area or "returning" larvae to the sampling line from farther north. Using the November ranges only, it can be inferred that only larvae spawned west of Cape Agulhas (approximately 240 km from the study area) were sampled. Nevertheless, even allowing for complex features in January and February, it is likely that the range may include areas east of Cape Agulhas.

Implications for recruitment

The positive correlation between monthly egg abundance and the birthdates of both anchovy and sardine recruits (Fig. 8) indicates the potential to determine a recruitment index from regular monitoring. A simple index could be established by summing the mean monthly egg abundances (to obtain an annual egg abundance), which would yield an estimate of recruitment (in numbers) from the equations given in Figure 8. Alternatively, each monthly egg abundance could be converted to numbers of recruits, which could then be accumulated through the season, enabling a "minimum" recruitment estimate to be made in January, at the start of the season's fishing. Continued sampling would allow the numerical relationship to be refined and validated on an ongoing basis. Comparisons from short time-series of two or three years of monitoring should at least facilitate a qualitative prediction of recruitment, i.e. better or worse recruitment than the previous year(s). Because growth rates may vary markedly between years (Waldron *et al.* 1989, 1992), the use of growth rates from an earlier season to construct a birthdate distribution for the present study is not ideal. Routine daily ageing studies are necessary for refining the egg-recruit relationship.

The poor correlation between monthly abundances of larvae and recruit birthdates is not unexpected, because larvae collected along the transect may range widely with age. This was particularly evident in the second half of the season, with anchovy and sardine larvae sampled during January and February displaying a potential age difference of one and two months respectively. Furthermore, recruit birthdates reflect survivorship, and mortality resulting from factors such as failed transport (i.e. offshore losses), predation and lack of food in the nursery area will influence the age structure of recruiting fish.

The main discrepancy between the proposed anchovy birthdate distribution and the observed abundances of eggs and larvae was during summer, when the front was frequently situated offshore as a result of sustained south-easterly winds. This could have resulted in the transport of ichthyoplankton beyond the transect, as indicated by the offshore peaks in both anchovy and sardine eggs in December (Figs 3a, c, 4b) and larvae in late January and February (Figs 4d, e). Advective loss of eggs and larvae of anchovy early in 1994 owing to strong south-easterly winds was proposed by Boyd *et al.* (1997), and the situation may have been similar during 1996. Fewer south-easterlies were recorded in 1993 and 1995, coinciding with strong anchovy recruitment. A similar pattern of recruitment is evident for sardine during those years (SF unpublished data), suggesting that a common process may be operating on an annual scale, although 1997 does not fit the trend.

The large disparity between sardine egg abundance and the number of recruits spawned during March is noteworthy. This could have resulted from fish spawning north of the transect, as observed during the November spawner biomass surveys in 1994 and 1995 (SF unpublished data). During SARP I and II, similar numbers of sardine eggs were found on the West Coast as on the western Agulhas Bank, although numbers in March were low (Painting *et al.* in press b). No adult sardine were detected along the West Coast during the March 1996 pre-recruit survey (J. D. Hewitson, formerly SF, pers. comm), but this could be a result of the coarse spacing of the survey grid. An alternative and perhaps more plausible scenario is that eggs or larvae passed beyond the transect during March, forced offshore by the sustained upwelling wind events. Sampling in early March followed three days of strong south-easterly winds, resulting in a broad band of upwelled water extending well beyond the transect, with no evidence of the jet current even 45 miles offshore.

An important feature of within-season ichthyoplankton surveys is that they permit advance warning of curtailed spawning. This would assist management of pelagic resources, enabling quotas to be adjusted before extensive fishing. It may be argued that a high incidence of gonad atresia among adult fish (specifically anchovy) during the November survey would yield similar information, but evidence of little spawning during subsequent months would serve as valuable confirmation. Because November is not within the period of peak sardine spawning, reduced abundance of sardine eggs detected during regular monitoring would be the only indication of a spawning failure in that species.

The periodic extension of sampling to 60 miles offshore in future surveys will determine the proportion and frequency of eggs and larvae being transported beyond the standard transect (increased to 40 miles in 1997), provided that sufficient cruises are completed. Sampling of the extended transect will be particularly important following sustained south-easterly winds, when the front moves farther offshore. As with any monitoring programme, increased benefits and insights will accumulate with each year of sampling.

ACKNOWLEDGEMENTS

We thank the Captains, officers and crew of the F.R.S. *Africana*, F.R.S. *Algoa*, R.S. *Sardinops*, and R.V. *Dr Fridtjof Nansen*, Mr R. J. Busby of M.F.V. *Osprey*, and all those who assisted with sampling. The assistance of our colleagues, Messrs A. du Randt and E. J. Malan with cruise preparations, Ms L. Swart for plotting the ADCP maps, Mr C. J. Giddey, Mrs S. M. Jones, Ms E. Wright and Ms D. Gianakouras for counting and identifying samples is gratefully acknowledged. We are indebted to other colleagues, Messrs A. J. Richardson and C. D. van der Lingen, Drs H. M. Verheye and G. C. Pitcher, as well as to Dr F. J. Neira (Marine and Freshwater Resources Institute, Victoria, Australia), whose comments and suggestions greatly improved the manuscript.

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