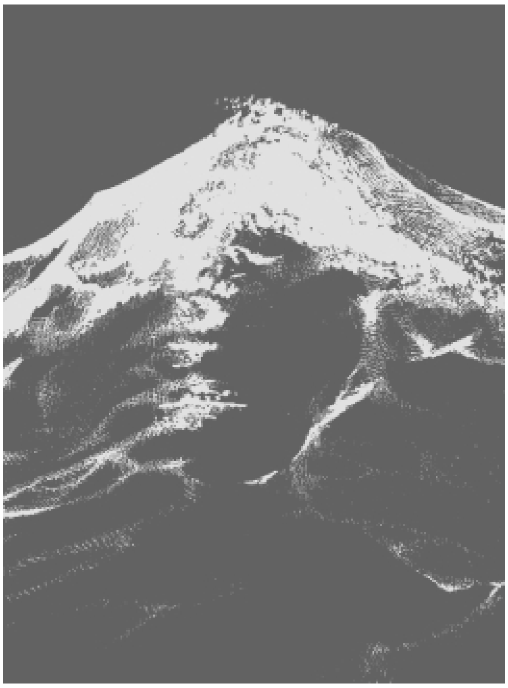
CSIRO Publishing



Marine & Freshwater Research

VOLUME 52, 2001

A journal for the publication of original contributions
in physical oceanography, marine chemistry,
marine and estuarine biology and limnology

All enquiries and manuscripts should be directed to:

Marine and Freshwater Research
CSIRO Publishing
PO Box 1139 (150 Oxford St)
Collingwood, Vic. 3066, Australia

Telephone: +61 3 9662 7618
Fax: +61 3 9662 7611
Email: mfr@publish.csiro.au

CSIRO PUBLISHING

Published by CSIRO Publishing
for CSIRO and the Australian Academy of Science

www.publish.csiro.au/journals/mfr

Mar. Freshwater Res., 2001, **52**, 631–6

Larval distribution and abundance of blue and spotted warehous (*Seriolella brama* and *S. punctata*: Centrolophidae) in south-eastern Australia

B. D. Bruce[A], *F. J. Neira*[B] *and R. W. Bradford*[A]

[A]CSIRO Marine Research, GPO Box 1538, Hobart, Tas. 7001, Australia
[B]Australian Maritime College (AMC), PO Box 21, Beaconsfield, Tas. 7270, Australia

Abstract. The early life histories of the commercially important blue and spotted warehous (*Seriolella brama* and *S. punctata*) were examined on the basis of archived ichthyoplankton samples collected over broad areas of southern Australia. Larvae of both species were widely distributed during winter and spring within shelf and slope waters. Larvae of *S. brama* were recorded from Kangaroo Island, South Australia (SA), to southern New South Wales (NSW). *Seriolella punctata* larvae were recorded from western Tasmania to southern NSW. Back-calculated spawning dates, based on otolith microstructure, indicated that spawning predominantly occurs during late July and August but that the timing of spawning varies between regions. The abundances of small larvae (<5.0 mm body length) were highest for both species off western Tasmania and southern NSW. No small *S. brama* larvae were recorded between southern Tasmania and southern NSW, whereas low but consistent numbers of small *S. punctata* larvae were found between these regions. The data suggest that there are separate spawning areas for *S. brama* in western and eastern regions of Australia's South East Fishery. The pattern for *S. punctata* is less clear, but suggests a more continuous link among populations in south-eastern Australia.

Introduction

Blue warehou (*Seriolella brama*) and spotted warehou (*S. punctata*) are medium-sized fishes found primarily in shelf and upper slope waters of south-eastern Australia and in New Zealand (Gomon *et al*. 1994). Both are commercially important across their range and are two of the main quota species within the South East Fishery (SEF) of south-eastern Australia (Tilzey 1998). *Seriolella brama* and *S. punctata* are targeted by both the trawl and the non-trawl sectors of the SEF. They are caught as by-catch in the Southern Shark Fishery, and juvenile *S. brama* are often caught by recreational anglers in bays and estuaries (Kailola *et al*. 1993). Commercial catches of both species reach a seasonal peak in winter–spring, although there is marked interannual variability in catches, possibly linked to environmental factors (e.g. water temperature) that may affect catchability and recruitment (Tilzey 1998). Catch rates and total catches of *S. brama* declined over the mid 1990s in both the trawl and non-trawl sectors and this was accompanied by a substantial reduction in the mean catch-at-age in some sectors of the fishery (MacDonald and Smith 1996). These effects have led to concerns over the population status of blue warehou stocks in south-eastern Australia (Smith 1995).

Both species are assumed to be single stocks within the SEF. However, no formal analysis of stock structure has been undertaken and there is some uncertainty with the single stock model. Both are believed to be highly mobile species (Gavrilov and Markina 1979), although the results of tagging studies in south-eastern Australia have been inconclusive (Knuckey, personal communication). The relationship between populations to the west and east of Bass Strait, where the bulk of the commercial catch is taken, is unknown. In addition, uncertainty about the stock structure and the effects of fishing on the spawning populations has caused conflict between the various sectors of the industry (Knuckey and Sivakumaran 2001).

A recent study by Knuckey and Sivakumaran (2001) has provided information on the reproductive biology of *S. brama* and confirmed previous observations by Smith (1989) of a winter–spring spawning across south-eastern Australia. They also reported regional differences in the timing of spawning, with fish east of Bass Strait spawning approximately one month earlier than those west of Bass Strait. However, the actual locations of spawning for both *S. brama* and *S. punctata* are still unknown and they have not been documented for Tasmanian waters. Similarly, the early life history of both species is poorly known. Grimes and Robertson (1981) described the eggs and yolk-sac larvae of *S. brama* from New Zealand, whereas full developmental sequences of larvae for both species were only recently described (Bruce *et al*. 1998). Last *et al*. (1983) reported that small juveniles of both species are commonly found under scyphomedusae in bays and estuaries of south-eastern Tasmania.

 10.1071/MF99150 1323-1650/01/040631

We report herein the distribution and occurrence of *S. brama* and *S. punctata* larvae in south-eastern Australia, based on the analysis of archived ichthyoplankton samples taken between 1984 and 1999. The data provide further details of the timing and location of spawning, as well as general aspects of the two species' early life history.

Materials and methods

Field sampling

In total, 6519 archived plankton samples from about 3000 stations collected between 1984 and 1999 were examined for the presence of *Seriolella* larvae. The available samples, covered a wide area of southern and south-eastern Australia (Fig. 1). Samples covered all seasons, including day and night tows, in shelf and open ocean areas, and were generally taken concurrently with hydrographic data. Most *Seriolella* larvae were retrieved from samples taken in 1984, 1985, 1986, 1993 and 1997.

Four net systems (surface, ring, Bedford Institute of Oceanography Net and Environment Sensing System [BIONESS] and bongo) were routinely used to collect samples, depending on the objectives of the original survey. Towing protocols and net types differed between systems and details are fully described in Bruce *et al.* (1996 and in press), Young *et al.* (1996) and Gunn *et al.* (1989). Net systems are briefly described below.

Surface net. The surface net consisted of a square frame with a mouth area of 1 m^2 and mesh size of 1000 µm. The net was towed beside the vessel from a davit rigged amidships and was usually deployed concurrently with other net systems towed astern or on departing a hydrographic station. The net in all cases was towed at a vessel speed of between 2.5 and 3.5 kn for 10–15 min.

Ring net. The ring net consisted of a circular framed net of 70 cm diameter and 500 µm mesh. This net was either towed amidships as a surface net, or towed obliquely from the stern through the water column at a vessel speed of 2.5–3.5 kn, the latter from within 10 m of the bottom (maximum depth 200 m) to the surface.

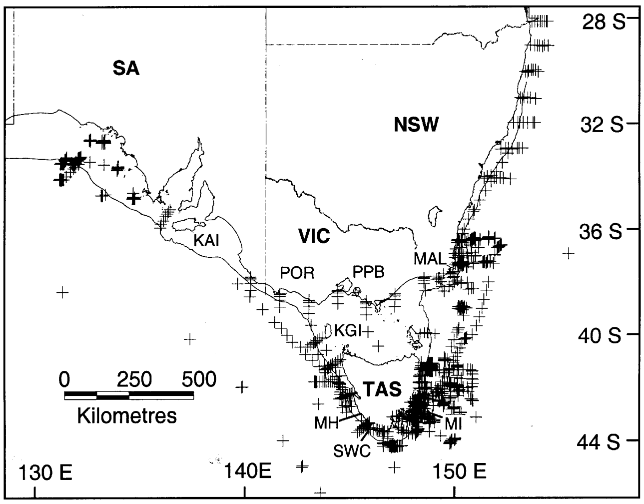


Fig. 1. Distribution of samples available for analyses of larval distribution in south-eastern Australia. NSW, New South Wales; VIC, Victoria; TAS, Tasmania; SA, South Australia; MAL, Mallacoota; PPB, Port Phillip Bay; POR, Portland; MI, Maria Island; SWC, South West Cape; MH, Macquarie Harbour; KGI, King Island; KAI, Kangaroo Island.

Bongo net. The bongo net consisted of two nets, each either 60 cm or 70 cm diameter, with a mesh size of either 1000 µm or 500 µm (depending on the study), and was towed from a central pivoting point. Bongo nets were towed either as a surface net or obliquely through the water column in a similar manner to the ring net. The depth of obliquely towed bongo nets was monitored in real time by sensors on the net relayed to the vessel via a conducting cable.

BIONESS net. The BIONESS net was used to examine vertical distribution. The BIONESS net consisted of a towed frame with a mouth opening of 1 m^2, fitted with up to 10 nets of either 335 µm or 500 µm mesh. Each net could be opened and closed from an on-board control system with communication between ship and net via a conducting tow cable. The tow cable also relayed real-time information to the vessel from sensors on the frame that provided net depth, rate of descent/ascent, elapsed fishing time and volume of water filtered. The system was towed from the stern of the vessel at a speed of about 3 kn. A typical tow profile consisted of deploying the sampler to the maximum depth and then sampling through discrete strata back to the surface. The maximum depth sampled and the resolution of depth strata varied according to water depth and, in some cases, the original target species. Most BIONESS tows were conducted seaward of the shelf break, where a typical tow profile consisted of an oblique set from the surface to 400 m over a 40 min period, followed by 10–20 min hauls from 400–300 m, 300–200 m, 200–100 m and 100 m to the surface.

A study during 1997 examined the vertical distribution of ichthyoplankton along the Victorian and south-eastern South Australian coasts on a series of eight fixed parallel transects between Gabo Island (37°36.0′S,149°55′E) and Port MacDonnell (37°49.0′S,140°17′E).

Each transect was located 65 nautical miles (nmiles) apart, and each contained five sampling stations at 2, 4, 8, 16 and 32 nmiles offshore. Sampling was conducted mostly during daylight hours. In stations where bottom depth was ≥100 m, discrete samples were obtained in the strata 100–75, 75–50, 50–25 and 25–0 m by the use of four 500 µm mesh nets. Each net was opened for 15 min while towing the BIONESS system obliquely at a speed of 1–2 kn. In stations <30 m deep, a 15 min oblique tow in the strata 25–0 m used the bongo sampler instead of the BIONESS net. Surface samples were also collected at each station in a bongo sampler described above. This study provided the best available information on vertical distribution.

The volume filtered was calculated for tows from each net system by the use of either Rigosha or General Oceanics flowmeters. Samplers were assumed to have the same filtration efficiency for the purpose of analyses. Day–night differences in the catchability of larvae have not been considered and the data have been standardized to numbers of larvae per 1000 m^3 for comparison.

Samples were fixed in either 10% formalin seawater buffered with sodium tetraborate or 98% ethanol (the latter for ageing).

Laboratory analyses and ageing of larvae

All *Seriolella* larvae were removed from the available samples and identified to species following the descriptions of Bruce *et al.* (1998). Body length (BL) was measured to the nearest mm (notochord length in preflexion larvae and standard length in flexion and postflexion larvae) under a dissecting microscope fitted with a calibrated eyepiece graticule, following the definitions of Neira *et al.* (1998).

Larvae of both *S. brama* and *S. punctata* were aged by examination of otolith microstructure that followed the procedure of Brothers *et al.* (1976). Increment formation was assumed to be daily, on the basis of the similarity of increment structure to that in species for which age validation has been previously documented (e.g. Jenkins 1987; Thresher *et al.* 1988), the concurrence of our back calculated spawning dates with documented spawning periods (Smith 1989; Knuckey and

Sivakumaran 2001), and the formation of increments in laboratory-reared *S. punctata* larvae (Bruce *et al.* 1996).

Increment counts were taken from whole, unprocessed sagittae mounted in a drop of lens immersion oil. Otoliths were examined under transmitted light at 1200–2500× under a Leitz Orthoplan microscope fitted with a high-resolution television camera (Ikegami CTC-6000) and linked to a high-resolution monitor. Increment age was estimated by averaging counts from both sagittae (where counts from a respective otolith set did not differ by >5%). Otolith pairs not satisfying these criteria were rejected from subsequent analyses (2.1%). Total age was estimated as increment age + 6 (based on the estimated period between fertilization and first increment formation for *S. punctata*; see Bruce *et al.* [1996] for details). Total age was used in all calculations of growth rate and in back-calculating spawning dates.

Otoliths from larvae collected between 1984 and 1986 had deteriorated and were unreadable, despite storage of specimens in 98% ethanol. Therefore we calculated age-at-length relationships from larvae collected in 1993 and whose otoliths were readable and in good condition. Growth in both species was essentially linear at sizes <7 mm BL and is best described by the following equations:

$$\textit{S. brama}: \quad [\text{age}] = 6.321[\text{BL}] - 18.71, \quad R^2 = 0.86;$$
$$\textit{S. punctata}: \quad [\text{age}] = 5.814[\text{BL}] - 17.32, \quad R^2 = 0.81.$$

Age was estimated for a randomly selected subset of larvae that were collected between 1984 and 1986 and that were less than 7.0 mm BL from these equations.

The spawning date for each aged larva was calculated by subtracting total age from the date of capture.

Results

Regional distribution

In total, 695 *S. brama* larvae and 739 *S. punctata* were recorded from the available samples. Larvae of both species were widely but unevenly distributed across south-eastern Australia and were primarily restricted to shelf and slope waters. Very low numbers were recorded seaward of the slope and none was recorded from samples >25 km offshore of the shelf break (Fig. 2).

Seriolella brama. Larvae were recorded from Kangaroo Island in South Australia to southern New South Wales (Fig. 2). They were low in abundance in South Australian samples but increased in abundance eastwards towards Bass Strait. Low numbers were recorded within western Bass Strait as far east as Port Phillip Bay in Victoria.

Larvae were most abundant between King Island and South West Cape along the coast of western Tasmania, with the maximum abundances recorded between King Island and Macquarie Harbour. Larval abundance decreased eastwards around southern Tasmania and they were only recorded in extremely low numbers between Maria Island on the east Tasmanian coast and north-eastern Victoria. Large numbers of larvae were again recorded in a restricted area between Mallacoota in north-eastern Victoria and Bermagui in southern NSW.

The distribution of small preflexion larvae (<5.0 mm BL) was assessed separately to provide an indication of possible spawning areas. In general, the distribution of small larvae mirrored that of all larvae combined (Fig. 3). Small larvae were primarily recorded from Kangaroo Island to South West Cape in Tasmania and off southern NSW. Small larvae were absent from Bass Strait and only three small larvae were recorded between South West Cape (Tas.) and Mallacoota (Vic.). Small larvae were most abundant between King Island and Macquarie Harbour off western Tasmania.

Seriolella punctata. Larvae were less widely distributed than those of *S. brama*. Larval *S. punctata* were absent from samples taken north of Sandy Cape (western Tasmania) and from samples taken either west of or within Bass Strait (Fig. 2). They were recorded from western Tasmania to southern NSW. The highest abundances of larvae were recorded off south-western and southern Tasmania, and off north-eastern Victoria and southern NSW. Larvae were consistently recorded between Maria Island (eastern Tasmania) and north-eastern Victoria, although in low numbers.

The distribution of small preflexion larvae (<5.0 mm BL) again mirrored that of all sizes combined (Fig. 3). Small larvae were most abundant off southern Tasmania and north-eastern Victoria/southern NSW, with low but consistent numbers between these two regions.

Vertical distribution

Very few *Seriolella* larvae were recorded in vertically stratified samples. A sample set collected in Bass Strait recorded small numbers of *S. brama* larvae that were too few to warrant a statistical analysis. *Seriolella brama* larvae were recorded from the surface to the 75–100 m stratum, with the highest abundances in the upper 50 m (Fig. 4).

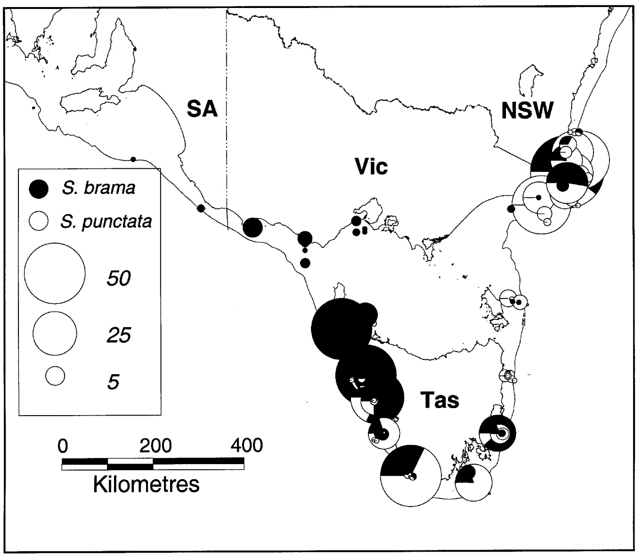


Fig. 2. Distribution of *S. brama* larvae and *S. punctata* larvae in southern Australia (all sizes combined). Scale, number of larvae per 1000 m^3.

Both *S. brama* and *S. punctata* were routinely recorded from surface tows in southern NSW. In addition, larvae as well as pelagic juveniles of both species were caught in association with scyphomedusae in surface waters of Storm Bay in Tasmania.

Age and growth

Larvae of both *Seriolella* species had a series of unambiguous bipartite increments extending from a central core to the edge in both sagitta.

Larvae used for ageing were taken from samples collected from 1993, and most were from specimens collected in both NSW and Tasmanian waters. *Seriolella brama* and *S. punctata* larvae used in ageing ranged from 2.9 to 18.6 mm (n = 34) and 2.8 to 12.0 mm (n = 165), respectively. Similar patterns of age and growth were recorded for each species and growth was best described by the following exponential equations over these size ranges.

S. brama: $[BL] = 3.2952e^{0.0303[age]}$, $R^2 = 0.85$;
S. punctata: $[BL] = 3.1736e^{0.0386[age]}$, $R^2 = 0.94$.

Back-calculated spawning dates

Back-calculated spawning dates indicated that spawning peaked in winter for both species. However, the range of spawning dates and timing of peak spawning varied between regions.

Seriolella brama. Spawning was recorded on 45 days over a 77-day period from 21 June to 6 September. Spawning dates for larvae collected from Tasmanian waters (primarily from the west coast) ranged from 5 July to 6 September, with a peak in mid to late August (Fig. 5). Spawning dates for larvae collected from north-eastern Vic./southern NSW ranged from 21 June to 8 August, with a spawning peak in late July, approximately one month earlier than that calculated from aged larvae caught in Tasmania.

Seriolella punctata. Spawning was recorded on 32 days over a 47-day period from 1 July to 17 August. Spawning dates for larvae collected from Tasmanian waters (primarily from the south coast) ranged from 18 July to 17 August, with a peak in early–mid August (Fig. 6). Spawning dates for larvae collected from north-eastern Vic./southern NSW ranged from 1 July to 11 August, with a spawning peak in late July–early August.

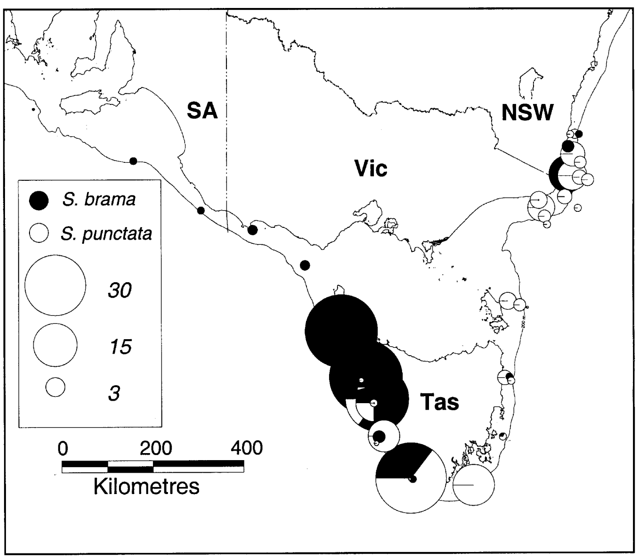


Fig. 3. Distribution of *S. brama* larvae and *S. punctata* larvae <5 mm BL. Scale, number of larvae per 1000 m^3.

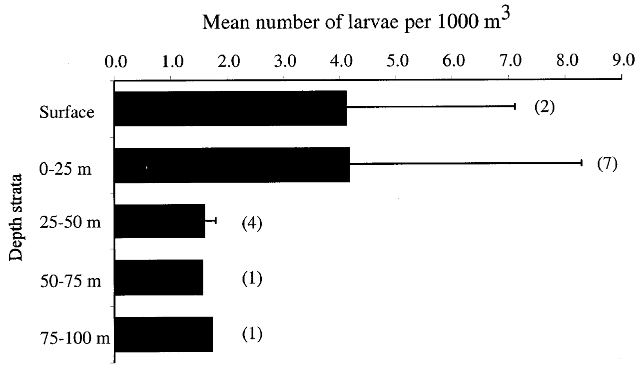


Fig. 4. Vertical distribution of *S. brama* larvae in Bass Strait (all records combined). Bars denote 1 s.d. Number in parentheses, number of tows that collected *S. brama* larvae within the specified depth stratum.

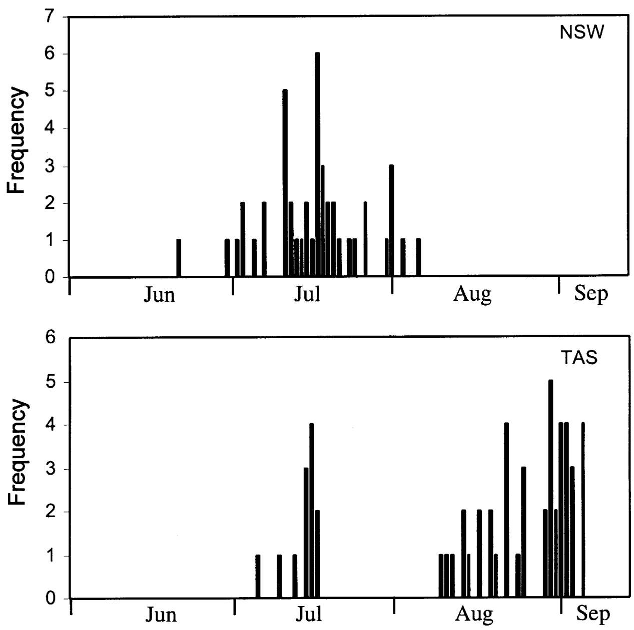


Fig. 5. Back-calculated spawning dates for *S. brama* larvae in southern Australia.

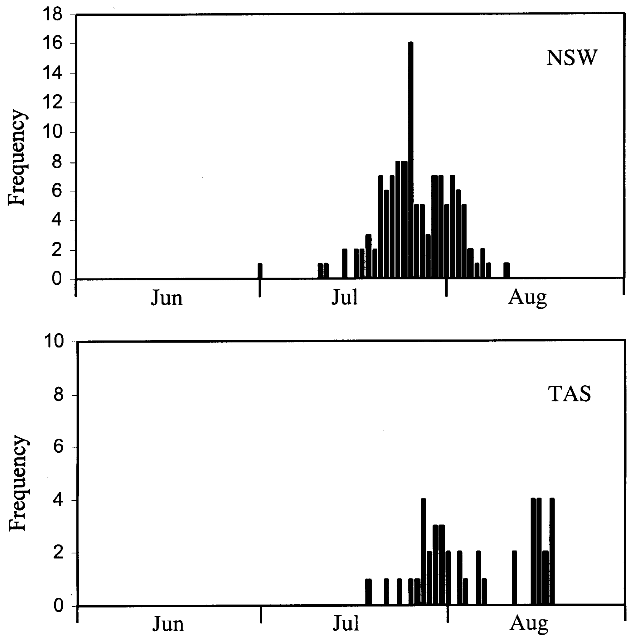


Fig. 6. Back-calculated spawning dates for *S. punctata* larvae in southern Australia.

Discussion

These data for larvae of both *Seriolella* species support previous work indicating that peak spawning occurs in winter, and that it occurs across broad areas of south-eastern Australia (Smith 1989; Knuckey and Sivakumaran 2001). However, the data also suggest that there are major regional differences in the magnitude and timing of spawning. This was most pronounced for *S. brama*.

The distribution of small *S. brama* larvae (<5.0 mm BL) suggests that this species spawns over a large area from Kangaroo Island in South Australia to southern Tasmania, with a major spawning ground located on the central-west and north-west coasts of Tasmania. However, we have based these conclusions on the distribution and age of small larvae (<5.0 mm BL) that are up to 10–13 days post-spawning. Hence, advection of larvae during this initial period has undoubtedly increased the area we attribute to spawning activity. These conclusions are consistent with field observations of running ripe *S. brama* in these areas (Knuckey and Sivakumaran 2001). Eggs of a *Seriolella* species were also recorded during blue grenadier egg surveys off the central-west coast of Tasmania in 1994 and 1995, further suggesting that this region is a spawning area (M. Lewis and C. Bulman, CSIRO Marine Research, personal communication).

The location of large concentrations of small *S. brama* larvae off eastern Vic./southern NSW combined with their almost complete absence between this area and southern Tasmania (including Bass Strait), suggests that separate major spawnings occur in this area. Similarly, differences in the timing of spawning between eastern Vic./southern NSW and western Tasmania also suggest separate spawning events. The timing of spawning from back-calculated age data was consistent with that derived from GSI data by Knuckey and Sivakumaran (2001) who also reported that *S. brama* east of Bass Strait spawned approximately one month earlier than those west of Bass Strait.

Very little information is available on spawning in *S. punctata*. Our data suggest a similar spawning period to that of *S. brama* in south-eastern Australia. The absence of *S. punctata* larvae in Victorian waters west of Bass Strait and in South Australia suggests that this species may not spawn in these areas. However, our sample coverage in these areas was poor, relative to other areas. *Seriolella punctata* appears to spawn between western Tasmania and southern NSW. Although there were peaks in the concentrations of larvae off both southern Tasmania and off southern NSW, small to moderate numbers of small *S. punctata* larvae were consistently captured between these two regions, suggesting that spawning by *S. punctata* is more continuous across this range. There was also considerably more overlap in back-calculated spawning dates for *S. punctata* between Tasmania and NSW, although there was a tendency for later spawning in more southerly locations.

There were very few vertically stratified samples taken in which *Seriolella* larvae were recorded, and thus our knowledge of their vertical distribution is limited. This limits the ability to adequately assess transport processes of larvae and the connectivity of regions through larval supply.

The ecology of small juveniles of each species is poorly documented, apart from observations of associations with scyphomedusae by Last *et al.* (1983). Juveniles are widespread in southern Australia and are often targeted by recreational fishers in bays and estuaries (Kailola *et al.* 1993), although no larvae or juveniles have been reported from Port Phillip Bay, Vic. (Neira, unpublished). Last *et al.* (1983) and Lyle and Ford (1993) reported that bays and estuaries of south-eastern Tasmania were major nursery areas for both species. The winter transport of larvae from spawning grounds off western Tasmania to nursery areas in coastal bays of south-eastern Tasmania by the Zeehan Current is well documented in blue grenadier (Gunn *et al.* 1989; Lyne and Thresher 1995). A similar transport of *Seriollela* larvae spawned in winter off the west coast of Tasmania is likely to be responsible for supplying the reported nursery areas in the south-east of that area.

Commercial catches of both *Seriolella* species peak during the spawning period and fishers regularly report the capture of running-ripe specimens (Smith 1989; Tilzey 1998). This suggests that both species aggregate during this period and are thus more susceptible to capture. Seasonal catch-rate trends in some regions also support a migration probably associated with spawning. Knuckey and Sivakumaran (2001) reported a marked decline in catch rates of *S. brama* off south-eastern Tasmania during winter, and suggested that this may indicate a north–south migration. An alternative explanation is that these fish migrate to primary spawning grounds off the west coast of Tasmania during this period.

In summary, the distribution and occurrence of larvae, as well as larval otolith data, support a winter or winter–spring spawning period for both *S. brama* and *S. punctata* in south-eastern Australia. Although spawning is widespread in both species, our data suggest that there are separate spawning grounds off the west coast of Tasmania and north-eastern Vic./southern NSW for *S. brama*. Spawning in *S. punctata* appears to occur in a more continuous region between south-western Tasmania and southern NSW. Whether *S. brama* is represented by separate eastern and western stocks in the SEF cannot be answered by these larval data alone and will depend on the extent of mixing in subadult and adult fish as well as spawning site fidelity. However, our data are not inconsistent with this hypothesis. The pattern for *S. punctata* is less clear, but our data suggest a more continuous link between populations in south-eastern Australia compared with that of *S. brama*.

Acknowledgments

This research was supported by grants from the Fisheries Research and Development Corporation (FRDC 92/019, 96/103 and 98/103). We thank I. Knuckey (MAFRI) for valuable discussions and T. Jones (CSIRO Marine Research) for assistance with database design.

References

Brothers, E. B., Mathews, C. P., and Lasker, R. (1976). Daily growth increments in otoliths from larval and adult fishes. *Fishery Bulletin (US)* **74**, 1–8.

Bruce, B. D., Sutton, C. A., and Thresher, R. E. (1996). An ichthyoplankton based analysis of the spawning distribution and stock structure of temperate Australian finfish. Final Report to FRDC #92/019. 65 pp.

Bruce, B. D., Sutton, C. A., and Neira, F. J. (1998). Centrolophidae – warehous. In 'The Larvae of Temperate Australian Fishes: a Laboratory Guide for Larval Fish Identification'. (Eds F. J. Neira, A. G. Miskiewicz and T. Trnski.) pp. 422–7. (University of Western Australia Press: Nedlands.)

Bruce, B. D., Young, J. W., Evans, K., Sutton, C. A., and Furlani, D. M. (In press). The influence of mesoscale physical oceanographic processes on larval distribution and stock structure in jackass morwong (*Nemadactylus macropterus*). *ICES Journal of Marine Science*.

Gavrilov, G. M., and Markina, N. P. (1979). The feeding ecology of fishes of the genus *Seriolella* (fam: Nomidae) on the New Zealand Plateau. *Journal of Ichthyology* **19**, 128–35.

Gomon, G. M., Glover, J. C. M., and Kuiter, R. H. (1994). 'The Fishes of Australia's South Coast.' (State Printer: Adelaide.) 992 pp.

Grimes, P. J., and Robertson, D. A. (1981). Egg and larval development of the silver warehou, *Seriolella punctata* (Pisces : Centrolophidae). *New Zealand Journal of Marine and Freshwater Research* **15**, 261–6.

Gunn, J. S., Bruce, B. D., Furlani, D. M., Thresher, R. E., and Blaber, S. J. M. (1989). Timing and location of spawning of blue grenadier, *Macruronus novaezelandiae* (Teleostei : Merlucciidae), in Australian coastal waters. *Australian Journal of Marine and Freshwater Research* **40**, 97–112.

Jenkins, G. P. (1987). Age and growth of co-occurring larvae of two flounder species, *Rhombosolea tapirina* and *Ammotretis rostratus*. *Marine Biology* **95**,157–66.

Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A., and Grieve, C. (1993). 'Australian Fisheries Resources.' (Bureau of Rural Resources and Fisheries Research and Development Corporation: Canberra.)

Knuckey, I. A., and Sivakumaran, K. P. (2001). Reproductive characteristics and per-recruit analyses of blue warehou (*Seriolella brama*): implications for the South East Fishery of Australia. *Marine and Freshwater Research* **52**, 575–87.

Last, P. R., Scott, E. O. G., and Talbot, F. H. (1983). 'Fishes of Tasmania.' (Tasmanian Fisheries Development Authority: Hobart, Australia.) 563 pp.

Lyle, J. M., and Ford, W. B. (1993). Review of trawl research 1979–1987, with summaries of biological information for the major species. Department of Sea Fisheries Tasmania Technical Report No. **46**, 169 pp.

Lyne, V. D., and Thresher, R. E. (1995). Dispersal and advection of *Macruronus novaezelandiae* larvae off Tasmania: simulation of the effects of physical forcing on larval distribution. In 'Multidisciplinary Studies of Recruitment of Australian Marine Populations'. (Ed. P. Sammarco.) (Springer: Berlin.)

MacDonald, C. M., and Smith, D. C. (1996). Blue warehou 1995, stock assessment report. South East Fishery Assessement Group. (Australian Fisheries Management Authority: Canberra.)

Neira, F. J., Miskiewicz, A. G., and Trnski, T. (1998). 'The Larvae of Temperate Australian Fishes: a Laboratory Guide for Larval Fish Identification.' (University of Western Australia Press: Nedlands.)

Smith, D. C. (1989). Summary of data available on the warehou *Seriolella brama* and *S. punctata*. Marine Science Laboratory Internal Report No.183. 26 pp. (Queenscliff: Australia.)

Smith, D. C. (1995). Blue warehou 1994, stock assessment report, South East Fishery Assessment Group. (Australian Fisheries Management Authority: Canberra.)

Thresher, R. E., Bruce, B. D., Furlani, D. M., and Gunn J. S. (1988). Distribution, advection and growth of larvae of the southern temperate gadoid *Macruronus novaezelandiae* in Australian coastal waters. *Fishery Bulletin US* **87**, 29–48.

Tilzey, R. D. J. (1998). Fishery assessment report. The South East Fishery 1998. (Bureau of Rural Sciences: Canberra.)

Young, J. W., Bradford, R. W., Lamb, T. D., and Lyne, V. D. (1996). Biomass of zooplankton and micronekton in the southern bluefin tuna fishing grounds off eastern Tasmania, Australia. *Marine Ecology Progress Series* **138**, 1–14.

Manuscript received 3 November 1999; revised and accepted 2 June 2000