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A synthesis of existing data on the early life history of southern Australian finfish

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NON-TECHNICAL SUMMARY

Studies on the early life history of fish can make valuable contributions to the management of fisheries by providing information on stock structure, regional connectivity of resources, the location and extent of spawning areas, spawning stock biomass and processes important in recruitment dynamics. Early life history studies can also provide information useful for identifying the aquaculture potential of species by means of information on growth rates, feeding ecology and larval duration. Pursuing these benefits has generated a wealth of sampling effort in particularly, southern and eastern Australian waters over the last two decades and has produced a significant information base on the early life history of finfish. However, accessing species - specific information has previously been hampered by the scattered nature and varied format of the literature. It has also been hampered by incomplete sample analyses and the lack of a coordinated way to summarise the available data. The primary goal of this project was to integrate the available data on the early life history of selected Australian finfish into an accessible format that would allow an immediate summary of available information on distribution and ecology. Such a format would also identify the extent of previous sampling effort in regions of interest and allow researchers to identify what data is available on target species in specific areas.

The Larval Fish Database (LFD) has been created in Microsoft Access. It is divided into two parts: a data module that houses raw data and an application module that automatically displays summaries of these data in a user-friendly fashion. By dividing the database into two parts, the user only has access to the specified data summaries, the raw data remain secure and the LFD can be updated as further data become available. Information summary page windows that display data and distribution plots are actively linked to their respective raw data fields. Thus when new data is added, these windows are automatically updated.

Data housed within the database comes from a combined sampling effort in southern and eastern Australia for a seventeen-year period from 1982 to 1999. Species-specific early life history data has been collated for 51 finfish for the area from the Head of the Great Australian Bight around the southern coast to Moreton Bay, Queensland.

The LFD is currently available in read-only format, so as to maintain current data integrity. Further development of the LFD to a web-based application will enable additional data entry and updates, although some issues remain regarding limits to the functionality moving the LFD to the web. This project has highlighted the benefits of archiving samples. The LFD, as it currently stands, provides a significant resource on the early life history of selected Australian finfish.

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INTRODUCTION

Background

Information on eggs and larvae (early life history stages - ELH) of many commercial species is contained in a diverse range of datasets and existing samples that together have the potential to contribute valuable information for understanding the connectivity between fisheries resources, the location of spawning regions and processes influencing variability in recruitment. Yet despite the potential of ELH data, its usefulness has been hampered by the inability to identify larvae of many species, the fragmented nature of available data sets, the lack of analysis of previously collected samples and poor sampling coverage over major areas of southern Australia. Over the last 10 years however, several initiatives have been addressing these shortcomings.

Sampling in the 1990s filled the major gaps in geographic coverage of southern and eastern Australia (e.g. CSIRO sampling of southern NSW, eastern Victoria, offshore waters of eastern and western Tasmania and the Great Australian Bight; MAFRI sampling of Bass Strait).

An ARBS/FRDC (FRDC 94/129) funded identification atlas for southern Australian fish larvae was published in 1998.

The accessibility of many previously collected larval fish samples was assured after the completion of an FRDC funded study (FRDC 94/55) to register and archive available larval fish samples in Museums (primarily the Australian Museum and the CSIRO fish collection).

Recent advances in oceanographic modeling permit more effective analyses of larval transport processes.

Despite these advances, finding information on specific species remained difficult and datasets fragmented. The information pay-back from these major initiatives would not be achieved until the existing ELH sampling and data sets were integrated, analysed and incorporated into an accessible format. This was the goal of the current project.

Need

For many Australian fisheries, particularly southern multi-species fisheries, several of the more difficult research and management issues remain unanswered: What is the stock structure? How connected are our regional fisheries resources? How do ocean and environmental variability impact fisheries resources - in particular recruitment dynamics? Many even more basic questions remain unresolved: When and where do some species spawn? What are the key critical habitats for early life history stages?

There is no one dataset or project that will solve these questions but a contributing factor to resolving them is information on early life history. A considerable amount of effort has been expended in southern Australia to collect data on the early life history of commercial fish

species over the last two decades. However, most sampling has either targeted specific species (and largely ignored the other material that was concurrently collected) or was regionally based and did not provide a complete picture for any one species. There has long been a need to understand just what information was already available from such samples in order to provide input into these research and management questions where possible and to plan future sampling to maximise the return from field efforts.

Objectives

The main objective of this study was to produce and populate a database that can display and summarise available data on the distribution of early life history stages of marine fish from Australian waters with specific emphasis on southeast Australia, where most sampling has been undertaken.

The specific objectives of the project were to:

1. Compile and analyse available information on the early life history of southern Australian fish in order to provide supporting data for the regional management of fisheries resources, assessment of stock structure and assessment of environmental forcing of recruitment processes.

2. Examine regional connectivity of fin-fish resources via the dispersal of larval stages

3. To produce an atlas (database) of ELH data for southern Australian finfish including information by species on larval distribution, timing and location of spawning, larval age and growth and larval dispersal patterns

METHODS

General

The primary basis for the project was the analysis of existing plankton and larval fish samples and the collation of data sets on larval distribution that had been derived from sampling across broad areas of southern and eastern Australia over the last 17 years (see Appendix E for cruise details). Some of these samples had been archived in the CSIRO Ian Munro Fish Collection, Australian Museum or South Australian Museum as part of the FRDC funded regional larval fish archive (FRDC94/55). Other samples or data sets were resident within the collections of collaborating institutions. The project focused its analyses on southern and southeast Australia spanning the area from the Great Australian Bight (GAB) to northern NSW. This region was selected for four reasons: First, sampling had been most intensive in this region and available data sets provided excellent spatial and seasonal coverage. Second, our ability to identify larvae to species was well developed in the region. Third, the oceanography of the region had been the subject of intensive study and provided a sound basis for linking biological data to physical processes. Fourth, additional sampling during the period of this project was scheduled that further enhanced sample coverage (specifically sampling by MAFRI in Bass Strait Bass Strait and sampling by CSIRO in the GAB).

The available data were collated and used to populate a purpose-designed database which is described below. Details of modeling, data handling and species-specific analyses are presented as part of the description of the database or in the attached Appendices. Individual species accounts are provided in Section x.x.

Description of Database

General

The Larval Fish Database (LFD) has been created in Microsoft Access. It has been divided into two parts: a data module that houses raw data and an application module that automatically displays summaries of these data in a user-friendly fashion. By dividing the database into two parts, the user only has access to the specified data summaries, the raw data remain secure and the LFD can be updated as further data become available.

The LFD incorporates an ActiveX component (MapInfo MapX) that allows the user to visualise spatial data and animations of modeled larval dispersal that are displayed using Microsoft's Media Player.

The LFD has been designed to allow expansion of its data holding capabilities as further data become available and/or the client perceives the need. Data summary page windows that display data and distribution plots are actively linked to their respective raw data fields. Thus when new data is added, these windows are automatically updated. However, the LFD is

currently available to users in read-only format, so as to maintain current data integrity. Further development of the LFD to a web-based application will enable additional data entry and updates (see Further Development), although some issues remain regarding limits to the functionality moving the LFD to the web. Appendix C contains a full list of the data fields (and their descriptions) that have been incorporated into the current version of the LFD.

Summary of data sets and their source

Data housed within the database comes from a combined sampling effort in southern and eastern Australia for a seventeen year period from 1982 to 1999. Details of the sample coverage are provided in Table 1 and Appendix E. In many cases, species–specific or regional components of the larval studies generating these samples have been published in the form of technical reports, final reports to funding agencies or variously in scientific and 'grey' literature. Literature pertaining to these studies are listed within the LFD.

Table 1: Summary statistics for sampling extent and species and species covered within the LFD.

Number of cruise records	141
Number of station records	6175
Number of species listed	605
primary species covered	32
secondary species covered	19*
Number of larval fish aged (via otoliths)	1774**
Number of references	1048
Temporal coverage of samples	1982 to 1999

*These include four genus level accounts (*Neosebastes* sp. – gurnad perch, F. Scorpaenadiae; *Seriola* sp. – kingfish/samsonfish, F. Carangidae; and *Tubbia* sp. – rudderfish. – F. Centrolophidae) and one *Seriolella* species (*Seriolella* sp. A – F. Centrolophidae, which we believe may be *Seriolella caerulea*) where species identifications have not been resolved.
** These data come from 10 of the primary species.

Sample coverage

The database contains listings of 6,175 samples. The samples range in their coverage from approximately 130 ˚E to about 154 ˚E, and from about 27.5 ˚S to about 54 ˚S. Most sampling effort has been concentrated in shelf waters of southern and southeast Australia. However, sampling effort extends up to 200 km offshore in southern NSW, 250 km off shore in eastern Tasmania and up to 1000 km offshore to the south of Tasmania (Figure 1).

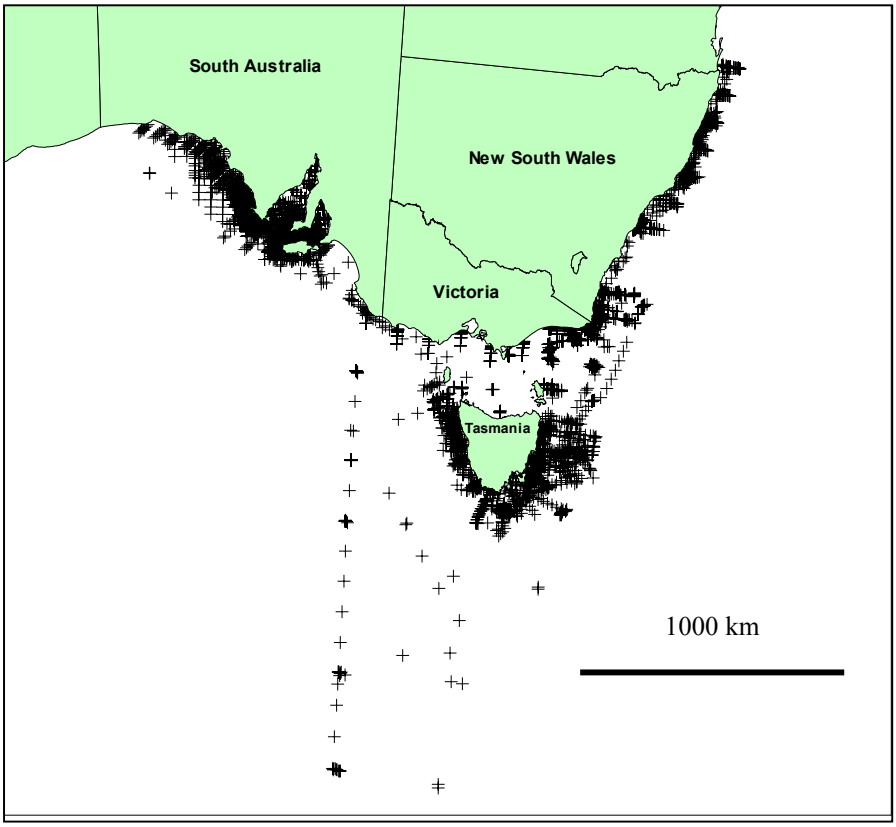


Figure 1: Sampling locations housed in the Larval Fish Database.

Appendix E provides details of individual cruise bounds, the institution responsible for collecting or holding samples and their data and, where available, references describing sampling methodologies.

Taxa covered

A total of 605 species names are loaded into the LFD. However, larval data are only available for 51 of these. Species data accounts are held within the LFD in two ways, as primary species' (those for which data summary pages are available and which are covered as completely as data permits – Table 2) and secondary species (which are handled by presence/absence distribution data only – Table 3).

Table 2: List of primary species covered in the Larval Fish Database (accounts for species marked with * include ageing data based on otolith microstructure).

Family	Scientific Name	Common Name
Clupeidae	*Sardinops sagax**	pilchard
Engraulidae	*Engraulis australis**	anchovy
Gonorynchidae	*Gonorynchus greyi*	beaked salmon
Ophidiidae	*Genypterus blacodes*	pink ling
	Genypterus tigerinus	rock ling
Macruronidae	*Macruronus novaezelandiae**	blue grenadier
Scomberesocidae	*Scomberesox saurus scomberoides*	saury
Berycidae	*Centroberyx affinis*	redfish
Platycephalidae	*Neoplatycephalus richardsoni*	tiger flathead
	Platycephalus bassensis	sand flathead
Scorpaenidae	*Helicolenus percoides**	ocean perch
Arripidae	*Arripis trutta*	eastern Australian salmon
Callanthiidae	*Callanthias australis*	splendid perch
Carangidae	*Pseudocaranx dentex*	silver trevally
	Pseudocaranx wrighti	sand trevally
	*Trachurus declivis**	jack mackerel
	*Trachurus novaezelandiae**	yellowtail scad
Cheilodactylidae	*Cheilodactylus spectabilis*	banded morwong
	*Nemadactylus macropterus**	jackass morwong
Pomatomidae	*Pomatomus saltatrix*	tailor
Sillaginidae	*Sillaginodes punctata**	King George whiting
	Sillago bassensis	western school whiting
	Sillago ciliata	sand whiting
	Sillago flindersi	eastern school whiting
Sparidae	*Acanthopagrus australis*	yellowfin bream
	Pagrus auratus	snapper
Gempylidae	*Rexea solandri*	gemfish
	*Thyrsites atun**	barracouta
Trichiuridae	*Lepidopus caudatus*	ribbonfish
Centrolophidae	*Seriolella brama**	blue warehou
	*Seriolella punctata**	silver warehou
Scombridae	*Scomber australasicus*	blue mackerel

Table 3: List of secondary species for which only distribution data has been included in the database.

Family	Scientific Name	Common Name
Carangidae	*Seriola* sp.	kingfish/samsonfish
Centrolophidae	*Seriolella* sp. A	white warehou (?)
	Tubbia sp.	rudderfish
Cheilodactylidae	*Cheilodactylus nigripes*	magpie perch
Clupeidae	*Etremeus teres*	maray
	Hyperlophus vittatus	sandy sprat
Emmelichthyidae	*Emmelichthys nitidus*	redbait
Gempylidae	*Paradiplospinus gracilis*	slender escolar
Girellidae	*Girella tricuspidata*	luderick
Hemiramphidae	*Hyperlophus melanochir*	southern sea garfish
Mugilidae	*Aldrichetta forsteri*	yelloweye mullet
	Liza argentea	flattail mullet
Platycephalidae	*Platycephalus speculator*	yank flathead
Scorpaenidae	*Gymnapistes marmoratus*	soldierfish
	Scorpaena papillosa	red rock cod
	Neosebastes sp.	gurnard perch
Sillaginidae	*Sillago maculata*	trumpeter whiting
Sparidae	*Acanthopagrus butcheri*	black bream
	Rhabdosargus sarba	tarwhine

Ageing of larvae based on otolith microstructure

Ageing data held within the LFD originates from either data from larvae of primary species larvae aged in previous studies or larvae which were aged as part of producing the LFD. The methodologies for ageing larvae via otolith microstructure are generally well defined and examples of protocols followed are found in Brothers *et al*. (1976), Thresher *et al*. (1988) and Bruce *et al*. (2001).

Using the database

Loading the Database

The database is supplied as a Microsoft Access 2000 application. This application will run on any PC computer running Windows 98 or a later version of the Microsoft operating system. In order to use the Larval Fish Database, it must be loaded onto the host computer. To do this,

the user inserts the disk and selects the set-up.exe file. This is an automatic set-up file with the user only needing to follow the on-screen prompts. Access to the database is via the 'Start' menu, in 'Programs' under 'Larval Fish Database'. On the first instance of using the database an 'open file' dialogue box will automatically open prompting the user to locate the data tables. If the user accepted the default folders for installation, the dialogue box will open to the folder containing the data tables, otherwise, the user will have to browse through the file structure to locate the data tables. By clicking on 'LarvalData.MDE' all the table links between the application file and the data file will be made. Note that this is a once-off occurrence. A full set of instructions for installation is contained within the inner sleeve of the CD-Rom.

Database Switchboard Features

The database is accessed through a central switchboard – this is the main window that the user is presented with on first opening the database. We have used a convention of placing fields or active link buttons that the user can choose to select within a grey 'working' area throughout the application module.

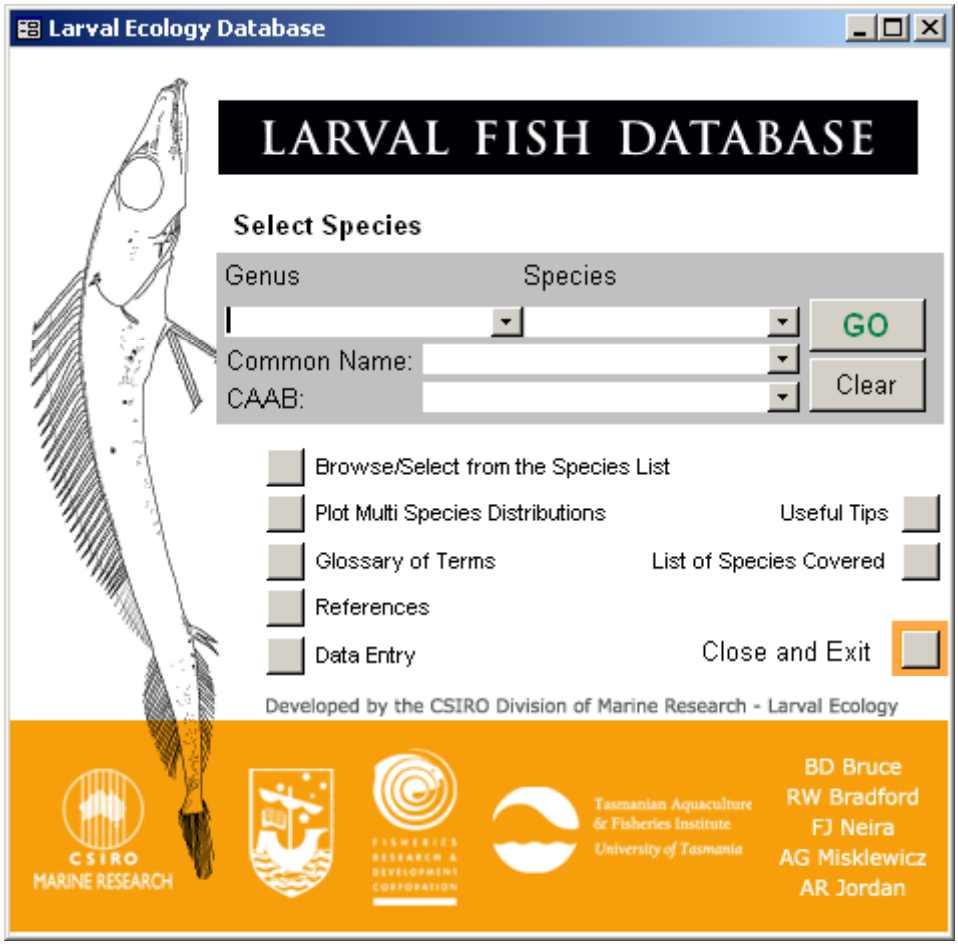


Figure 2: The switchboard – access page to the database

Opening species summaries within the database

There are three methods of accessing information on an individual species: by working in the *Select Species* box, choosing from the *Species Covered* window or browsing and selecting from a taxonomic tree.

Working within the Select Species box

There are four active field boxes that allow a user to select a species. Species may be selected by direct typing or by using the available drop–down menus. In each case, typing within the field box automatically commences a selection of matching entries in the database. This also serves as a spell-check for the query.

The curser is automatically located in the '*Genus*' text box when the database is opened so the user can immediately start typing. Once the genus has been entered, the user can either tab across to the '*Species*' text box or click within that text box. A list of species pertaining to that genus is automatically selected by the database for the user to choose from. Once the full taxonomic name has been entered, the user then clicks on '*Go*' to view the details for the selected species. Alternatively, the user may select a species by typing in a common name or a CAAB (Codes for Australian Aquatic Biota) number instead of a scientific name; then click '*Go*'. The user may also select genus, species, common name or the CAAB number from the drop–down menus located on the right hand side of each text box.

If a selected species does not contain any detailed information the user will be presented with a message box indicating there is no information, and prompts them to select a different species.

Choosing from the Species Covered window

Using this method, the user can quickly access the details for any of the primary species knowing that there will be data available. The list of species in the *Species Covered* window is 'hot-linked'. By clicking on a species, all relevant text boxes on the switchboard are automatically filled. The user then clicks the '*Go*' button', as before, to access the detailed species entry. If the species covered box is not visible in the window then it can be displayed by clicking on the *List of Species Covered* button.

Browsing and selecting from the taxonomic hierarchy tree

A full taxonomic tree of all species is available to users. With a single-click on the '*Browse/Select from the Species List*' button the taxonomic hierarchy is displayed (Figure 3). Navigating through the hierarchy, the user can find the species of interest then click on 'Select' to be returned to the switchboard with the appropriate fields populated.

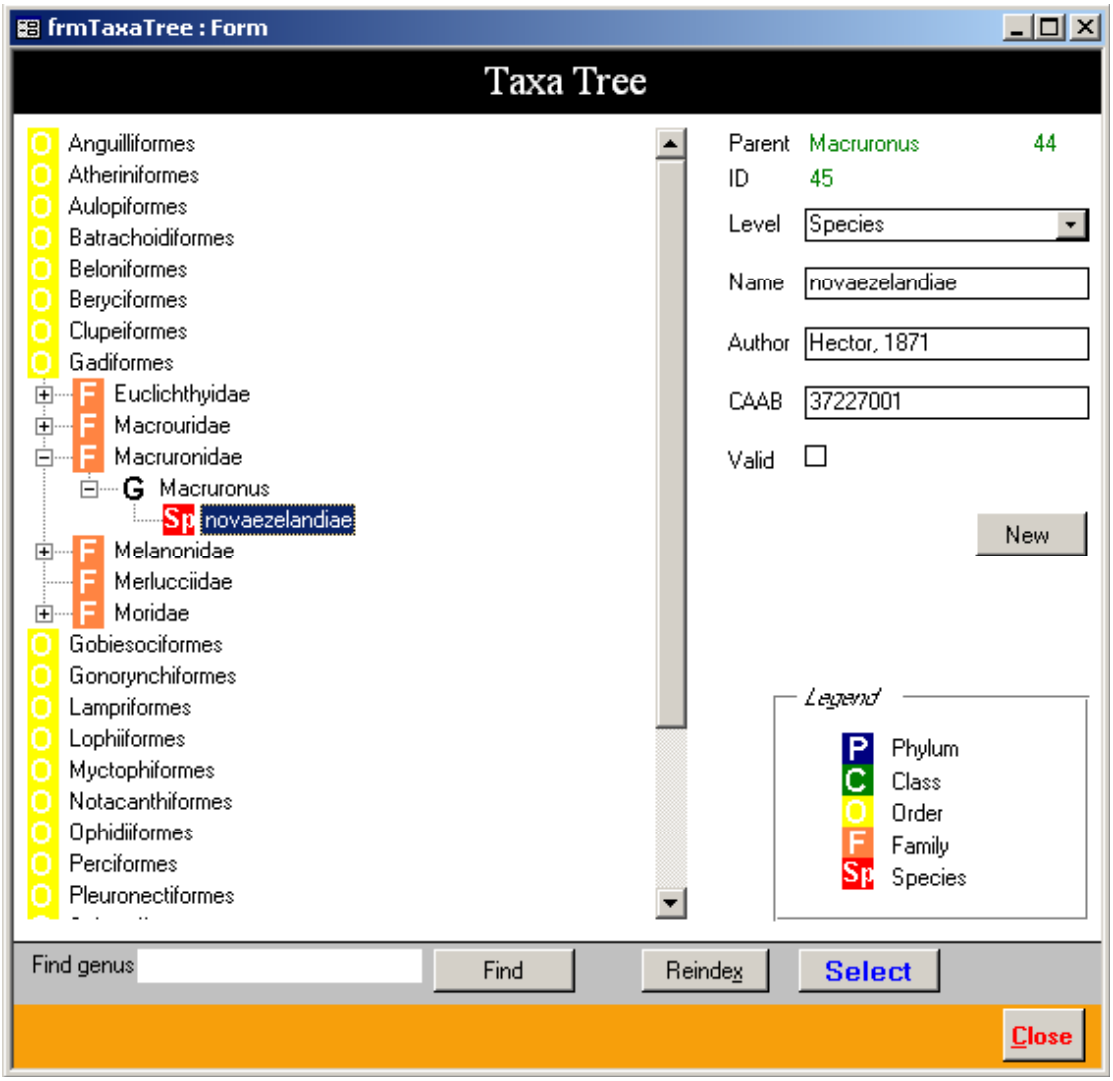


Figure 3: Selecting from the taxonomic tree

The user may also search for a particular genus of interest by using the *Find genus* box at the bottom of the page. The species within the target genus can then be selected from the taxonomic tree or the user may choose '*Select*' to be returned to the switchboard and choose the species from there.

In each case, once returned to the switchboard, the user must click on '*Go*' to proceed to the details for that species. Once again the same selection standards apply, that is the user is informed by message box if there are no data for the species selected.

The *Clear* button clears the selected species from the active text boxes in preparation for the next search. Alternatively, the user can just type in a new species and start the selection process again

Other switchboard features

Buttons below the Select Species box

Plot Multi Species Distributions

The LFD is primarily designed to allow a user to examine the details of one species at a time. However, there are times when the user may want to view the distribution of larvae of several species at the same time (Figure 4). A single click on the '*Plot Multi Species Distributions*' button will present the user with a window allowing the names of up to four species to be entered. The user enters the genus and species, as when using the switchboard, and clicks '*Go*' to view the distribution of the species selected. Each species is displayed as a standard sized, colour-coded dot which summarises data on presence/absence basis rather than standardised by volume filtered. The legend box identifies the colours assigned to each species. These dots have been staggered from their true latitude (±0.0001 degrees) and longitude (±0.00005 degrees) to allow the user to visualise the co-occurrence of species at the same station.

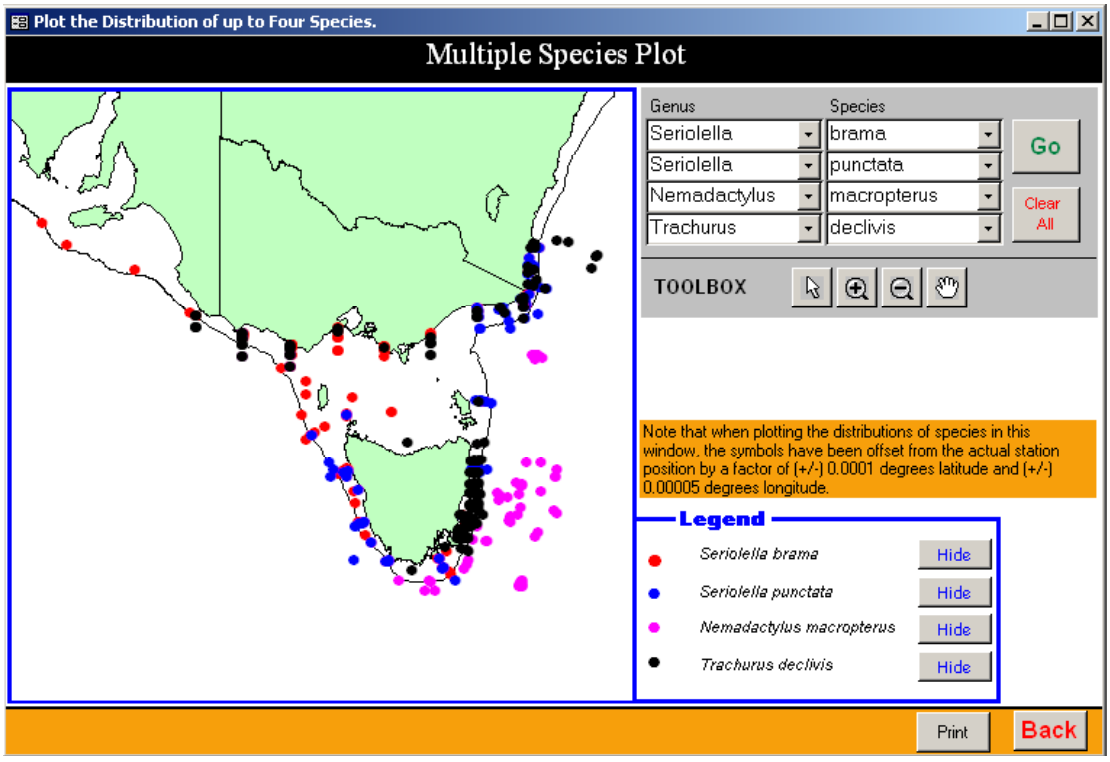


Figure 4: Plotting distributions via the multi-species plot option.

The user has control over the map window by using buttons located on the toolbox bar. These include *Select*, *Zoom-in*, *Zoom-out* and *Pan* tools (Figure 5).

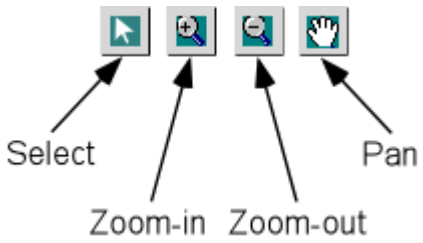


Figure 5: Map window controls

The *Select* tool allows the user to identify the sample from which the distribution data originates. Placing the *Select* arrow over a distribution point brings up a text box identifying the cruise code and station from which the data originates. These cruise codes and institution holding the data are listed in Appendix E.

The *Zoom-in* tool allows the user to zoom in on a selected area within the map window. The tool is activated by positioning it over an area in the window and using a single click of the right hand mouse button, or by holding down the right mouse button and drawing a box over the area to be zoomed to.

The *Zoom-out* tool allows the user to zoom out from the current map window view. The tool is activated by positioning it over an area in the window and using a single click of the right mouse button.

The *Pan* tool allows the user to reposition the view within the map window. The tool is activated by holding down the right mouse button and dragging the contents of the window to the desired view.

Legend box buttons

The legend box contains '*Hide*' and '*Refresh*' buttons that enable the user to toggle between viewing and hiding the distribution of the selected species. This provides an easy way to view the overlap of larval distributions.

Distribution data on secondary species (Table 3) are currently only accessible via multi species plots.

Glossary of Terms

The LFD includes definitions for various terms used in the summary pages. A single click on the '*Glossary of Terms*' button will bring up a searchable list of all terms in the glossary (Figure 6).

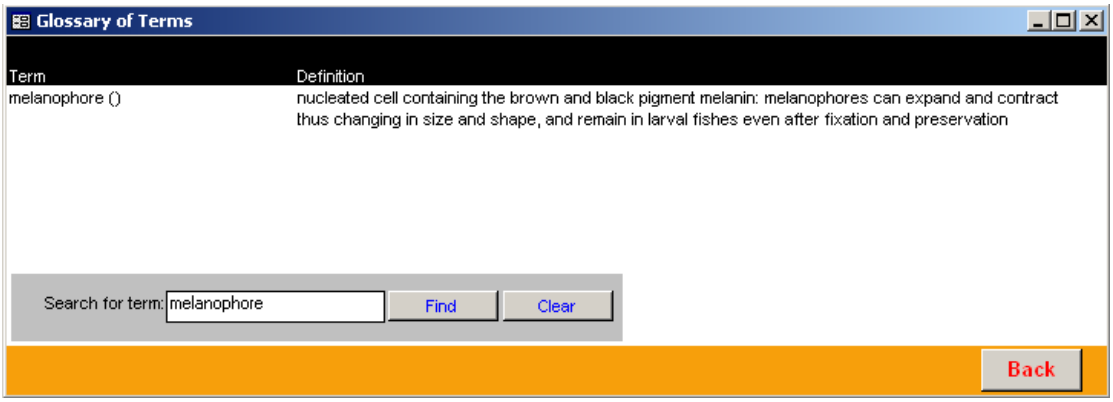


Figure 6: Searchable glossary of terms box (use melanophore as example)

The definition of a term listed in the glossary is also accessible when viewing data summary pages via a '*Glossary*' button located at the bottom of each page (see below). Definitions of terms can also be accessed by double-clicking on any term within database text boxes. Provided it is defined in the glossary, the definition of that term will appear in a '*Glossary*' text box (Figure 7).

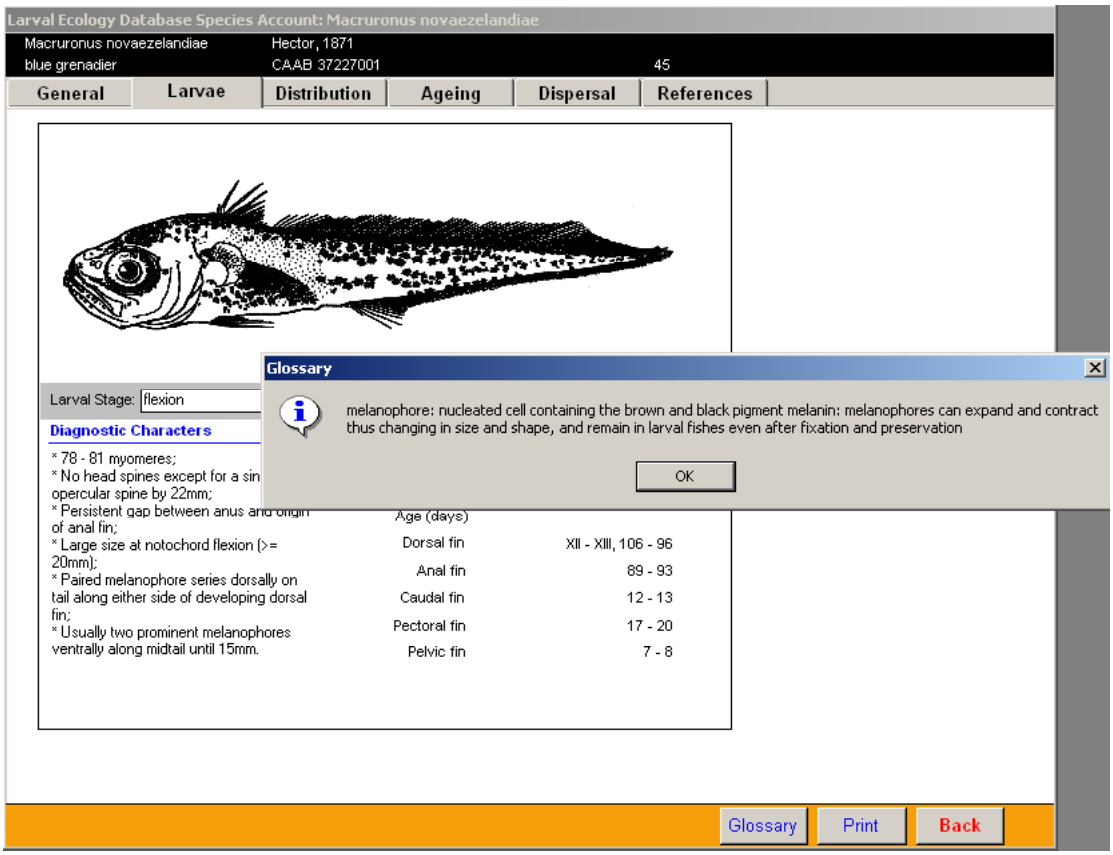


Figure 7: Activated glossary box while viewing data summary page

The user returns to the summary page by clicking on OK in the '*Glossary*' text box.

References

The LFD contains an extensive list of references on larval fish research. With a single-click on the *References* button the user will be presented with the full list of references (Figure 8).

This list is searchable by author name, reference title or keyword. The details of each reference may be viewed by clicking the reference and then a single-click on the *Details…* button.

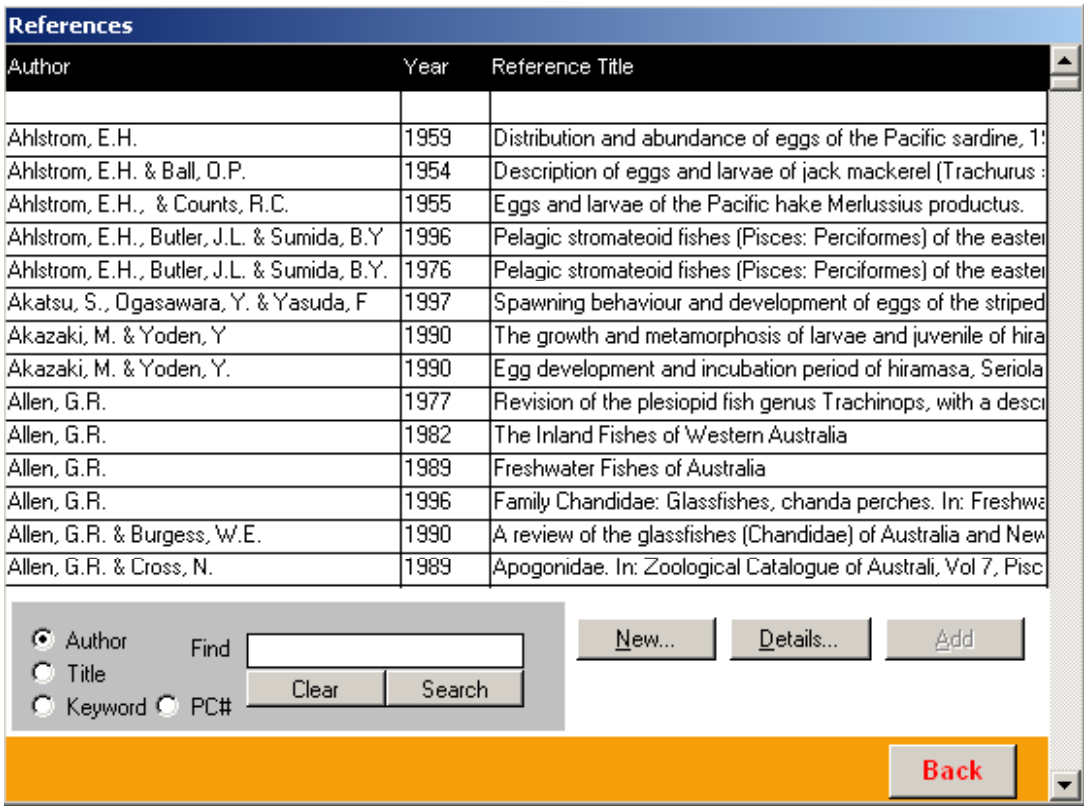


Figure 8: Searchable reference list.

Useful Tips

The '*Useful Tips*' window is opened when the database is first accessed. This window gives the user basic instructions on using the switchboard. However, once the details for a selected species have been accessed the '*Useful Tips*' window is closed and remains closed even if the user returns to the switchboard. The user can display the '*Useful Tips*' window by clicking on the button.

Species Covered

The list of primary species is located in a window labelled '*Species Covered*' to the right of the '*Useful Tips'* window. It is automatically opened when the database is first accessed. The list reappears whenever the user returns to the switchboard.

Close and Exit

This button allows the user to exit the LFD.

Database summary page windows

The primary features of the database are the species-specific data summary pages. The available windows are titled General, Larvae, Distribution, Ageing, Dispersal and References. The user can select a data summary page by clicking on its tab label below the black, species name bar. The contents and functionality of each summary page are detailed below using blue grenadier, *Macruronus novaezelandiae*, as an example (Figure 9).

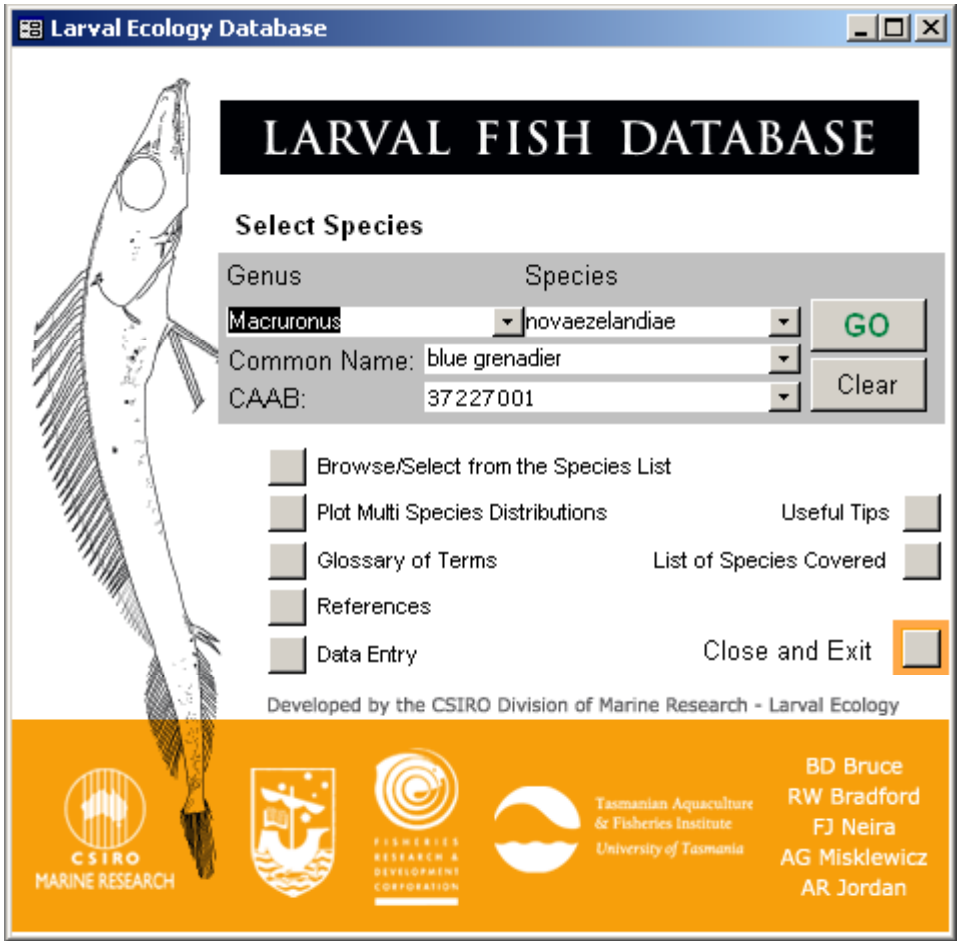


Figure 9: Larval Fish Database switchboard with *Macruronus novaezelandiae* (blue grenadier) selected.

The general features of each data summary page are a black, header bar featuring the scientific and common names of the selected species as well as its CAAB number and an orange footer bar featuring a '*Glossary*' button (which accesses the searchable glossary window) a '*Print'* button (which enables the user to print the page to their default printer) and the '*Back*' button which returns the user to the switchboard.

General summary page

The '*General*' summary page is the first window viewed when entering the detailed record for a species (Figure 10).

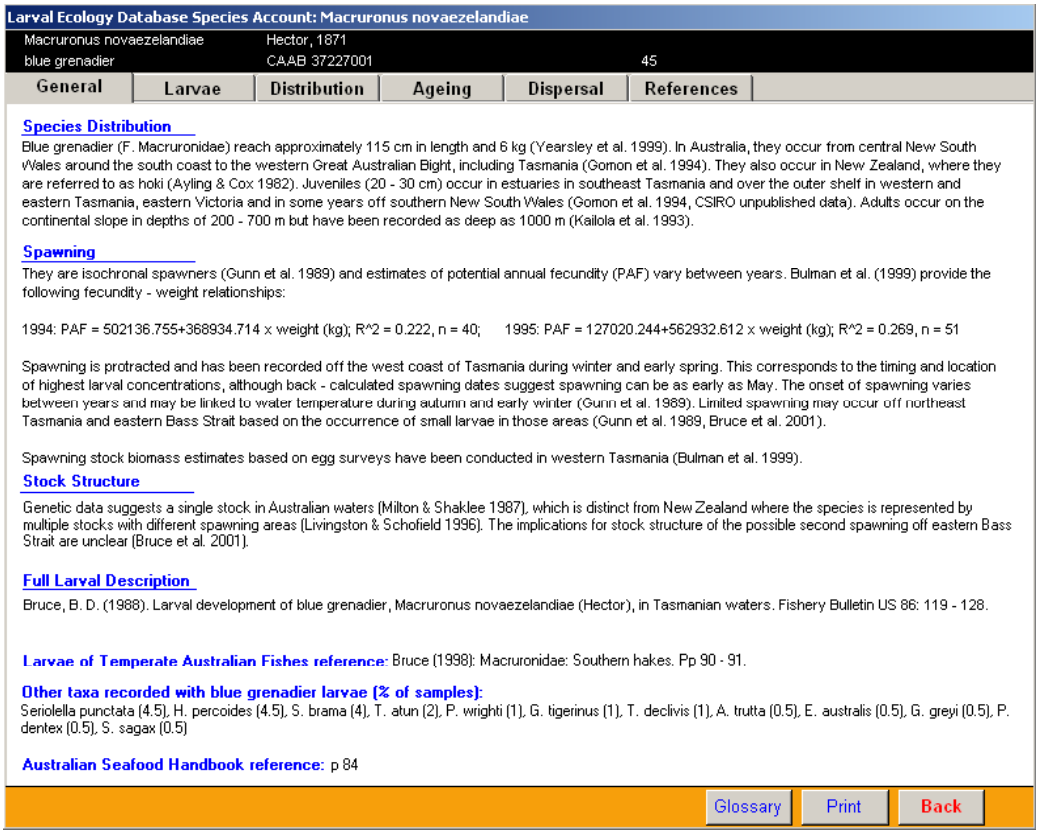


Figure 10: General summary page for blue grenadier

This general summary text is arranged under the following headings:

Species distribution

This provides basic information on size attained, distribution in Australian waters (and other regions if appropriate) and habitat notes for adults and juveniles.

Spawning

This provides information on the spawning mode and fecundity of the species, the reported location and timing of spawning, whether available larval data supports these and whether egg surveys might be a suitable means of estimating spawning stock biomass.

Stock structure

This provides information on stock structure and any implications from available larval data for its interpretation.

Full larval description

This provides reference details of a full larval description for the species if it exists.

Larvae of Temperate Australian Fishes reference

This provides the reference to where the species can be found (if covered) in Neira, F. J., Miskiewicz, A. G. and Trnski, T. (1998) The larvae of temperate Australian Fishes: A laboratory guide for larval fish identification. Uni WA Press Nedlands WA.

Australian Seafood Handbook reference

This provides the reference to where the species can be found (if covered) in Yearsley, G. K., Last, P. R. and Ward, R. D. (1999). Australian Seafood Handbook: An identification guide to Domestic Species. CSIRO Marine Research Hobart. 461 pp.

Other taxa recorded with blue grenadier larvae (% of samples)

This provides a list of species contained within the LFD whose larvae have been recorded in samples containing larvae of the selected (blue grenadier) species. The '% of samples' value was calculated by dividing the number of samples containing both taxa by the total number of samples containing blue grenadier larvae and converting into a percentage. For example, *Seriolella punctata* larvae occurred in 11 of the 246 samples (i.e. 4.5 %) containing blue grenadier larvae.

Larvae summary page

The '*Larvae*' summary page provides diagnostic larval characters for the selected species including a list of meristic characters specific to each listed larval stage (Figure 11). Images of the listed stages in larval development (e.g. preflexion, flexion, postflexion) can be selected and viewed via a drop–down menu located in the 'grey working' area.

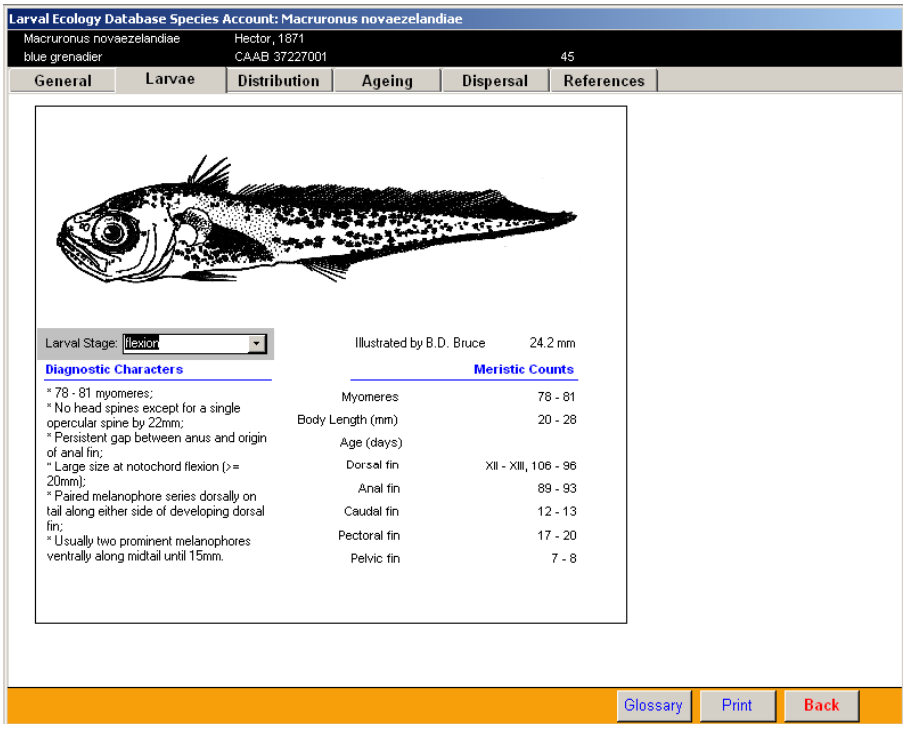


Figure 11: 'Larvae' summary page for blue grenadier.

Distribution summary page

The '*Distribution*' summary page enables the user to display the distribution of larvae based on all records contained within the database. There are three main areas to this page: the map display window, user controls (located within the grey working area) and the summary textbox (Figure 12).

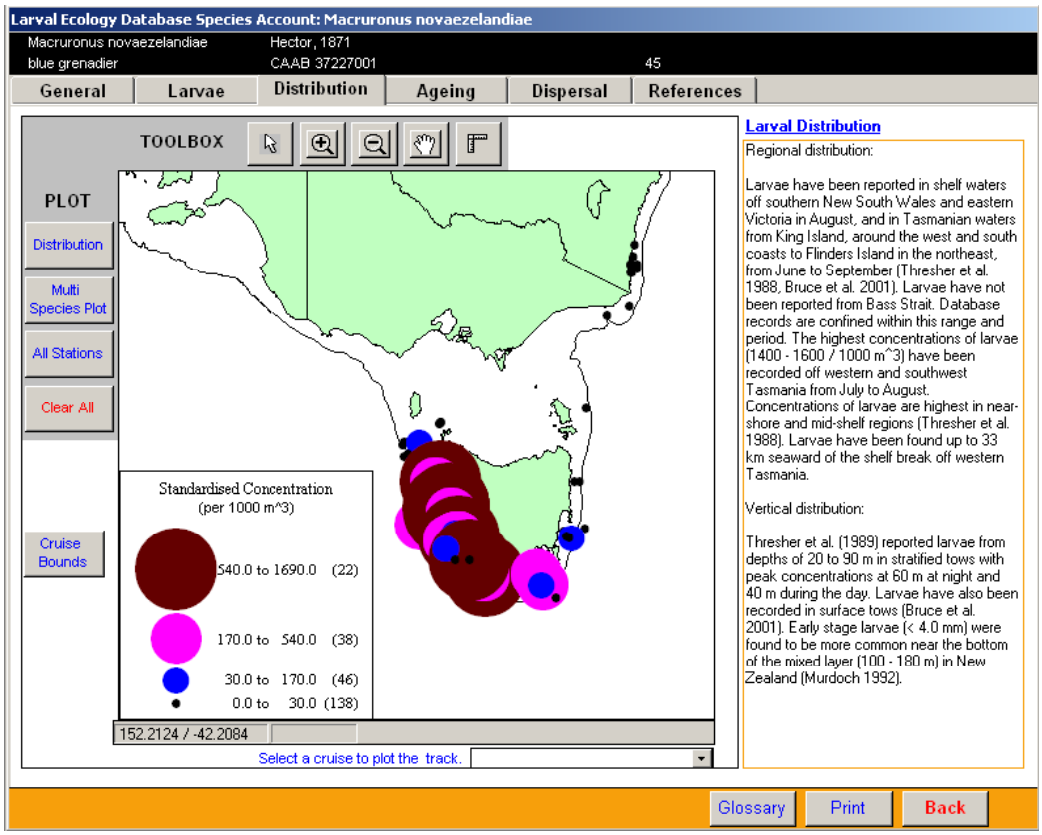


Figure 12: Distribution summary page for blue grenadier (note – with data plotted).

Map display window

The map display window allows the user to view larval distribution data for the target species. This window utilizes a map of Australia that, on default, only displays the southeast region (a geoset) of Australia. The user may zoom out to view a wider region of Australia. This geoset is a MapInfo MapX ActiveX component allowing for the display of spatial data. The base layer consists of the geoset of southeast Australia onto which the 200 m isobath has been applied as a separate layer. Distribution data are accessed via user control buttons and are applied as layers on top of this base.

User controls

User controls are contained within a grey working area and are subdivided into a set of buttons for plotting data (**Plot**) and for allowing the user to manipulate the window display (**Toolbox**).

*Using the **Plot** buttons*

Distribution: To view the larval distribution of the selected species, the user clicks on the '*Distribution*' button. This adds a thematic layer to the map window illustrating the standardised concentration of larvae by means of colour-coded, graduated dots. The values represented by the dots are presented in a legend box. Distribution data has been standardised to the numbers of larvae per 1000 m^3 (volume filtered) from original sampling records.

A 'Useful Tips' text box appears to the right of the map display window once the distribution data has been plotted. This provides brief instructions on the features of the distribution summary page.

Multi Species: The '*Multi-Species'* button allows the user to compare (on a presence-absence basis) the larval distribution of the selected species with the larval distributions of up to three other species. This is achieved by taking the user to the 'Plot Multi Species Distributions' page (as described in section x.x) but in this case, the selected species has already been loaded in one of the fields. Up to three additional species may be entered to compare their distributions with the selected species. The same toolbox options exist (*Select*, *Zoom-in*, *Zoom-out* and *Pan*) allowing the user to manipulate the window display.

All Stations: The '*All Stations*' button displays the location of all samples from which the LED may draw its information. This provides the user with an indication of total sampling effort.

Clear All: The '*Clear All*' button removes all layers except the base Australia map and the 200 m isobath.

*Using the **toolbox** buttons*

The toolbox provides a set of buttons that access tools that the user can choose to manipulate the map display. The tools are identical to those described in section x.x for *Plot multi-species distributions* (i.e. *Select*, *Zoom-in*, *Zoom-out* and *Pan*) but with the addition of a distance measuring tool or *Ruler* (Figure 13)

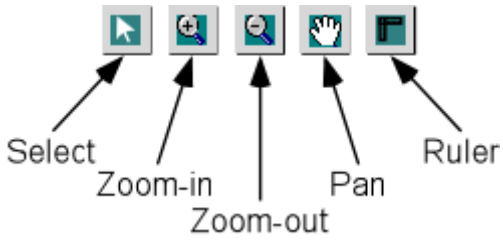


Figure 13. Toolbox buttons – distribution summary page.

The *Ruler* allows the user to measure distances (in kilometres) between any two points selected in the map window. The tool is activated by holding down the right mouse button on the point of origin and dragging the curser to the point whose distance from the origin is to be measured.

An additional feature also continuously displays the position of the curser (or tool) when within the map window. The position (decimal degrees) is provided at the bottom right of the map window (Figure 14).

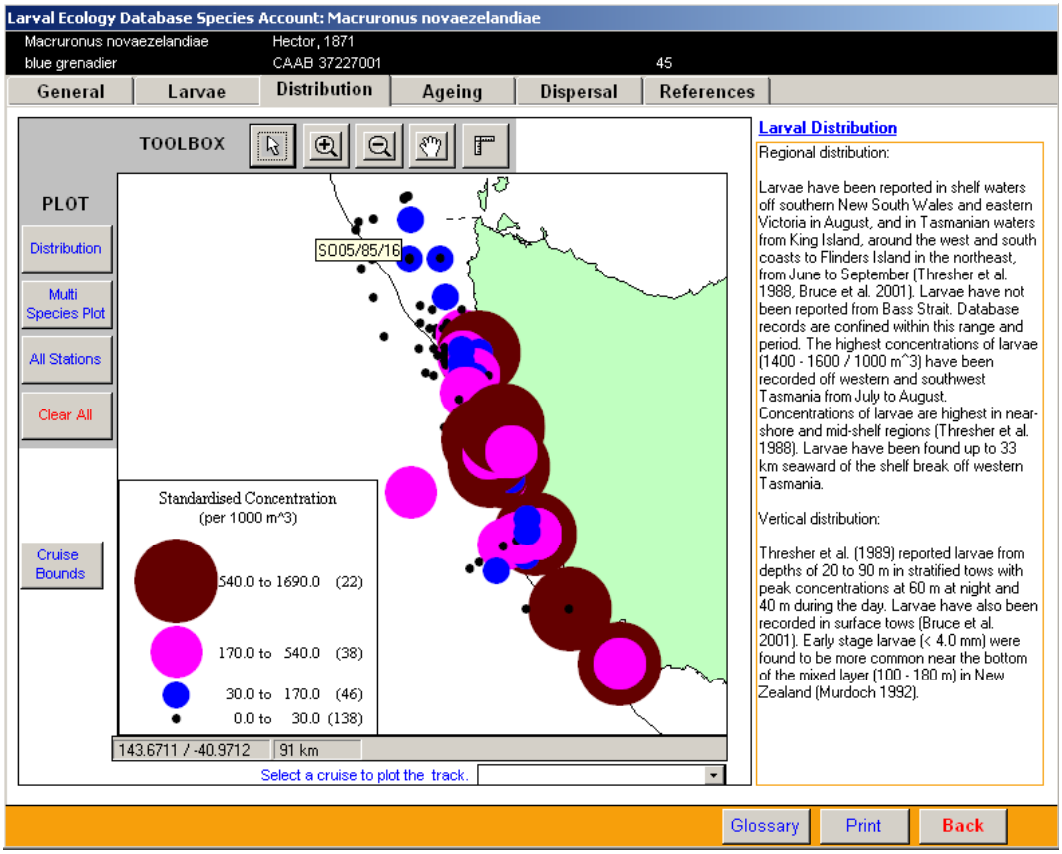


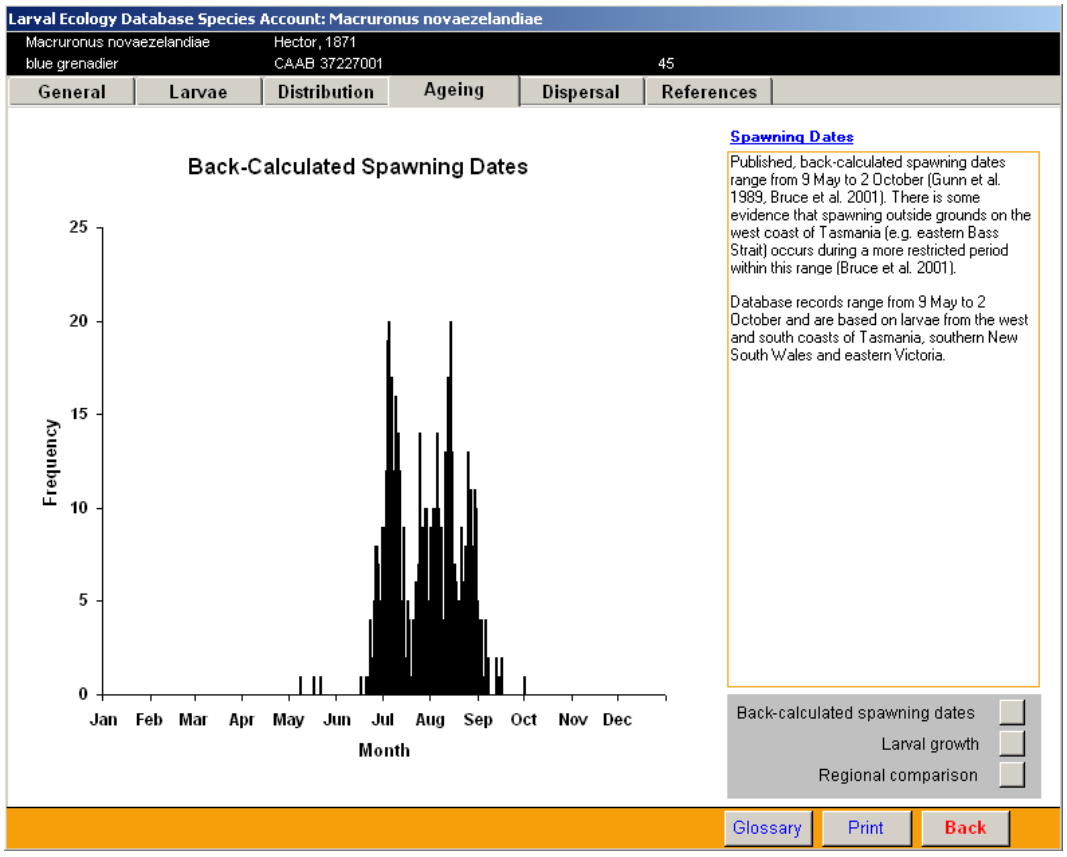
Figure 14: Zoomed view of blue grenadier distribution – west coast of Tasmania (sample S05/85/16 selected)

Summary text box

The summary textbox is labelled 'Larval Distribution' and provides a brief review of the published regional and vertical distributions of larvae including the time of year that larvae have been located and the maximum concentrations of larvae recorded. This review is updated to include any additional information arising from new data held within the database.

Ageing summary page

Selecting the 'Ageing' summary page allows the user to access two separate data summary views. The first details back-calculated spawning dates and the second provides a length – age plot. Both are based on data held within the LFD. There are three main areas to the ageing summary page: user controls (located within the grey working area), the data plot windows and the summary textboxes - specific to each data plot (Figure 15).



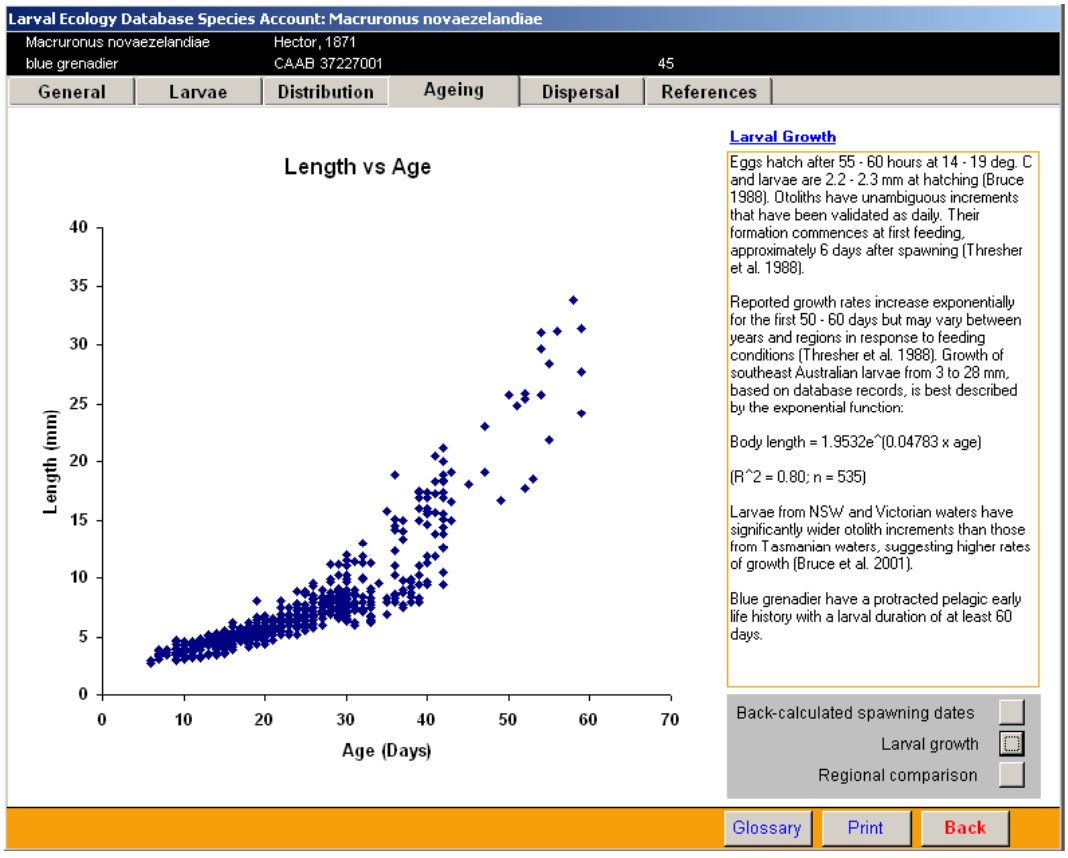


Figure 15. The ageing summary page for blue grenadier showing (a) back calculated spawning dates and (b) length – age plot.

User controls

User controls are contained within a grey working area and are subdivided into a set of buttons that will toggle between data plot windows and corresponding summary text boxes.

Back-calculated Spawning Dates button: This takes the user to the back-calculated spawning date window and its textbox.

Growth button: This takes the user to the back-calculated spawning date window and its textbox.

Regional comparison button: This displays length – age data on a regional basis (if available) using supplementary data (if available) that is not included in the database (Figure 16).

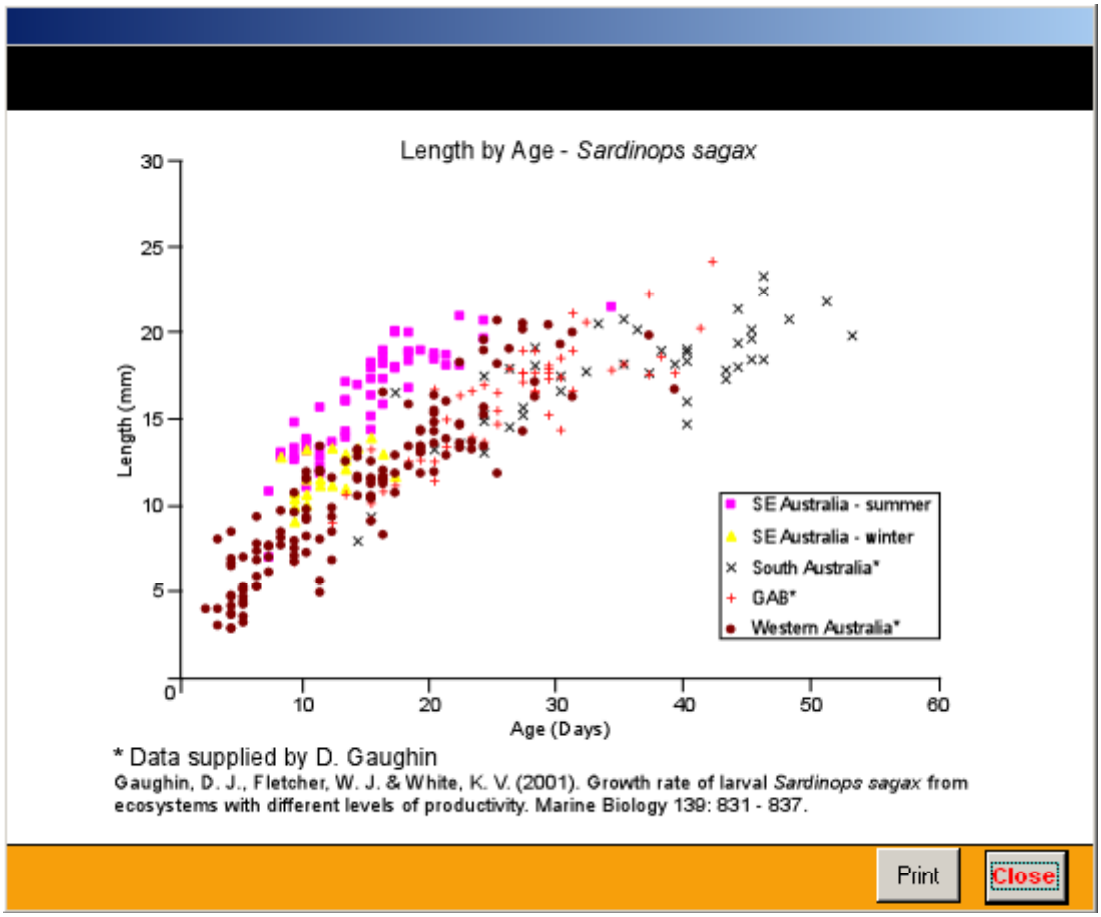


Figure 16: Regional comparison data for growth of larval pilchard (*Sardinops sagax*) incorporating data from Western Australia and South Australia.

Data plot windows

Back-calculated spawning date plot window

Back-calculated spawning dates are calculated within the LFD by subtracting the estimated age of individual larvae in days from their date of capture. The complete data set is figured as a spawning date histogram spanning a single 12 month period.

Summary textbox – Spawning Dates

The summary text box for this window is labelled ‘Spawning Dates’ and provides a brief review of published spawning dates and their regional variability. This review is updated to include any additional information arising from new data held within the database.

Growth data plot window

Length – age plots are figured as a scatter plot in this window.

Summary textbox – Larval Growth

The summary textbox for this window is labelled ‘Larval Growth’ and provides a brief review of embryonic development times and published growth rates. It provides a growth equation based on data held within the database for the selected species, comments on regional differences in growth and estimates of larval duration based on the oldest larvae recorded.

Dispersal summary page

The ‘Dispersal’ summary page displays an animation of the model output of larval dispersal (Figure 17). Animations are only available for the 10 species for which ageing data is held within the database. The model itself is not resident within the database, but rather, animation files have been loaded into the database that can be played to visualise modeled larval trajectories. The model structure and animation files are described in more detail in Appendix D. There are two main areas to the dispersal summary page: the animation window and the summary text box.

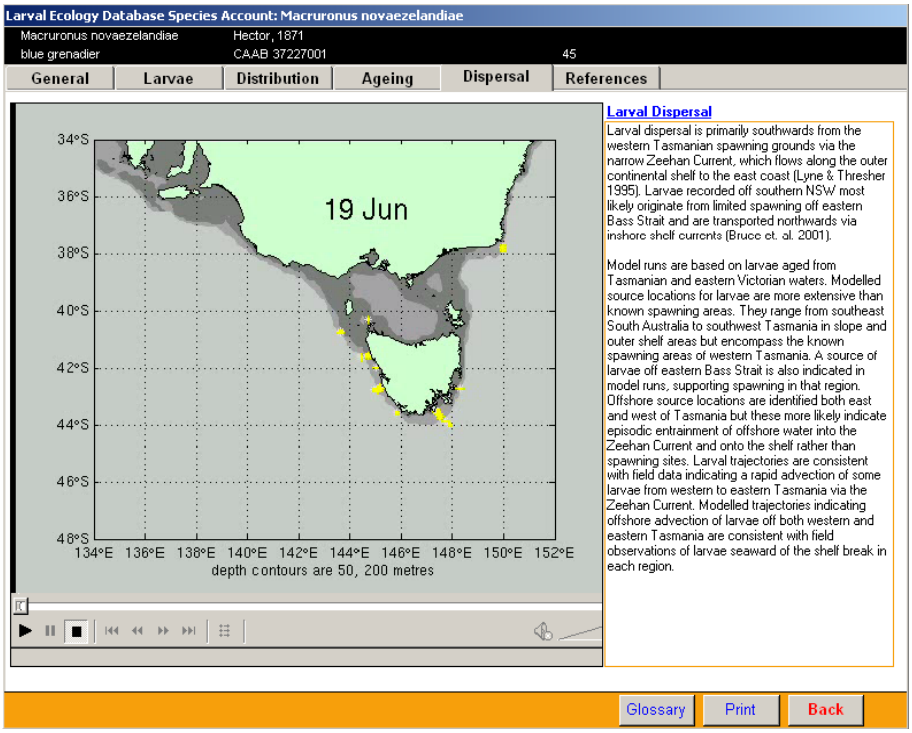


Figure 17: The dispersal summary page for blue grenadier.

Animation window

The animation window houses the animation display and user controls that allow the animation to be played, paused and stopped. Larval tracks are colour–coded. The capture locations of larvae from which the model simulations were derived are illustrated as a yellow asterisk. Predicted source locations (spawning sites) are shown in red. The particles (modeled larvae) are then tracked (in blue) for their nominated period of larval duration which in most cases has been set at 60 days. Particles are followed by a "tail" formed by joining their positions over the previous 5 days. Particles disappear from view after their nominated larval period. Animations feature a scrolling date field. This field commences on the day of the first back-calculated spawning date for the larvae used in generating the model output and concludes at the completion of larval duration for the last larva.

Summary textbox – Larval Dispersal

The summary textbox is labelled ‘Larval Dispersal’. It provides a brief review of larval dispersal patterns (if previously reported) and provides a brief explanation of the model output.

References summary page

The ‘References’ summary page lists those references within the LFD that specifically deal with the selected species (Figure 18). The reference list is featured in two sections, Book and book chapter references’ and ‘Journal articles’. The user can scroll through each list using the scroll bars on the right hand side of the window.

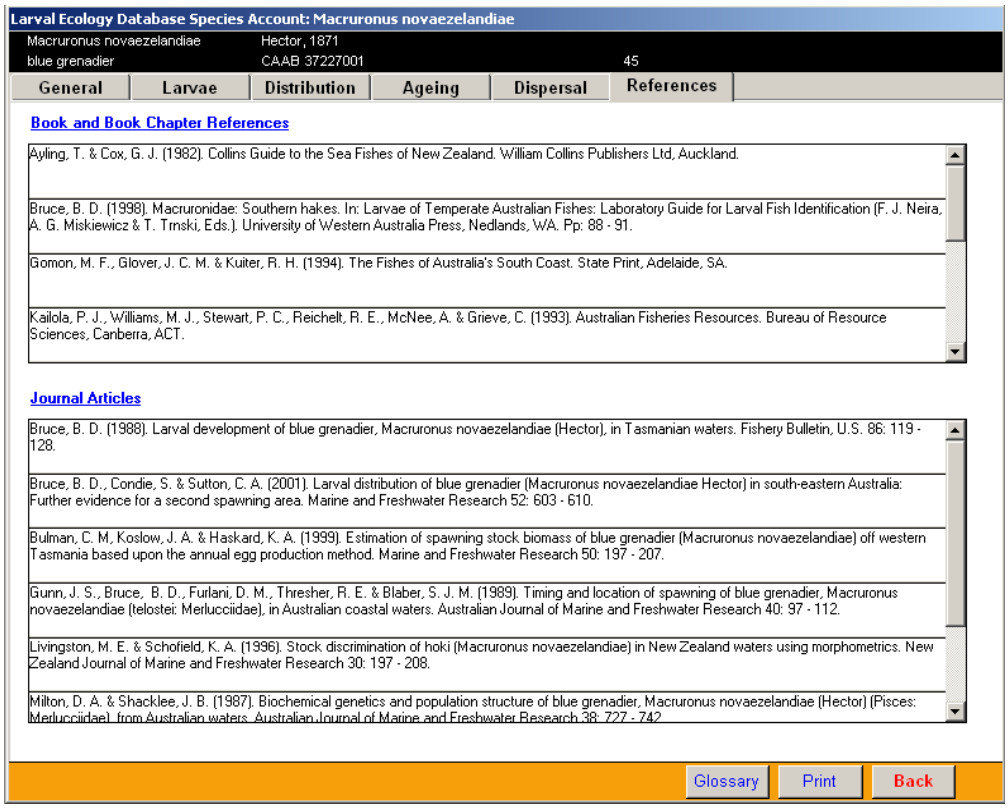


Figure 18: Reference summary page for blue grenadier

RESULTS

Full data summary page sets are displayed below for each primary species covered in the database. Secondary species are subsequently displayed as multi-species plots. Dispersal pages are printed showing only the combined source locations of larvae provided from the model output rather than complete larval trajectories.

Scientific outputs (manuscripts publishing species specific details from the database) are given in Appendix F.

Primary Species

Yellowfin bream (*Acanthopagrus australis*)

Acanthopagrus australis	Gunther, 1859	
yellowfin bream	CAAB 37353004	1212

Species Distribution

Yellowfin bream (F. Sparidae) reach approximately 55 cm in length and 4 kg (Rowland 1984, Yearsley et al. 1999). They are endemic to eastern Australia and occur from Townsville (Qld) south to the Gippsland Lakes (Vic) (Rowland 1984, West 1993, Gomon 1994). Post-larvae enter estuaries where they settle over seagrass beds (Pollock et al. 1983, Griffiths, 2001). Juveniles and adults occur in estuarine areas (Blaber & Blaber 1980). Adults commonly undertake spawning migrations to surf bars adjacent to estuaries (Pollock 1984), with some adults remaining on inshore reefs and around rocky headlands (Rowland 1984).

Spawning

Spawning mode and fecundity are unknown. They are protandrous with a proportion of the population changing sex from male to female following their first spawning season (Pollock 1984, Buxton & Garratt 1990).

Spawning is protracted, recorded throughout its range and is reportedly regionally variable in its timing (West 1993, T. Trnski, pers comm.). Spawning occurs in late autumn in southern and central NSW (State Pollution Control Commission 1981) and winter in Queensland where it peaks from July to August (Pollock 1982). The latter corresponds to the timing of highest larval concentrations in coastal waters of northern NSW. However, larvae have been recorded at all times of the year in NSW suggesting an even more protracted spawning period than reported. Spawning occurs within surf zones adjacent to estuaries (Pollock 1982, Pollock et al. 1983, Pollock 1984).

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown. Tagging studies, however, indicate that they are capable of migrating considerable distances; suggesting that a single stock of yellowfin bream exists at least between Tuggerah Lakes (central NSW) and Moreton Bay (Qld) (West 1993). Larvae occur throughout this area.

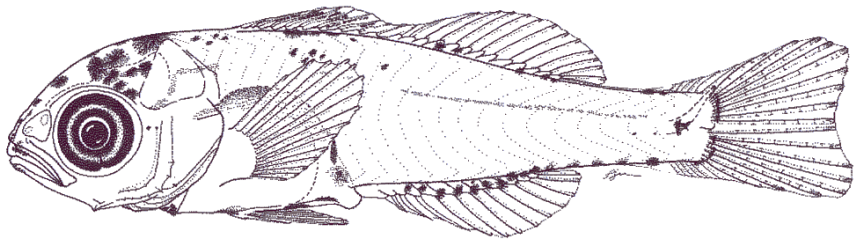
Full Larval Description

Larvae of Temperate Australian Fishes reference: Miskiewicz & Neira (1998): Sparidae: Breams, snappers. Pp 306 - 315.

Other taxa recorded with yellowfin bream larvae (% of samples):
E. australis (87), P. fuscus (70), P. saltatrix (60), S. sagax (50), G. greyi (33), P. auratus (33), T. novaezelandiae (33), S. ciliata (20), S. australasicus (17), S. flindersi (17), C. affinis (10), H. percoides (10), P. dentex (10), S. s. scomberoides (7), G. blacodes (3), L. caudatus (3), R. solandri (3), T. atun (3), T. declivis (3)

Australian Seafood Handbook reference: p 75

Acanthopagrus australis	Gunther, 1859	
yellowfin bream	CAAB 37353004	1212



Larval Stage: postflexion

Illustrated by F.J. Neira 8.8 mm

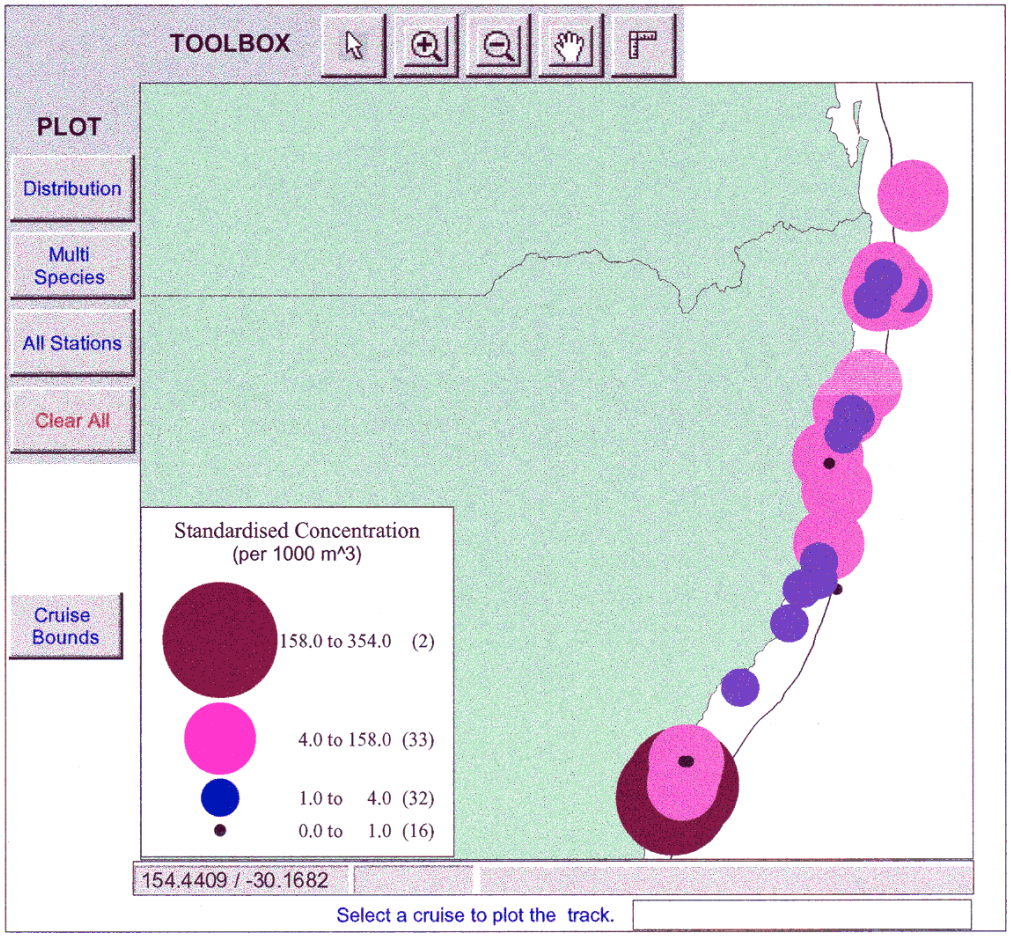
Diagnostic Characters

* 7-10 + 14-17 = 24 myomeres;
* Small anterior and posterior preopercular spines;
* 2 large melanophores on ventral surface of gut in preflexion and flexion larvae;
* 1-3 small melanophores under notochord tip.

Meristic Counts

Myomeres	24
Body Length (mm)	6 - 10
Age (days)	
Dorsal fin	X - XII, 10 - 13
Anal fin	III, 10 - 8
Caudal fin	17
Pectoral fin	14 - 16
Pelvic fin	1, 5

Acanthopagrus australis	Gunther, 1859	
yellowfin bream	CAAB 37353004	1212



Larval Distribution

Regional distribution:

Larvae have been reported entering Lake Macquarie (NSW) in all months of the year except November (Miskiewicz 1986, Miskiewicz 1987), entering Tuggerah Lakes (NSW) from January to May and September to October (Marsden 1986), and in shelf waters off Sydney (NSW) from November to July (Gray et al. 1992, Gray 1993). Database records range from Sydney (NSW) to southern Queensland from January to August. The highest concentration of larvae (354 / 1000 m^3) has been recorded in coastal waters off Sydney in February. Larvae occur throughout shelf waters and have been recorded up to 20 km seaward of the shelf break off southern Queensland.

Vertical distribution:

Gray et al. (1993, 2000) recorded the highest concentrations of larvae in the upper 30 m of the water column.

Acanthopagrus australis	Gunther, 1859	
yellowfin bream	CAAB 37353004	1212

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates	☐
Larval growth	☐
Regional comparison	☐

Acanthopagrus australis	Gunther, 1859	
yellowfin bream	CAAB 37353004	1212

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A. & Grieve, C. (1993). Australian Fisheries Resources. Bureau of Resource Sciences, Canberra, ACT.

Marsden, G. E. (1986). Fish larvae recruitment into Tuggerah Lakes. BSc (Hons.) Thesis. The University of New South Wales, Sydney, NSW.

Miskiewicz, A. G. (1986). The season and length at entry into a temperate Australian estuary of the larvae of Acanthopagrus australis, Rhabdosargus sarba and Chrysophrys auratus (Teleostei: Sparidae). In: Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes (T. Uyeno, R. Arai, T. Taniuchi & K. Matsuura, Eds.). Ichthyological Society of Japan, Japan. Pp: 740 - 747.

Miskiewicz, A. G. (1987). Taxonomy and ecology of fish larvae in Lake Macquarie and New South Wales coastal waters. PhD Thesis. The University of New South Wales, Sydney, NSW.

Miskiewicz, A. G. & Neira, F. J. (1998). Sparidae: Breams, snappers. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia, Nedlands, WA. Pp: 306 - 315.

Munro, I. S. R. (1944). The economic biology of the Australian black bream Roughleyia australis (Günther). MSc Thesis. The University of Queensland, Brisbane, Qld.

State Pollution Control Commission (SPCC) (1981). The ecology of fish in Botany Bay - Biology of commercially and recreationally valuable species. Government Printer, Technical Report BBS 23B, Sydney, NSW.

West, R. J. (1993). Estuarine fisheries resources of two south eastern Australian rivers. PhD Thesis. University of New South Wales, Sydney, NSW.

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

Journal Articles

Blaber, S. J. M & Blaber, T. G. (1980). Factors affecting the distribution of juvenile estaurine and inshore fish. Journal of Fish Biology 17: 143 - 162.

Buxton, C. D. & Garratt, P. A. (1990). Alternative reproductive styles in seabreams (Pisces: Sparidae). Environmental Biology of Fishes 28: 113 - 124.

Gray, C. A. (1993). Horizontal and vertical trends in the distribution of larval fishes in coastal waters off central New South Wales, Australia. Marine Biology 116: 649 - 666.

Gray, C. A., Otway, N. M., Laurenson, F. A., Miskiewicz, A. G. & Pethebridge, R. L. (1992). Distribution and abundance of marine fish larvae in relation to effluent plumes from sewage outfalls and depth of water. Marine Biology 113: 549 - 559.

Griffiths, S. P. (2001). Recruitment and growth of juvenile yellowfin bream, Acanthopagrus australis Gunther (Sparidae), in an Australian intermittently open estuary. Journal of Applied Ichthyology 22: 240 - 243.

Pollock, B. R. (1982). Spawning period and growth of yellowfin bream, Acanthopagrus australis (Günther) in Moreton Bay, Australia. Journal of Fish Biology 21: 349 - 355.

Pollock, B. R. (1984). Relations between migration, reproduction and nutrition in yellowfin bream Acanthopagrus australis. Marine Ecology Progress Series 19: 17 - 23.

Pollock, B. R., Weng, H. & Morton, R. M. (1983). The seasonal occurrence of postlarval stages of yellowfin bream, Acanthopagrus australis (Günther), and some factors affecting their movement into an estuary. Journal of Fish Biology 22: 409 - 415.

Rowland, S. J. (1984). Hybridization between the estuarine fishes yellowfin bream, Acanthopagrus australis (Günther), and black bream, A. butcheri (Munro) (Pisces: Sparidae). Australian Journal of Marine and Freshwater Research 35: 427 - 440.

Eastern Australian salmon (*Arripis trutta*)

Arripis trutta	Foster, 1801	
eastern Australian salmon	CAAB 37344002	1216

Species Distribution

Australian salmon (F. Arripidae) reach approximately 96 cm in length and 10.5 kg (Yearsley et al. 1999). In Australia, they occur from Brisbane (Qld) south to Port Phillip Bay (Vic) including Lord Howe and Norfolk islands and Tasmania (Gomon et al. 1994). They also occur in New Zealand where they are referred to as kahawai (Ayling & Cox 1982). Juveniles are also sometimes found in large schools over seagrass beds and in mangrove-lined creeks (Robertson 1982). Adults occur in shelf waters, commonly inhabiting surf zones, bays and estuaries to a depth of about 30 m.

Spawning

They are serial batch spawners (Stanley 1980). Fecundity is unknown.

Spawning has been recorded in late spring and through the summer between the Gippsland Lakes (Vic) and Bermagui (NSW) and its duration increases with distance north in this range (Stanley & Malcolm 1977). Spawning occurs off Eden from January to March and this corresponds to the location and timing of highest larval concentrations. However, the presence of larvae off Sydney and Tasmania suggests either transport of larvae away from this area via both inshore coastal currents and the EAC, or a more extensive spawning area.

Estimating spawning stock biomass via egg surveys has not been attempted but may be suitable if spawning is restricted to the reported southeast area.

Stock Structure

Genetic data suggests a single stock in eastern Australia (MacDonald 1983). The distribution of larvae is consistent with the known spawning region.

Full Larval Description

Neira, F. J., Miskiewicz, A. G. & Bruce, B. D. (1997). Larvae of five fish families with pattern 10 of the Ramus lateralis accessorius nerve (Arripidae, Girellidae, Kyphosidae, Microcanthidae and Scorpididae): relevance to relationships. Bulletin of Marine Science 60: 117 - 138.

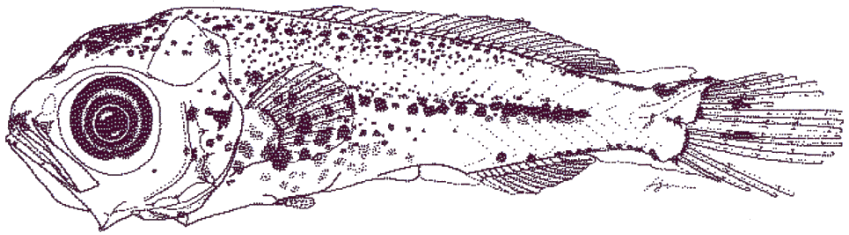
Larvae of Temperate Australian Fishes reference: Bruce et al. (1998): Australian salmons. Pp 180 - 183.

Other taxa recorded with eastern Australian salmon larvae (% of samples):

T. declivis (45), P. dentex (36), T. novaezelandiae (36), E. australis (27), C. australis (18), G. greyi (18), P. auratus (18), S. sagax (18), S. flindersi (18), C. affinis (9), M. novaezelandiae (9), N. richardsoni (9), P. bassensis (9), S. ciliata (9)

Australian Seafood Handbook reference: p 57

Arripis trutta Foster, 1801
eastern Australian salmon CAAB 37344002 1216



Larval Stage: postflexion

Illustrated by F.J. Neira 5.7 mm

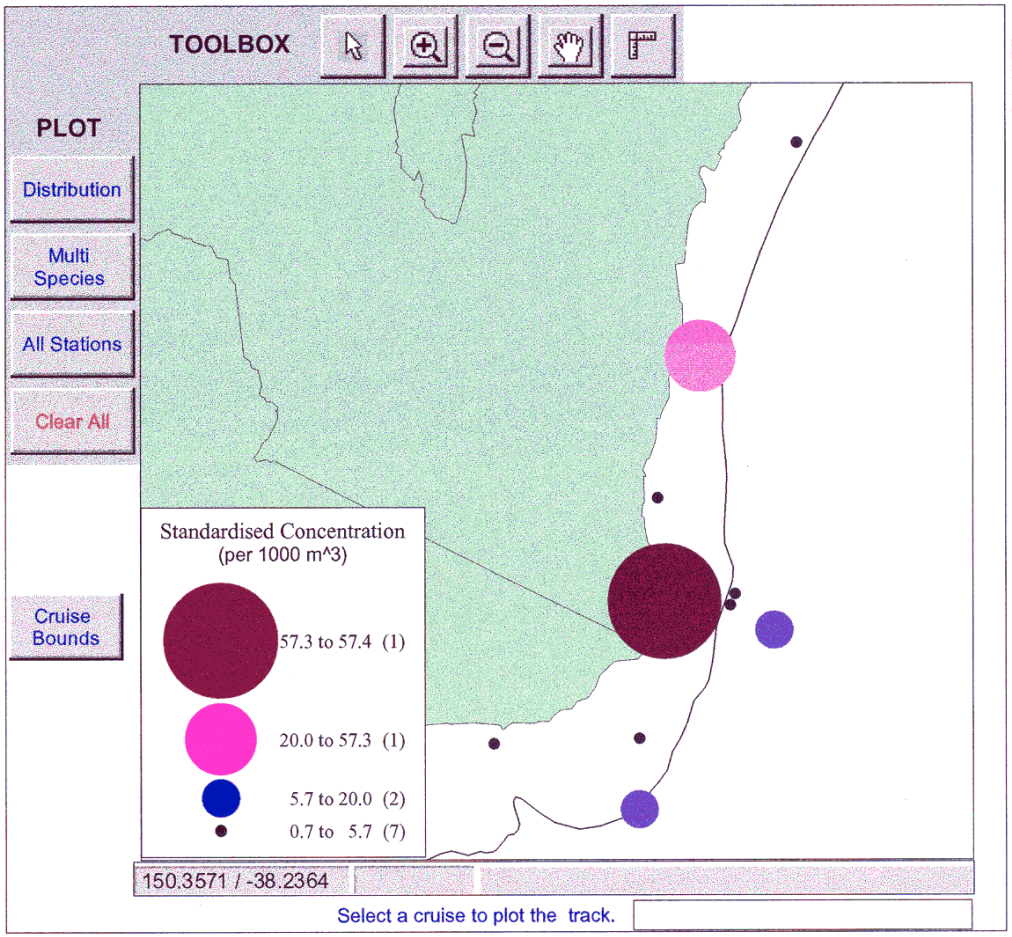
Diagnostic Characters

* 6-10 + 15-19 = 25-26 myomeres;
* Small preopercular spines by flexion stage;
* 5-6 internal melanophores along nape and anterior of trunk;
* 3-8 internal melanophores ventrally along posterior of notochord from late flexion stage, between postanal myomeres 15-23;
* Melanophores around notochord tip.

Meristic Counts

Myomeres	25
Body Length (mm)	5.7 - 8.3
Age (days)	
Dorsal fin	IX, 15 - 17
Anal fin	III, 10 - 9
Caudal fin	17
Pectoral fin	16 - 18
Pelvic fin	1, 5

Arripis trutta	Foster, 1801	
eastern Australian salmon	CAAB 37344002	1216



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off Sydney (NSW) from November to May (Gray 1995), and from shelf and offshore waters off eastern Tasmania between March and May (Bruce et al. 1998). Database records extend this distribution to include shelf and slope waters off southern NSW and eastern Victoria in January, February and May. The highest concentrations of larvae (up to 57 / 1000 m^3) have been recorded off southern NSW in February. Larvae occur throughout shelf waters and have been collected up to 23 km seaward of the shelf break off southern NSW.

Vertical distribution:

Unknown. However, most larvae have been recorded in surface tows and are likely to be neustonic.

Arripis trutta	Foster, 1801	
eastern Australian salmon	CAAB 37344002	1216

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates	☐
Larval growth	☐
Regional comparison	☐

Arripis trutta	Foster, 1801	
eastern Australian salmon	CAAB 37344002	1216

Book and Book Chapter References

Bruce, B. D., Neira, F. J. & Miskiewicz, A. G. (1998). Arripidae: Australian salmons. In: Larvae of Temperate Australian Fishes. Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz, & T. Trnski, Eds.). University of Western Australia, Nedlands, WA. Pp: 180 - 183.

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Gray, C. A. (1995). The influences of sewage plumes and oceanography on assemblages of larval fishes. PhD Thesis. The University of Sydney, Sydney, NSW.

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Paulin, C. D. (1993). Review of the Australasian fish family Arripididae (Percomorpha), with a description of a new species. Australian Journal of Marine and Freshwater Research 44: 459 - 471.

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Splendid perch (*Callianthias australis*)

Callanthias australis	Ogilby, 1899	
splendid perch	CAAB 37311055	682

Species Distribution

Splendid perch (F. Callanthiidae) reach approximatley 48 cm in length (Gomon et al. 1994). In Australia, they occur from Port Macquarie (NSW) to southwest of Shark Bay (WA) including Tasmania (Gomon et al. 1994, Trnski & Miskiewicz 1998). They also occur in New Zealand (Gomon et al. 1994). Juveniles and adults inhabit deep reefs at depths of 17 - 180 m (Gomon et al. 1994). They often seek the cover of caves and crevices at night and when disturbed (Anderson 1997).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has not been recorded but larvae are widely distributed in eastern Australia and occur from April to November suggesting a protracted spawning period.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown.

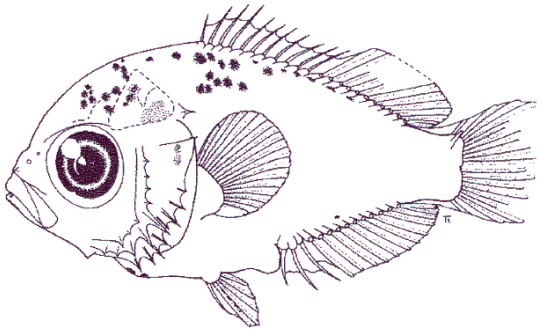
Full Larval Description

Larvae of Temperate Australian Fishes reference: Trnski & Miskiewicz (1998): Callanthiidae: Yellow-fin basses. Pp 189 - 191.

Other taxa recorded with splendid perch larvae (% of samples):
A. trutta (8), G. greyi (8), H. percoides (8), T. novaezelandiae (8), P. dentex (4), R. solandri (4), S. s. scomberoides (4), Seriolella punctata (4), T. declivis (4)

Australian Seafood Handbook reference: p [not included]

Callanthias australis	Ogilby, 1899	
splendid perch	CAAB 37311055	682



Larval Stage: postflexion

Illustrated by T. Trnski 6.7 mm

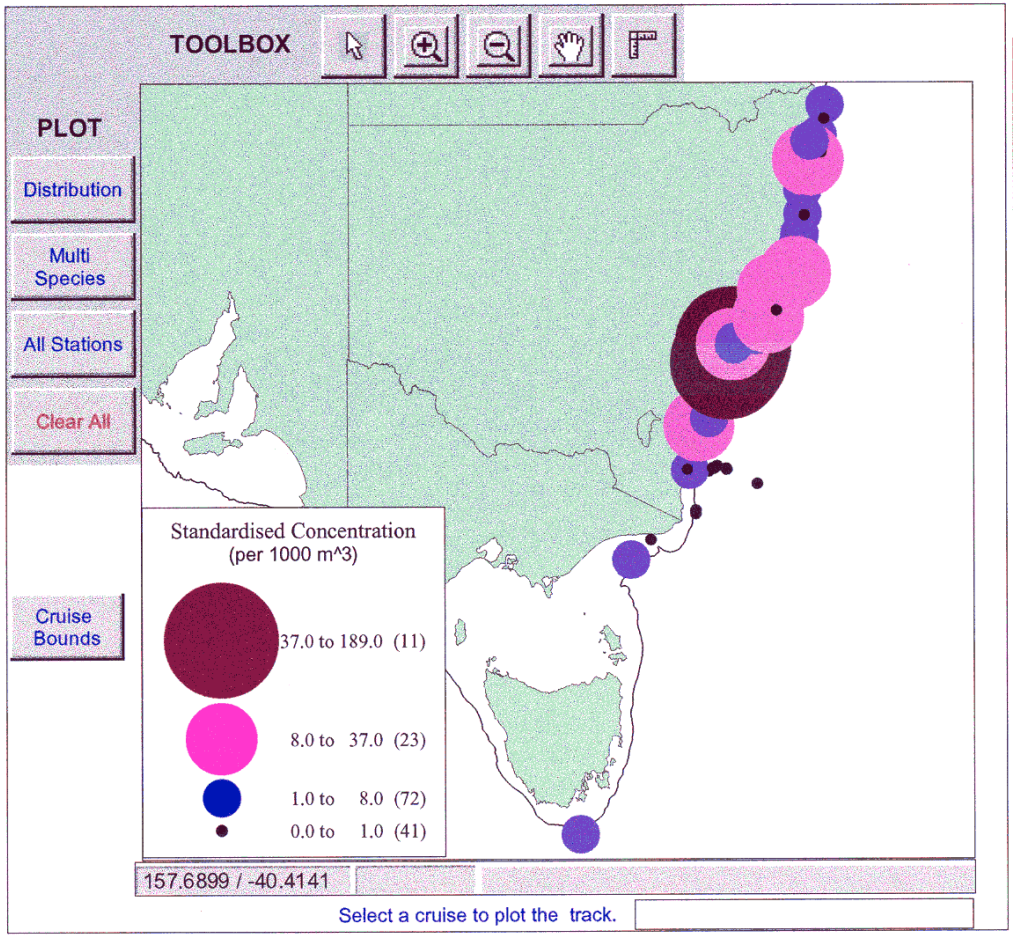
Diagnostic Characters

* 9-12 + 12-15 = 24 myomeres;
* Numerous large preopercular spines;
* One large supracleithral spine and several subopercular and interopercular spines;
* Scales form during flexion stage;
* Body lightly pigmented until flexion stage;
* Patch of pigment at tip of lower jaw.

Meristic Counts

Myomeres	24
Body Length (mm)	5.2 - 7.6
Age (days)	
Dorsal fin	XI, 10 - 12
Anal fin	III, 10 - 11
Caudal fin	17
Pectoral fin	18 - 23
Pelvic fin	1, 5

Callanthias australis	Ogilby, 1899	
splendid perch	CAAB 37311055	682



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off Sydney (NSW) between April and November (Gray 1993). Database records extend this distribution to include shelf and offshore waters off southern NSW / eastern Victoria in May, July and August, and off southern Tasmania in November. The highest concentrations of larvae (183 - 189 / 1000 m^3) have been recorded coastal waters off Sydney in April / May. Larvae occur across the shelf and slope, and have been recorded up to 150 km seaward of the shelf break off southern NSW.

Vertical distribution:

Unknown.

Callanthias australis splendid perch	Ogilby, 1899 CAAB 37311055	682

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Callanthias australis	Ogilby, 1899	
splendid perch	CAAB 37311055	682

Book and Book Chapter References

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Trnski, T. & Miskiewicz, A. G. (1998). Callanthiidae: Yellow-fin basses. In: Larvae of Temperate Australian Fishes. Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia, Nedlands, WA. Pp: 189 - 191.

Journal Articles

Gray, C. A. (1993). Horizontal and vertical trends in the distribution of larval fishes in coastal waters off central New South Wales, Australia. Marine Biology 116: 649 - 666.

Redfish (*Centroberyx affinis*)

Centroberyx affinis	Gunther, 1859	
redfish	CAAB 37258003	435

Species Distribution

Redfish (F. Berycidae) reach approximately 51 cm in length and 2 kg (Yearsley et al. 1999). In Australia, they occur from Moreton Bay (Qld) south to the western entrance to Bass Strait including northeast Tasmania (Gomon et al. 1994). They also occur in New Zealand, most commonly within northern waters (Paul 1986). Juveniles often school in the lower reaches of deeper estuaries and shallow coastal waters; adult fish similarly form large demersal schools in shelf and slope waters to a depth of about 500 m (May & Maxwell 1986, Rowling 1994, Chen et al. 1997, Miskiewicz et al. 1998).

Spawning

The spawning mode and fecundity are unknown.

Spawning has been recorded from late summer to autumn throughout their geographical range (Rowling 1994, Miskiewicz et al. 1998). This corresponds to the timing of highest concentrations of larvae in both northern and southern NSW. However, the period of larval occurrence (November to August) suggests a more protracted spawning period than reported.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown.

Full Larval Description

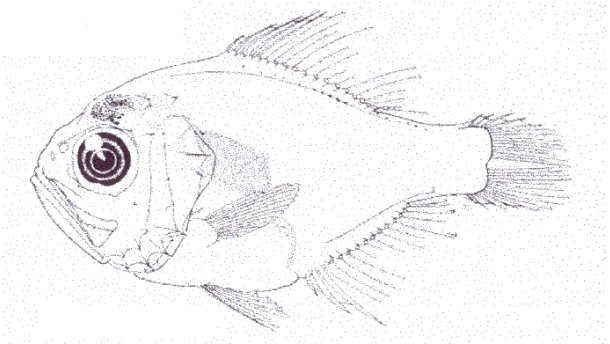
Larvae of Temperate Australian Fishes reference: Miskiewicz et al. (1998): Berycidae: Redfishes, nannygais, alfonsinos. Pp 104 - 107.

Other taxa recorded with redfish larvae (% of samples):

G. greyi (45), E. australis (36), S. sagax (33), P. fuscus (27), S. flindersi (24), P. auratus (15), T. novaezelandiae (15), P. dentex (12), A. australis (9), G. blacodes (9), P. saltatrix (9), S. ciliata (9), T. declivis (9), H. percoides (6), L. caudatus (6), R. solandri (6), S. australasicus (6), A. trutta (3)

Australian Seafood Handbook reference: p 210

Centroberyx affinis	Gunther, 1859	
redfish	CAAB 37258003	435



Larval Stage: late postflexion

Illustrated by T. Trnski 14.7 mm

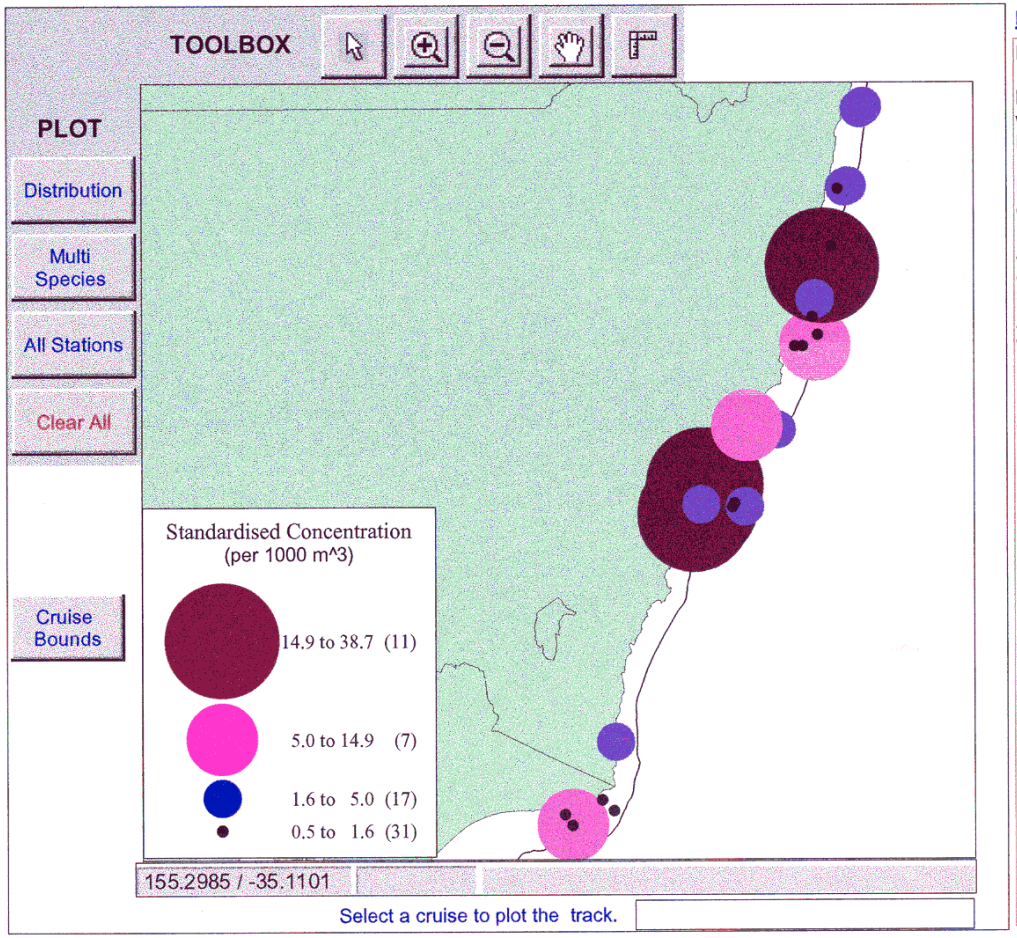
Diagnostic Characters

* 10-13 + 11-14 = 24-25 myomeres;
* Head spination from late flexion stage;
* Large, inflated gas bladder;
* Elongate, early forming pelvic-fin rays;
* Melanophores dorsally on head from late preflexion stage;
* 5 melanophores on ventral midline of posterior of tail in preflexion larvae, decreasing to 1 expanded melanophore in postflexion larvae.

Meristic Counts

Myomeres	24
Body Length (mm)	14.7
Age (days)	
Dorsal fin	VI - VII, 11 - 13
Anal fin	IV, 12
Caudal fin	19
Pectoral fin	13 - 14
Pelvic fin	1, 7

Centroberyx affinis Gunther, 1859
redfish CAAB 37258003 435



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off Sydney (NSW) between November and May (Gray et al. 1992, Gray 1993, Dempster et al. 1997, Smith 2000). Database records include shelf waters off eastern Victoria and southern NSW in February, and central to northern NSW from January to August. The highest concentration of larvae (39 / 1000 m^3) has been recorded coastal waters off Sydney in April / May. Larvae occur throughout shelf waters and have been recorded up to 25 km seaward of the shelf break off central NSW.

Vertical distribution:

Smith (2000) and Gray & Miskiewicz (2000) recorded the highest concentrations of larvae at 20 - 30 m in shelf waters off Sydney (NSW). Larvae show no indication of vertical migration (Smith 2000).

Centroberyx affinis	Gunther, 1859	
redfish	CAAB 37258003	435

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Centroberyx affinis	Gunther, 1859	
redfish	CAAB 37258003	435

Book and Book Chapter References

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Anchovy (*Engraulis australis*)

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225

Species Distribution

Anchovy (F. Engraulidae) reach approximately 16 cm in length and less than 0.1 kg (Yearsley et al. 1999). In Australia, they occur from Heron Island (Qld) around the south coast to the Swan Estuary (WA) including Tasmania and Lord Howe Island (Blackburn 1950, Gomon et al. 1994). They also occur in coastal waters of New Zealand (Gomon et al. 1994). Adult and juvenile anchovies are usually found in bays, inlets and estuaries (Ward et al. 2001). Fish more than 2.5 years old make regular migrations into open waters during winter, returning to more sheltered waters in spring (Arnott & McKinnon 1985).

Spawning

Their spawning mode and fecundity are unknown, however multiple spawning is common in other engraulids (Blaxter & Hunter 1982).

Spawning has been recorded throughout southern Australia from late spring to late summer or autumn with the period of spawning becoming more protracted further north (Blackburn 1950, Arnott & McKinnon 1985, Jenkins 1986, Hoedt & Dimmlich 1995). Year-round spawning has been recorded in northern NSW and southern Queensland (Blackburn 1950). The distribution of larvae and back - calculated spawning dates support widespread and protracted spawning.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning. However, eggs are readily identifiable.

Stock Structure

There are three populations, western, southeast and eastern Australia, which on further research may represent separate species (Blackburn 1950, Yearsley et al. 1999).

Full Larval Description

Miskiewicz, A. G. & Neira, F. J.: 54 - 57

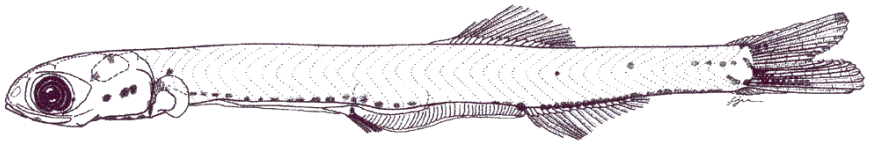
Larvae of Temperate Australian Fishes reference: Miskiewicz & Neira (1998): Engraulidae: Anchovies. Pp 54 - 57.

Other taxa recorded with anchovy larvae (% of samples):

S. sagax (55), G. greyi (29), P. fuscus (28), P. saltatrix (25), P. auratus (18), S. flindersi (16), T. novaezelandiae (16), A. australis (11), P. dentex (7), S. ciliata (7), T. declivis (7), S. australasicus (6), T. atun (6), C. affinis (5), G. blacodes (5), S. s. scomberoides (5), H. percoides (4), P. bassensis (3), R. solandri (2), L. caudatus (2), A. trutta (1), S. brama (1), S. bassensis (1), G. tigerinus (1), M. novaezelandiae (0.5), N. macropterus (0.5), P. wrighti (0.5), Seriolella punctata

Australian Seafood Handbook reference: p 145

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225



Larval Stage: Late postfelxion

Illustrated by F.J. Neira 20.3 mm

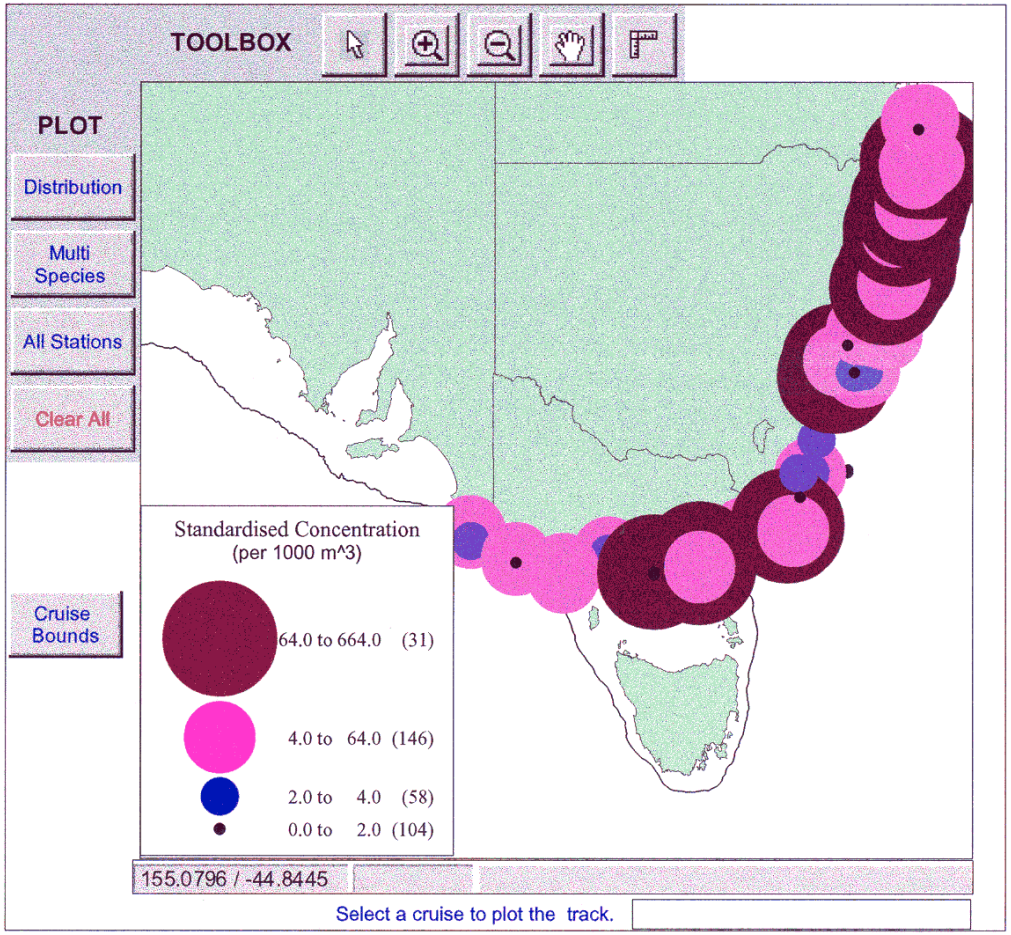
Diagnostic Characters

* 26-33 + 13-20 myomeres;
* Cross-hatched pattern of muscle fibres visible until 12mm;
* Anus migrates anteriorly from myomere 33 to 26 between 2.9 and 32.2mm;
* Posterior end of dorsal fin overlaps anterior end of anal fin by up to 3 myomeres;
* No melanophores along dorsal surface of hindgut prior to flexion stage.

Meristic Counts

Myomeres	40 - 48
Body Length (mm)	29
Age (days)	
Dorsal fin	13 - 18
Anal fin	17 - 19
Caudal fin	19
Pectoral fin	15 - 17
Pelvic fin	7

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225



Larval Distribution

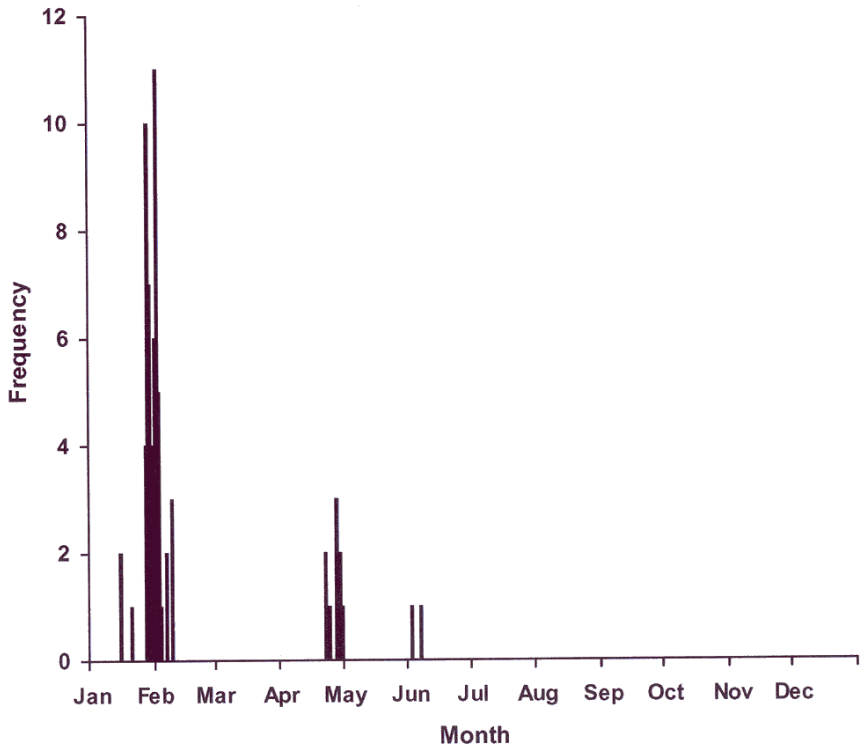
Regional distribution:

Larvae have been reported from estuarine and shelf waters in most months of the year (Miskiewicz & Neira 1998). Peak larval abundances have been recorded from the Swan and Nornalup-Walpole estuaries and Wilson Inlet (WA) from October to December (Gaughan et al. 1990, Neira & Potter 1992, 1994, Neira et al. 1992); Port Phillip Bay and Gippsland Lakes (Vic) in December (Arnott & McKinnon 1985, Jenkins 1986, Ramm 1986); Lake Macquarie, Tuggerah Lakes and in shelf waters off Sydney (NSW) from September to April (Marsden 1986, Miskiewicz 1987, Gray 1995). Database records range from southeast South Australia to southern Queensland (excluding Tasmania) from December to August. The highest concentrations (up to 664 / 1000 m^3) have been recorded off northern NSW in May. Larvae are widespread in shelf waters and have been recorded up to 110 km seaward of the shelf break.

Vertical distribution:

Gray et al. (1992) recorded similar concentrations of larvae between the surface and 20 m in shelf waters off Sydney (NSW), however, Gray & Miskiewicz (2000) recorded higher larval concentrations at 20 - 30 m than the surface.

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225



Spawning Dates

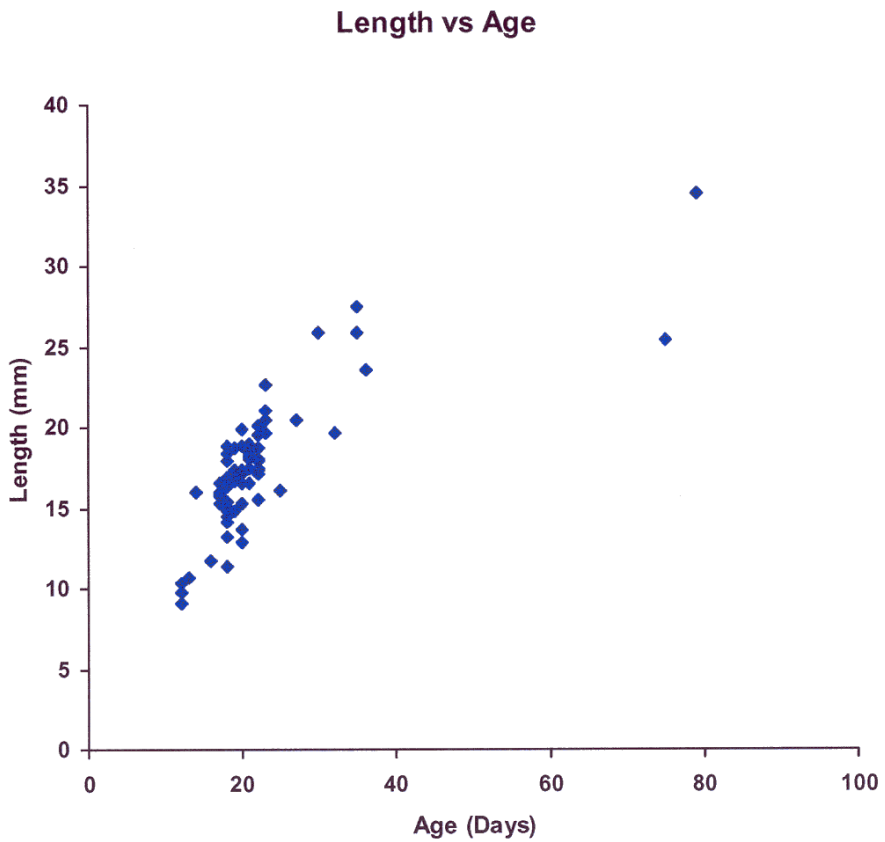
Database records range from 16 January to 7 June and are based on larvae from southern NSW and eastern Victoria.

Back-calculated spawning dates

Larval growth

Regional comparison

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225



Larval Growth

Otoliths have unambiguous increments that have been assumed to be daily.

Growth of southeast Australian larvae from 8 to 34 mm, based on database records, is best described by a von Bertalanffy growth function with parameters:

L (inf) = 35.587; k = 0.045; t(0) = 3.538

(R^2 = 0.76; n = 67)

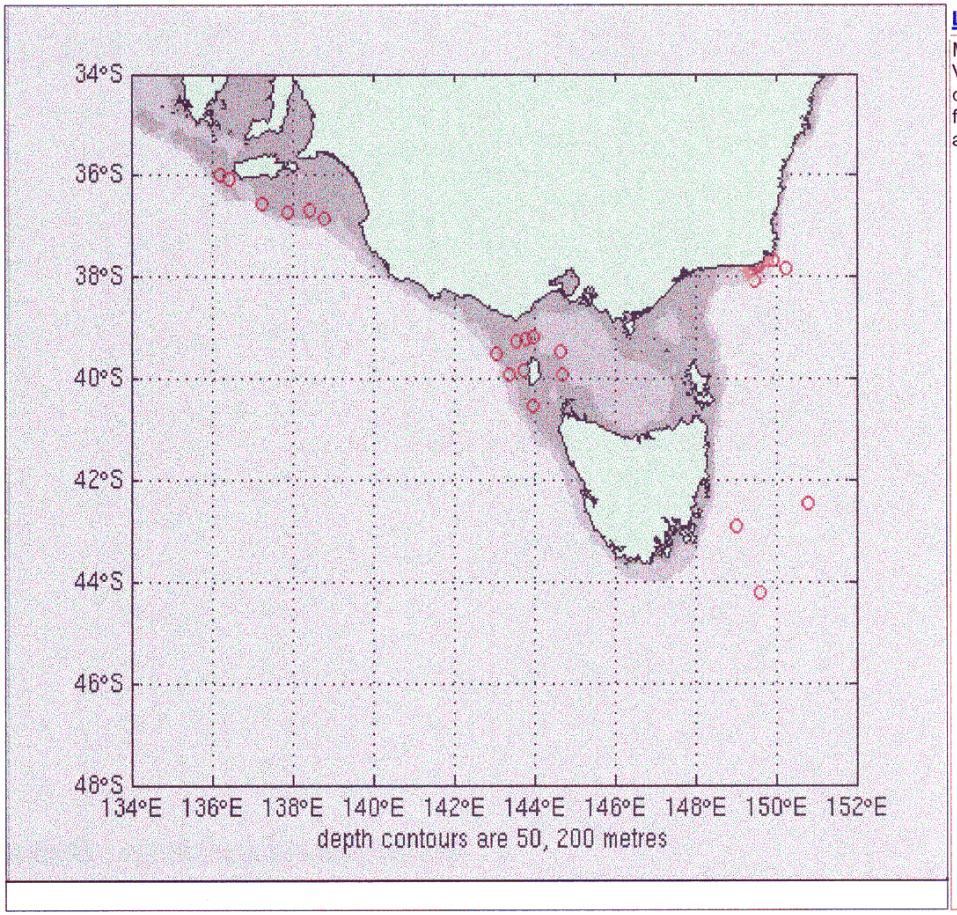
Anchovy have a larval duration of up to at least 80 days.

Back-calculated spawning dates

Larval growth

Regional comparison

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225



Larval Dispersal

Model runs are based on larvae aged from eastern Victoria. Modelled source locations are concentrated close to the capture locations. Too few sampling positions with aged larvae are available to fully assess larval dispersal processes.

Engraulis australis	White, 1790	
anchovy	CAAB 37086001	225

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Journal Articles

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Pink ling (*Genypterus blacodes*)

Genypterus blacodes	Forster, 1801	
pink ling	CAAB 37228002	414

Species Distribution

Pink ling (F. Ophidiidae) reach approximately 160 cm in length and 20 kg (Gomon et al. 1994, Yearsley et al. 1999). In Australia, they occur from Newcastle (NSW) around the south coast to Busselton (WA) including Tasmania (Gomon et al. 1994). They also occur in New Zealand and South America (Gomon et al. 1994). Juveniles are common over the shelf region, while adults generally occupy deeper waters to about 700 m (Furlani 1998).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has been recorded in late winter and early spring (Lyle & Ford 1993). This corresponds to the timing of highest larval concentrations off central and northern NSW. The distribution of larvae suggests this is an area of important spawning activity.

Egg surveys as a means of estimating spawning stock biomass have not been conducted but may be suitable off central and northern NSW.

Stock Structure

Genetic data do not suggest more than one stock. Larval distribution suggests a single spawning region in central and northern NSW.

Full Larval Description

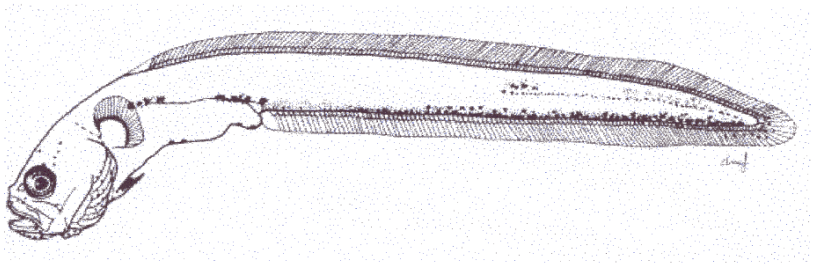
Larvae of Temperate Australian Fishes reference: Furlani (1998): Ophidiidae: Cusk eels, lings. Pp 80 - 85.

Other taxa recorded with pink ling larvae (% of samples):

H. percoides (58), S. sagax (52), R. solandri (35), S. australasicus (35), L. caudatus (31), P. auratus (23), E. australis (21), G. greyi (13), P. saltatrix (12), P. fuscus (10), S. flindersi (10), C. affinis (6), A. australis (2), P. dentex (2), T. atun (2), T. novaezelandiae (2), T. declivis (2)

Australian Seafood Handbook reference: p 160

Genypterus blacodes Forster, 1801
pink ling CAAB 37228002 414



Larval Stage: postflexion

Illustrated by D.M Furlani 15.6 mm

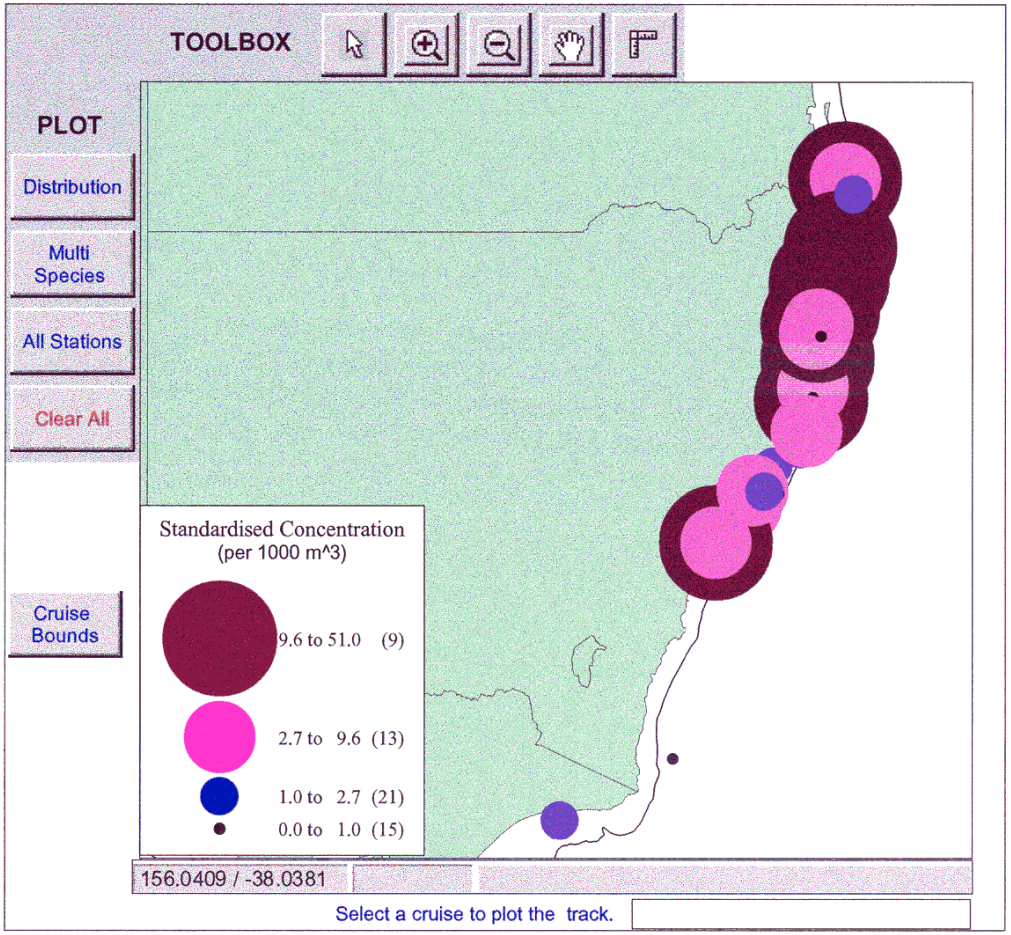
Diagnostic Characters

* 12-19 + 43-53 = 60-68 myomeres;
* Body elongate in postflexion larvae (BD 11-12%);
* Snout length typically < eye diameter;
* Series of melanophores along ventral midline of trunk and tail, single from isthmus to midbody, paired from midbody to caudal peduncle;
* No melanophores along dorsal midline of trunk and tail;
* Lateral midline pigment on posterior half of tail from 8mm.

Meristic Counts

Myomeres	68 - 70
Body Length (mm)	11.8 - 24
Age (days)	
Dorsal fin	140 - 154
Anal fin	105 - 114
Caudal fin	9
Pectoral fin	19 - 24
Pelvic fin	2

Genypterus blacodes	Forster, 1801	
pink ling	CAAB 37228002	414



Larval Distribution

Regional distribution:

Larvae have been reported from shelf and slope waters off NSW from July to September (Furlani 1998) and from coastal waters off Sydney (NSW) from April to August (Gray 1995). Records from Tasmanian waters (Furlani 1991) have been confirmed as G. tigerinus. Database records range from Sydney to southern Queensland from May to September, off southern NSW in August and off eastern Victoria in December. The highest concentrations of larvae (12 - 18 / 1000 m^3) have been recorded off northern NSW in July and August. Larvae are widely distributed in shelf waters and have been recorded up to 25 km seaward of the shelf break off Eden (NSW).

Vertical distribution:

Unknown.

Genypterus blacodes	Forster, 1801	
pink ling	CAAB 37228002	414

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Genypterus blacodes	Forster, 1801	
pink ling	CAAB 37228002	414

Book and Book Chapter References

Daley, R. K., Ward, R. D., Last, P. R., Reilly, A., Appleyard, S. A. & Gledhill, D. C. (2000). Stock delineation of the pink ling (Genypterus blacodes) in Australian waters using genetic and morphometric techniques. In: Fisheries Research and Development Corporation Project No. 97 / 117 (R. Daley, Eds.). Fisheries Research and Development Corporation, Canberra, ACT. Pp: 93.

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Furlani, D. M., Bruce, B. D., Gunn, J. S. & Thresher, R. E. (1991). Seasonal and spatial patterns of the distribution and abundance of larval fishes in Tasmanian coastal waters. In: Distribution and Seasonal Abundance and Dispersal Patterns of Commercially Important Finfish Species from Southern Australian Continental Shelf and Slope Waters. Fishing Industry Research & Development Council, Final Report No. 1988/71 (D. M. Furlani, Eds.).

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Gray, C. A. (1995). The influences of sewage plumes and oceanography on assemblages of larval fishes. PhD Thesis. The University of Sydney, Sydney, NSW.

Paul, L. J. (1986). New Zealand Fishes: An Identification Guide. Reed Methuen Press, Auckland.

Tilzey, R. D. J. (1994). Ling, Genypterus blacodes. In: The South East Fishery: A Scientific Review with Particular Reference to Quota Management (R. D. J. Tilzey, Eds.). Bureau of Resource Sciences, Canberra, ACT. Pp: 198 - 207.

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

Journal Articles

Lyle, J. M. & Ford, W. B. (1993). Review of trawl research 1979-1987, with summaries of biological information for the major species. Technical Report Department of Sea Fisheries, Tasmania 46: 1 - 169.

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Rock ling (*Genypterus tigerinus*)

Genypterus tigerinus	Klunzinger, 1872	
rock ling	CAAB 37228008	415

Species Distribution

Rock ling (F. Ophidiidae) reach approximately 120 cm in length and 9 kg (Yearsley et al. 1999). In Australia, they occur from Newcastle (NSW) around the south coast to Garden Island (WA) including Tasmania (Furlani 1998). They also occur in New Zealand. Juveniles are common over the shallow seagrass regions, while adults generally occupy caves and rocky recesses to about 60 m (Gomon et al. 1994).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has not been recorded but larvae are widely distributed in Tasmanian waters and eastern Victoria and southern NSW. Larvae have been recorded in most months of the year suggesting a protracted spawning period.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown. Larval distribution suggests widespread spawning in Tasmanian and eastern Victorian waters.

Full Larval Description

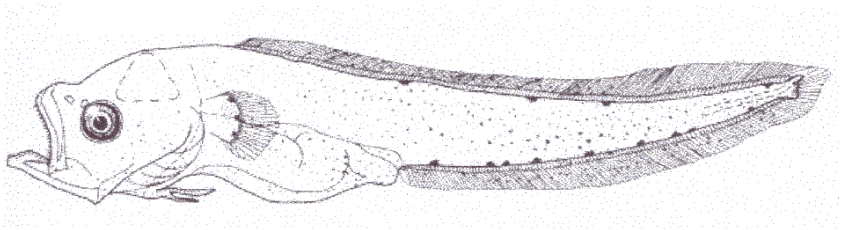
Larvae of Temperate Australian Fishes reference: Furlani (1998): Ophidiidae: Cusk eels, lings. Pp 80 - 85.

Other taxa recorded with rock ling larvae (% of samples):

H. percoides (37), T. atun (29), Seriolella punctata (28), S. brama (24), S. sagax (9), M. novaezelandiae (4), T. declivis (4), E. australis (3), P. dentex (3), P. wrighti (3), G. greyi (1), N. macropterus (1)

Australian Seafood Handbook reference: p 161

Genypterus tigerinus	Klunzinger, 1872	
rock ling	CAAB 37228008	415



Larval Stage: postflexion

Illustrated by D.M. Furlani 15.2 mm

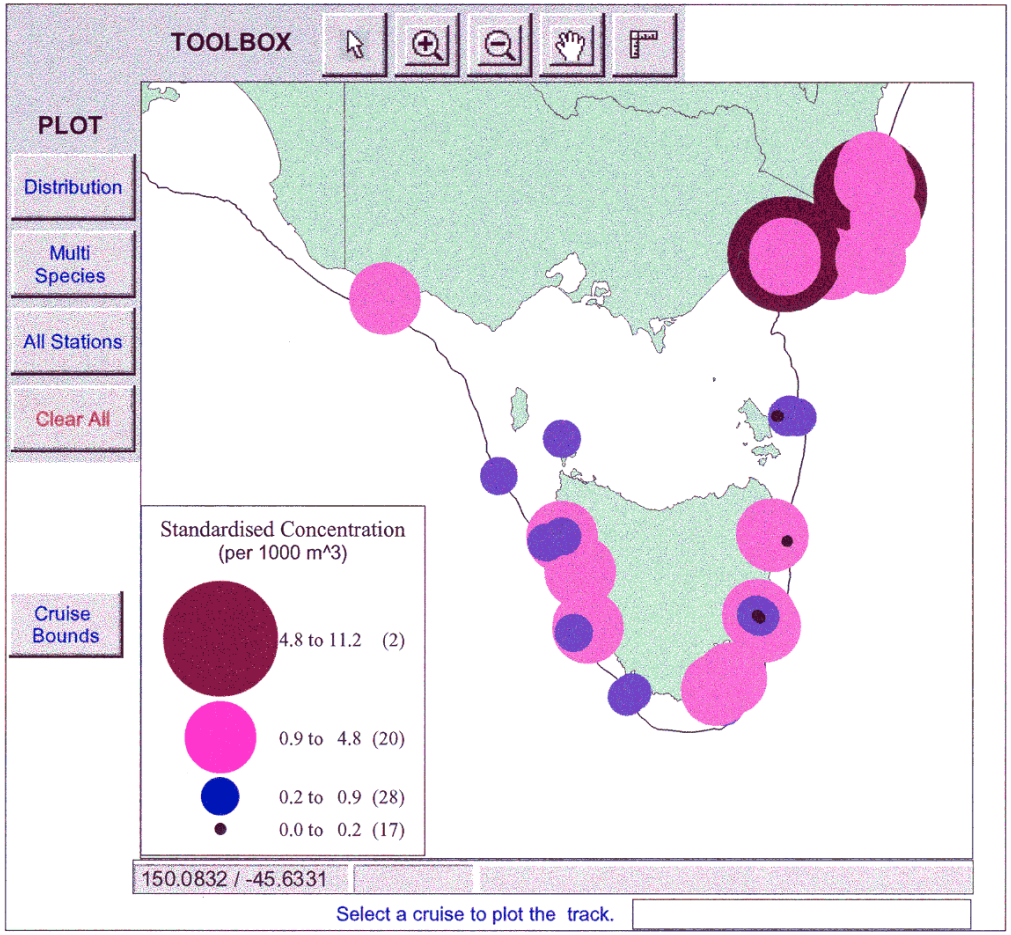
Diagnostic Characters

* 15-20 + 42-52 = 60-70 myomeres;
* Body elongate in postflexion larvae (BD 15-18%);
* Snout length >= eye diameter;
* Melanophores on ligament joining dentary and maxilla from 15mm;
* Pelvic fin pigmented from 12.3mm;
* Large melanophores scattered along dorsal and ventral midlines of tail.

Meristic Counts

Myomeres	68 - 70
Body Length (mm)	14.5 - 21
Age (days)	
Dorsal fin	144 - 162
Anal fin	107 - 118
Caudal fin	9
Pectoral fin	19 - 24
Pelvic fin	2

Genypterus tigerinus	Klunzinger, 1872	
rock ling	CAAB 37228008	415



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters around Tasmania (excluding Bass Strait) during spring and summer (Furlani 1998). Database records extend this distribution to include shelf waters off western Victoria from May to June, and eastern Victoria to southern NSW from July to December. They extend the period of occurrence in Tasmanian waters to include January to November. The highest concentrations of larvae (up to 11 / 1000 m^3) have been recorded off eastern Victoria and southern NSW. Larvae are widespread in shelf waters but have not been recorded seaward of the shelf break.

Vertical distribution:

Unknown.

Genypterus tigerinus	Klunzinger, 1872	
rock ling	CAAB 37228008	415

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Genypterus tigerinus	Klunzinger, 1872	
rock ling	CAAB 37228008	415

Book and Book Chapter References

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Gordon, D. J., Markle, D. F. & Olney, J. E. (1984). Ophidiiformes: development and relationships. In: Ontogeny and Systematics of Fishes. American Society of Ichthyologists and Herpetologists. Special Publication No. 1 (H. G. Moser, W. J. Richards, D. M. Cohen, M. P. Fahay, A. W. Kendall Jr. & S. L. Richardson, Eds.). Allen Press Inc, Lawrence, Kansas. Pp: 308 - 319.

Last, P. R., Scott, E. O. G. & Talbot, F. H. (1983). Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart, Tas.

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Okiyama, M. (1988). Ophidiidae. In: An Atlas of the Early Stage Fishes in Japan (M. Okiyama, Eds.). Tokai University Press, Tokyo. Pp: 335 - 341.

Paxton, J. R. & Hanley, J. E. (1989). Ophidiidae. In: Zoological Catalogue of Australia, Vol. 7, Pisces: Petromyzontidae to Carangidae (J. R. Paxton, D. F. Hoese, G. R. Allen & J. E. Hanley, Eds.). Australian Government Publishing Service, Canberra, ACT. Pp: 310 - 314.

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Ambrose, D. A., Butler, J. L., Moser, H. G., Sumida, B. Y., Sandkop, E. M. & Stevens, E. G. (1983). Description of the larvae of the cusk-eels Ophidion scrippsae and Chilara taylori (Ophidiidae). California Cooperative Oceanic Fishery Investigations Report 24: 226 - 234.

Brownell, C. L. (1979). Stages in the early development of 40 marine fish species with pelagic eggs from the Cape of Good Hope. Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology 40: 1 - 84.

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Beaked salmon (*Gonorynchus greyi*)

Gonorynchus greyi	Richardson, 1845	
beaked salmon	CAAB 37141001	227

Species Distribution

Beaked salmon (F. Gonorhynchidae) reach approximately 50 cm in length (Gomon et al. 1994). In Australia, they occur from Brisbane (Qld) around the south coast to Rottnest Island (WA), including Tasmania and Lord Howe Island (Gomon et al. 1994). They also occur in New Zealand (Last et al. 1983, Bruce 1998). Juveniles are pelagic in the open ocean (Last et al. 1983). Adults are found over sandy substrates to depths of about 160 m, occasionally being found within estuaries (Last et al. 1983).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has not been recorded, although Smith (2000) suggested that multiple spawning events occurred in January and April. Larvae are widely distributed and have been recorded from January to August, but the highest concentrations occur in central and northern NSW suggesting this is an area of important spawning activity.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown. Larval distribution suggests widespread spawning and larval dispersal in eastern Australia.

Full Larval Description

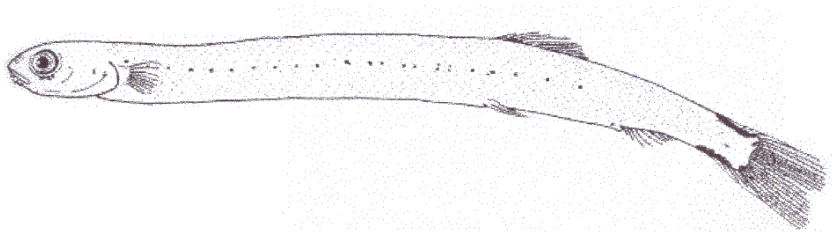
Larvae of Temperate Australian Fishes reference: Bruce (1998): Gonorhynchidae: Beaked salmons. Pp 60 - 63.

Other taxa recorded with beaked salmon larvae (% of samples):

E. australis (36), P. saltatrix (21), S. sagax (21), T. novaezelandiae (18), S. s. scomberoides (16), P. fuscus (13), C. affinis (8), P. dentex (7), A. australis (5), P. auratus (5), S. ciliata (4), G. blacodes (4), S. flindersi (4), H. percoides (3), S. australasicus (3), R. solandri (2), T. declivis (2), A. trutta (1), C. australis (1), L. caudatus (1), G. tigerinus (0.5), M. novaezelandiae (0.5), P. wrighti (0.5), S. brama (0.5), Seriolella punctata (0.5)

Australian Seafood Handbook reference: p [not included]

Gonorynchus greyi	Richardson, 1845	
beaked salmon	CAAB 37141001	227



Larval Stage: late postflexion

Illustrated by B.D. Bruce 32.8 mm

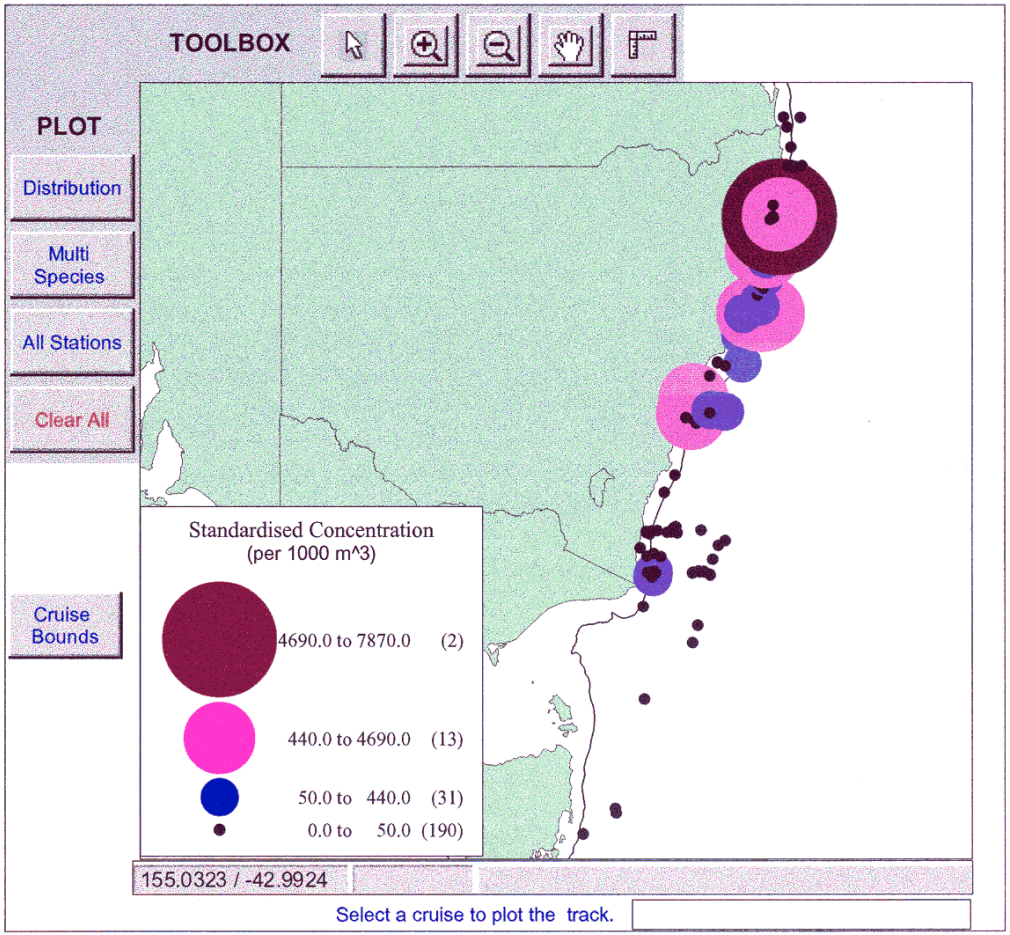
Diagnostic Characters

* 46-53 + 8-11 = 54-61 myomeres;
* Prominent striations on hindgut in larvae > 6.0mm;
* Gas bladder not apparent;
* Posteriorly placed dorsal, anal and pelvic fins; dorsal and anal fins do not overlap;
* Prominent pigment patch over dorsal and ventral midlines of caudal peduncle;
* Small melanophores along lateral midline of trunk and tail in postflexion larvae;
* 11-17 roughly alternating, evenly spaced internal melanophores dorsally along entire gut.

Meristic Counts

Myomeres	54 - 61
Body Length (mm)	32.8
Age (days)	
Dorsal fin	11 - 14
Anal fin	10 - 9
Caudal fin	19
Pectoral fin	8 - 10
Pelvic fin	10

Gonorynchus greyi	Richardson, 1845	
beaked salmon	CAAB 37141001	227



Larval Distribution

Regional distribution:

Larvae have been reported from coastal waters off south-western Australia in December, northern and central NSW between January and June (Bruce 1998) and off Sydney and Lake Macquarie (NSW) from October to July (Gray 1993, Smith & Suthers 1999, Smith 2000, Trnski 2001). Database records include offshore waters off eastern Tasmania (February to June), shelf and offshore waters off southern NSW (February, May and August) and shelf and slope waters from central NSW to southern Queensland from January to August. The highest concentrations of larvae (up to 7,870 / 1000 m^3) have been recorded off northern NSW in May. Larvae are widespread in shelf waters and have been recorded up to 160 km seaward of the shelf break.

Vertical distribution:

The highest concentrations of larvae have been recorded in surface tows during the day (Gray et al. 1992, Gray & Miskiewicz 2000). Smith (2000) suggested that small larvae underwent diel vertical migrations (being dispersed through the water column at night and concentrated at the surface during the day) whereas larger larvae did not migrate from the surface.

Gonorynchus greyi	Richardson, 1845	
beaked salmon	CAAB 37141001	227

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates	☐
Larval growth	☐
Regional comparison	☐

Gonorynchus greyi	Richardson, 1845	
beaked salmon	CAAB 37141001	227

Book and Book Chapter References

Bruce, B. D. (1998). Gonorhynchidae: beaked salmons. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification. (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 60 - 63.

Bruce, B. D. (2000). Gonorychidae (Sandfishes, Beaked Salmons). In: Fauna Malesiana Handbook 2. The Larvae of Indo-Pacific Coastal Fishes. An Identification Guide to Marine Fish Larvae. (J. M. Leis & B. M. Carson-Ewart, Eds.). Brill, Leiden. Pp: 92 - 95.

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Last, P. R., Scott, E. O. G. & Talbot, F. H. (1983). Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart, Tas.

Journal Articles

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Trnski, T. (2001). Diel and tidal abundance of fish larvae in a barrier-estuary channel in New South Wales. Marine and Freshwater Research 52: 995 - 1006.

Ocean perch (*Helicolenus percoides*)

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599

Species Distribution

Ocean perch (F. Scorpaenidae) reach approximately 47 cm in length and 1.98 kg (Gomon et al. 1994, Yearsley et al. 1999). In Australia, they occur from Port Hacking (NSW) to Champion Bay (WA) including Tasmania (Gomon et el. 1994). They also occur in New Zealand waters (Paulin 1989) and the genus occurs worldwide in shelf and upper slope waters of colder latitudes and on deep island and ridge waters in the tropics (Gomon et al. 1994). Adults are most commonly found in waters between 50 and 750 m, but have been collected or observed in waters as shallow as 10 m and as deep as 1015 m (Park 1994).

Spawning

They are ovoviviparous (Park 1993) and fertilisation is internal (Kreft 1961). Fecundity is unknown. However estimates from New Zealand ranged from 150,000 to 200,000 eggs for a fish of 30 cm FL. Of these, 40,000 to 50,000 were fertilised and developing embryos.

Spawning has been recorded from late winter to late summer in Tasmania (Furlani 1997). This corresponds to the timing of the highest concentrations of larvae in that region and off eastern Australia. The distribution of larvae suggests spawning is widespread in eastern Australia.

They do not have pelagic eggs and estimating spawning stock biomass via egg surveys is not applicable.

Stock Structure

Two species of ocean perch are currently recognised in Australia (the "inshore" H. percoides and "offshore" H. barathri), although there is still some taxonomic confusion and more species within the genus may occur in Australian waters (Yearsley et al. 1999). Despite this, they are managed within the South East Fishery (SEF) as a single stock. Larval distribution suggests widespread spawning in southeast Australia.

Full Larval Description

Paulin, C. D. (1989). Redescription of Helicolenus percoides (Richardson) and H. barathri (Hector) from New Zealand (Pisces, Scorpaenidae). Journal of the Royal Society of New Zealand 19: 319 - 325.

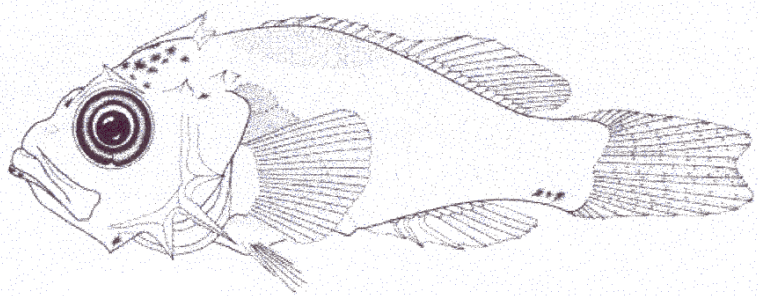
Larvae of Temperate Australian Fishes reference: Neira & Furlani (1998): Scorpaenidae: Scorpionfishes. Pp 140 - 149.

Other taxa recorded with ocean perch larvae (% of samples):

S. sagax (20), S. punctata (19), T. atun (15), G. blacodes (14), L. caudatus (13), S. brama (12), G. tigerinus (12), R. solandri (11), P. auratus (8), S. australasicus (7), T. declivis (6), M. novaezelandiae (5), E. australis (5), P. fuscus (5), S. flindersi (3), G. greyi (3), P. dentex (3), P. saltatrix (2), A. australis (1), P. wrighti (1), C. australis (1), C. affinis (1), P. bassensis (0.5), S. s. scomberoides (0.5)

Australian Seafood Handbook reference: p 194

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599



Larval Stage: postflexion

Illustrated by F.J. Neira 6.8 mm

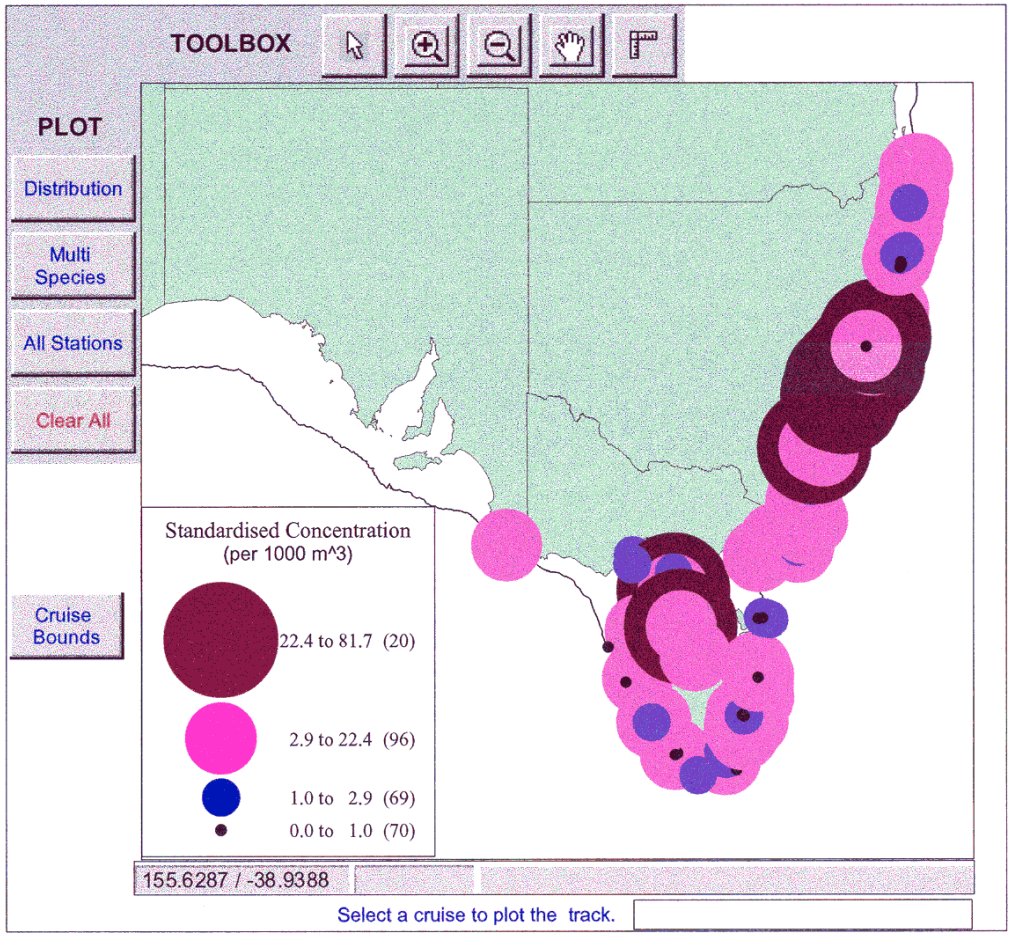
Diagnostic Characters

* 8-10 + 15-17 = 24-25 myomeres;
* Dermal sac encloses most of body;
* Mass of spongy tissue above trunk from late preflexion stage;
* Supraocular, parietal and posterior preopercular spines finely serrate by late flexion stage;
* 6-8 melanophores along ventral midline of tail, between myomeres 7-15.

Meristic Counts

Myomeres	25
Body Length (mm)	7.5 - 12.3
Age (days)	
Dorsal fin	XII, 11 - 12
Anal fin	III, 5
Caudal fin	15
Pectoral fin	18 - 20
Pelvic fin	1. 5

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599



Larval Distribution

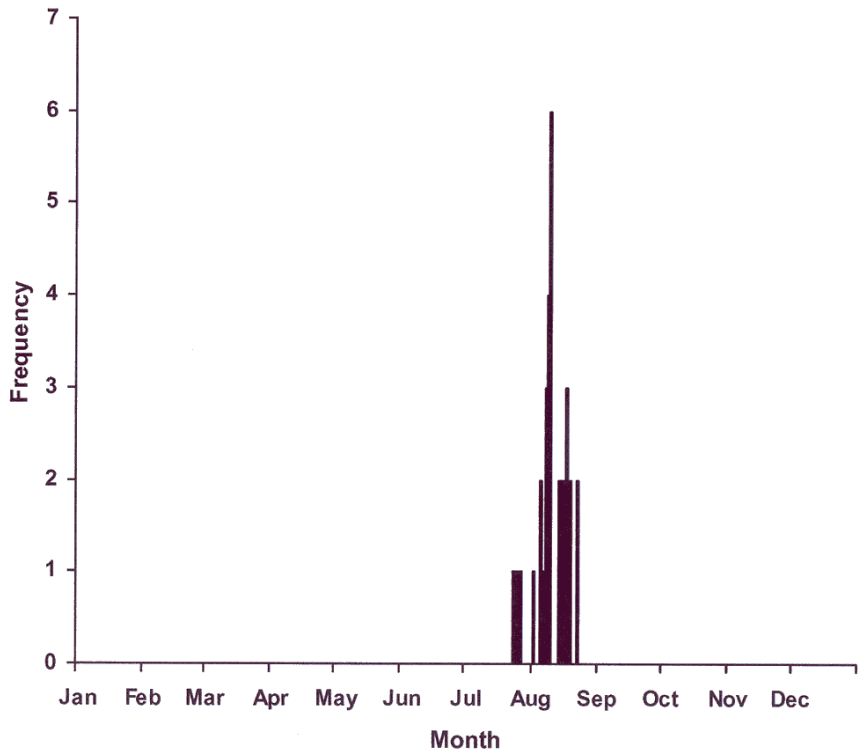
Regional distribution:

Larvae have been reported in shelf waters off Sydney (NSW) from May to December (Gray & Otway 1994, Gray 1995), Victoria in July and December (Neira et al. 2000) and Tasmania from October to February (Marshall & Jordan 1992, Furlani 1997). Database records range from western to eastern Victoria, including Bass Strait and Tasmania and along the entire NSW coastline. They extend the seasonal occurrence to include Tasmania from July to February, eastern Victoria and southern NSW waters in August and northern NSW waters in August and September. The highest concentration of larvae (81 / 1000 m^3) has been recorded in coastal waters off Sydney in July; high concentrations (14 - 57 / 1000 m^3) have also been recorded off eastern Tasmania (October to January), Bass Strait (July to December) and much of the NSW coast (August to September). Larvae occur throughout shelf waters and have been recorded up to 48 km seaward of the shelf break off southern NSW.

Vertical distribution:

Gray & Otway (1994) reported that larvae were restricted to the 100 m depth stratum off Sydney. Neira et al. (2000) reported the highest concentrations from the 25 - 50 m depth stratum in Bass Strait.

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599



Spawning Dates

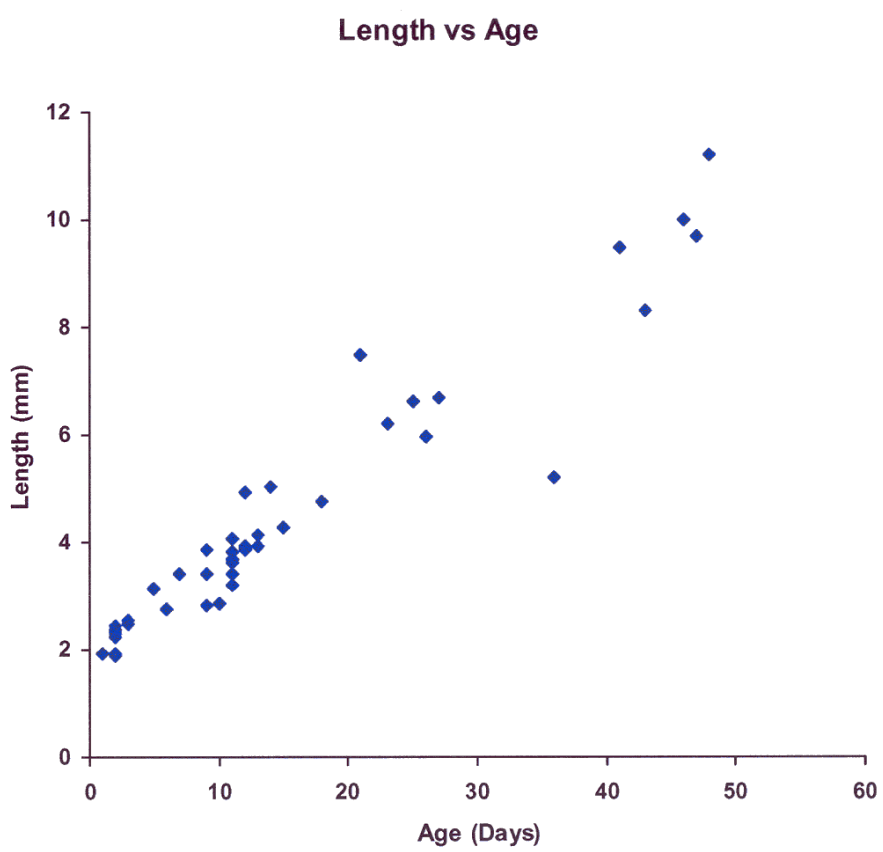
Database records range from 23 July to 21 August and are based on larvae from southern NSW, eastern Victoria and the east coast of Tasmania.

Back-calculated spawning dates

Larval growth

Regional comparison

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599



Larval Growth

Larvae are 2.1 - 2.7 mm when expelled (Furlani 1997). Otoliths have unambiguous increments which have been assumed to be daily (Furlani 1997).

Growth of southeast Australian larvae from 2 to 11 mm, based on data base records, is best described by the linear equation:

Body length = 0.1729 x age + 1.8721

(R^2 = 0.93; n = 35)

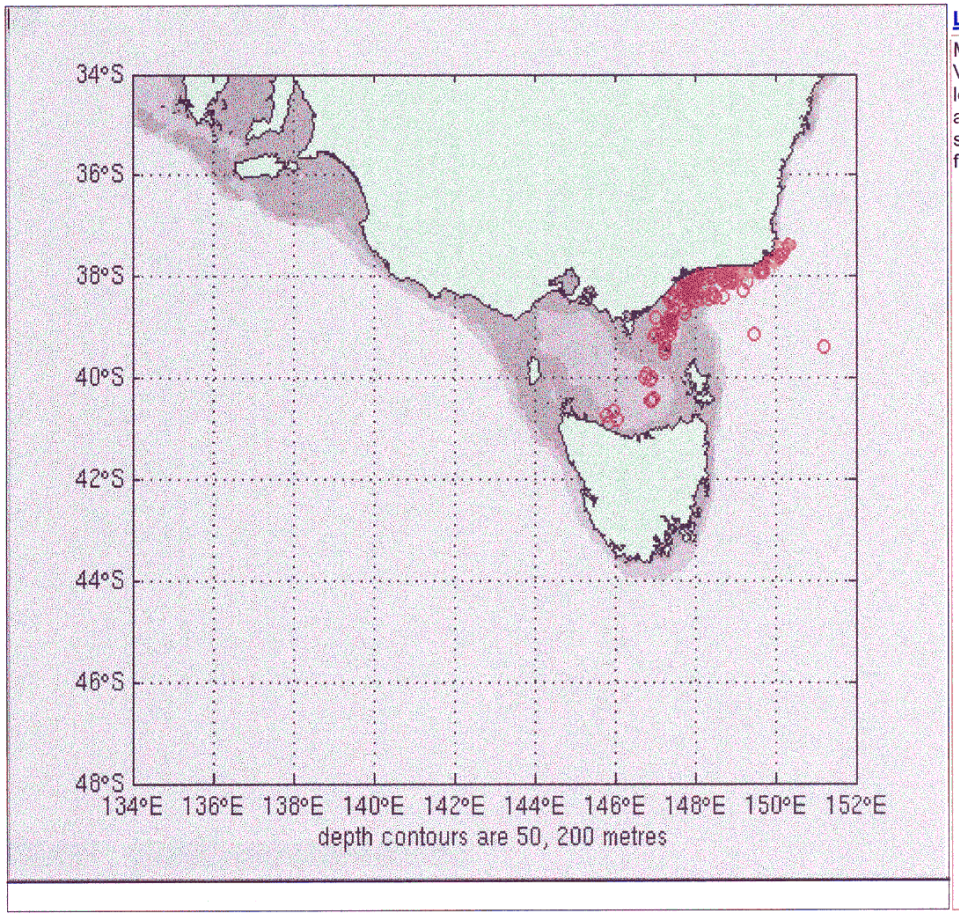
Ocean perch have a larval duration of at least 50 days.

Back-calculated spawning dates

Larval growth

Regional comparison

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599



Larval Dispersal

Model runs are based on larvae aged from eastern Victoria and southern NSW. Modelled source locations are concentrated in eastern Bass Strait and shelf waters of eastern Victoria. Too few sampling positions with aged larvae are available to fully assess larval dispersal processes.

Helicolenus percoides	Richardson, 1842	
ocean perch	CAAB 37287001	599

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Paulin, C. D. (1989). Redescription of Helicolenus percoides (Richardson) and H barathri (Hector) from New Zealand (Pisces, Scorpaenidae). Journal of the Royal Society of New Zealand 19: 319 - 325.

Ribbonfish (*Lepidopus caudatus*)

Lepidopus caudatus	Euphrasen, 1788	
ribbonfish	CAAB 37440002	1055

Species Distribution

Ribbonfish (F. Trichiuridae) reach approximately 200 cm in length and 8 kg (Gomon et al. 1994, Yearsley et al. 1999). In Australia, they occur from Newcastle (NSW) around the southern coast to Eyre (WA) including Tasmania (Gomon et al. 1994). They also occur throughout the oceans of the world (Gomon et al. 1994). Both adults and juveniles occur on the shelf and upper slope waters to a depth of about 600 m (Trnski & Miskiewicz 1998).

Spawning

Their spawning mode and fecundity are unknown.

Spawning not been recorded in Australia, but has been recorded in New Zealand where it occurs from spring to autumn (Robertson 1980). The distribution of larvae suggests that central NSW is an area of important spawning activity in August and September.

Estimating spawning stock biomass via egg surveys has not been attempted but may be suitable if spawning is restricted to central NSW.

Stock Structure

Stock structure is unknown. Larval distribution suggests a single spawning area in central NSW.

Full Larval Description

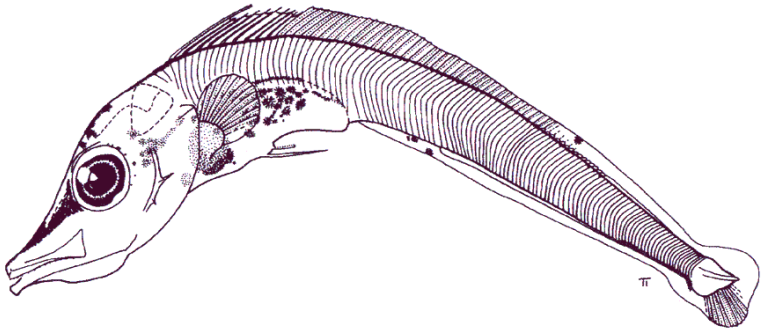
Larvae of Temperate Australian Fishes reference: Trnski & Miskiewicz (1998): Trichiuridae: Cutlassfishes, hairtails, frostfishes. Pp 416 - 419.

Other taxa recorded with ribbonfish larvae (% of samples):

H. percoides (82), G. blacodes (48), S. sagax (45), R. solandri (24), P. auratus (18), S. australasicus (18), E. australis (12), S. flindersi (12), P. fuscus (9), C. affinis (6), G. greyi (6), A. australis (3), P. saltatrix (3)

Australian Seafood Handbook reference: p 134

Lepidopus caudatus	Euphrasen, 1788	
ribbonfish	CAAB 37440002	1055



Larval Stage:

Illustrated by T. Trnski 11.1 mm

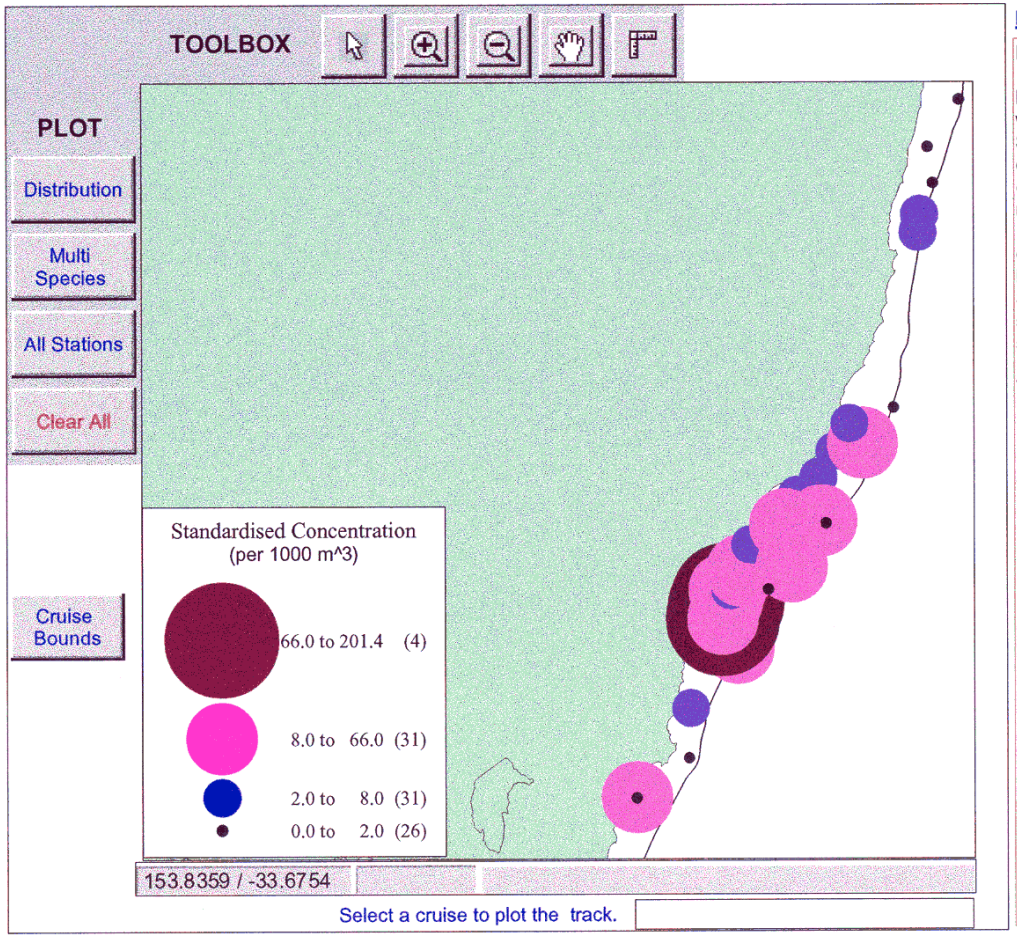
Diagnostic Characters

* 10-31 + 85-92 = 102-116 myomeres;
* Up to 2 small to moderate, smooth posterior preopercular spines;
* Early forming, elongate first dorsal-fin spine; dorsal-fin spines serrate laterally;
* Pelvic-fin spine serrate laterally and medially;
* 2 large pigment blotches on dorsal finfold and 1 on anal finfold;
* Shield of pigment on snout and head in early preflexion larvae.

Meristic Counts

Myomeres	
Body Length (mm)	
Age (days)	
Dorsal fin	
Anal fin	
Caudal fin	
Pectoral fin	
Pelvic fin	

Lepidopus caudatus	Euphrasen, 1788	
ribbonfish	CAAB 37440002	1055



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off northern NSW from May to September (Trnski & Miskiewicz 1998) and off Sydney (NSW) from April to November (Gray et al. 1992, Gray 1993). Database records range from southern to northern NSW from May to September. The highest concentration of larvae (201 / 1000 m^3) has been recorded in coastal waters off Sydney in July. Larvae are widespread in shelf waters but have not been recorded seaward of the shelf break.

Vertical distribution:

Gray & Miskiewicz (2000) recorded higher concentrations of larvae at 20 - 30 m than at the surface in shelf waters off Sydney (NSW).

Lepidopus caudatus	Euphrasen, 1788	
ribbonfish	CAAB 37440002	1055

Larval Growth

Eggs hatch after 153 h at 19.8 - 21.1 deg. C and larvae are 4.8 - 5.0 mm at hatching (Robertson 1980).

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Lepidopus caudatus	Euphrasen, 1788	
ribbonfish	CAAB 37440002	1055

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

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Robertson, D. A. (1980). Spawning of the frostfish, Lepidopus caudatus (Pisces: Trichiuridae), in New Zealand waters. New Zealand Journal of Marine and Freshwater Research 14: 129 - 136.

Blue grenadier *(Macruronus novaezelandiae)*

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45

Species Distribution

Blue grenadier (F. Macruronidae) reach approximately 115 cm in length and 6 kg (Yearsley et al. 1999). In Australia, they occur from central New South Wales around the south coast to the western Great Australian Bight, including Tasmania (Gomon et al. 1994). They also occur in New Zealand, where they are referred to as hoki (Ayling & Cox 1982). Juveniles (20 - 30 cm) occur in estuaries in southeast Tasmania and over the outer shelf in western and eastern Tasmania, eastern Victoria and in some years off southern New South Wales (Gomon et al. 1994, CSIRO unpublished data). Adults occur on the continental slope in depths of 200 - 700 m but have been recorded as deep as 1000 m (Kailola et al. 1993).

Spawning

They are isochronal spawners (Gunn et al. 1989) and estimates of potential annual fecundity (PAF) vary between years. Bulman et al. (1999) provide the following fecundity - weight relationships:

1994: PAF = 502136.755+368934.714 x weight (kg); R^2 = 0.222, n = 40; 1995: PAF = 127020.244+562932.612 x weight (kg); R^2 = 0.269, n = 51

Spawning is protracted and has been recorded off the west coast of Tasmania during winter and early spring. This corresponds to the timing and location of highest larval concentrations, although back - calculated spawning dates suggest spawning can be as early as May. The onset of spawning varies between years and may be linked to water temperature during autumn and early winter (Gunn et al. 1989). Limited spawning may occur off northeast Tasmania and eastern Bass Strait based on the occurrence of small larvae in those areas (Gunn et al. 1989, Bruce et al. 2001).

Spawning stock biomass estimates based on egg surveys have been conducted in western Tasmania (Bulman et al. 1999).

Stock Structure

Genetic data suggests a single stock in Australian waters (Milton & Shaklee 1987), which is distinct from New Zealand where the species is represented by multiple stocks with different spawning areas (Livingston & Schofield 1996). The implications for stock structure of the possible second spawning off eastern Bass Strait are unclear (Bruce et al. 2001).

Full Larval Description

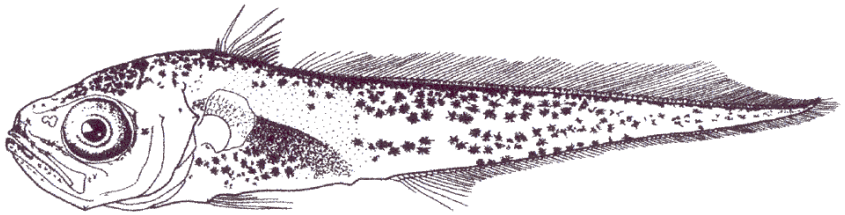
Bruce, B. D. (1988). Larval development of blue grenadier, Macruronus novaezelandiae (Hector), in Tasmanian waters. Fishery Bulletin US 86: 119 - 128.

Larvae of Temperate Australian Fishes reference: Bruce (1998): Macruronidae: Southern hakes. Pp 90 - 91.

Other taxa recorded with blue grenadier larvae (% of samples):
Seriolella punctata (4.5), H. percoides (4.5), S. brama (4), T. atun (2), P. wrighti (1), G. tigerinus (1), T. declivis (1), A. trutta (0.5), E. australis (0.5), G. greyi (0.5), P. dentex (0.5), S. sagax (0.5)

Australian Seafood Handbook reference: p 84

Macruronus novaezelandiae Hector, 1871
blue grenadier CAAB 37227001 45



Larval Stage: flexion

Illustrated by B.D. Bruce 24.2 mm

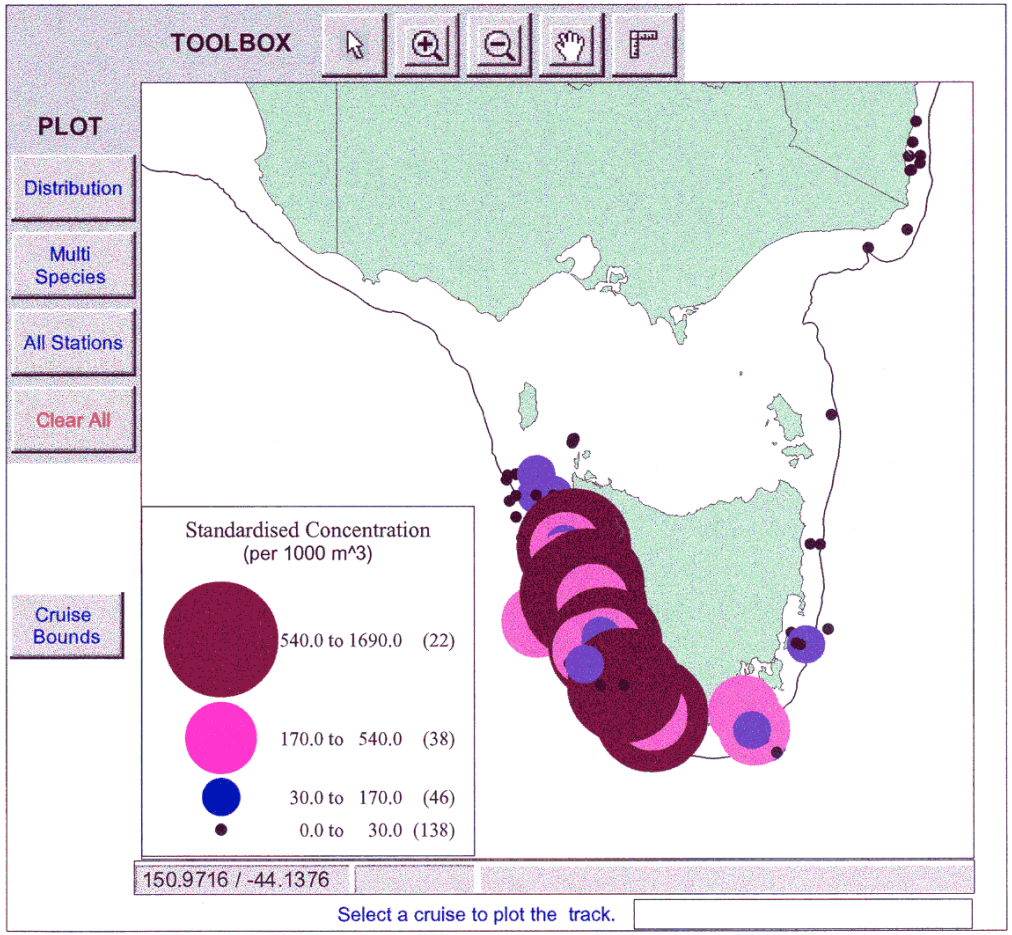
Diagnostic Characters

* 78 - 81 myomeres;
* No head spines except for a single opercular spine by 22mm;
* Persistent gap between anus and origin of anal fin;
* Large size at notochord flexion (>= 20mm);
* Paired melanophore series dorsally on tail along either side of developing dorsal fin;
* Usually two prominent melanophores ventrally along midtail until 15mm.

Meristic Counts

Myomeres	78 - 81
Body Length (mm)	20 - 28
Age (days)	
Dorsal fin	XII - XIII, 106 - 96
Anal fin	89 - 93
Caudal fin	12 - 13
Pectoral fin	17 - 20
Pelvic fin	7 - 8

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45



Larval Distribution

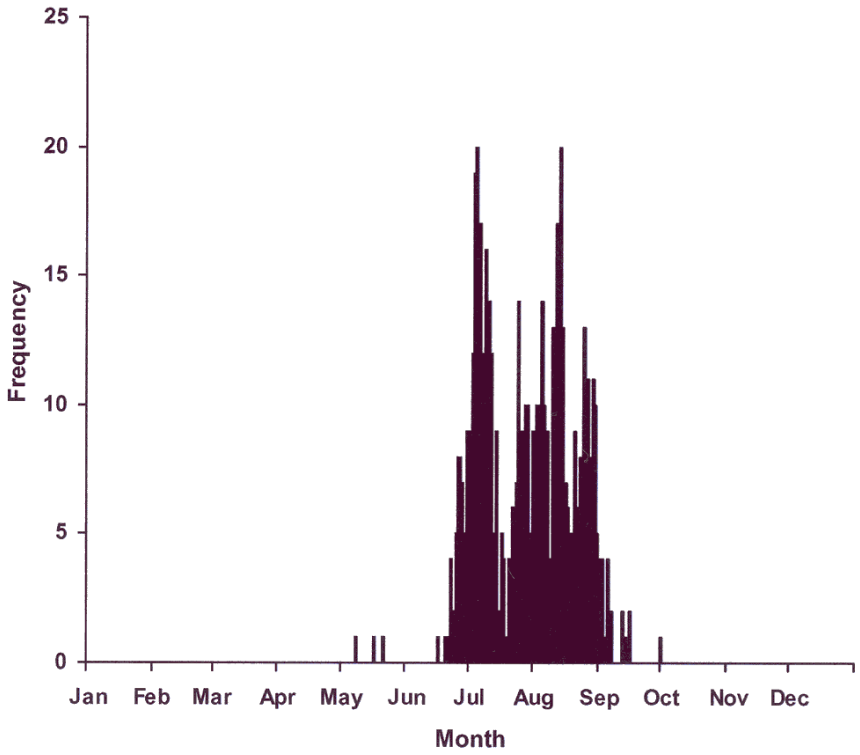
Regional distribution:

Larvae have been reported in shelf waters off southern New South Wales and eastern Victoria in August, and in Tasmanian waters from King Island, around the west and south coasts to Flinders Island in the northeast, from June to September (Thresher et al. 1988, Bruce et al. 2001). Larvae have not been reported from Bass Strait. Database records are confined within this range and period. The highest concentrations of larvae (1400 - 1600 / 1000 m^3) have been recorded off western and southwest Tasmania from July to August. Concentrations of larvae are highest in near-shore and mid-shelf regions (Thresher et al. 1988). Larvae have been found up to 33 km seaward of the shelf break off western Tasmania.

Vertical distribution:

Thresher et al. (1989) reported larvae from depths of 20 to 90 m in stratified tows with peak concentrations at 60 m at night and 40 m during the day. Larvae have also been recorded in surface tows (Bruce et al. 2001). Early stage larvae (< 4.0 mm) were found to be more common near the bottom of the mixed layer (100 - 180 m) in New Zealand (Murdoch 1992).

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45



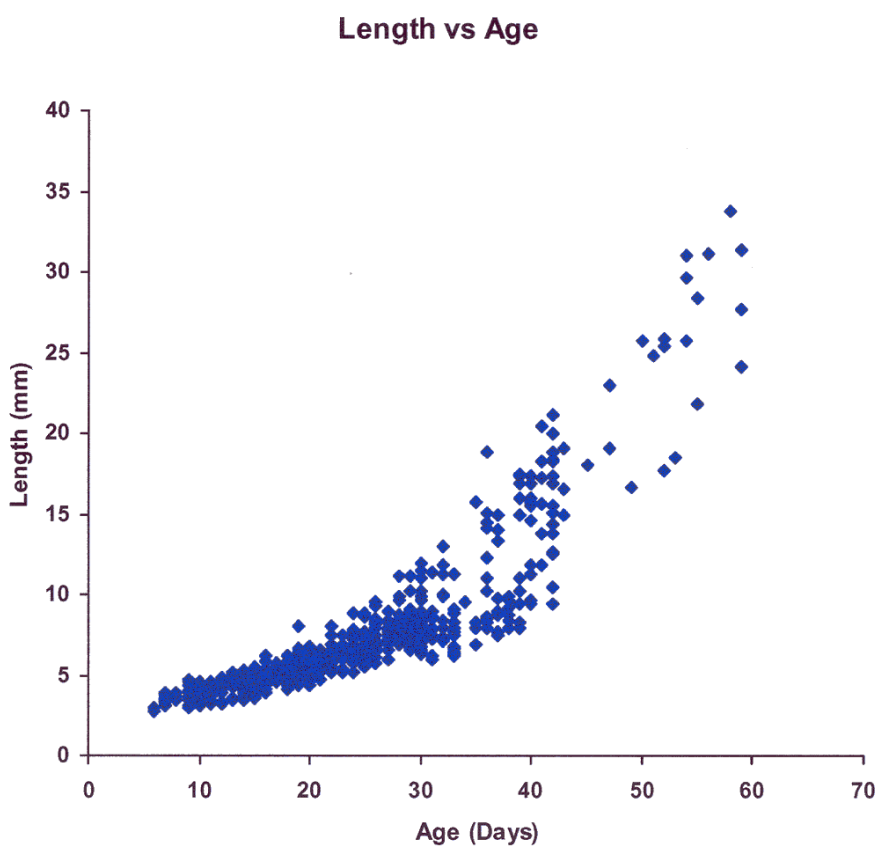
Spawning Dates

Published, back-calculated spawning dates range from 9 May to 2 October (Gunn et al. 1989, Bruce et al. 2001). There is some evidence that spawning outside grounds on the west coast of Tasmania (e.g. eastern Bass Strait) occurs during a more restricted period within this range (Bruce et al. 2001).

Database records range from 9 May to 2 October and are based on larvae from the west and south coasts of Tasmania, southern New South Wales and eastern Victoria.

Back-calculated spawning dates
Larval growth
Regional comparison

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45



Larval Growth

Eggs hatch after 55 - 60 hours at 14 - 19 deg. C and larvae are 2.2 - 2.3 mm at hatching (Bruce 1988). Otoliths have unambiguous increments that have been validated as daily. Their formation commences at first feeding, approximately 6 days after spawning (Thresher et al. 1988).

Reported growth rates increase exponentially for the first 50 - 60 days but may vary between years and regions in response to feeding conditions (Thresher et al. 1988). Growth of southeast Australian larvae from 3 to 28 mm, based on database records, is best described by the exponential function:

Body length = 1.9532e^(0.04783 x age)

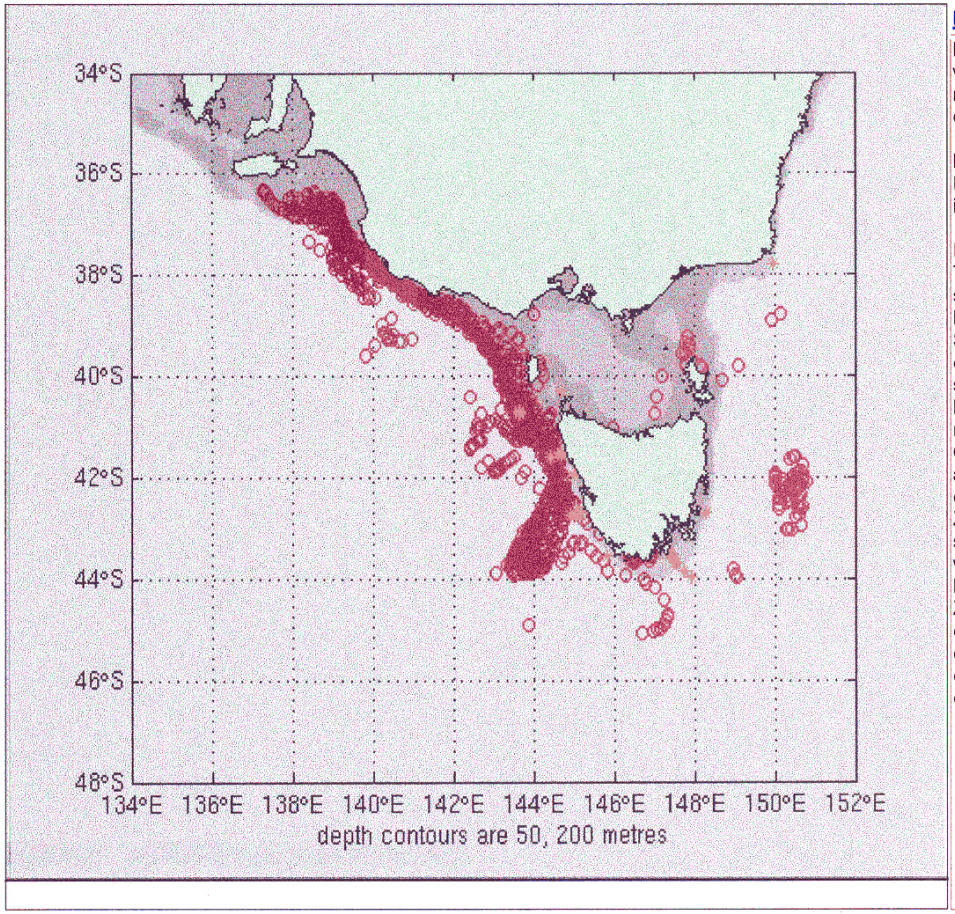
(R^2 = 0.80; n = 535)

Larvae from NSW and Victorian waters have significantly wider otolith increments than those from Tasmanian waters, suggesting higher rates of growth (Bruce et al. 2001).

Blue grenadier have a protracted pelagic early life history with a larval duration of at least 60 days.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45



Larval Dispersal

Larval dispersal is primarily southwards from the western Tasmanian spawning grounds via the narrow Zeehan Current, which flows along the outer continental shelf to the east coast (Lyne & Thresher 1995). Larvae recorded off southern NSW most likely originate from limited spawning off eastern Bass Strait and are transported northwards via inshore shelf currents (Bruce et. al. 2001).

Model runs are based on larvae aged from Tasmanian and eastern Victorian waters. Modelled source locations for larvae are more extensive than known spawning areas. They range from southeast South Australia to southwest Tasmania in slope and outer shelf areas but encompass the known spawning areas of western Tasmania. A source of larvae off eastern Bass Strait is also indicated in model runs, supporting spawning in that region. Offshore source locations are identified both east and west of Tasmania but these more likely indicate episodic entrainment of offshore water into the Zeehan Current and onto the shelf rather than spawning sites. Larval trajectories are consistent with field data indicating a rapid advection of some larvae from western to eastern Tasmania via the Zeehan Current. Modelled trajectories indicating offshore advection of larvae off both western and eastern Tasmania are consistent with field observations of larvae seaward of the shelf break in each region.

Macruronus novaezelandiae	Hector, 1871	
blue grenadier	CAAB 37227001	45

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Ayling, T. & Cox, G. J. (1982). Collins Guide to the Sea Fishes of New Zealand. William Collins Publishers Ltd, Auckland.

Bruce, B. D. (1998). Macruronidae: Southern hakes. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 88 - 91.

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Kailola, P. J., Williams, M. J., Stewart, P. C., Reichelt, R. E., McNee, A. & Grieve, C. (1993). Australian Fisheries Resources. Bureau of Resource Sciences, Canberra, ACT.

Lyne, V. D. & Thresher, R. E. (1995). Dispersal and advection of Macruronus novaezelandiae (Gadiformes: Merlucciidae) larvae off Tasmania: simulation of the effects of physical forcing on larval distribution. In: The Biophysics of Marine Larval Dispersal. Coastal and Estuarine Studies (, Eds.). American Geophysical Union, Washington. Pp: 109 - 136.

Murdoch, R. C. (1992). A review of the ecology of hoki, Macruronus novaezelandiae (Hector), larvae in New Zealand waters. In: Bureau of Rural Resources Proceedings No. 15. Larval Biology. Australian Society for Fish Biology Workshop, Hobart, 20 August 1991 (D. A. Hancock, Eds.). Australian Government Printing Service, Canberra. Pp: .

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

Journal Articles

Bruce, B. D. (1988). Larval development of blue grenadier, Macruronus novaezelandiae (Hector), in Tasmanian waters. Fishery Bulletin, U.S. 86: 119 - 128.

Bruce, B. D., Condie, S. & Sutton, C. A. (2001). Larval distribution of blue grenadier (Macruronus novaezelandiae Hector) in south-eastern Australia: Further evidence for a second spawning area. Marine and Freshwater Research 52: 603 - 610.

Bulman, C. M, Koslow, J. A. & Haskard, K. A. (1999). Estimation of spawning stock biomass of blue grenadier (Macruronus novaezelandiae) off western Tasmania based upon the annual egg production method. Marine and Freshwater Research 50: 197 - 207.

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

Livingston, M. E. & Schofield, K. A. (1996). Stock discrimination of hoki (Macruronus novaezelandiae) in New Zealand waters using morphometrics. New Zealand Journal of Marine and Freshwater Research 30: 197 - 208.

Jackass morwong *(Nemadactylus macropterus)*

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819

Species Distribution

Jackass morwong (F. Cheilodactylidae) reach approximately 70 cm in length and 4.5 kg (Yearsley et al. 1999). In Australia, they occur from central NSW around the south coast to Rottnest Island (WA) including Tasmania (Gomon et al. 1994). The species also occurs in New Zealand, where they are referred to as tarakihi (Ayling and Cox 1982) and have been reported from South America and the Amsterdam and St Paul Islands in the Indian Ocean (Smith & Heemstra 1986). Newly settled juveniles occur in estuaries in SE Australia (Thresher et al. 1994). Adults and larger juveniles are demersal on the continental shelf and upper slope to about 350 m.

Spawning

They are serial spawners (Hobday & Wankowski 1987). Estimates of fecundity range from 100,400 to 1,419,000 eggs (Hobday & Wankowski 1987) related to length (L) and age (A) as follows:

Length: Fecundity = 0.84 x L + 3.72; Age: Fecundity = 117,210 x A - 194,518

Spawning is protracted and has been recorded in eastern Bass Strait and southeast Tasmania during summer and autumn. There is some evidence of regional variability in the timing of spawning with peak spawning occurring from February - May in Tasmania and April - June in Victoria (Hobday & Wankowski 1987, Lyle & Ford 1993, Jordan 1997, Bruce et al. 2001). These correspond to the timing of highest concentrations of larvae off southeast Australia and to their back-calculated spawning dates.

Estimating spawning stock biomass via egg surveys has not been attempted but may be possible if spawning is spatially discrete.

Stock Structure

Genetic data suggest a single stock in Australian waters (Elliott & Ward 1984, Grewe et al. 1994) that is distinct from New Zealand. Otolith microchemistry suggests more complex substructuring and up to four distinct population units (Thresher et al. 1994). Larval data suggests regionally self-sustaining populations in NSW / eastern Victoria and western / southern Tasmania combined with areas of mixed recruitment (Bruce et al. 2001).

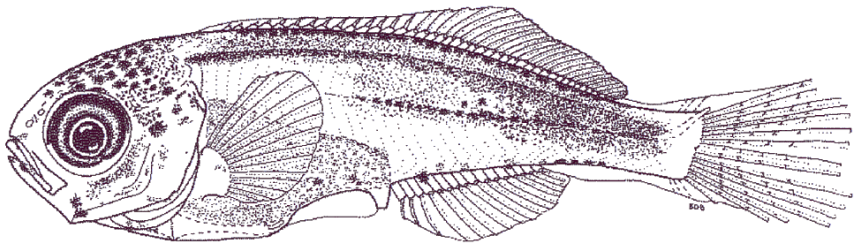
Full Larval Description

Larvae of Temperate Australian Fishes reference: Bruce (1998): Cheilodactylidae: Morwongs. Pp 210 - 213.

Other taxa recorded with morwong larvae (% of samples):
C. spectabilis (19), S. sagax (5), E. australis (2), G. tigerinus (2), S. s. scomberoides (2)

Australian Seafood Handbook reference: p 186

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819



Larval Stage: postflexion

Illustrated by B.D. Bruce 9.2 mm

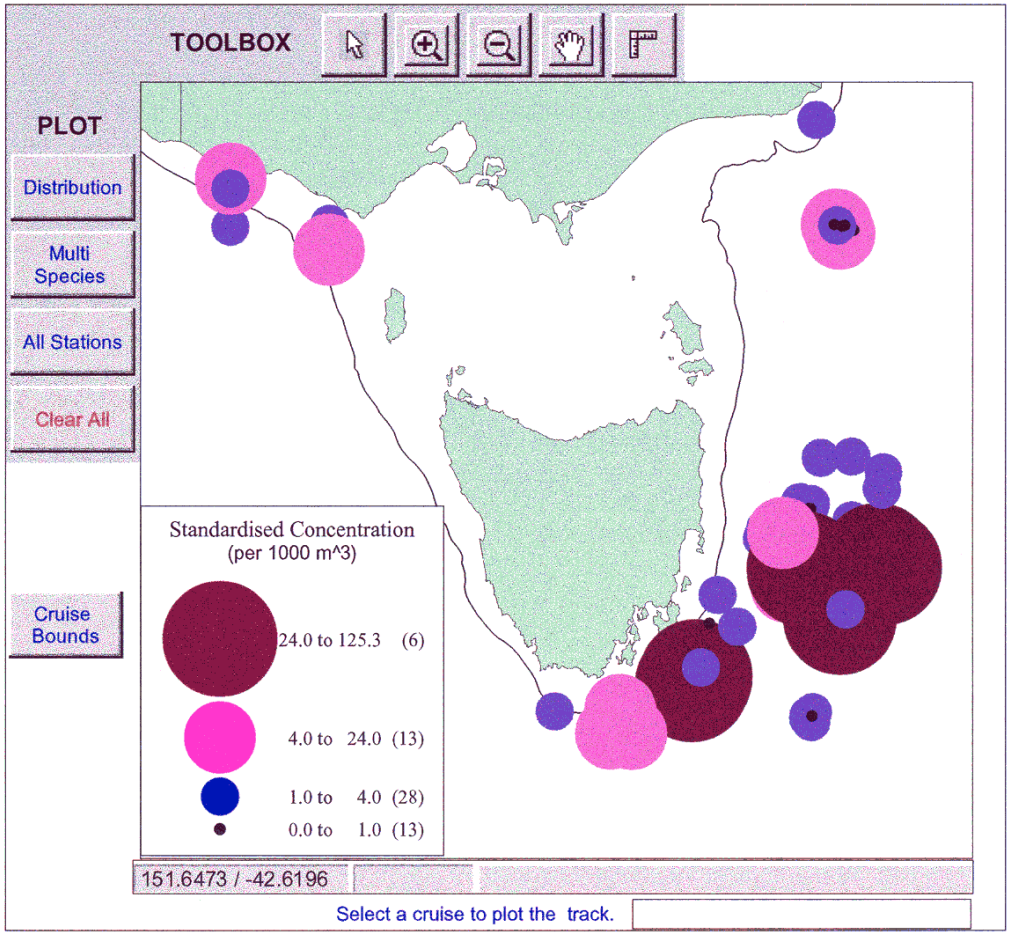
Diagnostic Characters

* 14-15 + 20-22 = 34-36 myomers;
* Body moderate to deep from 12.5mm (BD > 35%);
* Two ventral keels, the prominent anterior keel extending from the isthmus to the anus, the less obvious posterior keel situated along the caudal peduncle
* Conspicuous melanophore above the angle of the the lower jaw from flexion stage;
* 8-10 melanophores along the ventral midline of the tail.

Meristic Counts

Myomeres	35
Body Length (mm)	7.5 - 60
Age (days)	
Dorsal fin	XVII - XVIII, 25 - 28
Anal fin	III, 14 - 15
Caudal fin	15
Pectoral fin	14 - 15
Pelvic fin	1, 5

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819



Larval Distribution

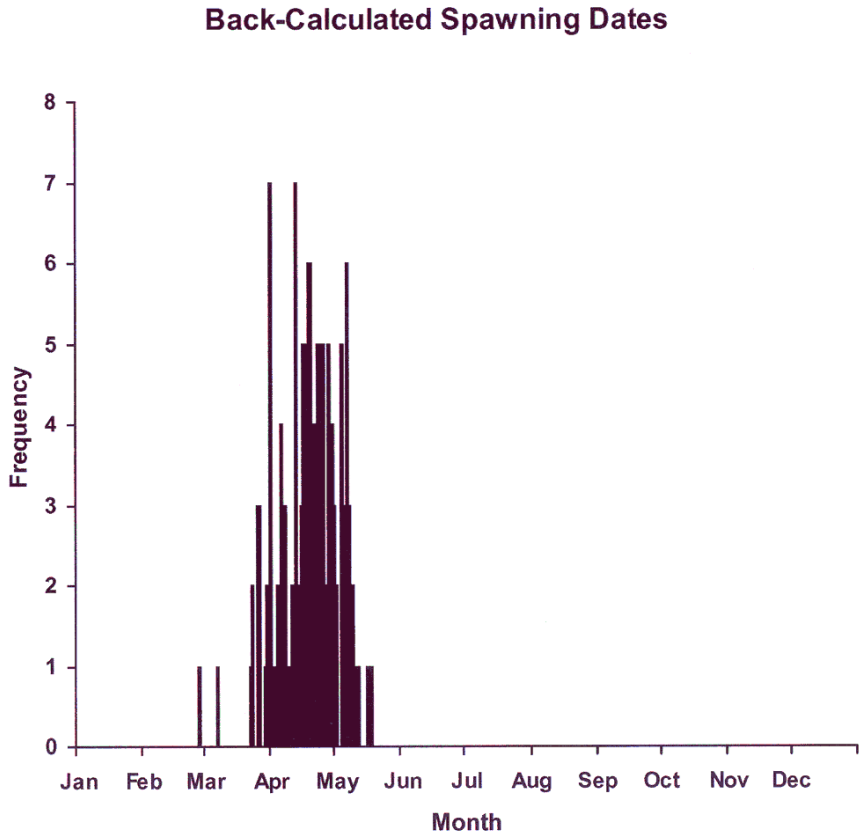
Regional distribution:

Larvae have been reported in offshore waters of southern and eastern Tasmania and east of Bass Strait from February to June (Bruce et al. 1996, 2001). Database records extend this distribution to include western Victoria, eastern Victoria and southern New South Wales within the reported period. Larvae have not been reported from Bass Strait. The highest concentrations of larvae (up to 125 / 1000 m^3) have been recorded in offshore waters off southeast Tasmania in May. Concentrations of larvae are highest in waters seaward of the continental shelf and larvae have been recorded up to 250 km seaward of the shelf break off eastern Tasmania with larvae increasing in size and age with distance offshore (Bruce et al. 2001).

Vertical distribution:

Larvae are neustonic and are rarely caught in oblique tows (Bruce et al. 2001). There appears to be no diurnal vertical movement away from the surface. Eggs have also been reported from surface tows (Robertson 1978).

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819



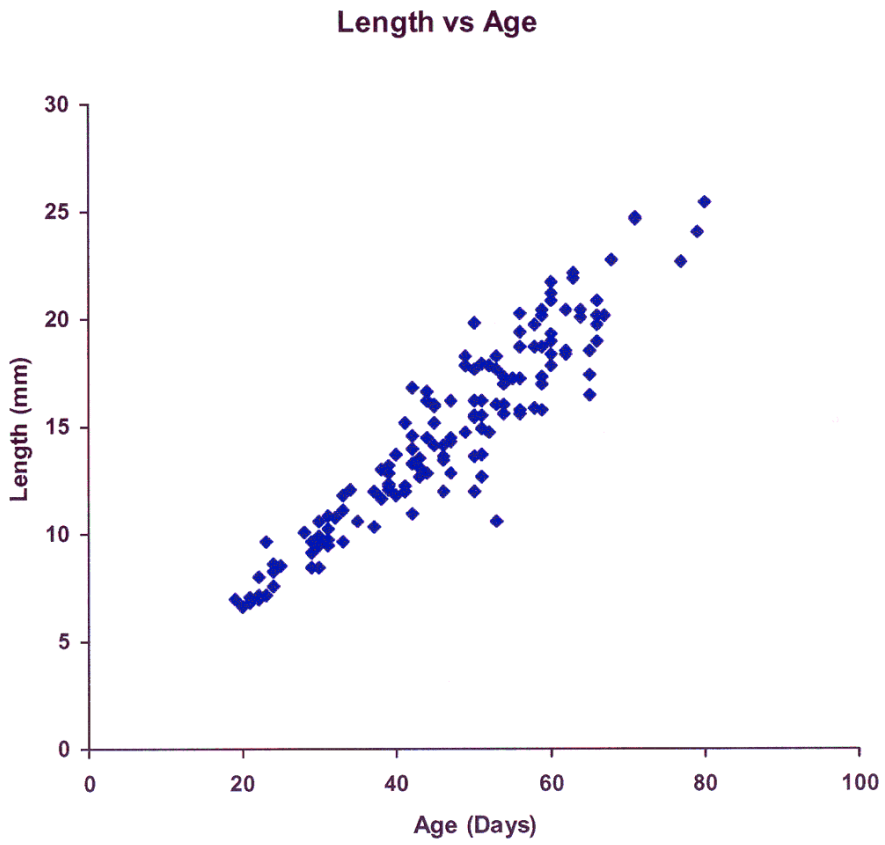
Spawning Dates

Published, back calculated spawning dates range from 10 February to 21 May with a peak in mid-late April (Bruce et al. 2001). Spawning is regionally variable and is earlier in NSW compared to Tasmania.

Database records range from 27 February to 18 May and are based on larvae from offshore waters of eastern and southern Tasmania.

Back-calculated spawning dates
Larval growth
Regional comparison

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819



Larval Growth

Eggs hatch after 70 h at 18.5 - 20.0 deg. C and larvae are 2.87 - 3.17 mm within 20 h of hatching (Robertson 1978). Otoliths have unambiguous increments which have been assumed to be daily (Bruce et al. 2001).

Growth of southeast Australian larvae from 6 to 26 mm, based on database records, is best described by the exponential function:

Body length = 5.7724e^(0.01955 x age)

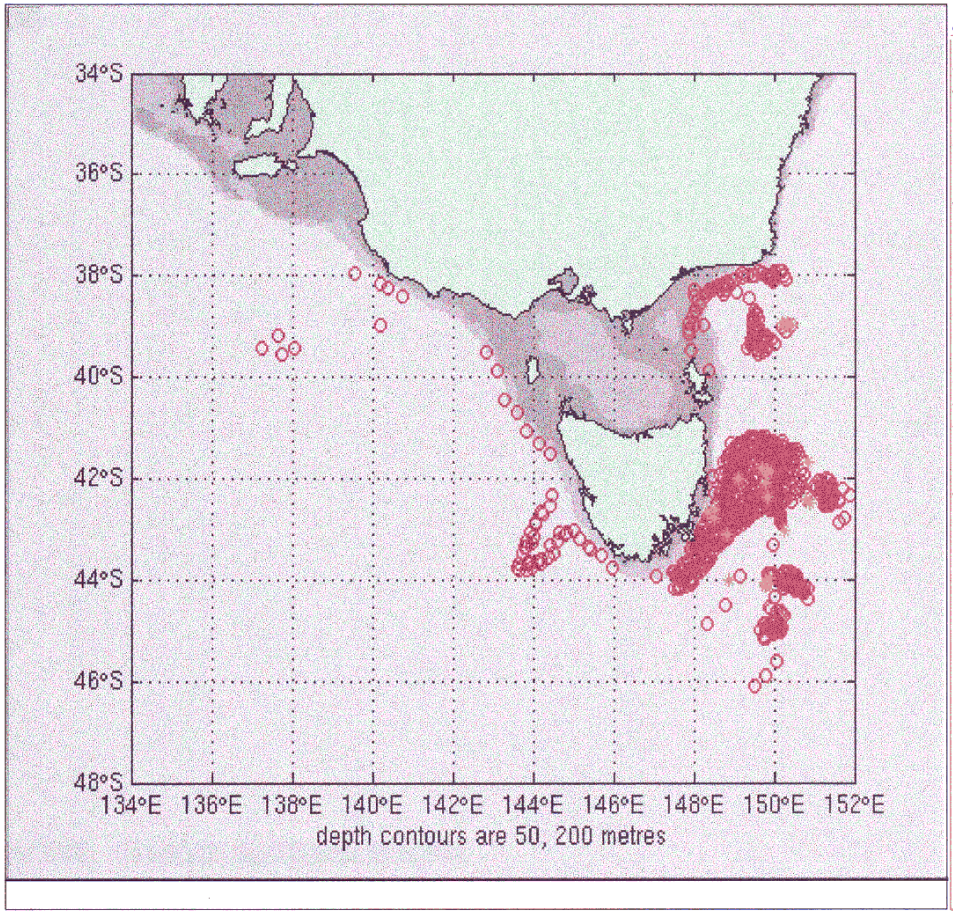
(R^2 = 0.86; n = 144)

Larvae captured in East Australian Current waters have significantly wider otolith increments than those from cooler Subtropical Convergence Zone waters, suggesting higher rates of growth (Bruce et al. 2001).

Jackass morwong have an extremely protracted pelagic early life history with a combined larval and specialised pelagic juvenile ('paperfish') duration of up to 8 - 10 months.

Back-calculated spawning dates
Larval growth
Regional comparison

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819



Larval Dispersal

Larval dispersal in the south Tasman Sea appears to be linked to mesoscale oceanographic processes within the East Australian Current (EAC) and the Subtropical Convergence Zone (STCZ) (Bruce et al. 2001).

Model runs are based on larvae aged from offshore waters of eastern Tasmania and eastern Victoria. Modelled source locations suggest separate spawning areas for larvae caught off Tasmania and those caught off eastern Victoria. Although source locations are primarily offshore in the model runs, this more likely reflects the degree of larval retention in these areas rather than actual spawning events. The separation of source locations and trajectories for larvae caught off eastern Victoria (in waters of the EAC) and off eastern Tasmania (in waters of the STCZ) supports the conclusion of Bruce et al. (2001) that circulation patterns may facilitate regionally self-recruiting populations in western and southern Tasmania as well as southern NSW-eastern Victoria with a region of mixed recruitment between.

Nemadactylus macropterus	Bloch & Schneider, 1801	
morwong	CAAB 37377003	819

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Tiger flathead *(Neoplatycephalus richardsoni)*

Neoplatycephalus richardsoni	Castelnau, 1872	
tiger flathead	CAAB 37296001	629

Species Distribution

Tiger flathead (F. Platycephalidae) reach approximately 65 cm in length and 3 kg (Gomon et al. 1994, Yearsley et al. 1999). They are endemic to southeastern Australia occurring from Coffs Harbour (NSW) around the south coast to Portland (Vic.) including Tasmania (Paxton et al. 1989, Gomon et al. 1994, Rowling 1994). Juveniles are thought to inhabit shallow inshore nursery areas (Rowling 1994, Jordan 1997). However, despite the proximity of spawning fish (Jordan 1997) and larvae (A. R. Jordan, pers. comm.) juveniles were absent from shallow habitats off southern and eastern Tasmania. Adults are associated with sandy or muddy substrates at depths between 10 and 400 m (Jordan 1997).

Spawning

They are serial batch spawners Fairbridge (1952). Estimates of fecundity (F) range from 700,000 to 1,350,000 eggs (Hobday & Wankowski 1987) related to age (A), length (L) and (gutted) weight (GW) as follows:

Age: $F = 128626 \times A - 298382$ ($R^2 = 0.74$); Length: $F = 37788 \times L - 1091768$ ($R^2 = 0.72$); Gutted weight: $F = 0.000963 \times GW - 68459$ ($R^2 = 0.73$)

Spawning has been recorded during late spring and summer throughout their geographical range (Fairbridge 1952, Hobday & Wankowski 1987). However, Jordan (1997) found no evidence for spring spawning in Tasmanian waters, suggesting that spawning begins and ends earlier in more northern regions of their distribution. The distribution of larvae supports a summer spawning in Tasmania.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown. However, Wankowski & Hobday (1984) inferred eastern Bass Strait and NSW fish comprise a shared stock, based on tag-recapture methods. Records of larvae do not offer further clues to stock structure.

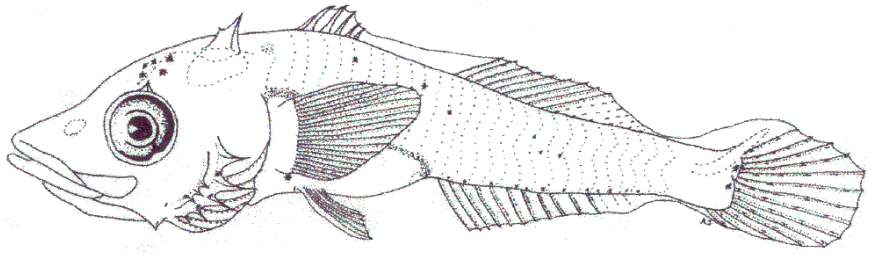
Full Larval Description

Larvae of Temperate Australian Fishes reference: Not Included

Other taxa recorded with tiger flathead larvae (% of samples):
T. declivis (89), P. bassensis (44), Arripis trutta (6)

Australian Seafood Handbook reference: p 119

Neoplatycephalus richardsoni	Castelnau, 1872	
tiger flathead	CAAB 37296001	629



Larval Stage: postflexion

Illustrated by A.R. Jordan 8.5 mm

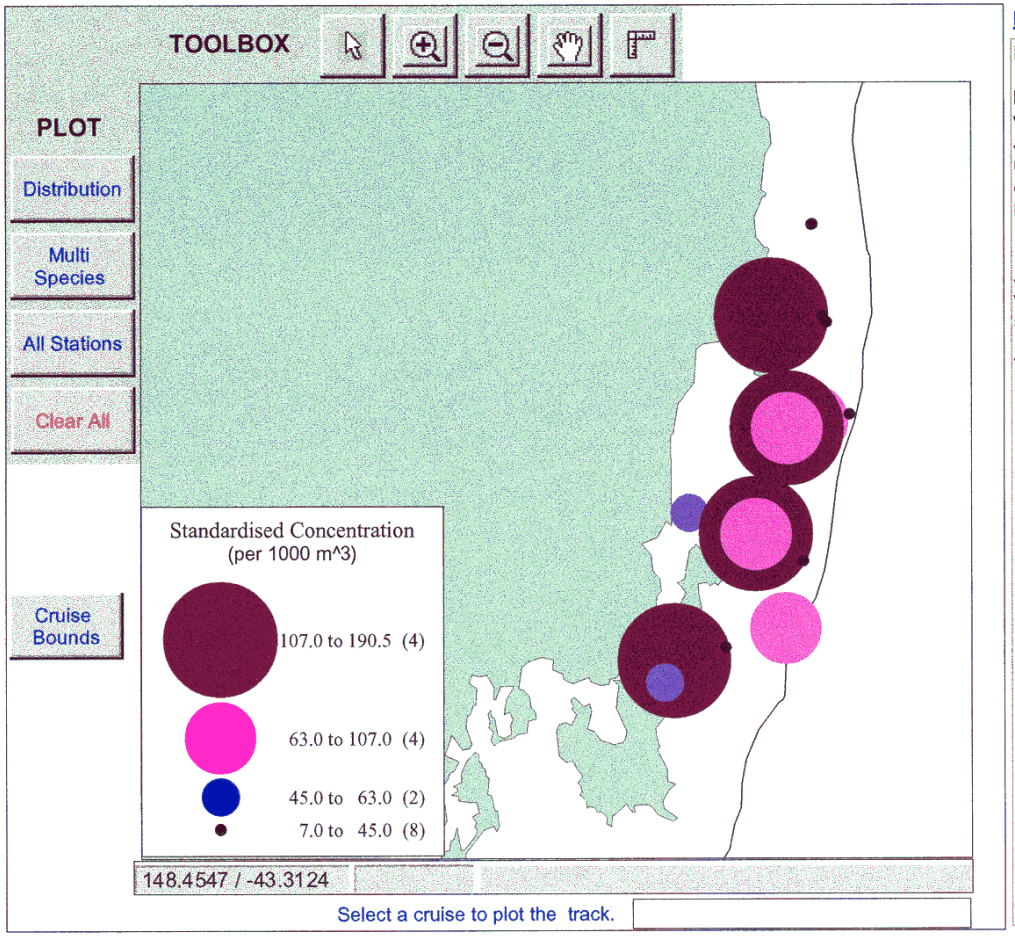
Diagnostic Characters

* 10-11 + 16-17 = 27-28 myomeres;
* Single internal melanophore on nape;
* Single series of 15-18 melanophores along ventral midline of tail;
* Several melanophores on caudal fin base;
* Single melanophore on pectoral fin base and angle of lower jaw;
* Teeth present in postflexion larvae.

Meristic Counts

Myomeres	27
Body Length (mm)	8.6 - 12.2
Age (days)	
Dorsal fin	IX - VIII, 14
Anal fin	14
Caudal fin	15
Pectoral fin	19
Pelvic fin	1, 5

Neoplatycephalus richardsoni	Castelnau, 1872	
tiger flathead	CAAB 37296001	629



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off the east coast of Tasmania from January to February (A. Jordan, TAFI, unpublished data). Database records are confined within this range and period. The highest concentrations of larvae (up to 190 / 1000 m^3) have been recorded off the Freycinet Peninsula (eastern Tasmania) in January. Larvae are restricted to shelf waters and have not been recorded seaward of the shelf break.

Vertical distribution:

Unknown.

Neoplatycephalus richardsoni	Castelnau, 1872	
tiger flathead	CAAB 37296001	629

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Neoplatycephalus richardsoni	Castelnau, 1872	
tiger flathead	CAAB 37296001	629

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Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

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Snapper (*Pagrus auratus*)

Pagrus auratus	Foster, 1801	
snapper	CAAB 37353001	751

Species Distribution

Snapper (F. Sparidae) reach approximately 130 cm in length and 20 kg (Yearsley et al. 1999). In Australia, they occur from Hinchinbrook Island (Qld) along the south coast to Barrow Island (WA) including northern Tasmania (MacDonald 1982, Gomon et al. 1994). They also occur in New Zealand and Japan (Miskiewicz & Neira 1998). Juveniles and small adults inhabit bays, estuaries and inlets, often over mud and seagrass (MacDonald 1982, Gomon et al. 1994). Larger adults inhabit coastal rocky reefs at depths up to 300 m, but more commonly to about 35 m (Gomon et al. 1994).

Spawning

They are serial spawners and spawning occurs on a daily basis in the majority of individuals. Estimates of batch fecundity are about 100,000 eggs per kg weight (Scott & Pankhurst 1992, Scott et al. 1993, Hobby & Pankhurst 1997).

Spawning has been recorded throughout their geographical range and is regionally variable in its timing. In southern Australia, spawning occurs between late October and early March (Lenanton 1974). In more northern waters, spawning occurs during winter between Late May and August (Kailola et al. 1993). These correspond to the timing of highest larval concentrations in eastern Victoria and northern NSW respectively. However, the period of larval occurrence off Sydney (all year) suggests a more protracted spawning period than reported, or transport of larvae from both north and south into the Sydney area.

Estimating spawning stock biomass via egg surveys has been conducted in Spencer Gulf (SA) and Shark Bay (WA) and may be feasible in other regions (McGlennon & Jones 1997, G. Jackson WA Fisheries pers. comm.).

Stock Structure

Both tagging and genetic studies indicate that snapper form discrete stocks or breeding units in Australian waters with considerable overlap in the distribution of these populations (Sanders 1974, MacDonald 1982, Johnson et al. 1986, Francis & Winstanley 1989, Donnellan & McGlennon 1996). Reported larval distribution is consistent with the sampling of the eastern Australian stock.

Full Larval Description

Cassie, R. M. (1956). Early development of the snapper, Chrysophrys auratus Forster. Transactions of the Royal Society of New Zealand 83: 705 - 713. Supplemented by: Kingsford, M. J. & Atkinson, M. H. (1994). Increments in otoliths and scales: How they relate to the age and early development of reared and wild larval and juvenile Pagrus auratus (Sparidae). Australian Journal of Marine and Freshwater Research 45: 1007 - 1021.

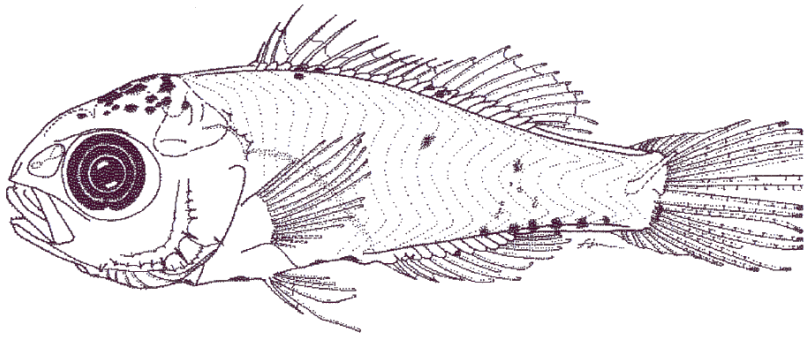
Larvae of Temperate Australian Fishes reference: Miskiewicz & Neira (1998): Sparidae: Breams, snappers. Pp 306 - 315.

Other taxa recorded with snapper larvae (% of samples):

S. sagax (66), E. australis (62), P. fuscus (49), S. flindersi (31), S. australasicus (25), H. percoides (24), P. saltatrix (21), G. blacodes (18), A. australis (15), G. greyi (15), T. novaezelandiae (15), R. solandri (12), T. declivis (12), L. caudatus (9), P. dentex (9), C. affinis (7), S. ciliata (7), P. bassensis (4), A. trutta (3), S. bassensis (1), T. atun (1)

Australian Seafood Handbook reference: p 73

Pagrus auratus	Foster, 1801	
snapper	CAAB 37353001	751



Larval Stage: postflexion

Illustrated by F.J. Neira 10.1 mm

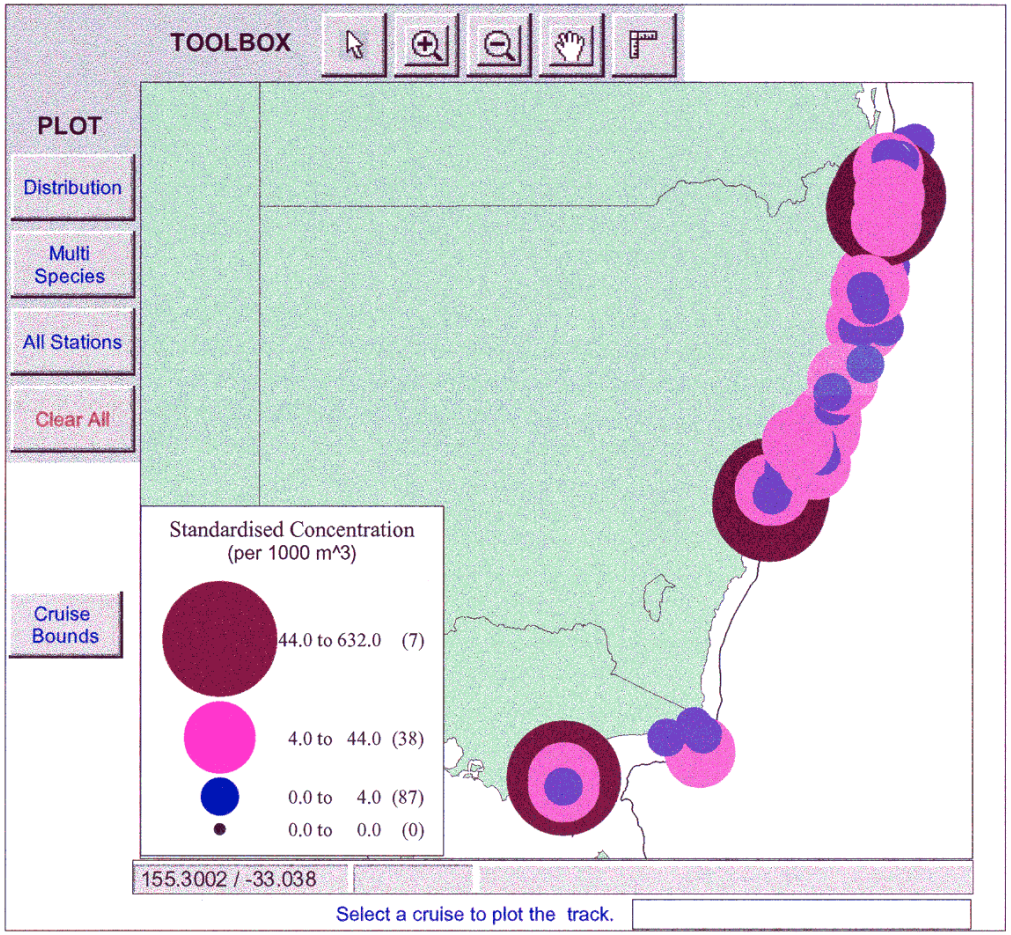
Diagnostic Characters

* 8-10 + 14-17 = 24-25 myomeres;
* Elongate posterior preopercular spines in preflexion and flexion larvae; supracleithral and interopercular spines in flexion larvae;
* 1 large internal melanophore over nape;
* 2 large melanophores ventrally on gut;
* 1-3 small melanophores under notochord tip.

Meristic Counts

Myomeres	24
Body Length (mm)	6.6 - 12
Age (days)	
Dorsal fin	XII, 10 - 9
Anal fin	III, 8 - 9
Caudal fin	17
Pectoral fin	15 - 16
Pelvic fin	1, 5

Pagrus auratus	Foster, 1801	
snapper	CAAB 37353001	751



Larval Distribution

Regional distribution:

Larvae have been reported entering estuarine waters in Western Australia between December and January (Neira & Potter 1992), in Port Phillip Bay (Vic.) between December and March (Jenkins 1986), entering Tuggerah Lakes (NSW) from August to October (Marsden 1986); and in shelf waters off Sydney throughout the year (Gray 1995). Database records extend this distribution to include eastern Victoria (December to February) and central NSW to southern Queensland from May to September. The highest concentrations of larvae (up to 84 / 1000 m^3) have been recorded off eastern Victoria in December. High concentrations have also been recorded off central NSW from June to July and northern NSW in August. Larvae are widespread in shelf waters up to 40 km seaward of the shelf break.

Vertical distribution:

Gray & Miskiewicz (2000) recorded higher concentrations of larvae at 20 - 30 m than at the surface in shelf waters off Sydney (NSW).

Pagrus auratus	Foster, 1801	
snapper	CAAB 37353001	751

Larval Growth

No data on back-calculated spawning dates or larval growth are available in the database.

Eggs hatch after 72 - 96 h at 18.0 - 21.0 deg. C and larvae are approximately 3.1 mm in length at hatching (Cassie 1956, Battaglene & Talbot 1992). Otoliths have unambiguous increments which form on a daily basis beginning one day after hatching (Kingsford & Atkinson 1994).

Reported growth of New Zealand larvae, from 3 - 9 mm, was linear (Kingsford and Atkinson 1994).

1985: Body length = 0.25 x age + 0.89

(R^2 = 0.90; n = 20)

Snapper have a pelagic early life history of 18 - 40 days (Francis et al. 1992, Pankhurst et al. 1991, Battaglene and Talbot 1992, Kingsford and Aitkinson 1994).

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Pagrus auratus	Foster, 1801	
snapper	CAAB 37353001	751

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Sand flathead (*Platycephalus bassensis*)

Platycephalus bassensis	Cuvier, 1829	
sand flathead	CAAB 37296003	630

Species Distribution

Sand flathead (F. Platycephalidae) reach approximately 55 cm in length and 3 kg (Winstanley 1985, Yearsley et al. 1999). They are endemic to southeast Australia occurring from central NSW to eastern South Australia including Tasmania (Keenan 1988, Gomon et al.1994). Adults and juveniles occur on sandy bottoms in coastal bays and estuaries, extending onto the continental shelf to a depth of about 100 m (Dredge 1976, Jordan 2001).

Spawning

They are single spawners (Brown 1978). Fecundity is unknown.

Spawning has been recorded throughout their geographical range and is regionally variable in its timing. In Tasmania, it has been recorded over an extended period between October and March (Jordan 2001), while in Port Phillip Bay (Vic) it has been recorded between August and October (Brown 1978). The majority of spawning takes place in estuaries, coastal embayments and inshore shelf waters (Jordan 2001). The distribution of larvae suggests at least spring - summer spawning in Tasmania and Victoria.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown.

Full Larval Description

Jordan, A. R. (2001). Reproductive biology, early life-history and settlement distribution of sand flathead (Platycephalus bassensis) in Tasmania. Marine and Freshwater Research 52: 589 - 601.

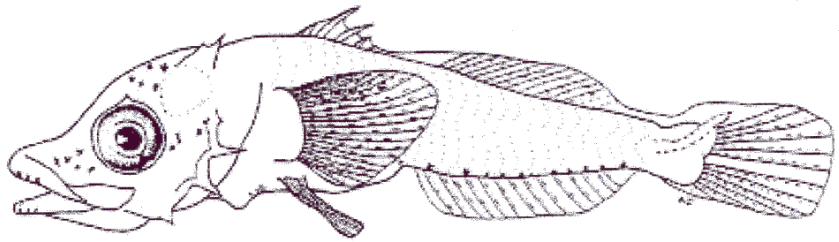
Larvae of Temperate Australian Fishes reference: not included

Other taxa recorded with sand flathead larvae (% of samples):

T. declivis (50), S. sagax (30), T. atun (25), E. australis (20), N. richardsoni (20), S. flindersi (15), P. fuscus (12), S. bassensis (10), P. auratus (8), P. dentex (8), S. australasicus (8), A. trutta (2), H. percoides (2)

Australian Seafood Handbook reference: p 117

Platycephalus bassensis	Cuvier, 1829	
sand flathead	CAAB 37296003	630



Larval Stage: postflexion

Illustrated by A.R. Jordan mm

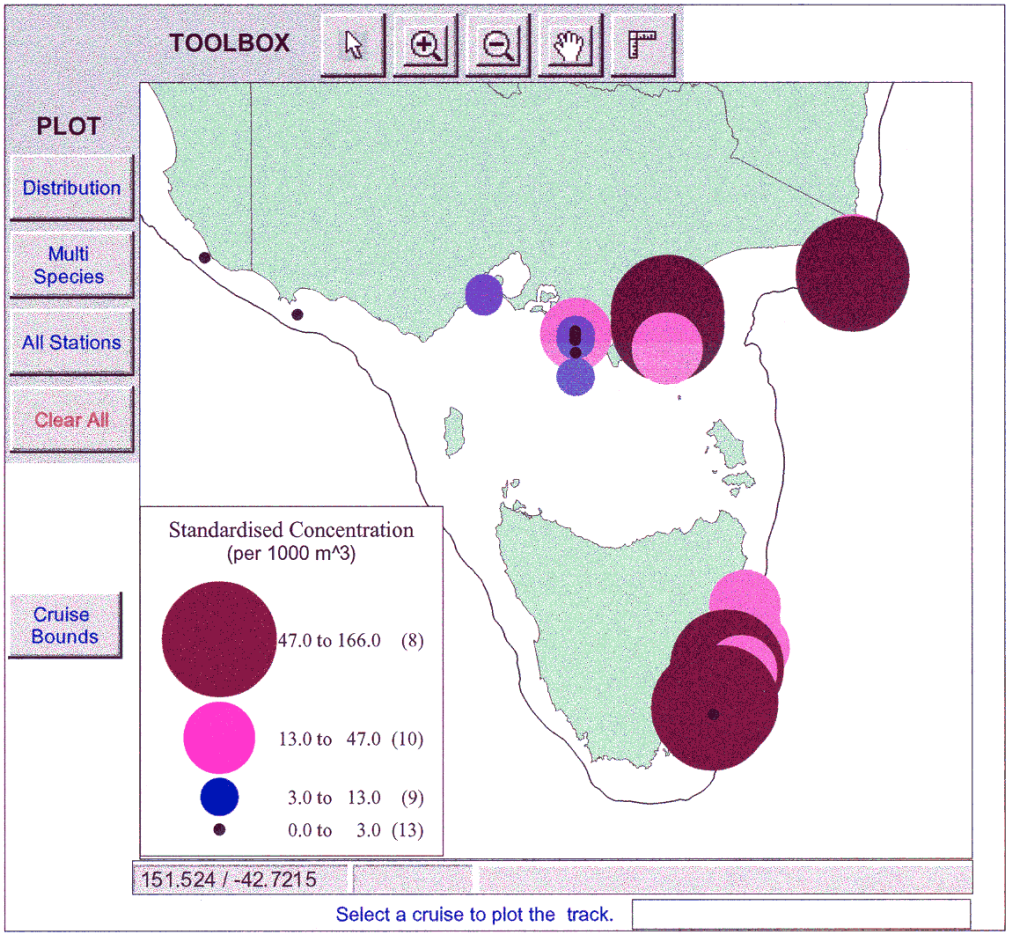
Diagnostic Characters

* 10-11 + 16-17 + 27-28 myomeres;
* Light pigment on upper and lower jaws and snout;
* Single series of 13-17 melanophores along ventral midline of tail;
* Light pigment on dorsal surface of head and ventral surface of trunk.

Meristic Counts

Myomeres	27
Body Length (mm)	8.4 – 20
Age (days)	
Dorsal fin	IX – VIII, 14
Anal fin	14
Caudal fin	15
Pectoral fin	19
Pelvic fin	1, 5

Platycephalus bassensis	Cuvier, 1829	
sand flathead	CAAB 37296003	630



Larval Distribution

Regional distribution:

Larvae have been reported from coastal and inner-shelf waters of the east coast of Tasmania in November and January (Jordan et al. 1998, Jordan 2001) and from Victorian waters in December and January (Neira et al. 2000). Database records are confined to this range and period. The highest concentration of larvae (up to 165 / 1000 m^3) has been recorded in Norfolk Bay (southeast Tasmania) in November. High concentrations have also been recorded in shelf waters off eastern Tasmania in January and eastern Bass Strait in December. Larvae are restricted to shelf waters and concentrations are highest in inshore regions.

Vertical distribution:

Jordan (2001) recorded the highest concentrations of larvae within the 20 - 30 m depth stratum in Tasmanian waters in areas where cross shelf currents were suitable for retaining larvae in inshore waters. Neira et al. (2000) recorded the highest concentrations of larvae from 25 - 75 m in Bass Strait.

Platycephalus bassensis	Cuvier, 1829	
sand flathead	CAAB 37296003	630

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Platycephalus bassensis	Cuvier, 1829	
sand flathead	CAAB 37296003	630

Book and Book Chapter References

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Keenan, C. P. (1988). Systematics and evolution of Australian species of flatheads (Pisces, Platycephalidae). PhD Thesis. The University of Queensland, Brisbane, Qld.

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Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

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Gray, C. A., Otway, N. M., Laurenson, F. A., Miskiewicz, A. G. & Pethebridge, R. L. (1992). Distribution and abundance of marine fish larvae in relation to effluent plumes from sewage outfalls and depth of water. Marine Biology 113: 549 - 559.

Jordan, A. R. (2001). Reproductive biology, early life-history and settlement distribution of sand flathead (Platycephalus bassensis) in Tasmania. Marine and Freshwater Research 52: 589 - 601.

Tailor (*Pomatomus saltatrix*)

Pomatomus saltatrix	Linnaeus, 1766	
tailor	CAAB 37334002	710

Species Distribution

Tailor (F. Pomatomidae) reach approximately 120 cm in length and 14 kg (Yearsley et al. 1999). In Australia, they occur from Fraser Island (Qld) south and west to Onslow (WA), including Tasmania, although records in the Great Australian Bight are rare (Gomon et al. 1994). They are also widely distributed throughout all subtropical and temperate continental-shelf waters (Juanes et al. 1996, Miskiewicz et al. 1996, Trnski et al. 1998). Adults are commonly found adjacent to ocean beaches. Juveniles prefer sheltered inshore waters including estuaries (Morton et al. 1993, Miskiewicz et al. 1996, Zeller et al. 1996).

Spawning

They are serial spawners (van der Elst 1976). Estimates of fecundity range from 370,000 to 1,240,000 eggs, with some differences between eastern and western Australian populations (Juanes et al. 1996).

Spawning has been recorded from October to November in the central region of Western Australia and in March and April in the south (Lenanton et al. 1996, Juanes et al. 1996). Spawning is protracted off eastern Australia and has been recorded from June to October in inshore waters of Fraser, Moreton and Stradbroke Islands (Qld) (Zeller et al. 1996). The location and timing of highest concentrations of larvae suggests spawning also occurs off northern NSW from January to May (Miskiewicz et al. 1996).

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature of spawning.

Stock Structure

There is distinct genetic structuring between eastern and western tailor populations in Australia (Nurthen et al. 1992, Goodbred & Graves 1996, Lenanton et al. 1996). In WA, otolith oxygen:carbon ratios suggest fish from Shark Bay may be a separate stock from those further south (Lenanton et al. 1996). Reported larval distribution is consistent with sampling the eastern Australian stock.

Full Larval Description

Bertolini, F., D'Ancona, U., Padoa Montalenti, E., Ranzi, S., Sanzo, L., Sparta, A., Tortonese, E., and Vialli, M. (1956). Uova, larve e stadi giovanili di Teleostei. Fauna Flora Golfo Napoli, Monographica. 38:1-1064.

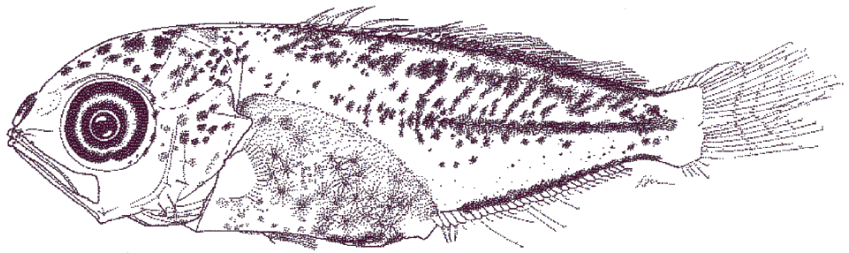
Larvae of Temperate Australian Fishes reference: Trnski et al. (1998): Pomatomidae: Tailor, bluefish. Pp 274 - 277.

Other taxa recorded with tailor larvae (% of samples):

E. australis (78), G. greyi (54), P. fuscus (46), T. novaezelandiae (45), S. sagax (38), A. australis (24), S. flindersi (20), P. auratus (18), P. dentex (16), S. ciliata (12), G. blacodes (8), S. australasicus (8), H. percoides (7), C. affinis (4), S. s. scomberoides (3), L. caudatus (1), R. solandri (1)

Australian Seafood Handbook reference: p 272

Pomatomus saltatrix	Linnaeus, 1766	
tailor	CAAB 37334002	710



Larval Stage: postflexion

Illustrated by F.J. Neira 8.5 mm

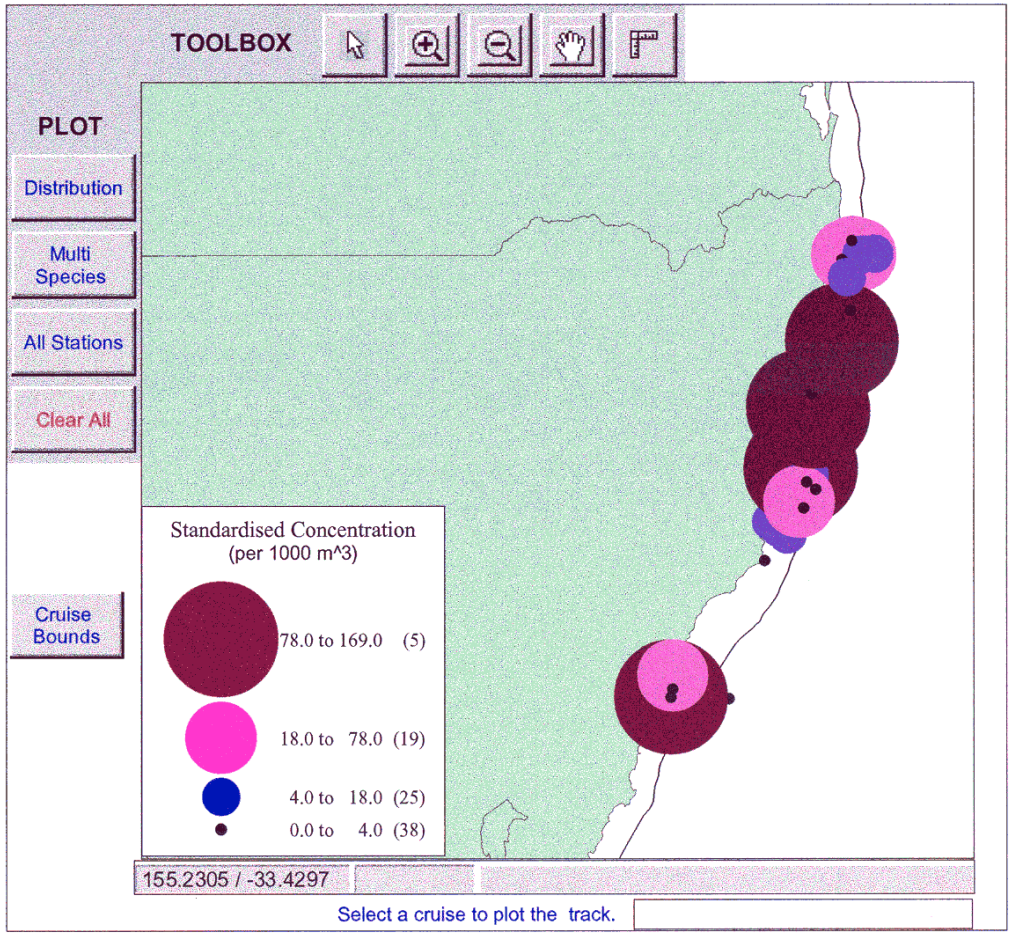
Diagnostic Characters

* 10-11 + 14-17 = 25-27 myomeres;
* Internal pigment at nape;
* Melanophore series along dorsal midline of tail restricted to dorsal-fin base;
* Melanophore series along lateral midline of tail from 3.3mm, between myomeres 14-24;
* Melanophore series along ventral midline of posterior of tail.

Meristic Counts

Myomeres	26
Body Length (mm)	5.3 – 14
Age (days)	
Dorsal fin	VII – VIII + 1, 23 – 28
Anal fin	I – III, 23 – 28
Caudal fin	17
Pectoral fin	16 – 17
Pelvic fin	1, 5

Pomatomus saltatrix	Linnaeus, 1766	
tailor	CAAB 37334002	710



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off central and northern NSW from January to May (Miskiewicz et al. 1996). Database records are confined within this range but also include larvae off northern NSW from July to August. The highest concentrations of larvae (up to 125 / 1000 m^3) have been recorded off northern NSW in May. Larvae are widespread in shelf waters and have been recorded up to 30 km seaward of the shelf break.

Vertical distribution:

Unknown. However, larvae are most commonly recorded in surface tows.

Pomatomus saltatrix	Linnaeus, 1766	
tailor	CAAB 37334002	710

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Eggs hatch after 48 h at approximately 20 deg. C (Deuel et al. 1966).

Reported growth rates of Northwest Atlantic and Baltic Sea larvae range from 0.3 - 0.8 mm per day (Salekhova 1959, Deuel et al. 1966, Hare & Cowan 1994).

Back-calculated spawning dates ☐

Larval growth ☐

Regional comparison ☐

Pomatomus saltatrix	Linnaeus, 1766	
tailor	CAAB 37334002	710

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Trnski, T., Neira, F. J. & Miskiewicz, A. G. (1998). Pomatomidae: Tailor, bluefish. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz, T. Trnski, Eds.). University of Western Australia, Nedlands, WA. Pp: 274 - 277.

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

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Goodbred, C. O. & Graves, J. E. (1996). Genetic relationship among geographically isolated populations of bluefish (Pomatomus saltatrix). Marine and Freshwater Research 47: 347 - 355.

Hare, J. A. & Cowen, R. K. (1994). Ontogeny and otolith microstructure of bluefish Pomatomus saltatrix (Pisces: Pomatomidae). Marine Biology 118: 541 - 550.

Juanes, F., Hare, J. A. & Miskiewicz, A. G. (1996). Comparing early life history strategies of Pomatomus saltatrix: a global approach. Marine and Freshwater Research 47: 365 - 380.

Lenanton, R. C., Ayvazian, S. G., Pearce, A. F., Streckis, R. A. & Young, G. C. (1996). Tailor (Pomatomus saltatrix) off Western Australia: where does it spawn and how are the larvae distributed? Marine and Freshwater Research 47: 337 - 346.

Miskiewicz, A. G., Bruce, B. D. & Dixon, P. (1996). Distribution of tailor (Pomatomus saltatrix) larvae along the coast of New South Wales, Australia. Marine and Freshwater Research 47: 331 - 336.

Miskiewicz, A. G., Juanes, F. & Hare, J. A. (1996). ILFC Symposium. Early life history of Pomatomus saltatrix: Introduction. Marine and Freshwater Research 47: 309.

Morton, R. M., Halliday, I. & Cameron, D. (1993). Movement of tagged juvenile tailor (Pomatomus saltatrix) in Moreton Bay, Queensland. Australian Journal of Marine and Freshwater Research 44: 811 - 816.

Silver trevally (*Pseudocaranx dentex*)

Pseudocaranx dentex	Bloch & Schneider, 1801	
silver trevally	CAAB 37337062	27

Species Distribution

Silver trevally (F. Carangidae) reach approximately 94 cm in length and up to 10 kg (Yearsley et al. 1999). In Australia, they occur from northeast Queensland around the south coast to North West Cape (WA), including Tasmania, Lord Howe Island and Norfolk Island (Kailola et al. 1993). They are also widely distributed throughout warm temperate and subtropical waters of the Indian, Atlantic and Pacific Oceans (Gomon et al. 1994). Large adults have been found over deeper shelf waters to depths of 120 m (Last et al. 1983). Juveniles usually inhabit estuaries, bays and shallow continental shelf waters (Kailola et al. 1993).

Spawning

They are partial batch spawners (Annala et al. 1999). Estimates of fecundity range from 30,000 - 220,000 eggs for fish 23 - 37 cm in length (Rowling & Raines 2000).

Spawning has been recorded off northern NSW in spring and early summer (Roughly 1951) and in other regions of NSW from late spring to autumn (Rowling and Raines 2000). The distribution of larvae suggests that spawning is widespread, protracted and regionally variable in timing across its Australian range.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown. Genetic data from New Zealand suggest that silver trevally form a single stock, at least along the west coast of the North Island (Gauldie & Johnston 1980). However, a tagging study by James (1984) indicated that trevally move over a limited distance suggesting discrete unit stocks were possible. Larval distribution suggests widespread spawning in southeast Australia.

Full Larval Description

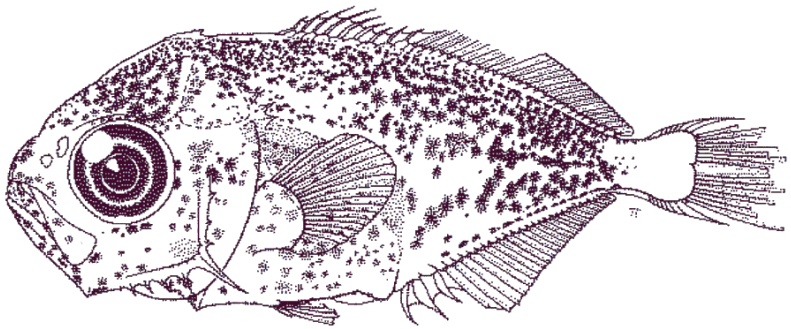
Larvae of Temperate Australian Fishes reference: Trnski (1998): Carangidae: Trevallys, jacks. Pp 192 - 203.

Other taxa recorded with silver trevally larvae (% of samples):

T. novaezelandiae (32), E. australis (30), T. declivis (28), S. sagax (26), G. greyi (25), P. saltatrix (21), T. atun (19), Seriolella punctata (12), S. flindersi (12), H. percoides (11), P. auratus (11), A. trutta (7), C. affinis (7), P. fuscus (7), S. brama (7), A. australis (5), P. bassensis (5), G. tigerinus (4), P. wrighti (4), S. s. scomberoides (4), S. ciliata (4), C. australis (2), G. blacodes (2), M. novaezelandiae (2), R. solandri (2)

Australian Seafood Handbook reference: p 271

Pseudocaranx dentex	Bloch & Schneider, 1801	
silver trevally	CAAB 37337062	27



Larval Stage: postflexion

Illustrated by T. Trnski 8.9 mm

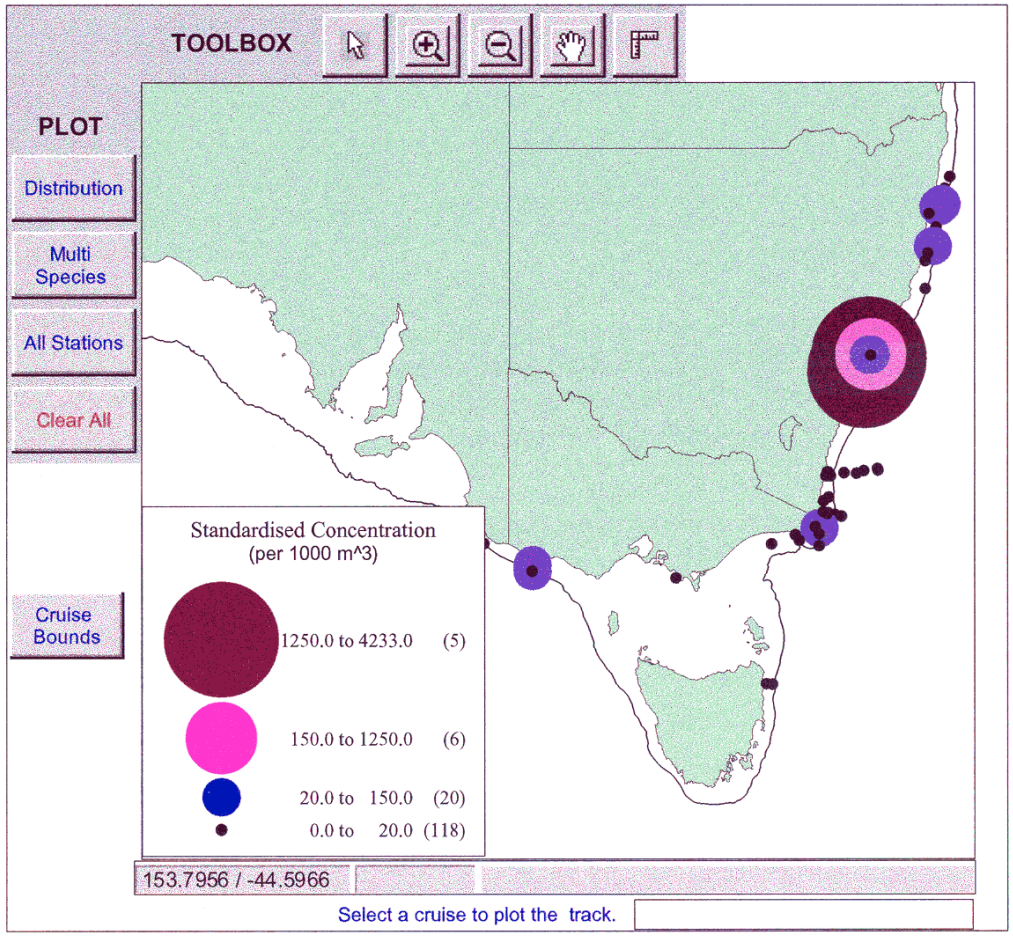
Diagnostic Characters

* 10-12 + 12-15 = 24-25 myomeres;
* Posterior preopercular spine at angle long from early preflexion stage;
* Supraoccipital crest high and serrate, with a single peak posteriorly;
* One supracleithral spine from early flexion stage, a second spine in postflexion stage;
* Paired melanophore series along dorsal midline of trunk and tail.

Meristic Counts

Myomeres	25
Body Length (mm)	5.6 - 13
Age (days)	
Dorsal fin	VIII - VIII + 1, 25 - 28
Anal fin	II - II + 1, 21 - 25
Caudal fin	17
Pectoral fin	18 - 21
Pelvic fin	1, 5

Pseudocaranx dentex	Bloch & Schneider, 1801	
silver trevally	CAAB 37337062	27



Larval Distribution

Regional distribution:

Larvae have been reported from Lake Macquarie (NSW) between December and February (Miskiewicz 1987), in coastal waters off Sydney between August and May (Gray et al. 1992), and in eastern and western Victoria (including Bass Strait) from December to January and May to July (Neira et al. 2000). Database records include shelf and offshore waters off southern NSW from August to May, and off northeast Tasmania in March. The highest concentration of larvae (4233 / 1000 m^3) has been recorded in in coastal waters off Sydney in August / September. High concentrations have also been recorded off northern NSW in May. Larvae are widespread in shelf waters and have been recorded up to 110 km seaward of the shelf break off southern NSW.

Vertical distribution:

Gray et al. (1992) and Gray & Miskiewicz (2000) recorded higher concentrations of larvae at 20 - 30 m than at the surface in shelf waters off Sydney (NSW).

Pseudocaranx dentex	Bloch & Schneider, 1801	
silver trevally	CAAB 37337062	27

Larval Growth

Eggs hatch after approximately 28 h at 21 deg. C and larvae are 1.55 - 2.06 mm at hatching (James 1976).

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Pseudocaranx dentex	Bloch & Schneider, 1801	
silver trevally	CAAB 37337062	27

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

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Roughley, T. C. (1964). Fish and Fisheries of Australia. Angus and Robertson, Sydney, NSW.

Rowling, K. & Raines, L. (2000). Description of the biology and an assessment of the fishery for silver trevally off New South Wales. In: Final Report to FRDC, Project No. 97/125 (, Eds.). New South Wales Fisheries Research Institute, Cronulla, NSW. Pp: .

Trnski, T. (1998). Carangidae: Trevallys, jacks. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 192 - 203.

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Gauldie, R, W. & Johnston, A. J. (1980). The geographical distribution of phosphoglucomutase and glucose phosphate isomerase alleles of some New Zealand fishes. Comparative Biochemistry and Physiology Part B 66: 171 - 183.

Gray, C. A., Otway, N. M., Laurenson, F. A., Miskiewicz, A. G. & Pethebridge, R. L. (1992). Distribution and abundance of marine fish larvae in relation to effluent plumes from sewage outfalls and depth of water. Marine Biology 113: 549 - 559.

James, G. D. (1976). Eggs and larvae of the trevally Caranx georgianus (Teleostei: Carangidae). New Zealand Journal of Marine and Freshwater Research 10: 301 - 310.

Sand trevally (*Pseudocaranx wrighti*)

Pseudocaranx wrighti	Whitley, 1931	
sand trevally	CAAB 37337063	28

Species Distribution

Sand trevally (F. Carangidae) reach approximately 35 cm in length and 10 kg (Yearsley et al. 1999). In Australia, they occur from eastern Bass Strait along the south coast to Exmouth (WA) including Tasmania (Gomon et al. 1994). Both adult and juvenile sand trevally form dense schools in estuaries, bays and coastal waters to a maximum depth of about 30 m (Gomon et al. 1994, Trnski 1998).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has not been recorded. Reported distribution and confirmed records of larvae suggest widespread spawning from spring to autumn across their geographical range.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown.

Full Larval Description

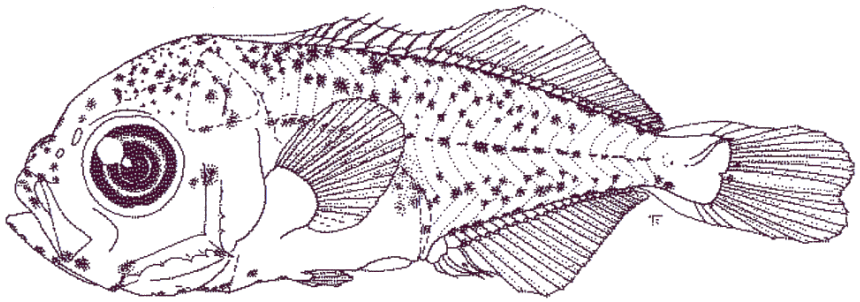
Larvae of Temperate Australian Fishes reference: Trnski (1998): Carangidae: Trevallys, jacks. Pp 192 - 203.

Other taxa recorded with sand trevally larvae (% of samples):

H. percoides (50), M. novaezelandiae (50), T. declivis (50), G. tigerinus (33), P. dentex (33), Seriolella punctata (33), T. atun (33), T. novaezelandiae (33), E. australis (17), G. greyi (17), S. sagax (17)

Australian Seafood Handbook reference: p 271

Pseudocaranx wrighti	Whitley, 1931	
sand trevally	CAAB 37337063	28



Larval Stage: postflexion

Illustrated by T. Trnski 7.9 mm

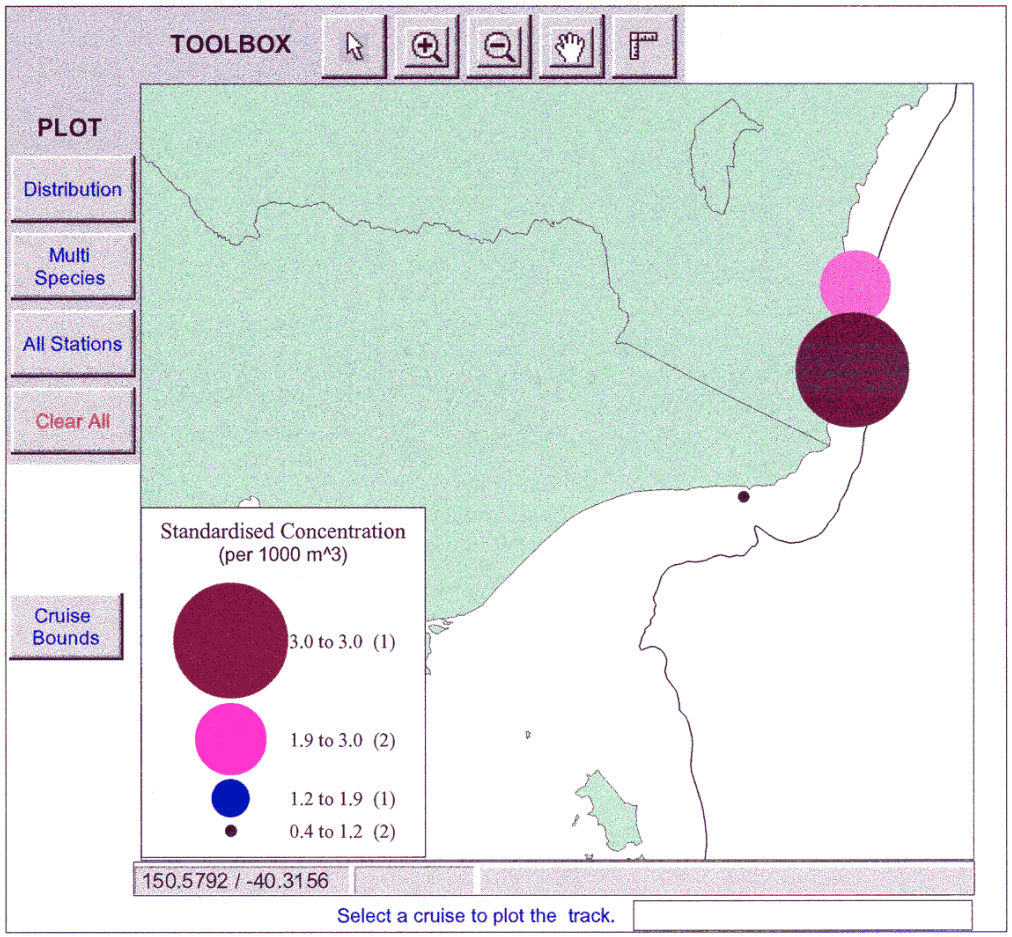
Diagnostic Characters

* 9-12 + 12-15 = 24-25 myomeres;
* Posterior preopercular spine at angle long from early postflexion stage to about 8 mm;
* Supraoccipital crest low, weakly serrate and without a peak, absent from late postflexion stage;
* 1 supracleithral spine;
* Low pterotic ridge from 8.3mm;
* Expanded melanophore laterally on gut below pectoral-fin base until early postflexion stage;
* 8 or more (rarely 5) expanded melanophores along dorsal midline of trunk and tail.

Meristic Counts

Myomeres	24
Body Length (mm)	6.1 – 14
Age (days)	
Dorsal fin	VIII – VIII + 1, 22 – 26
Anal fin	II – II + 1, 18 – 22
Caudal fin	17
Pectoral fin	18 – 19
Pelvic fin	1, 5

Pseudocaranx wrighti	Whitley, 1931	
sand trevally	CAAB 37337063	28



Larval Distribution

Regional distribution:

Larvae have been reported from Cockburn Sound and the lower Swan Estuary (WA) (Neira et al. 1992, Jonker 1993), and in the upper Spencer Gulf from September through to March (Trnski 1998). Database records include larvae in eastern Bass Strait during February, and off southern NSW in May and August. The highest concentrations of larvae (up to 3 per 1000 m^3) have been recorded from shelf waters off southern NSW in August. Larvae are restricted to shelf waters.

Vertical distribution:

Unknown.

Pseudocaranx wrighti	Whitley, 1931	
sand trevally	CAAB 37337063	28

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Pseudocaranx wrighti	Whitley, 1931	
sand trevally	CAAB 37337063	28

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Jonker, L. J. (1993). Comparisons of the larval fish assemblages in healthy and degraded seagrass meadows in Cockburn Sound, Western Australia. BSc (Hons.) Thesis. Murdoch University, Perth, WA.

Trnski, T. (1998). Carangidae: Trevallys, jacks. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 192 - 203.

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

Journal Articles

Neira, F. J., Potter, I. C. & Bradley, J. S. (1992). Seasonal and spatial changes in the larval fish fauna within a large temperate Australian estuary. Marine Biology 112: 1 - 16.

Platell, M. E., Sarre, G. A. & Potter, I. C. (1997). The diets of two co-occurring marine teleosts, Paraquula melbournensis and Pseudocaranx wrighti, and their relationships to body size and mouth morphology, and the season and location of capture. Environmental Biology of Fishes 49: 361 - 376.

Gemfish (*Rexea solandri*)

Rexea solandri	Cuvier, 1832	
gemfish	CAAB 37439002	1048

Species Distribution

Gemfish (F. Gempylidae) reach approximately 120 cm in length and 15 kg (Yearsley et al. 1999). In Australia, they occur from about northern NSW around the south coast to mid Western Australia including Tasmania (Williams 1992, Gomon et al. 1994, Rowling 1994). They also occur off both the east and west coasts of New Zealand (Gomon et al. 1994). Both adult and juvenile gemfish occur over the deeper shelf and upper slope waters between about 100 and 800 m (Gomon et al. 1994, Rowling 1994).

Spawning

Their spawning mode is unknown. Estimates of fecundity range from 500,000 to 1,500,000 eggs (Rowling 1994).

Spawning has been recorded off northern NSW in late winter (Rowling 1994, Prince et al. 1999) and, for western gemfish, off southwest Western Australia during summer (Lyle & Ford 1993, Rowling 1994, Smith 1994). Larval distribution suggests spawning over a more protracted period off central and / or northern NSW from July to September.

Estimating spawning stock biomass via egg surveys has not been attempted but may be suitable given the restricted period of spawning.

Stock Structure

Genetic data, the timing of spawning and analysis of parasites indicates two stocks of gemfish in Australia one either side of Bass Strait (Sewell & Lester 1995, Colgan & Paxton 1997). Reported larval distribution is consistent with the sampling of the eastern Australian stock.

Full Larval Description

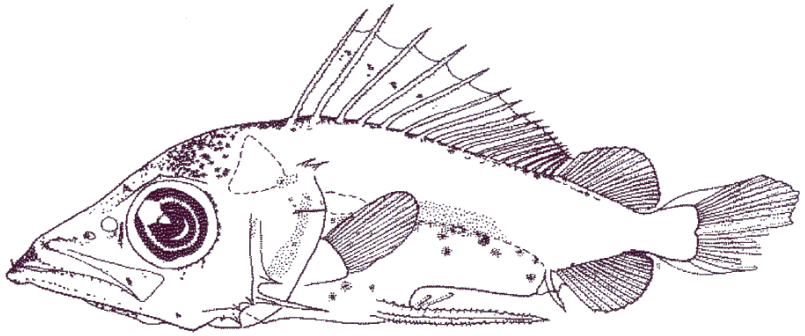
Larvae of Temperate Australian Fishes reference: Miskiewicz & Trnski (1998): Gempylidae: Gemfishes, snake mackerels, escolars. Pp 406 - 411.

Other taxa recorded with gemfish larvae (% of samples):

H. percoides (59), S. sagax (51), G. blacodes (46), S. australasicus (26), L. caudatus (21), P. auratus (21), E. australis (13), P. fuscus (13), G. greyi (10), S. flindersi (10), C. affinis (5), Seriolella punctata (5), A. australis (3), C. australis (3), P. saltatrix (3), P. dentex (3), S. s. scomberoides (3), T. atun (3), T. declivis (3)

Australian Seafood Handbook reference: p 133

Rexea solandri	Cuvier, 1832	
gemfish	CAAB 37439002	1048



Larval Stage: postflexion

Illustrated by T. Trnski 10.7 mm

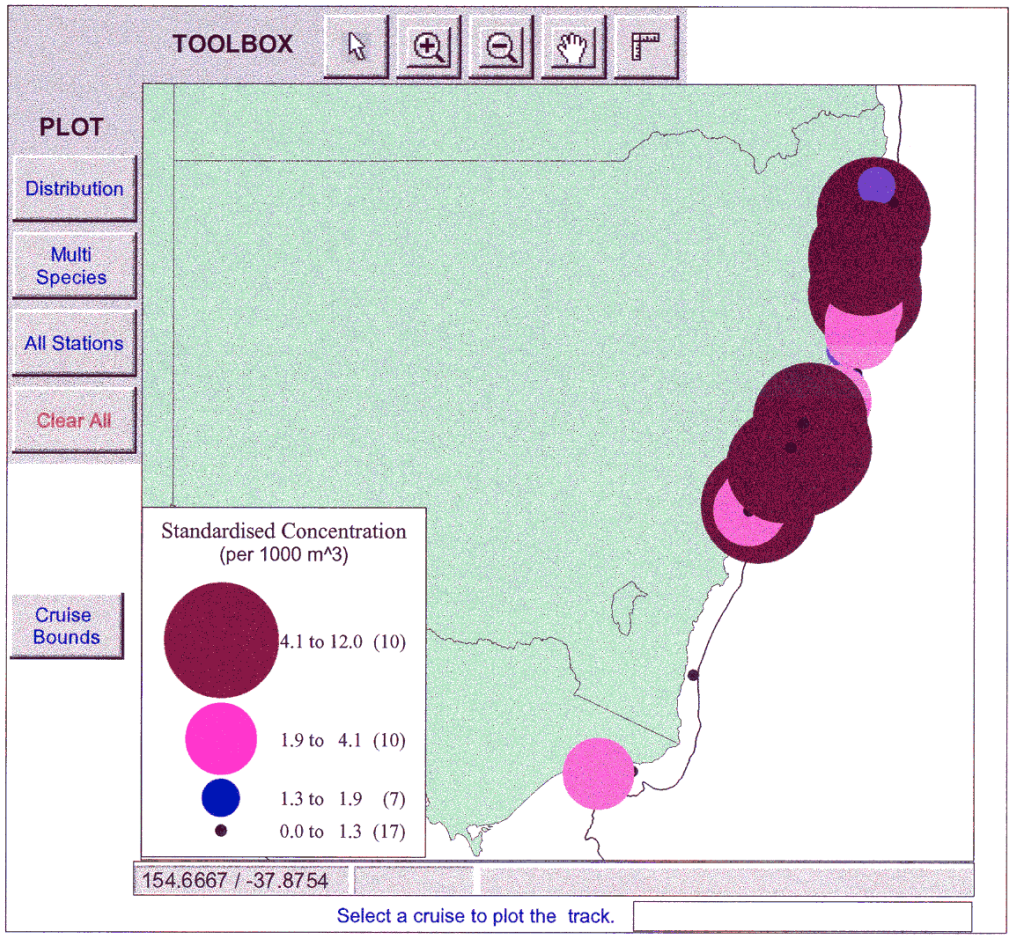
Diagnostic Characters

* 6-20 + 16-30 = 35-36 myomeres;
* Up to 4 posterior preopercular spines, spine at angle long from flexion stage and finely serrate by 10.4mm;
* Early forming dorsal-fin elements; dorsal-fin spines long, and serrate anteriorly and laterally from late preflexion stage;
* Pelvic-fin spine strongly serrate ventrally, laterally and medially by late preflexion stage;
* 1-2 melanophores on ventral midline of tail, becoming internal by 4.5mm.

Meristic Counts

Myomeres	35 - 36
Body Length (mm)	10.1 - 16.7
Age (days)	
Dorsal fin	XVII - XVIII + 1, 16 - 19 + 2
Anal fin	I - II, 13 - 16 + 2
Caudal fin	17
Pectoral fin	13 - 15
Pelvic fin	1, 2 - 3

Rexea solandri Cuvier, 1832
gemfish CAAB 37439002 1048



Larval Distribution

Regional distribution:

Larvae have been reported in shelf waters from Sydney to northern NSW from July to September (Gorman et al. 1987, Miskiewicz et al. 1987, Gray 1995). Database records extend this range to include southern NSW and eastern Victoria in August. The highest concentrations of larvae (up to 12 / 1000 m^3) have been recorded off central and northern NSW in September. Larvae are widely distributed in shelf waters and are rarely recorded seaward of the shelf break.

Vertical distribution:

Unknown.

Rexea solandri	Cuvier, 1832	
gemfish	CAAB 37439002	1048

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Rexea solandri	Cuvier, 1832	
gemfish	CAAB 37439002	1048

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Pilchard (*Sardinops sagax*)

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222

Species Distribution

Pilchards (F. Clupeidae) reach approximately 30 cm in length and 0.1 kg (Yearsley et al. 1999). In Australia, they occur from Hervey Bay (Qld) around the south coast to Red Bluff (WA), including Tasmania (Fletcher 1990). They also occur throughout temperate waters of most continents (Fletcher 1990). Both adults and juveniles occur on the continental shelf to water depths of about 200 m (Fletcher 1990). In South Australia juveniles, at about 8 - 12 months of age, move offshore to join adult schools (Mackie 1995).

Spawning

Pilchards are synchronous multiple-batch spawners (Fletcher et al. 1996). Estimates of batch fecundity (F) range from 10,000 to 47,000 eggs (Joseph 1981) related to body weight (BW) and gonad weight (GW):

Body weight: F = 2.629 x 100 BW^1.1081; Gonad weight: F = 10870 x GW^0.91

Spawning is protracted and has been recorded throughout its geographical range, at all times of the year but is regionally variable in its timing. It has been recorded off the WA coast during autumn and winter, off SA between summer and autumn, Vic and Tas between spring and summer, and along the NSW / Qld coast from autumn to spring (Blackburn 1950, 1951, Fletcher 1990, Neira et al. 1999). These spawning periods correspond to the distribution of larvae.

Estimates of spawning stock biomass via egg surveys and the daily egg production method have been conducted in Western Australia (Fletcher et al. 1996, White & Fletcher 1998, Cochrane 1999) and in South Australia (Ward et al. 1998, 2001).

Stock Structure

Blackburn (1951) suggested three distinct stocks in Australian waters. More recent work suggests a higher degree of population substructuring (Dixon et al. 1993, Fletcher et al. 1996, Cochrane 1999). Larvae are widespread in southern and eastern Australia.

Full Larval Description

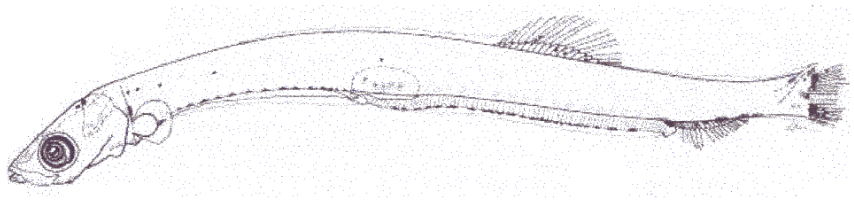
Larvae of Temperate Australian Fishes reference: Miskiewicz & Neira (1998): Clupeidae: Herrings, sardines, shads, sprats. Pp 38 - 53.

Other taxa recorded with pilchard larvae (% of samples):

E. australis (13), S. flindersi (5), P. auratus (4), T. declivis (4), G. greyi (4), H. percoides (4), S. australasicus (4), T. atun (3), P. saltatrix (3), G. blacodes (3), R. solandri (2), S. ciliata (1.5), A. australis (1.5), L. caudatus (1.5), P. dentex (1.5), P. bassensis (1), C. affinis (1), S. bassensis (1), S. brama (1), T. novaezelandiae (1), G. tigerinus (0.6), S. s. scomberoides (0.5), N. macropterus (0.3), Seriolella punctata (0.3), A. trutta (0.2), C. spectabilis (0.1), M.

Australian Seafood Handbook reference: p 148

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222



Larval Stage: postflexion

Illustrated by F.J. Neira 18.9 mm

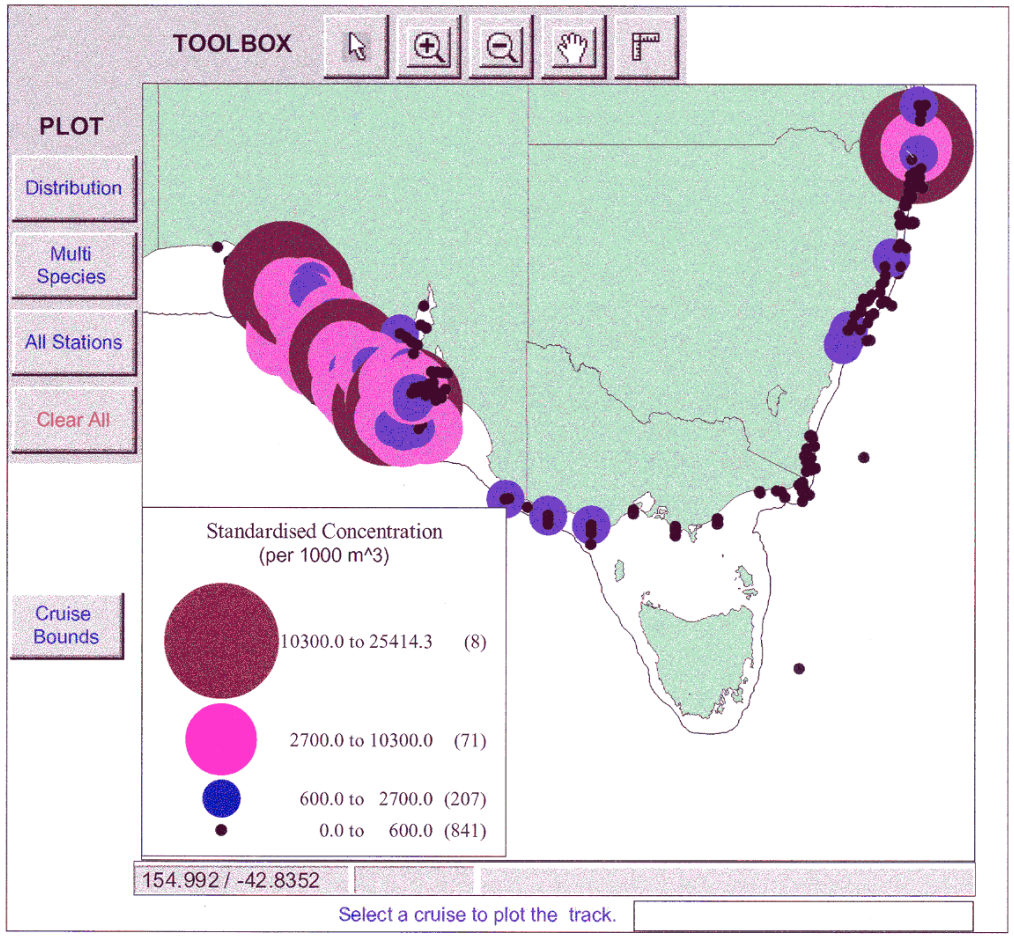
Diagnostic Characters

* 36-42 + 10-13 = 48-53 myomeres;
* Cross-hatched pattern of muscle fibres visible until 14mm;
* Anus migrates anteriorly from myomere 42 to 36 between 3.9 and 25.1mm;
* Posterior end of dorsal fin 4-6 myomeres in front of origin of anal fin;
* Series of internal melanophores dorsally along hindgut in preflexion larvae.

Meristic Counts

Myomeres	47 - 53
Body Length (mm)	13.5 - 35
Age (days)	
Dorsal fin	17 - 20
Anal fin	16 - 21
Caudal fin	19
Pectoral fin	16 - 19
Pelvic fin	8 - 9

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222



Larval Distribution

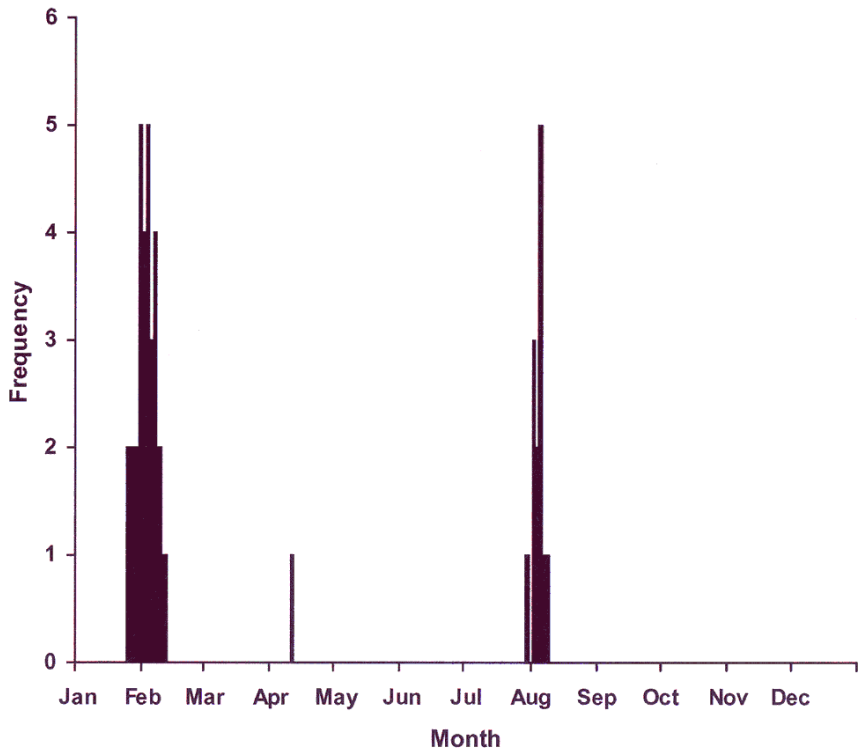
Regional distribution:

Larvae have been reported from the Swan Estuary (WA) in July and December (Gaughan et al. 1990, Neira et al. 1992), off Albany (WA) from November to April (Fletcher & Tregonning 1992, Fletcher et al. 1994), in Victorian waters from November to April, and less commonly May to July (Hoedt & Dimmlich 1995, Neira et al. 2000), Sydney from December to March (Gray et al. 1992, Gray 1993) and entering Lake Macquarie (NSW) throughout the year (Miskiewicz 1987). The highest concentrations of larvae (up to 25,414 / 1000 m^3) have been recorded off South Australia in January (Ward et al. 2001a & b). Larvae are widespread throughout shelf waters but concentrations are highest in nearshore and midshelf regions. Larvae have been found up to 100 km seaward of the shelf break off eastern Tasmania.

Vertical distribution:

Concentrations of larvae are highest below the surface layer in depths to 50 m (Gray 1996, Fletcher 1999, Neira et al. 2000). However, Fletcher (1999) noted that concentrations showed some diel variability, with larvae occurring in deeper strata at night.

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222



Spawning Dates

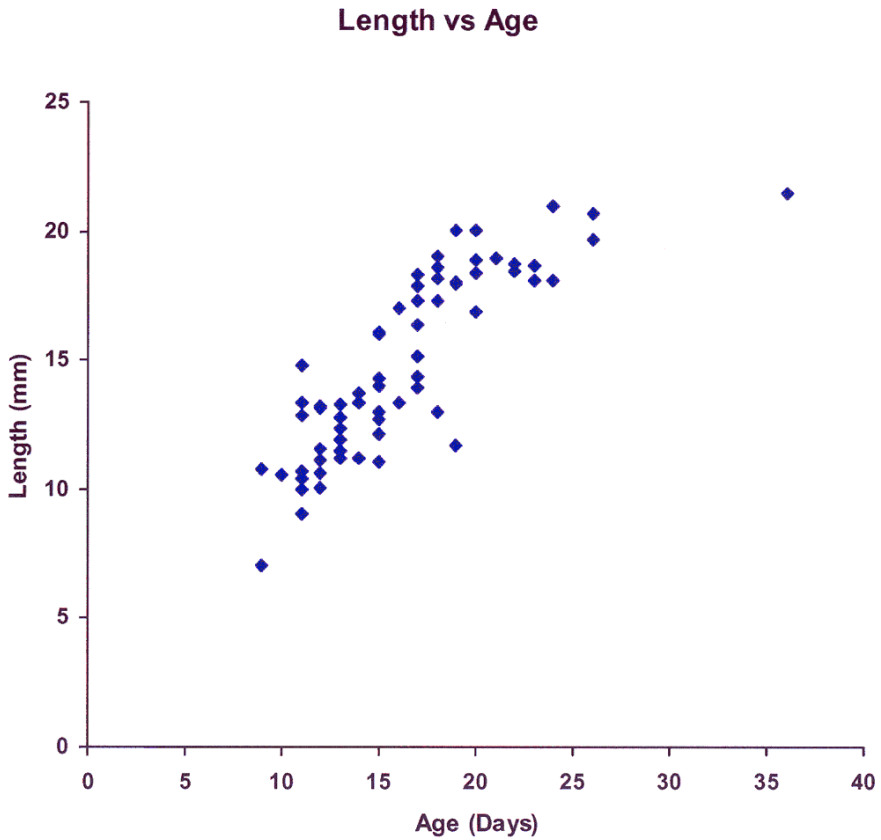
Database records range from 27 January to 11 August and are based on larvae from southern NSW and eastern Victoria.

Back-calculated spawning dates

Larval growth

Regional comparison

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222



Larval Growth

Eggs hatch after 45 - 58 h depending on temperature (Baker 1972, Fletcher 1990, Mackie 1995). Otoliths have unambiguous increments that have been assumed to be daily (Gaughan et al. 2001) based on their similarity to those of the Japanese sardine which have been validated (Hayashi et al. 1989). Their formation, in that species, commence at first feeding approximately 3 days after hatching (Hayashi et al. 1989).

Reported growth rates range from 0.62 to 0.48 mm per day for larvae up to 30 d and are regionally variable (Gaughan et al. 2001). Growth of southeast Australian larvae from 8 to 37 mm, based on database records, is best described by a von Bertalanffy growth function with parameters:

L (inf) = 25.391; k = 0.065; t(0) = 1.772

(R^2 = 0.74; n = 74)

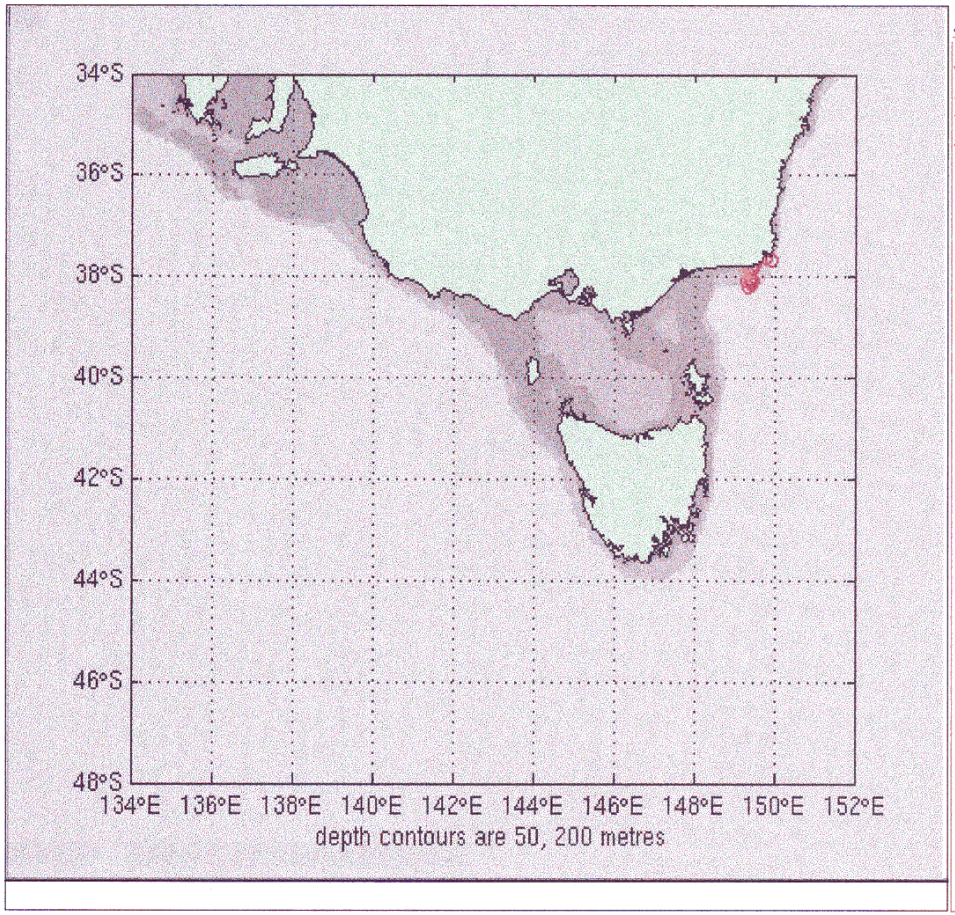
Pilchard have a larval duration of at least 35 days.

Back-calculated spawning dates

Larval growth

Regional comparison

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222



Larval Dispersal

Model runs are based on larvae aged from eastern Victoria. Modelled source locations are concentrated close to the capture locations. Too few sampling positions with aged larvae are available to fully assess larval dispersal processes.

Sardinops sagax	Steindachner, 1879	
pilchard	CAAB 37085002	222

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Silver warehou (*Seriolella punctata*)

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089

Species Distribution

Silver warehou (F. Centrolophidae) reach approximately 66 cm in length and 5.5 kg (Yearsley et al. 1999). In Australia, they occur from mid NSW around the south coast to Spencer Gulf (SA) including Tasmania (Last et al. 1983, Gomon et al. 1994). They also occur in New Zealand and off both coasts of South America (Gomon et al. 1994). Adults occur over the shelf and upper slope to a depth of at least 650 m (Lyle & Ford 1993, Gomon et al. 1994). Late post flexion larvae and small juveniles are commonly found in association with drifting jellyfish; larger juveniles can be found in bays and estuaries (Last et al. 1983).

Spawning

Their spawning mode is unknown. Estimates of fecundity range from 1,100,000 to 1,600,000 eggs (Gavrilov 1976).

Spawning has been recorded off western Bass Strait and western Tasmania in late winter and spring (Smith 1989). This corresponds to the timing and location of high concentrations of larvae in this area. The distribution of larvae also suggests southern NSW is an area of important spawning activity and that spawning may be widespread between these regions. Back-calculated spawning dates indicate slightly earlier spawning off southern NSW (Bruce et al. 2001).

Estimating spawning stock biomass via egg surveys has not been attempted may not be suitable due to the spatial extent of spawning.

Stock Structure

Stock structure is unknown. Larval distribution suggests continuity of spawning across southeast Australia.

Full Larval Description

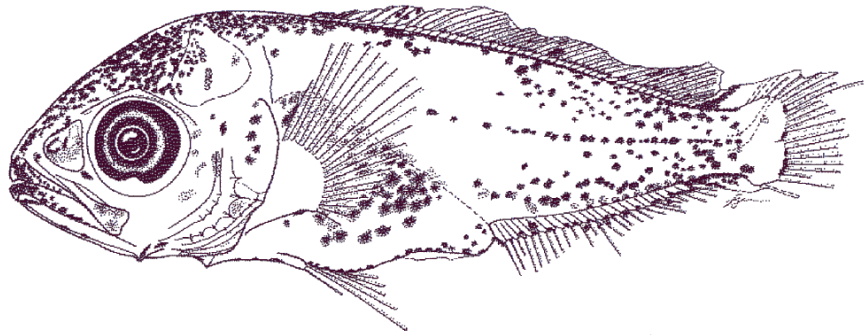
Larvae of Temperate Australian Fishes reference: Bruce et al. (1998): Centrolophidae: Warehous, medusafishes. Pp 422 - 427.

Other taxa recorded with silver warehou larvae (% of samples):

H. percoides (43), S. brama (34), T. atun (24), G. tigerinus (21), M. novaezelandiae (12), P. dentex (8), S. sagax (3), P. wrighti (2), R. solandri (2), C. australis (1), E. australis (1), S. s. scomberoides (1), T. declivis (1)

Australian Seafood Handbook reference: p 255

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089



Larval Stage: postflexion

Illustrated by F.J. Neira 10.6 mm

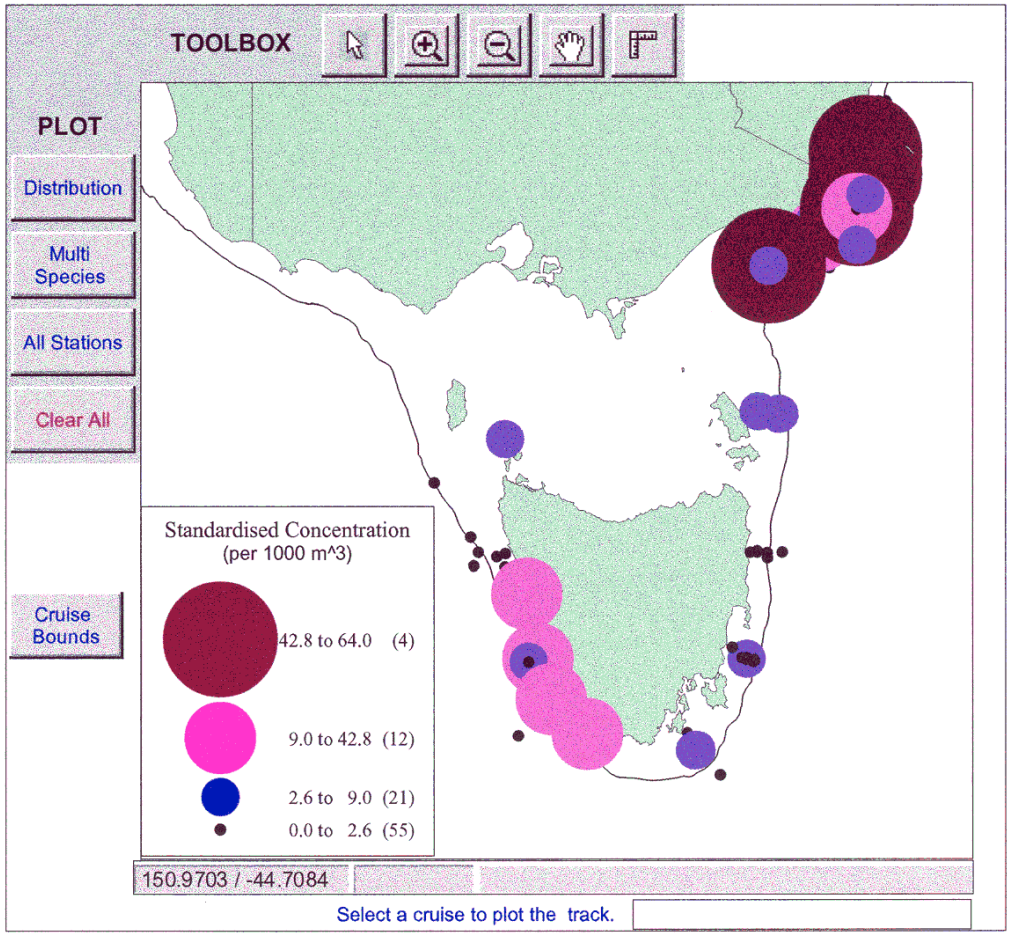
Diagnostic Characters

* 11-12 + 13-14 = 25 myomeres;
* 5 large, stellate melanophores dorsally between nape and caudal peduncle in preflexion and flexion larvae;
* 4-5 melanophores on dorsal finfold above dorsal midline melanophores;
* About 1 melanophore distally on base of each dorsal- and anal-fin ray in late postflexion larvae;
* Pigment on membrane above and below caudal peduncle during flexion stage;
* No pigment on pelvic fin.

Meristic Counts

Myomeres	25
Body Length (mm)	10.6
Age (days)	
Dorsal fin	IX, 39
Anal fin	III, 24
Caudal fin	17
Pectoral fin	24
Pelvic fin	1, 5

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089



Larval Distribution

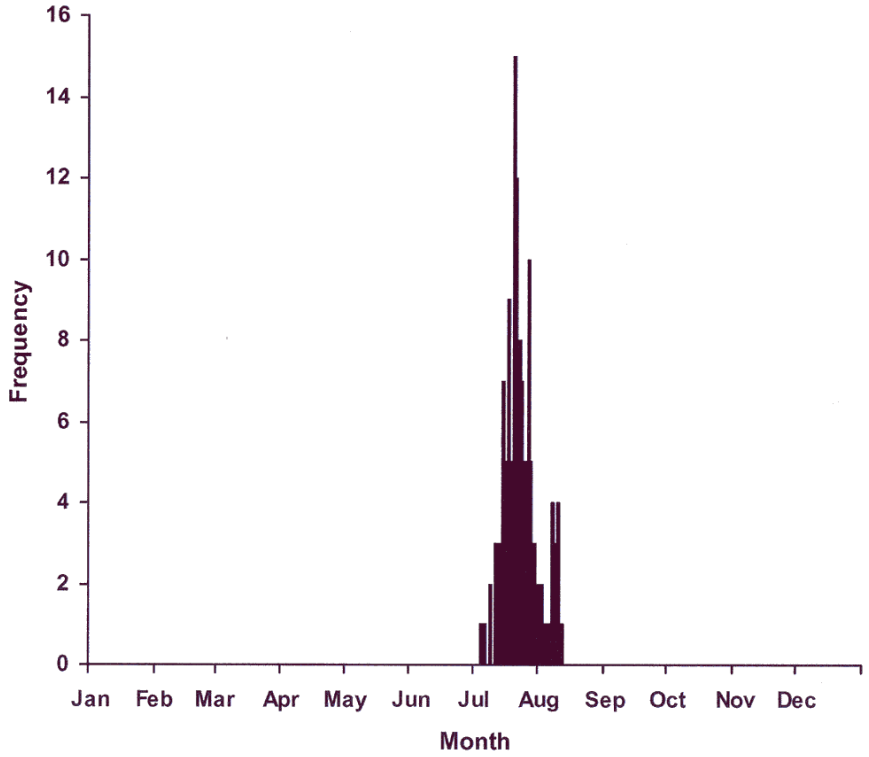
Regional distribution:

Larvae have been reported from shelf waters off western, southern and eastern Tasmania, eastern Victoria and southern NSW from July and October (Bruce et al. 2001). Larvae have not been reported from Bass Strait. Database records range from northwest Tasmania around the southern and eastern Tasmanian coast to southern NSW. They extend the period of occurrence in Tasmanian waters to include July to December. The highest concentrations of larvae (up to 64 / 1000 m^3) have been recorded off eastern Victoria and southern NSW in August but high concentrations (30 - 40 /1000 m^3) have also been recorded off western Tasmania in September. Larvae occur throughout shelf waters and have been recorded up to 56 km seaward of the shelf break off southwest Tasmania.

Vertical distribution:

Neira et al. (2000) reported larvae throughout the upper 75 m of the water column off eastern Victoria with the highest concentrations in the upper 50 m. Bruce et al. (2001) reported that larvae were routinely recorded from surface tows and Last et al. (1983) reported that larvae and juveniles are often associated with scyphomedusae.

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089



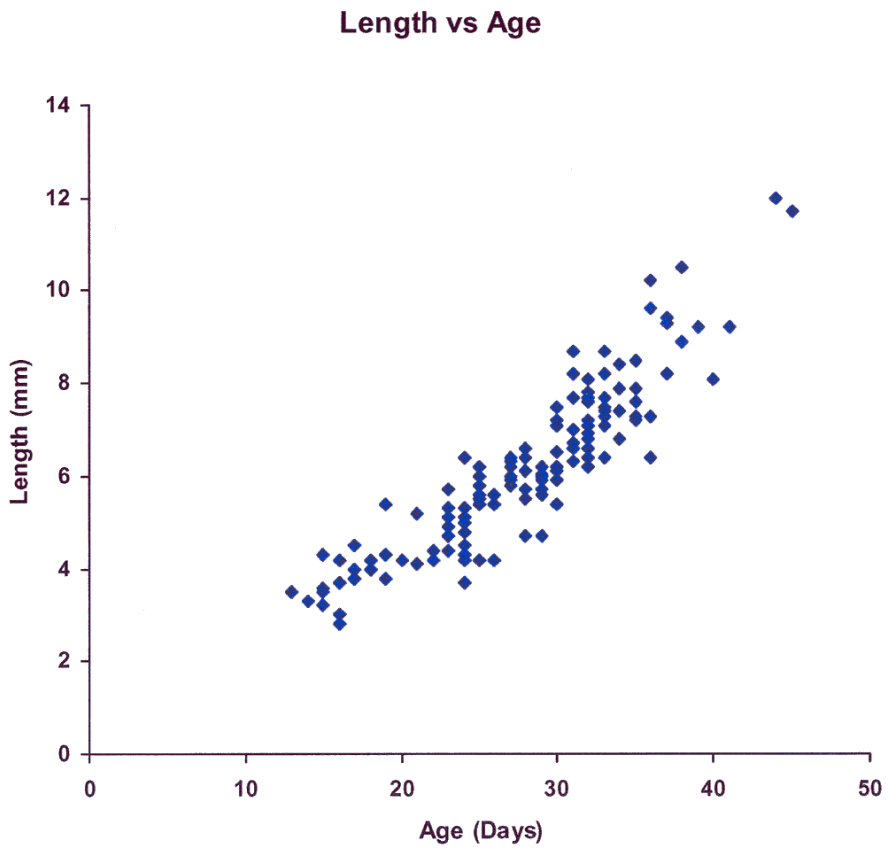
Spawning Dates

Published back-calculated spawning dates range from 1 July to 17 August (Bruce et al. 2001). Spawning is regionally variable and is earlier in NSW compared to Tasmania.

Database records range from 5 July to 12 August and are based on larvae from southern NSW and western Tasmania.

Back-calculated spawning dates
Larval growth
Regional comparison

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089



Larval Growth

Eggs hatch after 146 h at 10 - 13 deg. C or after 53 h at 16 - 19 deg. C and larvae are 2.3 - 2.8 mm at hatching (Grimes & Robertson 1981, Bruce et al. 1996). Otoliths have unambiguous increments which have been assumed to be daily (Bruce et al. 2001). Their formation commences at first feeding approximately 6 days after spawning (Bruce et al. 1996).

Growth of southeast Australian larvae from 3 to 12 mm, based on database records, is best described by the exponential function:

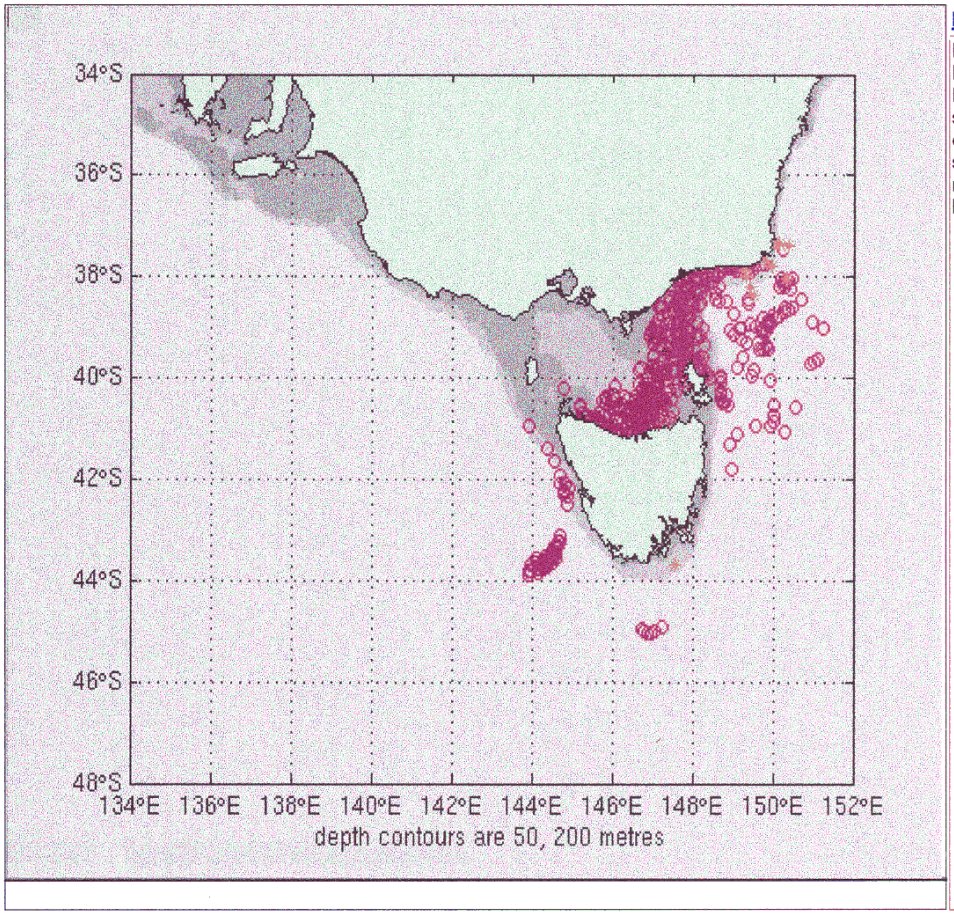
Body length = 1.9415e^(0.040341 x age)

(R^2 = 0.85; n = 142)

Silver warehou have a larval duration of at least 50 days.

Back-calculated spawning dates
Larval growth
Regional comparison

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089



Larval Dispersal

Model runs are based on larvae aged from southern NSW, eastern Victoria and southern Tasmania. Modelled source locations are concentrated off southern NSW and western Tasmania in the vicinity of known spawning areas. However, a considerable source region is indicated within Bass Strait that is not supported by either the distribution of larvae or known spawning activity.

Seriolella punctata	Forster, 1801	
silver warehou	CAAB 37445006	1089

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Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

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Blue warehou (*Seriolella brama*)

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088

Species Distribution

Blue warehou (F. Centrolophidae) reach approximately 80 cm SL and 7 kg (Yearsley et al. 1999). In Australia, they occur from central NSW around the south coast to the Great Australian Bight including Tasmanian (Gomon et al. 1994). They also occur in New Zealand, where they are referred to as common warehou (Ayling and Cox 1982). Adults occur over the continental shelf and upper slope to about 520 m. Late postflexion larvae and small juveniles commonly associate with jellyfish, juveniles and sub-adults occur in estuaries and coastal waters (Gomon et al. 1994).

Spawning

They are partial batch spawners with determinate fecundity ranging from 430,000 to 1,350,000 oocytes. Batch fecundity ranges from 210,000 to 360,000 eggs (Knuckey & Sivakumaran 2001) related to length as follows:

$$\text{Ln(annual fecundity)} = 2.896 \times \text{Ln(length)} + 2.458$$

Spawning has been recorded off southeast NSW, northeast Victoria and off western Bass Strait and western Tasmania during winter and spring (Knuckey & Sivakumaran 2001). There is some evidence of regional variability in timing with spawning occurring from May - August off NSW and June - September off western Tasmania. (Knuckey & Sivakumaran 2001, Bruce et al. 2001). This corresponds to the timing and location of highest concentrations of larvae.

Estimating spawning stock biomass via egg surveys has not been attempted but may if spawning is primarily restricted to western Bass Strait / western Tasmania and southern NSW.

Stock Structure

Stock structure is unknown. Differences in size / age compositions, timing of spawning and in inferred recruitment patterns suggest separate populations east and west of Bass Strait (Knuckey & Sivakumaran 2001). Larval data suggests two spatially discrete spawning areas with a discontinuous larval distribution in southeast Australia.

Full Larval Description

None

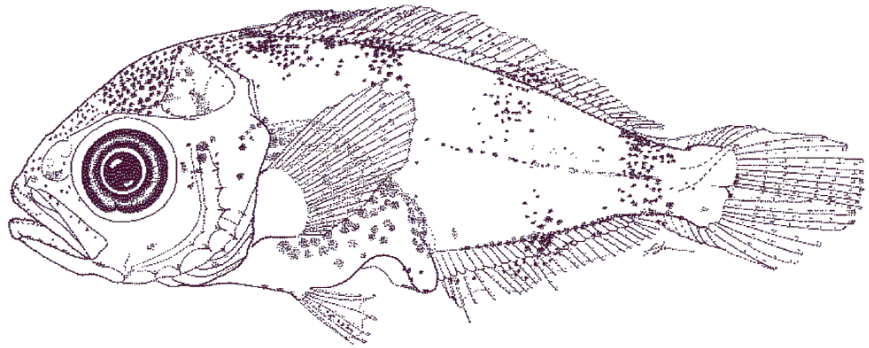
Larvae of Temperate Australian Fishes reference: Bruce et al. (1998): Centrolophidae: Warehous, medusafishes. Pp 422 - 427.

Other taxa recorded with blue warehou larvae (% of samples):

T. atun (30), Seriolella punctata (25), H. percoides (21), G. tigerinus (13), M. novaezelandiae (8), S. sagax (8), T. declivis (8), P. dentex (3), E. australis (2), S. australasicus (2), S. bassensis (2), S. flindersi (2), G. greyi (1)

Australian Seafood Handbook reference: p 253

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088



Larval Stage: postflexion

Illustrated by F.J. Neira 11.7 mm

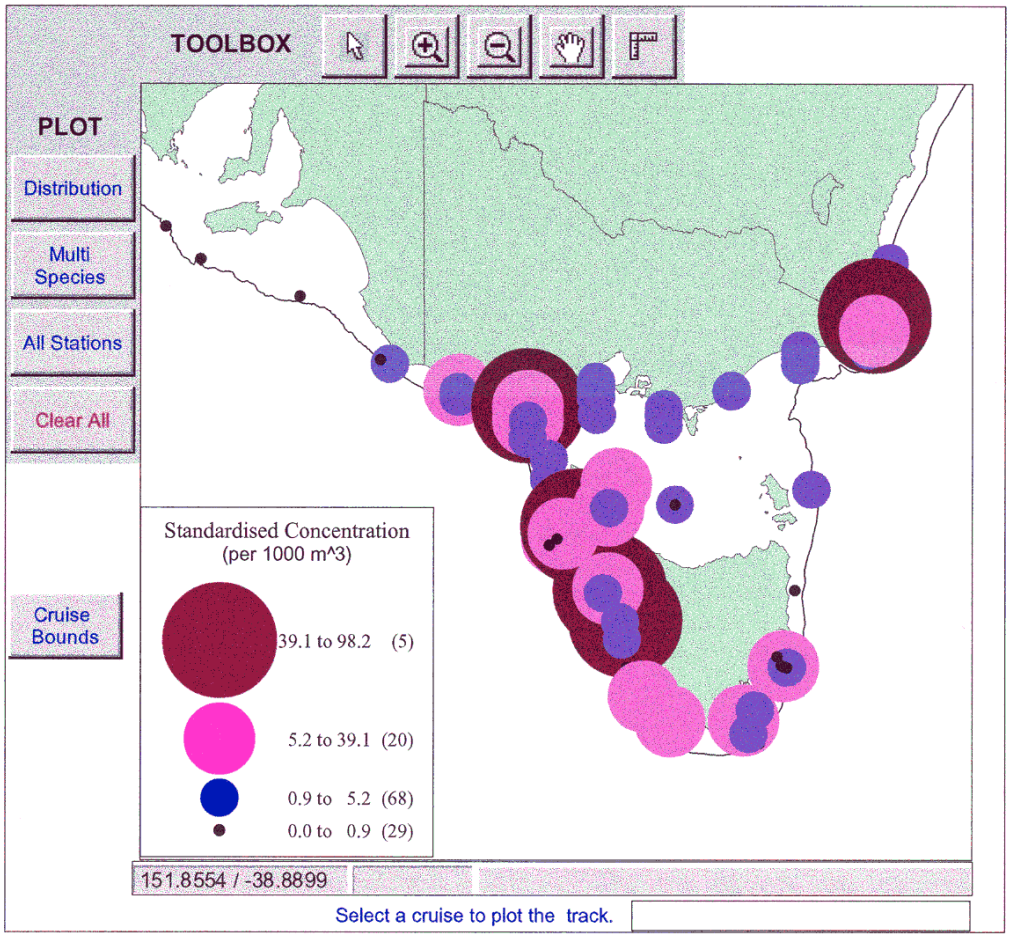
Diagnostic Characters

* 11-12 + 14 = 25-26 myomeres;
* 4 large, stellate melanophores dorsally from nape to caudal peduncle, extending ventrally and forming pigment bands in postflexion larvae;
* Pigment on pelvic fin by 9.2mm.

Meristic Counts

Myomeres	25
Body Length (mm)	11.7
Age (days)	
Dorsal fin	IX, 29
Anal fin	III, 23
Caudal fin	17
Pectoral fin	22
Pelvic fin	1, 5

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088



Larval Distribution

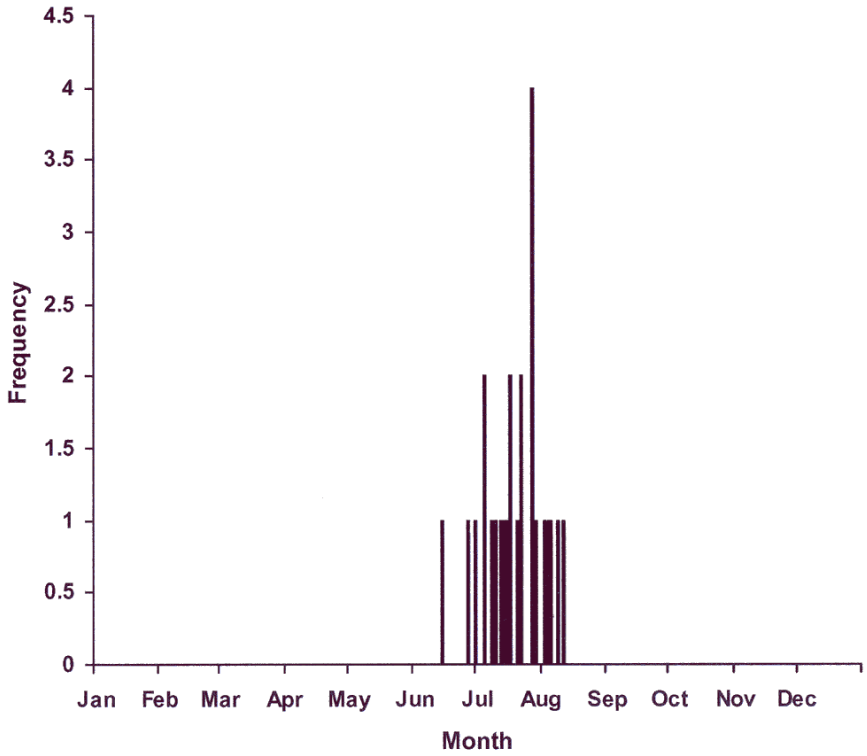
Regional distribution:

Larvae have been reported from shelf waters off South Australia, western, southern and eastern Tasmania, Victoria (including low concentrations in Bass Strait) and southern NSW from July to January (Neira et al. 2000, Bruce et al. 2001). Very few larvae have been recorded off northeast Tasmania. Database records range from shelf waters south of Spencer Gulf (SA) to southern NSW including Tasmania. They extend the period of occurrence to include Tasmanian and southern NSW waters from June to January. The highest concentrations of larvae (66 - 98 / 1000 m^3) have been recorded off western Bass Strait and western Tasmania in August and September and off southeast NSW in August. Larval concentrations are highest in nearshore and midshelf regions (Bruce et al. 1996, 2001). Records of larvae in offshore waters are rare, however, small numbers have been found up to 14 km seaward of the shelf break off western Tasmania.

Vertical distribution:

Bruce et al. (2001) reported larvae throughout the upper 100 m of the water column in Bass Strait, with the highest concentrations in the upper 50 m. Larvae are commonly collected from surface waters and are often associated with scyphomedusae (Last et al. 1983).

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088



Spawning Dates

Published, back-calculated spawning dates range from 21 June to 6 September (Bruce et al. 2001). Spawning is regionally variable and is earlier in NSW compared to Tasmania.

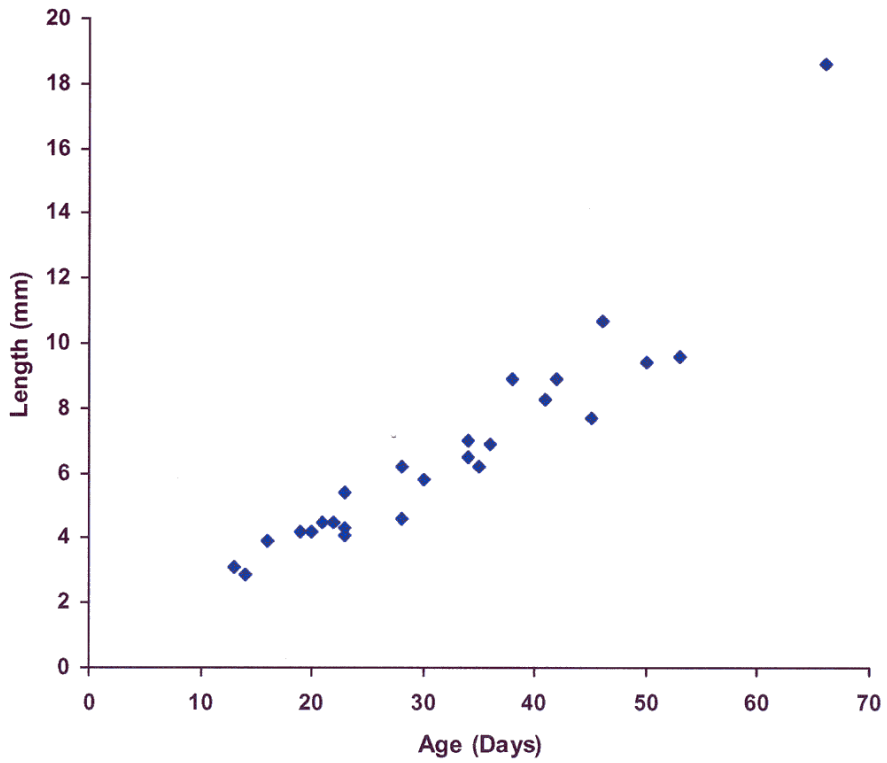
Database records range from 15 June to 12 August and are based on larvae from southern NSW and western Tasmania.

Back-calculated spawning dates

Larval growth

Regional comparison

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088



Larval Growth

Eggs hatch after 94 h at 16.1 - 16.6 deg. C and larvae are 4.2 mm at hatching (Robertson 1973). Otoliths have unambiguous increments which have been assumed to be daily (Bruce et al. 2001).

Growth of southeast Australian larvae from 3 to 19 mm, based on database records, is best described by the exponential function:

Body length = 2.22345e^(0.03134 x age)

(R^2 = 0.94; n = 25)

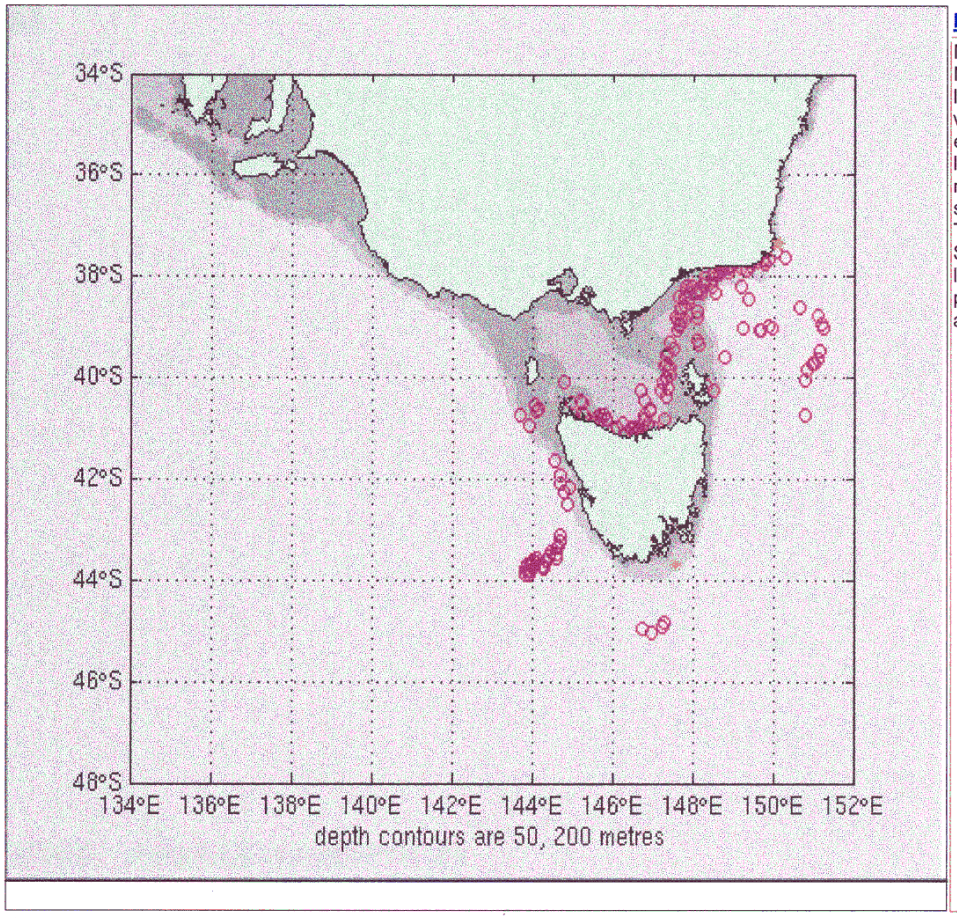
Blue warehou have a larval duration of at least 65 days.

Back-calculated spawning dates

Larval growth

Regional comparison

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088



Larval Dispersal

Model runs are based on larvae aged from southern NSW and southern Tasmania. Modelled source locations are concentrated off northwest Tasmania, western Tasmania and eastern Bass Strait, which encompass known spawning areas. Some source locations are also indicated in Bass Strait off northern Tasmania. Larval trajectories suggest some mixing of larvae between northwest Tasmania and southern NSW is possible via Bass Strait and supports the observed distribution of larvae in Bass Strait. However, too few sampling positions with aged larvae are available to fully assess larval dispersal processes.

Seriolella brama	Gunther, 1860	
blue warehou	CAAB 37445005	1088

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Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Last, P. R., Scott, E. O. G. & Talbot, F. H. (1983). Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart, Tas.

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Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

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Bruce, B. D., Neira, F. J. & Bradford, R. W. (2001). Larval distribution and abundance of blue and spotted warehous (Seriolella brama and S. punctata) in south-eastern Australia. Marine and Freshwater Research 52: 631 - 636.

Bruce, B. D., Sutton, C. A., & Thresher, R. E. (1996). An ichthyoplankton based analysis of the spawning distribution and stock structure of temperate Australian finfish. Final Report to Fisheries Research and Development Corporation 92: 65 pp.

Knuckey, I. A. & 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 - 587.

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King George whiting (*Sillaginodes punctata*)

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706

Species Distribution

King George whiting (F. Sillaginidae) reach approximately 72 cm in length and 4.8 kg (Gomon et al. 1994). They are the largest members of the whiting family and are endemic to Australian waters (Hyndes et al. 1998). They occur from Sydney (NSW) around the south coast to Jurian Bay (WA), including northern Tasmania (Kailola et al. 1993). Adults occur in coastal waters in depths usually less than 50 m (Yearsley et al. 1999) but have been reported from up to 200 m (Kailola et al. 1993). Juveniles occur in shallow protected bays and estuaries where they remain for up to 3 - 4 years before moving into coastal waters (Jones et al. 1996).

Spawning

They are multiple batch spawners with asynchronous development and indeterminate fecundity (Fowler et al. 1999). Batch fecundity has been estimated to range between 5,250 and 152,191 eggs depending on fish size and geographic location, with estimates of annual fecundity ranging between 110,250 to 6,087,640 eggs (Fowler et al. 1999).

Spawning is protracted, regionally variable and has been recorded in from late summer to spring in South Australia and Western Australia (Bruce 1995, Hyndes et al. 1998). Spawning grounds appear to be extremely limited compared to the distribution of adults (Fowler et al. 1999). Spawning has been reported from late February to July in SA and June to September in WA (Bruce 1989, Jenkins & May 1994, Hyndes et al. 1996, Fowler et al. 1999). Spawning has not been confirmed in Victorian waters. The distribution of larvae and back-calculated spawning dates support late summer to winter spawning in South Australia.

Estimating spawning stock biomass via egg surveys has not been attempted but may be possible if spawning is regionally restricted in its location.

Stock Structure

Stock structure is unknown. Larvae are long-lived and, based on dispersal patterns, Victorian recruits originate from South Australian waters (Jenkins et al. 2000). Larval distribution in South Australia suggests a common stock in both Spencer Gulf and Gulf St Vincent.

Full Larval Description

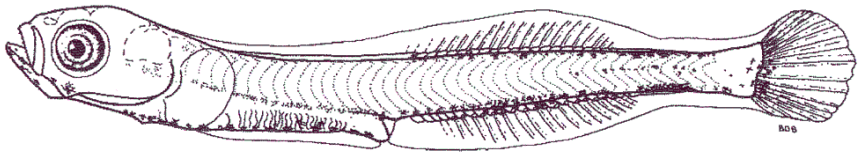
Bruce, B.D. (1995). Larval development of King George whiting (Sillaginodes punctata,), school whiting (Sillago bassensis,) and yellow fin whiting (Sillago schomburgkii,) (Percoidei: Sillaginidae) from South Australian waters. Fishery Bulletin 96: 27-43

Larvae of Temperate Australian Fishes reference: Bruce & Miskiewicz (1998): Sillaginidae: Whitings, sand smelts. Pp 294 - 305.

Other taxa recorded with King George whiting larvae (% of samples):
S. bassensis (3), T. atun (1)

Australian Seafood Handbook reference: p 279

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706



Larval Stage: postflexion

Illustrated by B.D. Bruce 8.5 mm

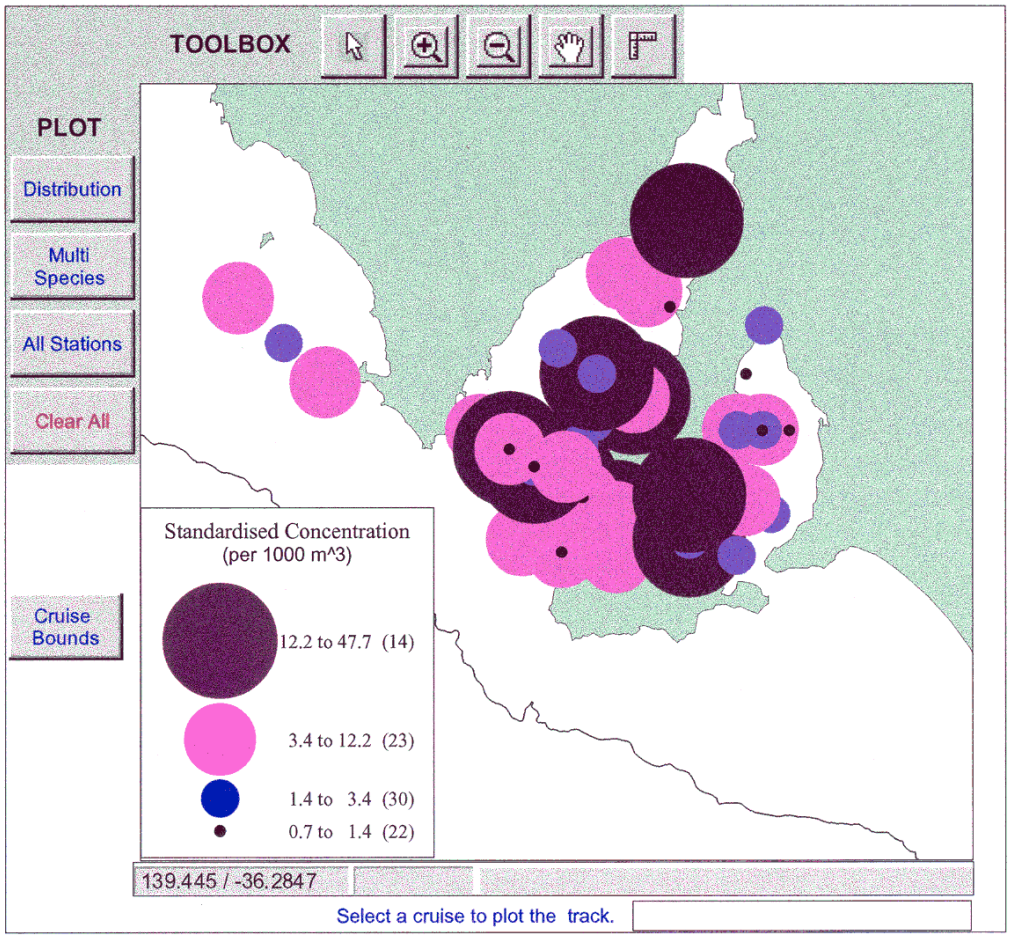
Diagnostic Characters

* 16-21 + 23-27 = 42-45 myomeres;
* No head spines;
* Gut coils after settlement (21-24mm);
* Melanophore series along dorsal midline of trunk and tail disappear by end of flexion stage except melanophores between myomeres 31-40 which become prominent;
* 4-6 discrete pigment patches dorsally along trunk and tail in postflexion larvae, each comprising 3-4 pairs of stellate melanophores;
* 0-3 melanophores, usually 1-2, above and 2-4 below notochord tip in preflexion larvae.

Meristic Counts

Myomeres	
Body Length (mm)	
Age (days)	
Dorsal fin	
Anal fin	
Caudal fin	
Pectoral fin	
Pelvic fin	

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706



Larval Distribution

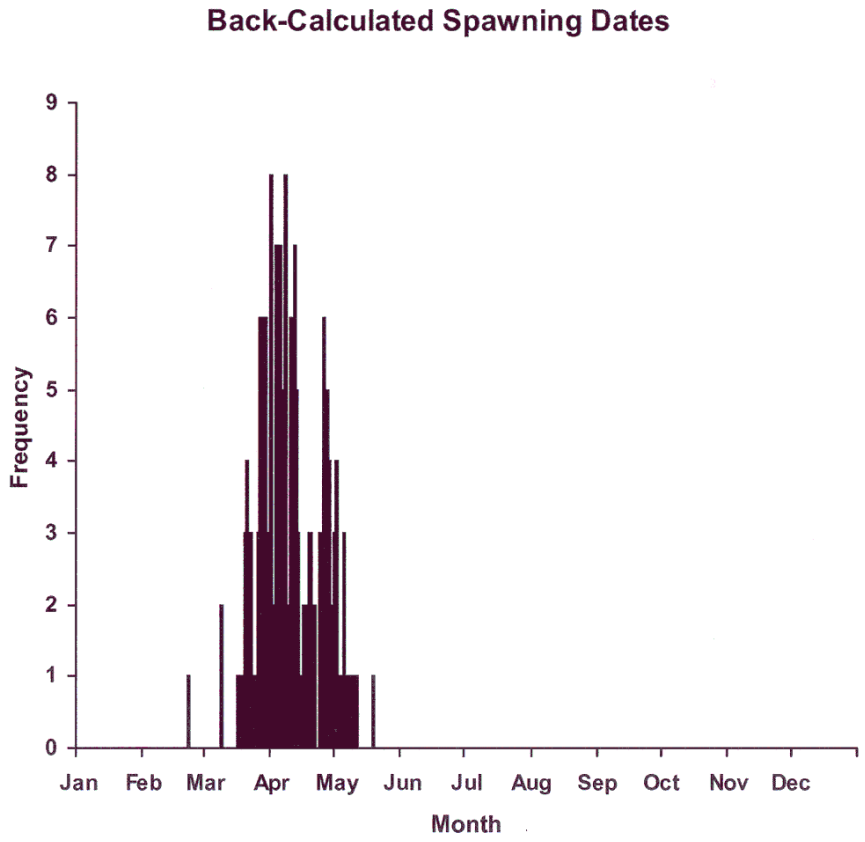
Regional distribution:

Larvae have been reported from Spencer Gulf, Gulf St Vincent and Investigator Strait in South Australia from March to September (Bruce 1989, Bruce and Short 1991, Bruce and Miskiewicz 1998) and from Portland Bay (Vic) in July (Neira et al. 2000). Pre-settlement larvae have also been taken in Port Phillip Bay, Victoria (Jenkins and May 1994, Jenkins et al. 1998). Database records extend this range to include shelf waters west of Spencer Gulf (SA) in May. The highest concentrations of larvae (up to 48 / 1000 m^3) have been recorded in Investigator Strait, South Australia. Larvae are restricted to coastal waters.

Vertical distribution:

Unknown. However, larvae just prior to settlement display a reverse diurnal vertical migration, being located near the surface during the day and diffusing through the water column at night in Port Phillip Bay (Jenkins et al. 1999).

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706



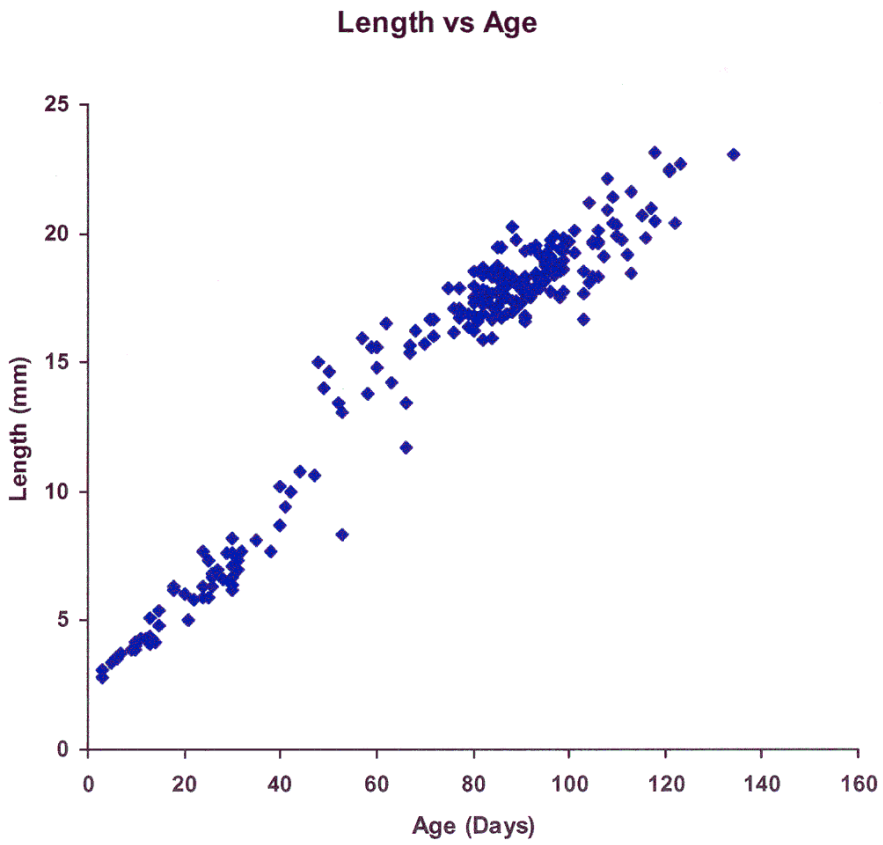
Spawning Dates

Published back calculated spawning dates range from 28 February to 19 July with a peak in spawning activity from May to June (Bruce 1989, Jenkins and May 1994, Fowler and Short 1996).

Database records range from 22 February to 19 May and are based on larvae and newly settled juveniles from South Australia.

Back-calculated spawning dates
Larval growth
Regional comparison

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706



Larval Growth

Eggs hatch after 48 - 60 hours at 16.5 deg. C and larvae are 2.00 - 2.15 mm at hatching (Bruce 1995). Otoliths from larvae and newly settled juveniles have unambiguous increments that have been validated as daily (Fowler and Short 1996). Their formation commences at first feeding approximately 4 to 6 days after hatching.

Reported growth rates range from 0.06 to 0.25 mm per day depending on age and time of year (Jenkins and May 1994, Fowler and Short 1996) and may be regionally variable. Growth of South Australian larvae from 4 to 23 mm, based on database records, is best described by a von Bertalanffy growth function with parameters:

L (inf) = 32.144; k = 0.009; t(0) = -3.858

(R^2 = 0.97; n = 236)

King George whiting have a protracted early life history with a larval duration ranging from 50 to 130 days (Bruce 1989, Jenkins and May 1994, Fowler and Short 1996).

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706

Larval Dispersal

Hydrodynamic modelling of larval advection predicts King George whiting from Victoria originate from the southeast South Australian/southwest Victoria region (Jenkins et al. 1998). Larvae in South Australian Gulf waters increase in age with distance northwards and circulation patterns appear to advect larvae into both Gulfs from spawning areas in lower Spencer Gulf and in Investigator Strait near Kangaroo Island. The origin of larvae settling to coastal embayments on South Australia's West Coast has not been confirmed, but they most likely come from spawning in local, coastal waters of the Great Australian Bight.

Sillaginodes punctata	Cuvier, 1829	
King George whiting	CAAB 37330001	706

Book and Book Chapter References

Bruce, B. D. & Miskiewicz, A. G. (1998). Sillaginidae: Whitings, sand smelts. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 294 - 305.

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Western school whiting (*Sillago bassensis*)

Sillago bassensis	Cuvier, 1829	
western school whiting	CAAB 37330002	707

Species Distribution

Western school whiting (F. Sillaginidae) reach approximately 33 cm in length and 0.5 kg (McKay 1985, Gomon et al. 1994, Yearsley et al. 1999). They are endemic to the south coast of Australia, occurring from the western end of Ninety Mile Beach (Vic) along the south coast to Geralton (WA) (Dixon et al. 1987, Gomon et al. 1994). Both adult and juveniles occur in sheltered coastal bays and estuaries to about 40 m depth over a sandy bottom (Gomon et al. 1994, Hyndes & Potter 1996). However, adults migrate to deeper water to spawn (Hyndes & Potter 1996, Hyndes et al. 1996).

Spawning

They are multiple spawners with asynchronous oocyte development (Hyndes & Potter 1996). Fecundity is unknown.

Spawning is protracted and has been recorded in Western Australia from spring to autumn with a peak in summer (Hyndes & Potter 1996). The distribution of larvae suggests spawning is widespread in summer and early autumn in South Australia and Victoria. Spawning takes place in the deeper waters of the inner shelf (Hyndes & Potter 1996, Hyndes et al. 1996).

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the spatial extent of spawning.

Stock Structure

Preliminary genetic data suggests separate stocks in South Australia and Western Australia (Dixon et al. 1987). Larvae are widespread in South Australia and Victoria.

Full Larval Description

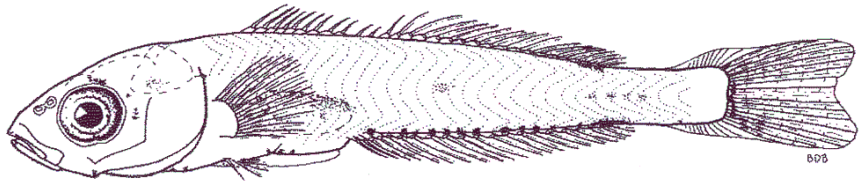
Larvae of Temperate Australian Fishes reference: Bruce & Miskiewicz (1998): Sillaginidae: Whitings, sand smelts. Pp 294 - 305.

Other taxa recorded with western school whiting larvae (% of samples):

Thyrsites atun (41), Sardinops sagax (34), Trachurus declivis (28), Platycephalus bassensis (12), Engraulis australis (9), Platycephalus fuscus (9), Seriolella brama (9), Sillaginodes punctata (9), Sillago flindersi (9), S. australasicus (6), P. auratus (3)

Australian Seafood Handbook reference: p 281

Sillago bassensis	Cuvier, 1829	
western school whiting	CAAB 37330002	707



Larval Stage: settlement

Illustrated by B.D. Bruce 12.7 mm

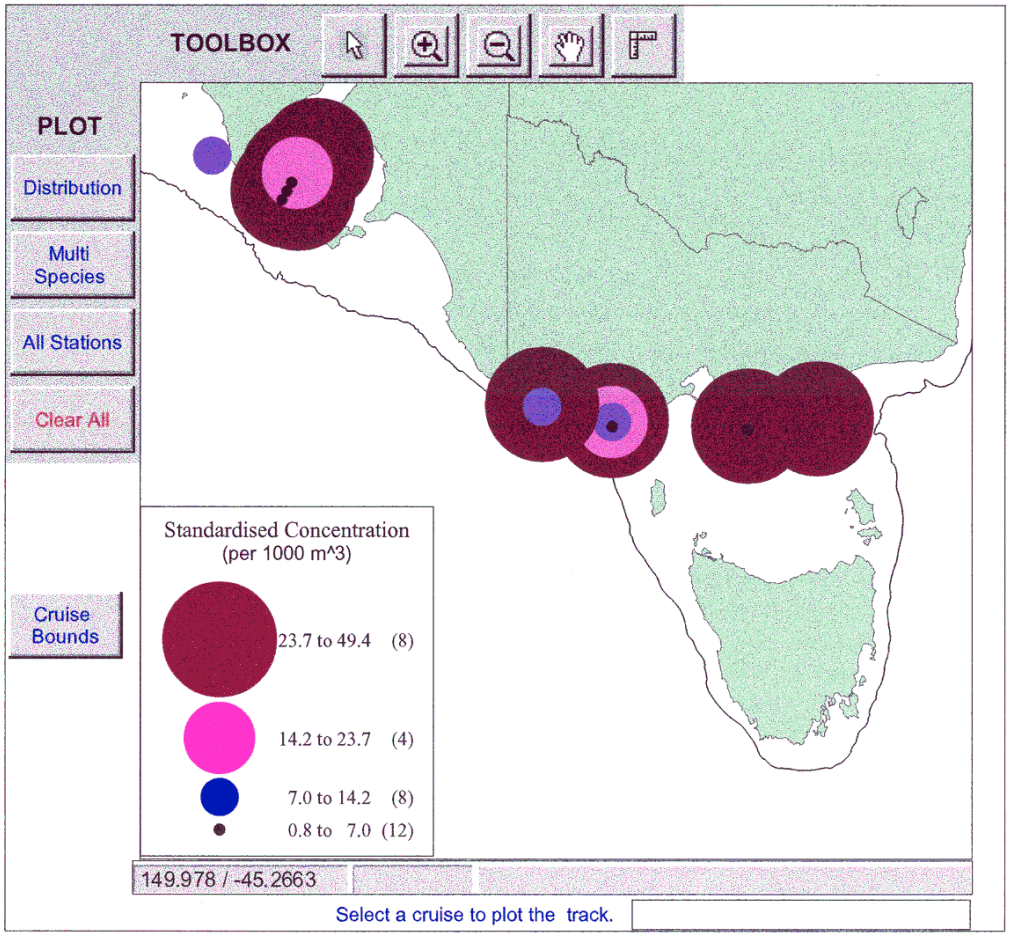
Diagnostic Characters

* 11-15 + 19-23 = 32-35 myomeres;
* Gut coils in preflexion larvae by 4.1mm;
* 1 minute posterior preopercular spine in early postflexion larvae by 7.8mm, not visible after settlement;
* Melanophores along dorsal midline of trunk and tail reduced to 0-3 posterior to dorsal-fin base by early flexion stage; pigment reappears after settlement as a series of discrete pigment patches each comprising 3-6 pairs of stellate melanophores;
* 1-2 melanophores under notochord tip in preflexion larvae.

Meristic Counts

Myomeres	33 - 35
Body Length (mm)	12 - 13
Age (days)	
Dorsal fin	X - XII + 1, 16 - 19
Anal fin	II, 18 - 20
Caudal fin	17
Pectoral fin	15 - 16
Pelvic fin	1, 5

Sillago bassensis	Cuvier, 1829	
western school whiting	CAAB 37330002	707



Larval Distribution

Regional distribution:

Larvae have been reported from coastal and shelf waters of South Australia between January and April (Bruce & Miskiewicz 1998). Database records extend this range to include from western Victoria to just east of Wilson's Promontory in December and January. The highest concentrations of larvae (up to 50 per 1000 m^3) have been recorded off Cape Liptrap in December. Larvae are restricted to nearshore and midshelf regions.

Vertical distribution:

Concentrations of larvae were highest in the 25 - 50 m depth stratum in western Victoria and in the 0 - 25 m stratum off Cape Liptrap (F. J. Neira, AMC, pers comm.).

Sillago bassensis	Cuvier, 1829	
western school whiting	CAAB 37330002	707

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates

Larval growth

Regional comparison

Sillago bassensis	Cuvier, 1829	
western school whiting	CAAB 37330002	707

Book and Book Chapter References

Bruce, B. D. & Miskiewicz, A. G. (1998). Sillaginidae: Whitings, sand smelts. In: Larvae of Temperate Australian Fishes: Laboratory Guide for Larval Fish Identification (F. J. Neira, A. G. Miskiewicz & T. Trnski, Eds.). University of Western Australia Press, Nedlands, WA. Pp: 294 - 305.

Dixon, P. I., Crozier, R. H., Black, M. & Church, A. (1987). Stock identification and discrimination of commercially important whitings in Australian waters using genetic criteria. In: FIRTA Final Report, Project No. 83 / 16 (, Eds.). Centre for Marine Science, University of New South Wales. Pp: 1 - 69.

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Yearsley, G. K., Last, P. R. & Ward, R. D. (1999). Australian Seafood Handbook: An Identification Guide to Domestic Species. CSIRO Marine Research, Hobart, Tas.

Journal Articles

Hyndes, G. A. & Potter, I. C. (1996). Comparisons between the age structures, growth and reproductive biology of two co-occurring sillaginids, Sillago robusta and S. bassensis, in temperate coastal waters of Australia. Journal of Fish Biology 49: 14 - 32.

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Eastern school whiting (*Sillago flindersi*)

Sillago flindersi	McKay, 1985	
eastern school whiting	CAAB 37330014	708

Species Distribution

Eastern school whiting (F. Sillaginidae) reach approximately 32 cm in length and 0.4 kg (Yearsley et al. 1999). They are endemic to southeast Australia and occur from Moreton Bay (Qld) south to Anxious Bay (SA) including Tasmania (McKay 1985, Dixon et al. 1987). Both juveniles and adults occur throughout inner shelf waters (Smith 1994). However, juveniles are generally found inshore of adult fish and within bays and estuaries over deep sandy substrate (Wankowski et al. 1986, Hobday & Wankowski 1987, Smith et al. 1987, Burchmore et al. 1988).

Spawning

They are multiple spawners (Hobday & Wankowski 1987). Mean potential fecundity has been estimated to range between 39,000 and 115,000 eggs depending on age (Hobday & Wankowski 1987).

Spawning is protracted and regionally variable in its timing. It has been recorded in Bass Strait from October to March (Hobday & Wankowski 1986, Hobday & Wankowski 1987) and off northern NSW, spawning peaks in winter (Smith 1994). The distribution of larvae supports these regionally variable times of spawning but suggests it may be more protracted than report off NSW with larvae recorded year - round off Sydney.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Genetic data indicate at least three separate stocks: north of Newcastle (NSW), Jervis Bay (NSW) to west of Portland (Vic.), west of Portland (Vic.) to southeast South Australia (Dixon et al. 1987). Larval distribution is disjunct and clustered in the former two areas. Fish in Tasmania may represent one-way flow of larvae across Bass Strait from eastern Victoria (Dixon et al. 1987).

Full Larval Description

Larvae of Temperate Australian Fishes reference: [not included]

Other taxa recorded with eastern school whiting larvae (% of samples):

S. sagax (76), E. australis (63), P. fuscus (45), P. auratus (34), P. saltatrix (24), T. declivis (15), C. affinis (13), S. australasicus (13), G. greyi (11), H. percoides (11), P. dentex (11), S. ciliata (11), T. novaezelandiae (11), P. bassensis (10), A. australis (8), G. blacodes (8), L. caudatus (6), R. solandri (6), S. brama (5), S. bassensis (5), T. atun (5), A. trutta (3)

Australian Seafood Handbook reference: p 281

Sillago flindersi	McKay, 1985	
eastern school whiting	CAAB 37330014	708

Larval Stage:

Illustrated by mm

Diagnostic Characters

Meristic Counts

Myomeres

Body Length (mm)

Age (days)

Dorsal fin

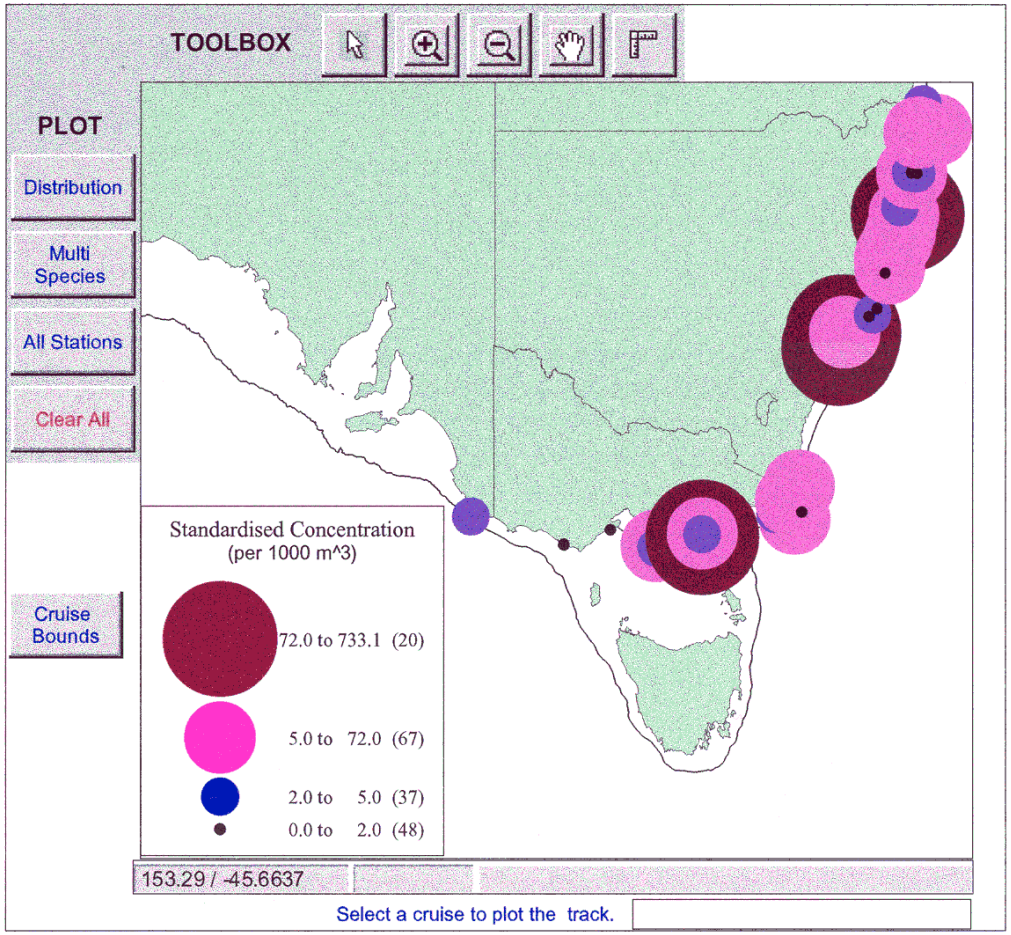
Anal fin

Caudal fin

Pectoral fin

Pelvic fin

Sillago flindersi	McKay, 1985	
eastern school whiting	CAAB 37330014	708



Larval Distribution

Regional distribution:

Larvae have been reported from coastal waters off Sydney (NSW) throughout the year, though they were more commonly recorded during spring and summer (Gray & Miskiewicz 2000) and in Victorian waters from December to February (Neira et al. 2000). Database records range from western Victoria to southern NSW (December to February) and central to northern NSW (January to September). The highest concentrations of larvae (46 - 99 / 1000 m^3) have been recorded off northern NSW in May, central NSW in January and Victorian waters in December. Larvae occur throughout shelf waters and have been recorded up to 30 km seaward of the shelf break off northern NSW.

Vertical distribution:

Gray & Miskiewicz (2000) recorded higher concentrations of larvae at 20 - 30 m than at the surface in shelf waters off Sydney (NSW). Neira et al. (2000) recorded larvae in the upper 50 m in Bass Strait.

Sillago flindersi	McKay, 1985	
eastern school whiting	CAAB 37330014	708

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Sillago flindersi	McKay, 1985	
eastern school whiting	CAAB 37330014	708

Book and Book Chapter References

Dixon, P. I., Crozier, R. H., Black, M. & Church, A. (1987). Stock identification and discrimination of commercially important whitings in Australian waters using genetic criteria. In: FIRTA Final Report, Project No. 83 / 16 (, Eds.). Centre for Marine Science, University of New South Wales. Pp: 1 - 69.

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Wankowski, J. W. J., Williams, S., and Hyduke, E. (1986). School whiting: population age structure and mortality rates in south-east Australian waters. In: Internal Report No. 147 (, Eds.). Victoria, Victorian Department of Conservation, Forests and Lands, Fisheries and Wildlife Service, Queenscliff, Vic. Pp: 1 - 34.

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Barracouta (*Thyrsites atun*)

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050

Species Distribution

Barracouta (F. Gempylidae) reach approximately 140 cm in length and 6 kg (Yearsley et al. 1999). In Australia, they occur from Morton Bay (Qld) around the south coast to Fremantle (WA) including Tasmania (Last et al. 1983, Gomon et al. 1994). They also occur throughout the temperate oceans of the Southern Hemisphere (Last et al. 1983, Gomon et al. 1994). Adults and juveniles form large schools in shelf and slope waters, mainly close to the surface, but have been recorded to a depth of about 550 m. Adults and juveniles also occur in estuaries and open bays (Gomon et al. 1994).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has been recorded across their geographical range and is regionally variable in its timing (Blackburn & Gartner 1954) Spawning has been recorded in Bass Strait and eastern Tasmania during spring and summer, eastern Victorian and New South Wales in winter and spring and South Australia and Western Australia in autumn and winter. The distribution of larvae suggests year round spawning in Tasmania and widespread spawning in southern Australia.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Based on differences in the timing of spawning, size composition of adults, age and growth and seasonal movements, up to five populations of barracouta may exist in Australian water: Bass Strait, eastern Tasmania, eastern Victoria, New South Wales, and South Australia / Western Australia (Blackburn & Gartner 1954, Grant et al. 1978). Larvae are widespread in southeast Australian waters.

Full Larval Description

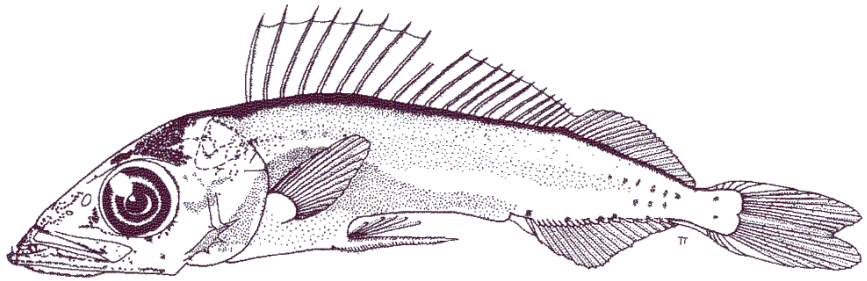
Larvae of Temperate Australian Fishes reference: Miskiewicz & Trnski (1998): Gempylidae: Gemfishes, snake mackerels, escolars. Pp: 406 - 411.

Other taxa recorded with barracouta larvae (% of samples):

S. brama (21), T. declivis (19), S. sagax (18), H. percoides (18), S. punctata (13), G. tigerinus (11), E. australis (9), S. bassensis (7), P. dentex (6), P. bassensis (6), S. australasicus (3), M. novaezelandiae (3), P. fuscus (3), S. flindersi (2), P. wrighti (1), A. australis (0.5), G. blacodes (0.5), P. auratus (0.5), R. solandri (0.5), S. s. scomberoides (0.5), Sillaginodes punctata (0.5)

Australian Seafood Handbook reference: p 131

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050



Larval Stage: settlement

Illustrated by T. Trnski 15 mm

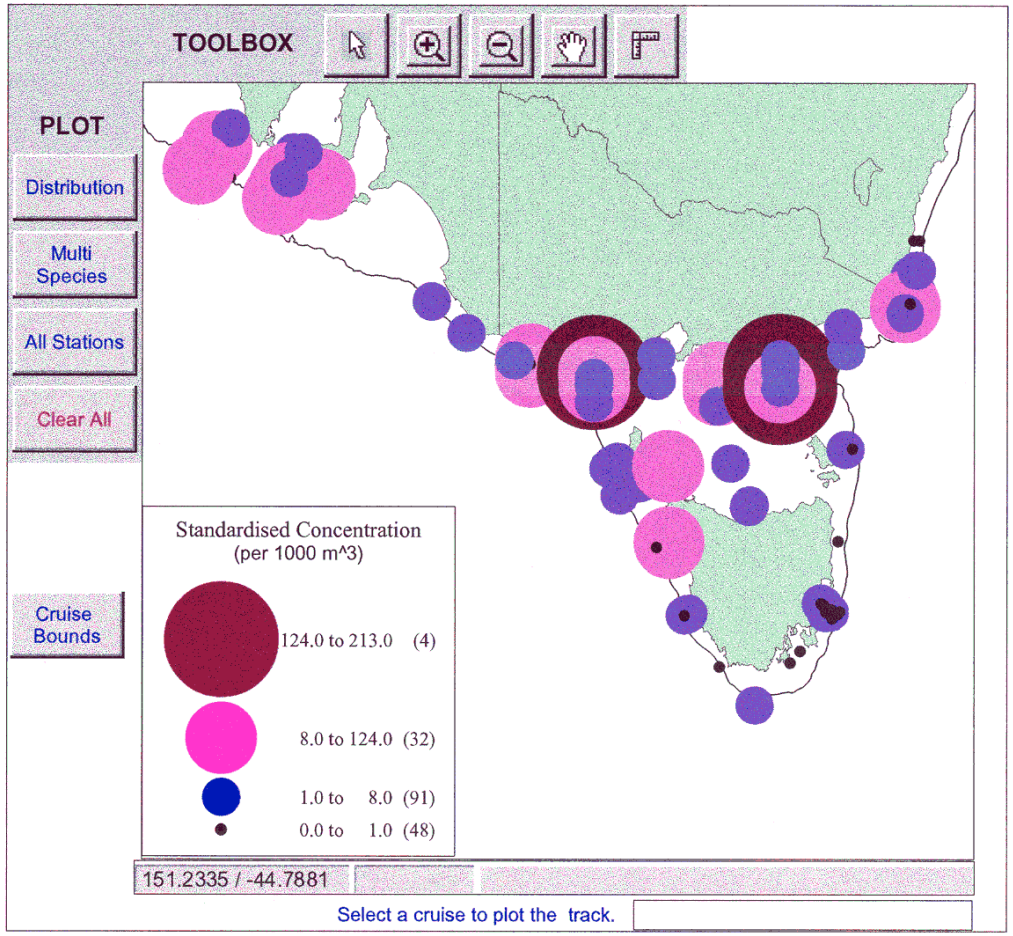
Diagnostic Characters

* 7-17 + 18-29 = 34-36 myomeres;
* Up to 4 posterior preopercular spines, moderate and smooth;
* Dorsal-fin spines long and serrate laterally from flexion stage;
* Pelvic-fin spine strongly serrate ventrally and medially from flexion stage;
* Up to 8 melanophores along ventral midline of tail, antermost becoming internal during flexion stage.

Meristic Counts

Myomeres	35
Body Length (mm)	15.7
Age (days)	
Dorsal fin	XIX - XXI, 11 - 13 + 5 - 7
Anal fin	I, 10 - 12 + 5 - 7
Caudal fin	17
Pectoral fin	13 - 15
Pelvic fin	1, 5

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050



Larval Distribution

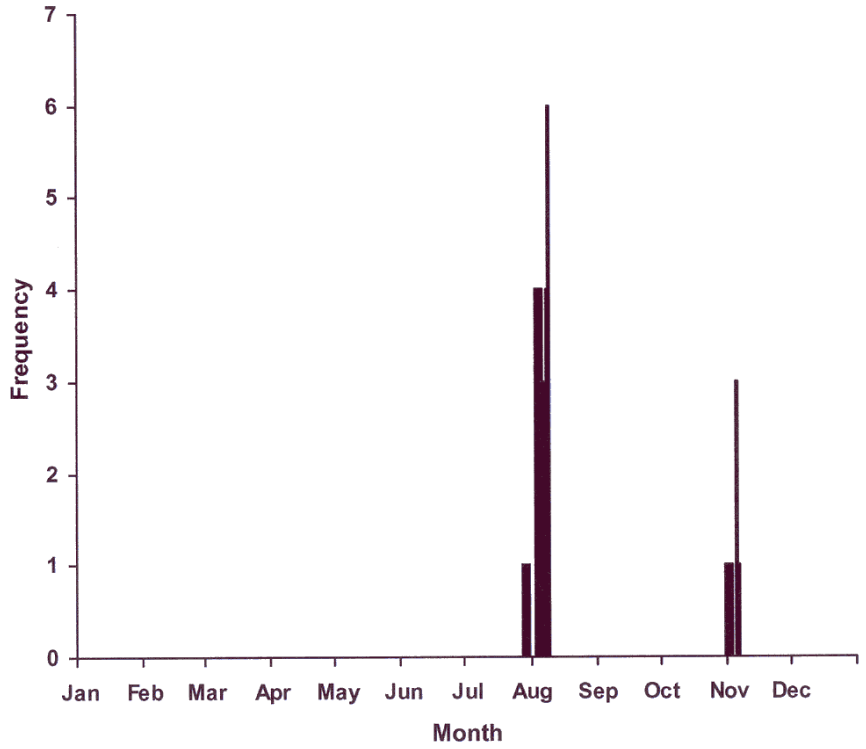
Regional distribution:

Larvae have been reported from shelf waters off Tasmania from November to April (Miskiewicz & Trnski 1998) and in coastal waters of Victoria from December to January and, less commonly, from May to July (Neira et al. 2000). Database records range from shelf waters south of Coffin Bay (SA) throughout Victorian and Tasmanian waters (including Bass Strait) to southern NSW. Larvae have been recorded from Coffin Bay (SA) to western Victoria from August to March, in Tasmanian waters throughout the year, throughout Bass Strait from October to February and May to July and eastern Victoria to southern NSW in July, August and December. The highest concentrations of larvae (124 - 213 / 1000 m^3) have been recorded in western Bass Strait in July and eastern Bass Strait in December. Larvae are widespread in shelf waters but have not been recorded seaward of the shelf break.

Vertical distribution:

Neira et al. (2000) recorded larvae throughout the water column to 75 - 100 m.

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050

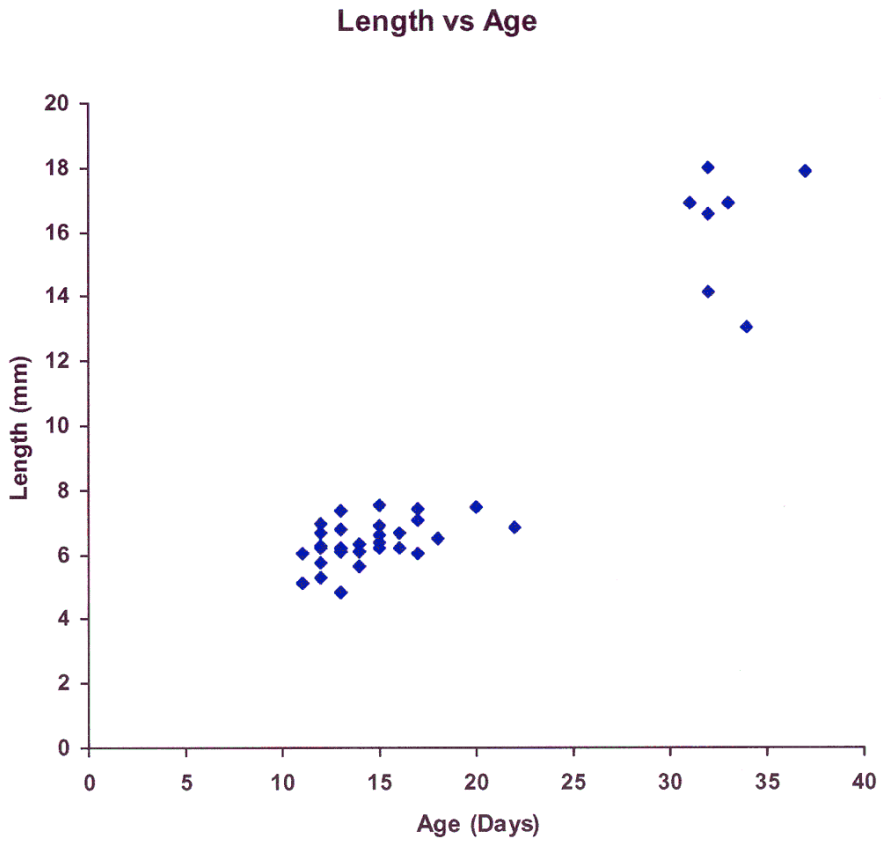


Spawning Dates

Database records range from 28 July to 5 November and are based on larvae from southern NSW and Tasmania.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050



Larval Growth

Eggs hatch after 49 h at 18.5 deg. C (De Jager 1955). Otoliths have unambiguous increments which have been assumed to be daily based on their similarity to that in species which have been validated.

Reported growth rates in reared larvae average 0.2 mm per day (De Jager 1955). Growth of southeast Australian larvae from 5 to 18 mm, based on database records, is best described by the exponential function:

Body length = 3.2026e^(0.04872 x age)

(R^2 = 0.90; n = 37)

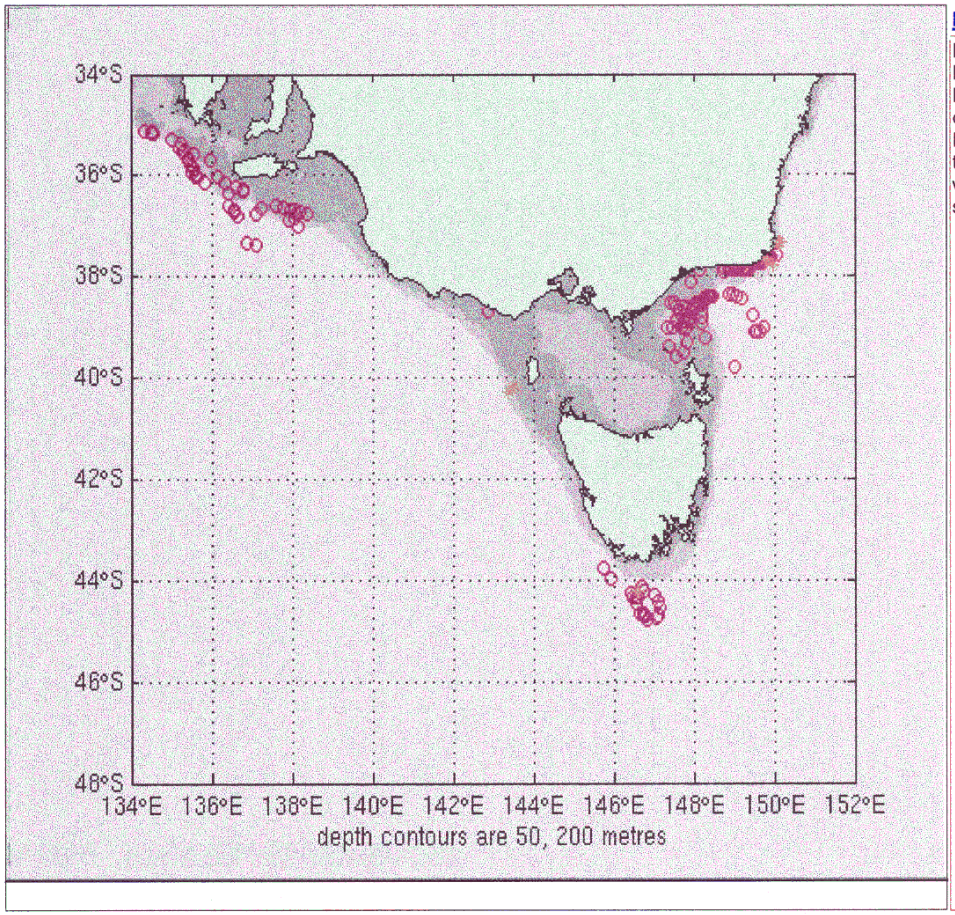
Barracouta have a larval duration of at least 37 days.

Back-calculated spawning dates

Larval growth

Regional comparison

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050



Larval Dispersal

Model runs are based on larvae aged from western Bass Strait, southern Tasmania and southern NSW. Modelled source locations include shelf waters east of Kangaroo Island, southern Tasmania and eastern Bass Strait. Larval trajectories indicate a rapid transport of larvae from South Australian waters to western Tasmania and from eastern Bass Strait to southern NSW.

Thyrsites atun	Euphrasen, 1791	
barracouta	CAAB 37439001	1050

Book and Book Chapter References

Gomon, M. F., Glover, J. C. M. & Kuiter, R. H. (1994). The Fishes of Australia's South Coast. State Print, Adelaide, SA.

Last, P. R., Scott, E. O. G. & Talbot, F. H. (1983). Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart, Tas.

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Saury (*Scomberesox saurus scomberoides*)

Scomberesox saurus scomberoides	Schneider	
saury	CAAB 37236001	432

Species Distribution

Saury (F. Scomberesocidae) reach approximately 45 cm in length (Gomon et al. 1994). In Australia, they occur from Port Macquarie (NSW) around the south coast to Geralton (WA) including Tasmania (Gomon et al. 1994, Bruce & Sutton 1998). They also occur throughout temperate waters of the Southern Hemisphere (Gomon et al. 1994). Both juvenile and adult saury are most commonly found seaward of the continental shelf break, although schools occasionally enter bays and estuaries (Bruce & Sutton 1998).

Spawning

Their spawning mode and fecundity are unknown.

Spawning has not been recorded. However, eggs have been collected off southern NSW in May (Bruce & Sutton 1998). The distribution of larvae suggests spawning is widespread and occurs during summer and autumn over its geographical range.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Stock structure is unknown.

Full Larval Description

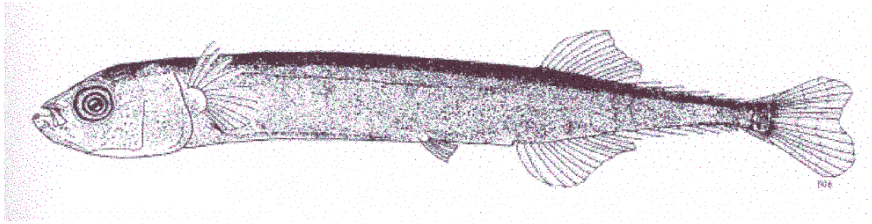
Larvae of Temperate Australian Fishes reference: Bruce & Sutton (1998): Scomberesocidae: Sauries. Pp 98 - 101.

Other taxa recorded with saury larvae (% of samples):

G. greyi (50), E. australis (18), S. sagax (8), A. australis (3), P. saltatrix (3), P. dentex (3), T. declivis (3), T. novaezelandiae (3), C. australis (2), H. percoides (2), N. macropterus (2), P. fuscus (2), R. solandri (2), Seriolella punctata (2), S. ciliata (2), T. atun (2)

Australian Seafood Handbook reference: p [not included]

Scomberesox saurus scomberoides Schneider
saury CAAB 37236001 432



Larval Stage:

Illustrated by B.D. Bruce 24.3 mm

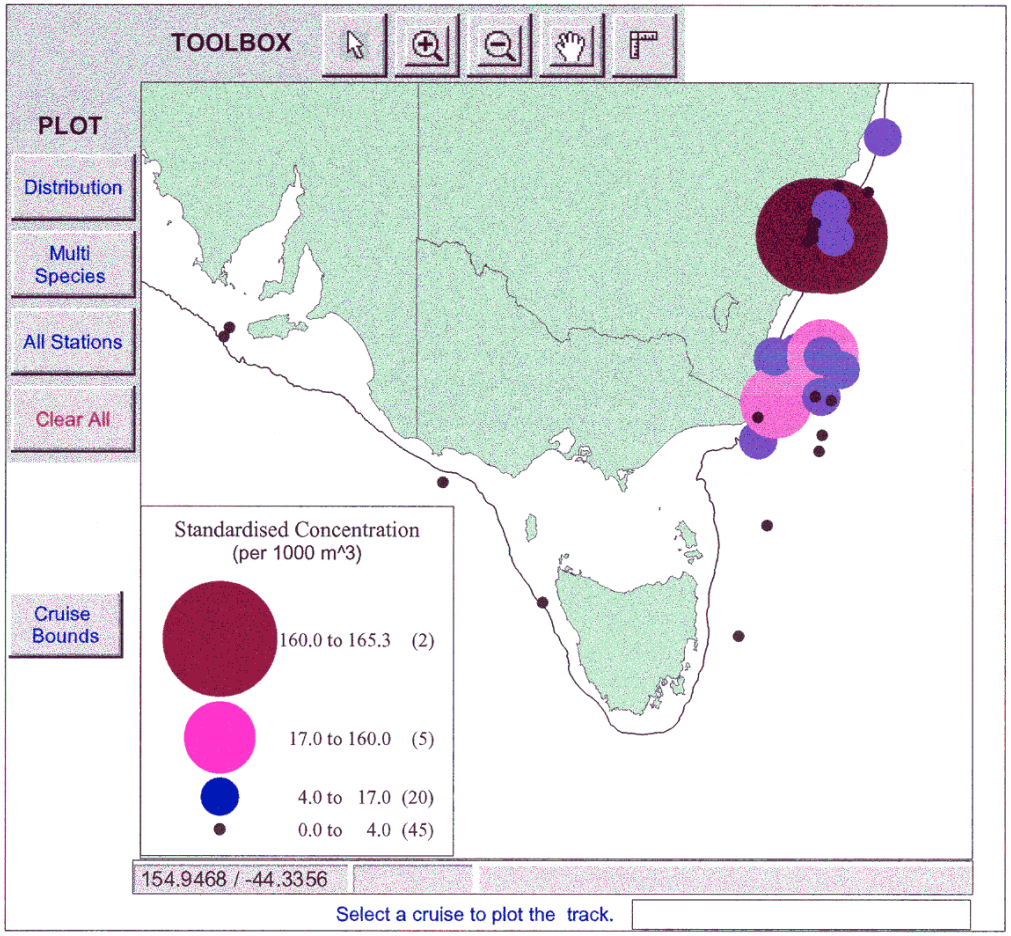
Diagnostic Characters

* 64-68 myomeres (obscured by pigment);
* Lower jaw slightly projected beyond upper jaw;
* Dorsal fin directly opposite anal fin;
* Body heavily pigmented;
* Expanded melanophore at base of caudal-fin rays.

Meristic Counts

Myomeres
Body Length (mm)
Age (days)
Dorsal fin
Anal fin
Caudal fin
Pectoral fin
Pelvic fin

Scomberesox saurus scomberoides Schneider
saury CAAB 37236001 432



Larval Distribution

Regional distribution:

Larvae have been reported from shelf and offshore waters of northern NSW from January to May, Tasmania from February to May and South Australia from January to April (Bruce and Sutton 1998). Database records include central to southern NSW and eastern Victoria in January and from May to July and extend the period of occurrence off South Australia to include January to May. The highest concentrations of larvae (up to 165 / 1000 m^3) have been recorded off central NSW in January. Larvae occur in shelf waters but are more commonly encountered in offshore waters and have been recorded up to 170 km seaward of the shelf break.

Vertical distribution:

Larvae are neustonic and have been recorded almost exclusively in surface tows.

Scomberesox saurus scomberoides	Schneider	
saury	CAAB 37236001	432

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐

Larval growth ☐

Regional comparison ☐

Scomberesox saurus scomberoides saury	Schneider CAAB 37236001	 432

Book and Book Chapter References

Journal Articles

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Blue mackerel (*Scomber australasicus*)

Scomber australasicus	Cuvier, 1832	
blue mackerel	CAAB 37441001	1068

Species Distribution

Blue mackerel (F. Scombridae) reach approximately 50 cm in length and 1.5 kg (Yearsley et al. 1999). In Australia, they occur from Moreton Bay (Qld) along the south coast to Northwest Cape (WA) including Tasmania (Gomon et al. 1994). They also occur throughout the central and western Pacific (Gomon et al. 1994). Juveniles are usually found inshore of adults, which inhabit the continental shelf in depths between 40 and 200 m (Trnski & Neira 1998).

Spawning

They are serial spawners (Jones 1983). Fecundity is unknown.

Spawning has not been recorded but Stevens et al. (1984) suggested it occurs around March in the Great Australian Bight. The distribution of larvae suggests spawning is widespread and variable in its timing, occurring in summer in southern Australia and progressively later northwards along the east coast with spawning in winter off northern NSW.

Estimating spawning stock biomass via egg surveys has not been attempted but may be suitable on a regional basis similar to pilchards.

Stock Structure

Stock structure is unknown.

Full Larval Description

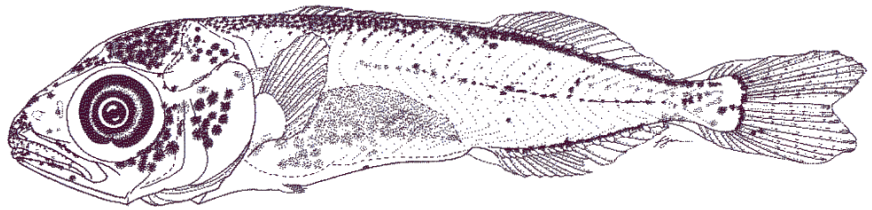
Larvae of Temperate Australian Fishes reference: Trnski & Neira (1998): Scombridae: Tunas, mackerels, bonitos. Pp 412 - 415.

Other taxa recorded with blue mackerel larvae (% of samples):

S. sagax (88), G. blacodes (43), P. auratus (40), E. australis (36), H. percoides (36), P. fuscus (33), R. solandri (24), S. flindersi (19), G. greyi (14), L. caudatus (14), P. saltatrix (14), T. atun (14), T. declivis (14), A. australis (12), P. bassensis (7), S. brama (7), C. affinis (5), S. bassensis (5), P. dentex (2)

Australian Seafood Handbook reference: p 165

Scomber australasicus	Cuvier, 1832	
blue mackerel	CAAB 37441001	1068



Larval Stage:

Illustrated by F.J. Neira 12.6 mm

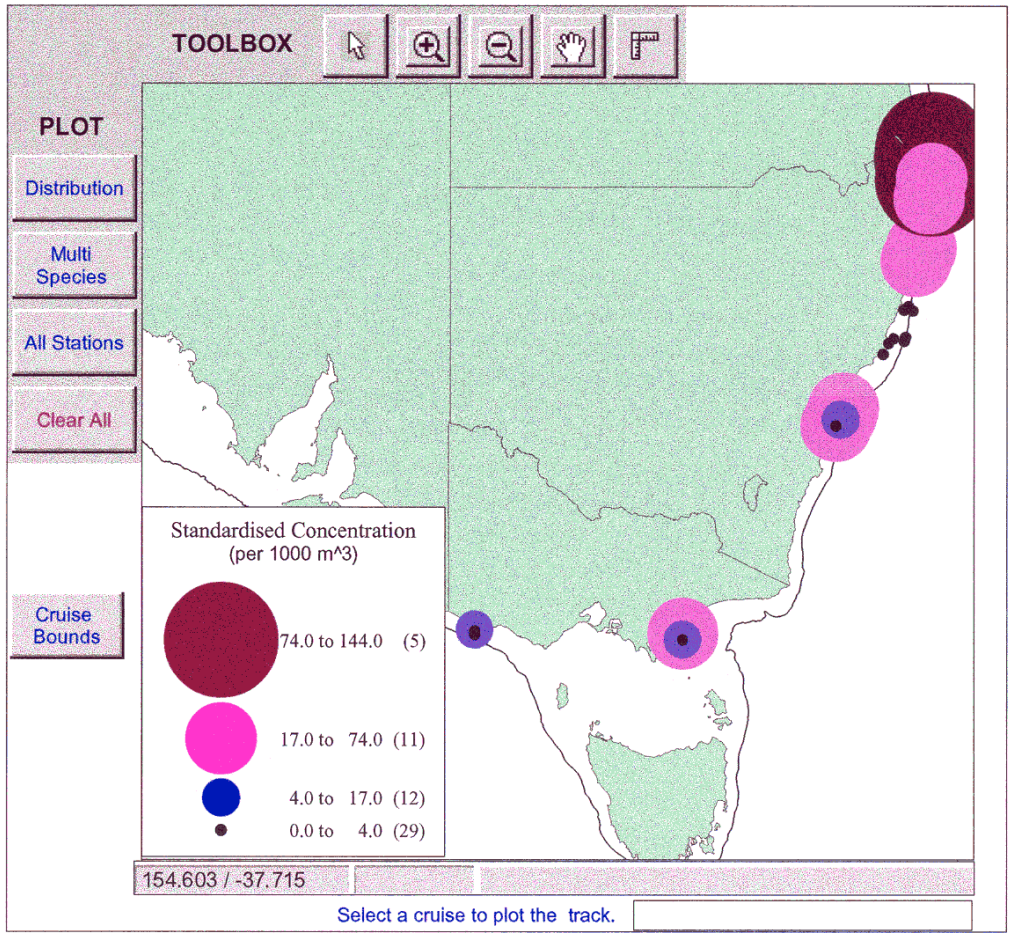
Diagnostic Characters

* 10-15 + 16-20 = 30-32 myomeres;
* Head spines restricted to low, smooth supraocular and supracleithral ridges;
* Mouth slightly subterminal from flexion stage;
* Large gap between anus and origin of anal fin, reduced with growth;
* Melanophore dorsally on nape, becoming internal in late preflexion larvae from 4.9mm;
* Series of melanophores along ventral midline of tail, anteriormost becoming internal during flexion stage.

Meristic Counts

Myomeres	
Body Length (mm)	
Age (days)	
Dorsal fin	
Anal fin	
Caudal fin	
Pectoral fin	
Pelvic fin	

Scomber australasicus Cuvier, 1832
blue mackerel CAAB 37441001 1068



Larval Distribution

Regional distribution:

Larvae have been reported from shelf waters off Sydney from May to September (Gray 1995). Database records include western Victoria in January, eastern Victoria in December and northern NSW in July and August. The highest concentrations of larvae (74 - 144 / 1000 m^3) have been recorded off northern NSW in August. Larvae are widespread in shelf waters and have rarely been recorded seaward of the shelf break.

Vertical distribution:

Unknown.

Scomber australasicus	Cuvier, 1832	
blue mackerel	CAAB 37441001	1068

Larval Growth

No data on back-spawning dates or larval growth are available in the database.

Back-calculated spawning dates ☐

Larval growth ☐

Regional comparison ☐

Scomber australasicus	Cuvier, 1832	
blue mackerel	CAAB 37441001	1068

Book and Book Chapter References

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Jack mackerel (*Trachurus declivis*)

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33

Species Distribution

Jack mackerel (F. Carangidae) reach a maximum length of about 64 cm and 1.6 kg (Gomon et al. 1994, Yearsley et al. 1999). In Australia, they occur from Wide Bay (Qld) around the south coast to Shark Bay (WA), including Tasmania and Lord Howe Island (Gomon et al. 1994, Trnski 1998). They also occur off New Zealand (Gomon et al. 1994). Adults and juveniles occur in coastal and continental shelf waters, forming dense schools over much of the year (Kailola et al. 1993). They may move closer to the seabed during winter, descending to a maximum of about 500 m close to the shelf break (Yearsley et al. 1999).

Spawning

Jack mackerel are serial spawners (Marshall et al. 1993). Fecundity is unknown.

Spawning has been recorded in the Great Australian Bight in summer (Stevens et al. 1984) and off New South Wales and Tasmania in late spring and summer (Maxwell 1979, Williams et al. 1987, Jordan 1994, Jordan et al. 1995). It is thought to occur throughout their geographical range (Marshall et al. 1993, Jordan et al. 1995). The distribution of larvae and back calculated spawning dates confirm a summer peak in spawning activity in southeast Australia.

Egg and larval surveys have occurred off the east coast of Tasmania (Jordan 1992, Jordan et al. 1995), however, estimating spawning stock biomass via egg surveys may not be suitable due to the protracted nature and spatial extent of spawning A. Jordan, TAFI, pers. comm.).

Stock Structure

Genetic data suggest that there are distinct subpopulations in Western Australia and the possibility of several geographically overlapping but genetically distinct subpopulations in the south-east region of Australia (Richardson 1982, Smolenski et al. 1994). Larvae are widespread in southeast Australia.

Full Larval Description

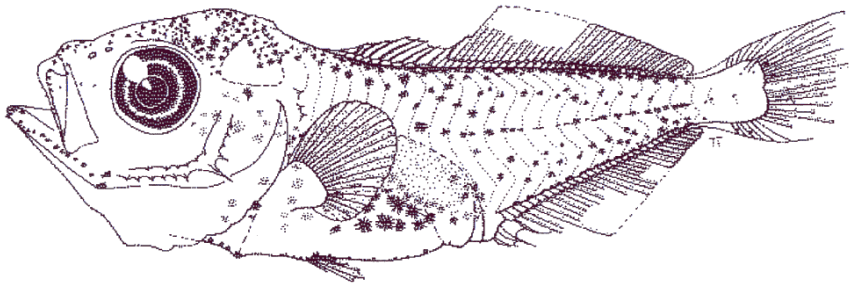
Larvae of Temperate Australian Fishes reference: Trnski (1998): Carangidae: Trevallys, jacks. Pp 192 - 203.

Other taxa recorded with jack mackerel larvae (% of samples):

S. sagax (22), T. atun (17), P. bassensis (10), E. australis (9), N. richardsoni (8), P. dentex (8), H. percoides (6), S. brama (5), S. bassensis (5), S. flindersi (5), P. auratus (4), S. australasicus (3), T. novaezelandiae (3), A. trutta (3), P. fuscus (3), C. affinis (2), G. tigerinus (2), G. greyi (2), P. wrighti (2), S. ciliata (2), M. novaezelandiae (1), S. s. scomberoides (1), A. australis (0.5), C. australis (0.5), G. blacodes (0.5), R. solandri (0.5), Seriolella punctata (0.5)

Australian Seafood Handbook reference: p 267

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33



Larval Stage: late postflexion

Illustrated by T. Trnski 12.8 mm

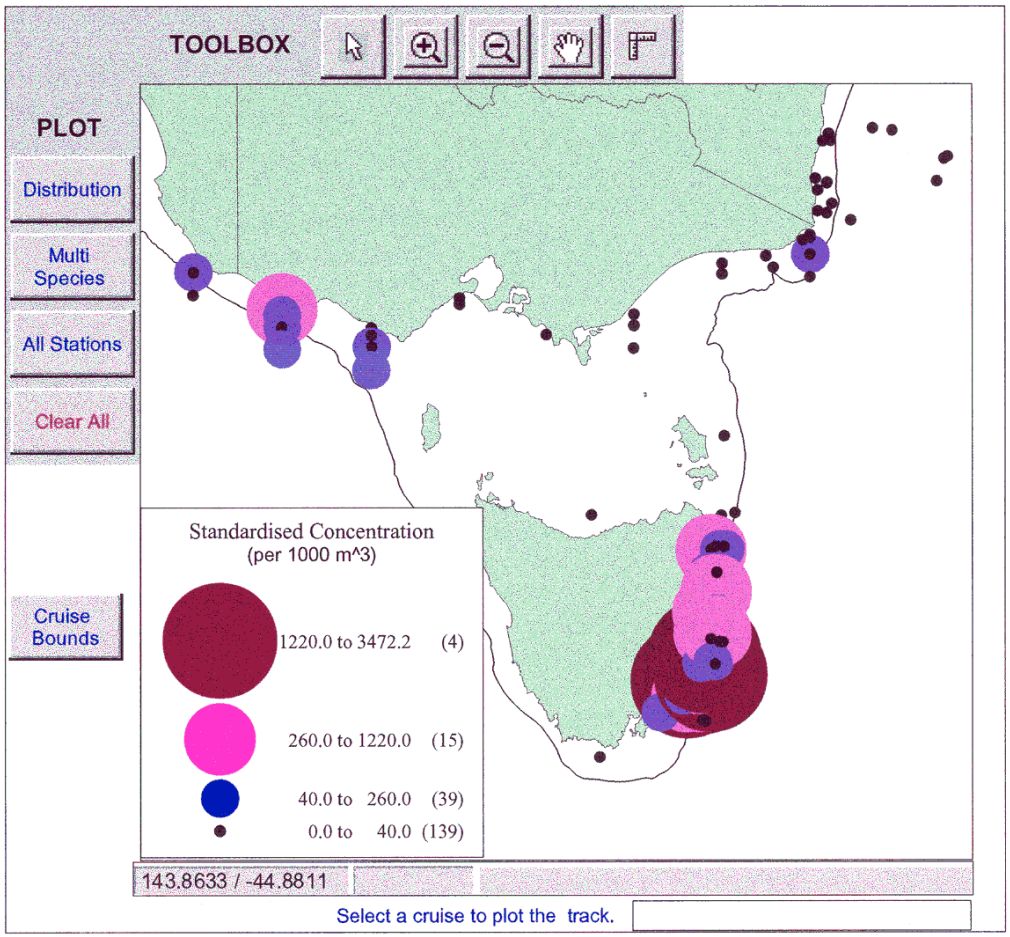
Diagnostic Characters

* 10-13 + 11-14 = 25 myomers;
* Serrate supraoccipital crest from mid-preflexion stage;
* One melanophore laterally on gut below pectoral-fin base, becoming internal by late preflexion stage;
* Melanophores along dorso- and ventrolateral surfaces of body by end of preflexion stage.

Meristic Counts

Myomeres	24
Body Length (mm)	12.8
Age (days)	
Dorsal fin	VIII - VIII + 1, 29 - 35
Anal fin	II - II + 1, 29 - 35
Caudal fin	17
Pectoral fin	21 - 21
Pelvic fin	1, 5

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33



Larval Distribution

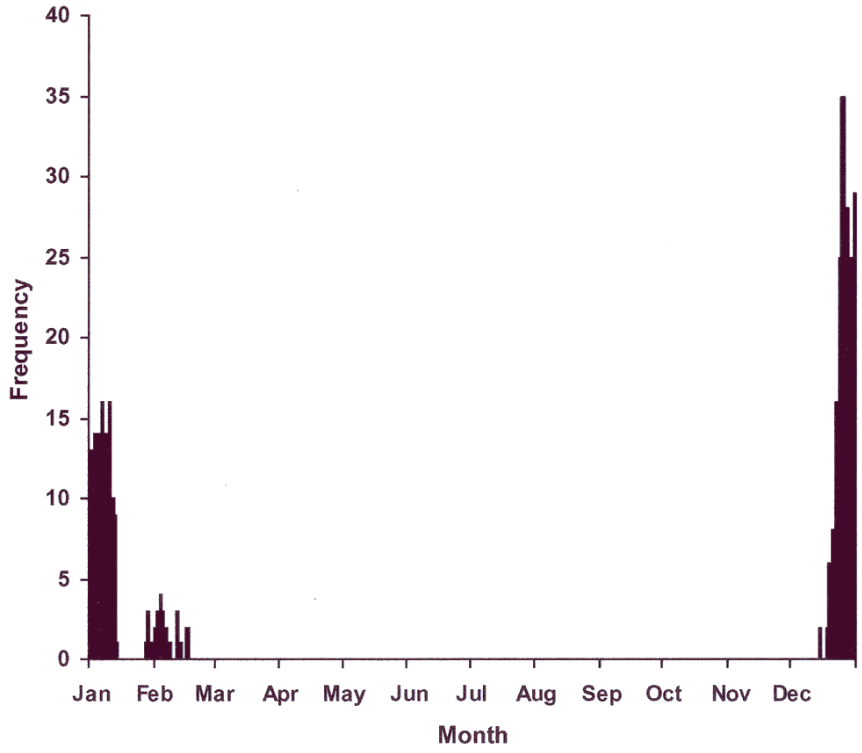
Regional distribution:

Larvae have been reported from the east coast of Tasmania between January and February (Jordan et al. 1995) and in Victorian waters from December to January (Neira et al. 2000). Database records extend this distribution to include shelf and offshore waters off southern NSW and eastern Victoria in February, May and August. The highest concentrations of larvae (1220 - 3472 / 1000 m^3) have been recorded off eastern Tasmania in January. Larvae are widely distributed in shelf waters and have been recorded up to 160 km seaward of the shelf break off Eden (NSW).

Vertical distribution:

Neira et al. (2000) recorded the highest concentrations of larvae in the 0 - 25 m and 25 - 50 m strata in Bass Strait. Jordan et al. (1995) noted that larvae appear to be concentrated in the 20 - 30 m depth stratum when the water column is stratified, but may be more evenly distributed when the water column is well mixed.

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33



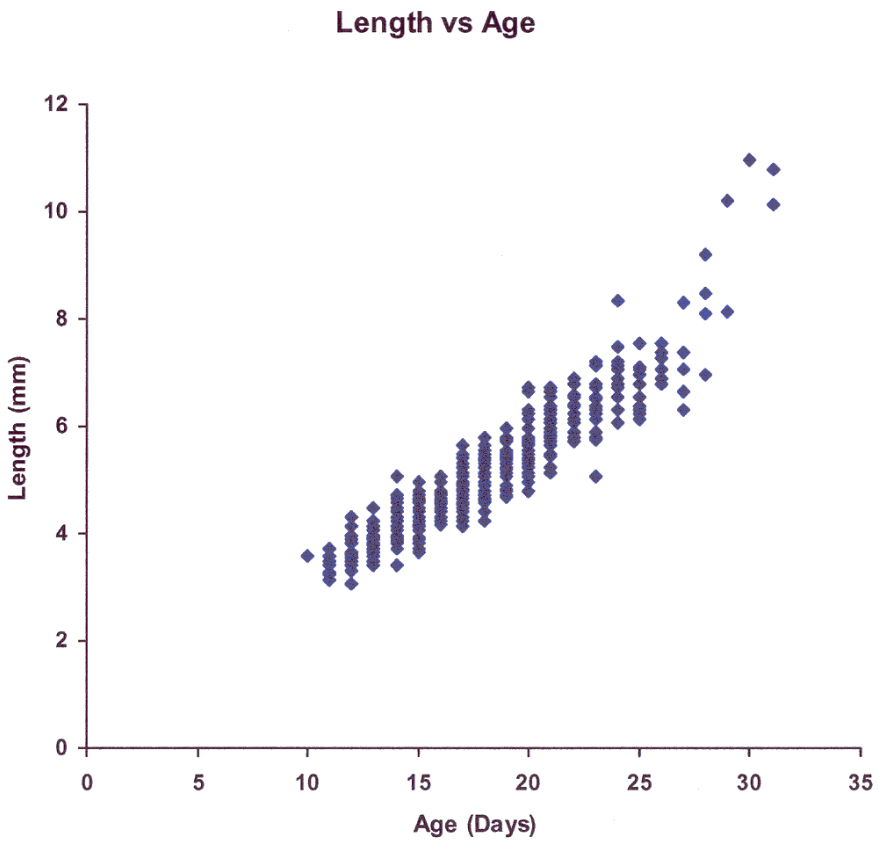
Spawning Dates

Published back-calculated spawning dates range from 10 December to 17 February with peaks in spawning associated with full and new moons (Jordan 1994).

Database records range from 15 December to 17 February and are based on larvae from eastern Tasmania.

Back-calculated spawning dates
Larval growth
Regional comparison

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33



Larval Growth

Otoliths have unambiguous increments that have been assumed to be daily. Their formation commences approximately 8 days after spawning (Jordan 1994).

Reported growth rates increase exponentially for the first 15 days, but may vary between years (Jordan 1994). Growth of southeast Australian larvae from 3 to 11 mm, based on database records, is best described by the exponential function:

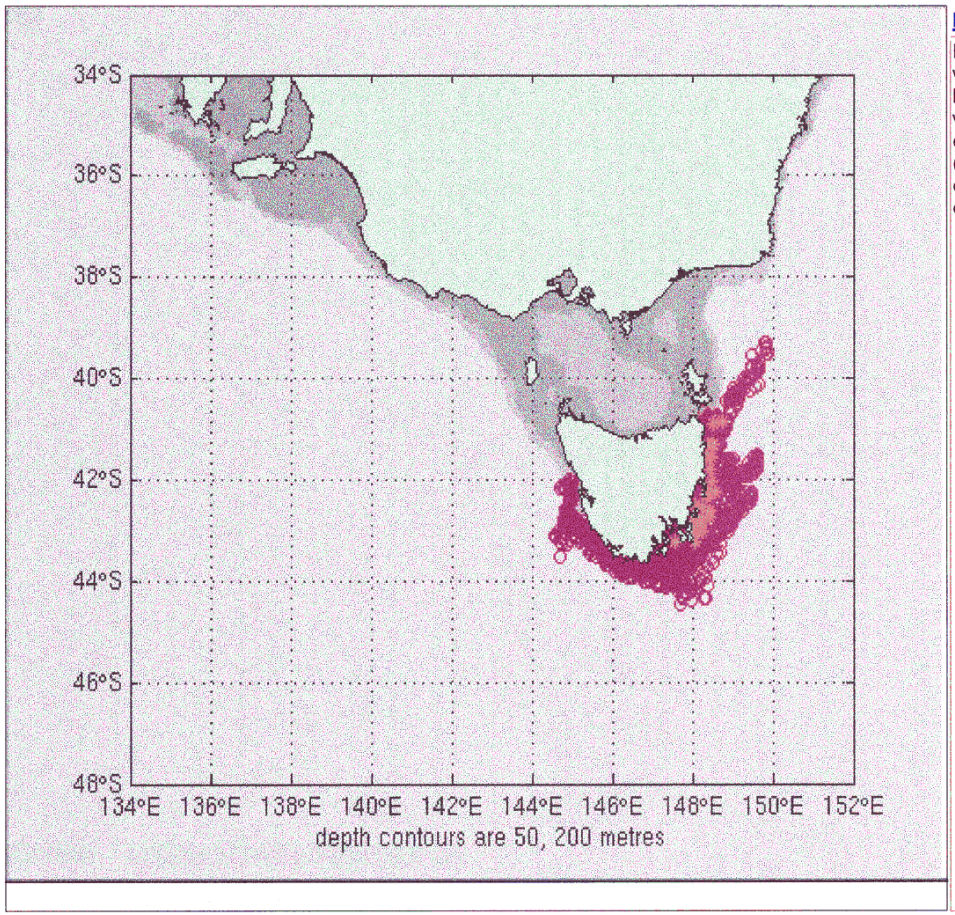
Body length = 1.9845e^(0.05174 x age)

(R^2 = 0.90; n = 503)

Jack mackerel have a protracted larval duration of at least 31 days.

Back-calculated spawning dates
Larval growth
Regional comparison

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33



Larval Dispersal

Model runs are based on larvae aged from shelf waters of eastern Tasmania. Modelled source locations range along the east coast, south and west coasts of Tasmania and encompass the east coast spawning region identified by Jordan et al. (1995). Larval trajectories are consistent with field data indicting distribution of larvae in both shelf and offshore waters.

Trachurus declivis	Jenyns, 1841	
jack mackerel	CAAB 37337002	33

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Yellowtail scad (*Trachurus novaezelandiae*)

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34

Species Distribution

Yellowtail (F. Carangidae) reach a maximum length of about 50 cm and 1 kg (Yearsley et al. 1999). In Australia, they occur from Wide Bay (Qld) around the south coast to Exmouth Gulf (WA) including Tasmania and Lord Howe Island (Gomon et al. 1994). They also occur in New Zealand (Horn 1991). Both adults and juveniles occur in large schools within estuaries, bays and shallow coastal waters and have been recorded to depths of 500 m (Trnski 1998).

Spawning

Yellowtail is most likely a serial spawner (Horn 1991). Fecundity is unknown.

Spawning has not been recorded in Australia; however, in New Zealand yellowtail eggs were present from October through to February (Crossland 1981). The distribution of larvae suggests widespread spawning in eastern Australia with peak activity in summer and autumn, however larvae have been recorded at all times of the year off Sydney suggesting spawning may be more protracted.

Estimating spawning stock biomass via egg surveys has not been attempted and may not be suitable due to the protracted nature and spatial extent of spawning.

Stock Structure

Morphometric analysis suggests two separate stocks - one in the Great Australian Bight, the other in south eastern Australia (Lindholm & Maxwell 1988) although these data are not conclusive. Larvae have only been recorded from eastern Australia.

Full Larval Description

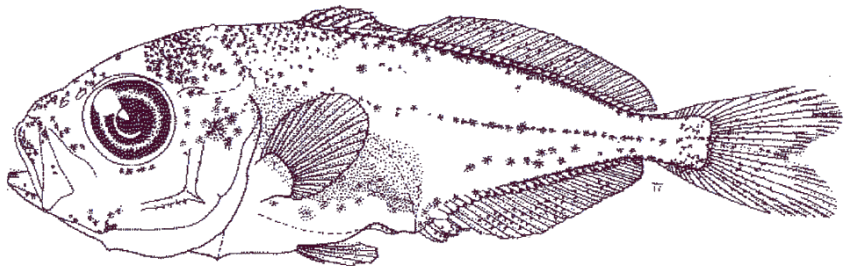
Larvae of Temperate Australian Fishes reference: Trnski (1998): Carangidae: Trevallys, jacks. Pp 192 - 203.

Other taxa recorded with yellowtail scad larvae (% of samples):

E. australis (67), G. greyi (61), P. saltatrix (60), P. fuscus (33), P. dentex (32), A. australis (18), P. australis (18), S. sagax (14), S. flindersi (12), T. declivis (11), C. affinis (9), A. trutta (7), S. ciliata (5), C. australis (4), P. wrighti (4), S. s. scomberoides (4), G. blacodes (2)

Australian Seafood Handbook reference: p 276

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34



Larval Stage: late postflexion

Illustrated by T. Trnski 13.8 mm

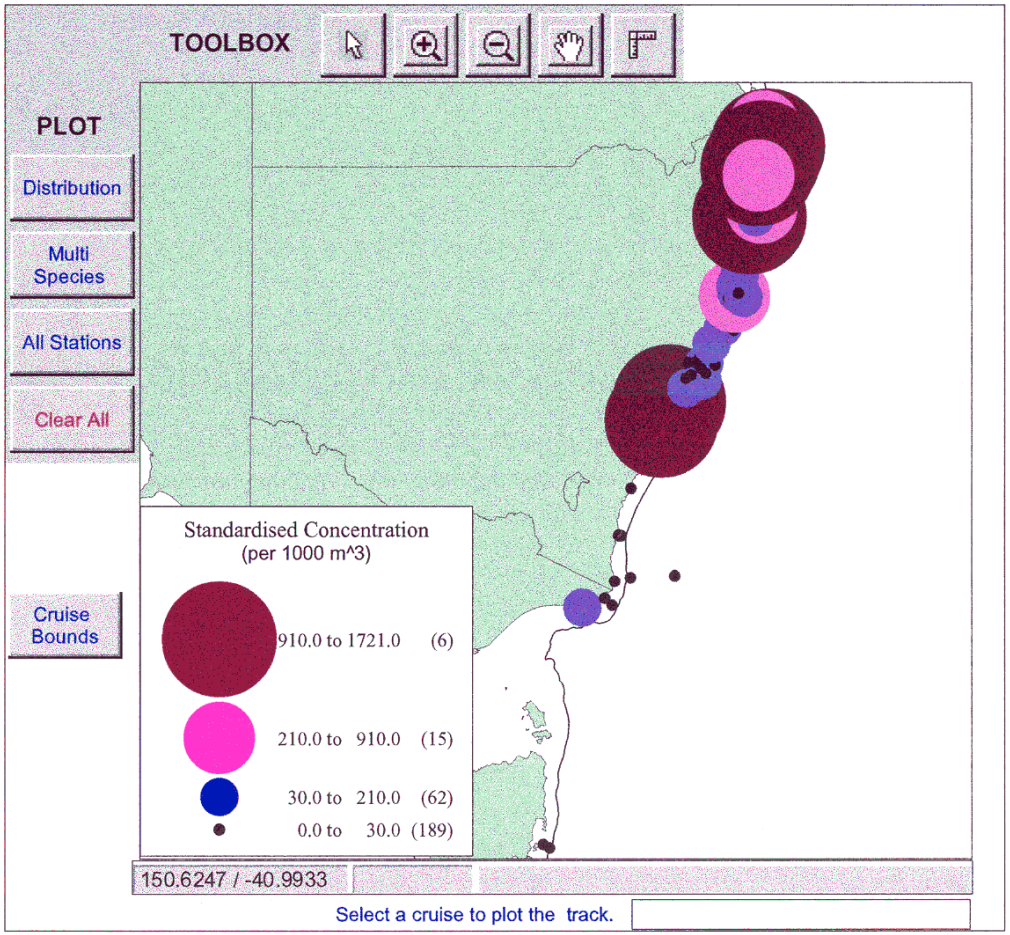
Diagnostic Characters

* 9-12 + 12-15 = 24 myomeres;
* Serrate supraoccipital crest from early preflexion stage, low by 10mm;
* Melanophore laterally on gut below pectoral-fin base usually present, internal by 7-9mm;
* Melanophores along dorso- and ventrolateral surfaces of body from early postflexion stage

Meristic Counts

Myomeres	24
Body Length (mm)	13.8
Age (days)	
Dorsal fin	VIII - VIII + 1, 27 - 33
Anal fin	II - II + 1, 22 - 29
Caudal fin	17
Pectoral fin	21 - 22
Pelvic fin	1. 5

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34



Larval Distribution

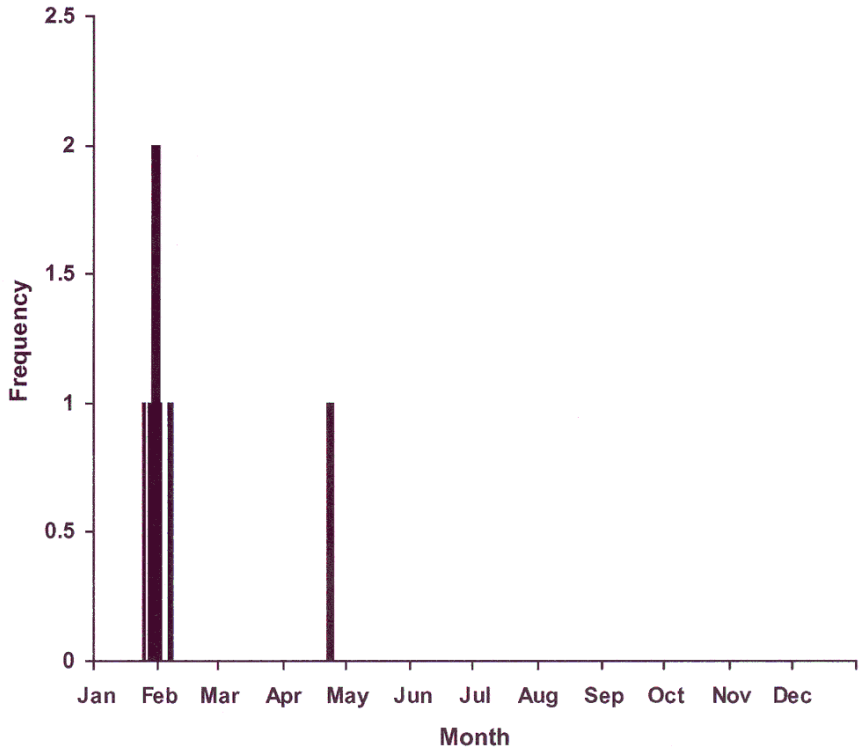
Regional distribution:

Larvae have been reported from coastal waters off Sydney (NSW) throughout the year (Gray et al. 1992, Gray 1993, Smith et al. 1999). Database records extend this distribution to include shelf and offshore waters off southern NSW and eastern Victoria in February and May, and shelf waters off northern NSW in May. The highest concentration of larvae (1721 / 1000 m^3) has been recorded in coastal waters off Sydney in April / May. Larvae are widely distributed in shelf waters and have been recorded up to 100 km seaward of the shelf break off Eden (NSW).

Vertical distribution:

Gray & Miskiewicz (2000) recorded higher concentrations of larvae at 20 - 30 m than at the surface in shelf waters off Sydney (NSW).

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34



Spawning Dates

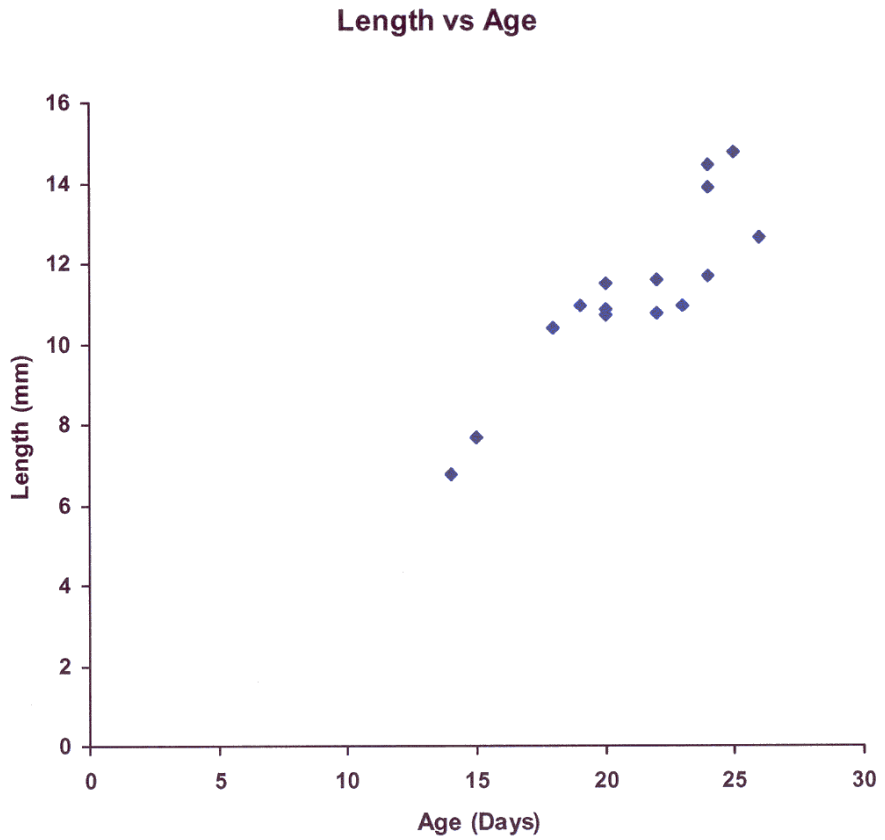
Database records range from 25 January to 24 April and are based on larvae from southern NSW and eastern Victoria.

Back-calculated spawning dates

Larval growth

Regional comparison

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34



Larval Growth

Otoliths have unambiguous increments that have been assumed to be daily.

Growth of southeast Australian larvae from 6 to 16 mm, based on database records, is best described by a von Bertalanffy growth function with parameters:

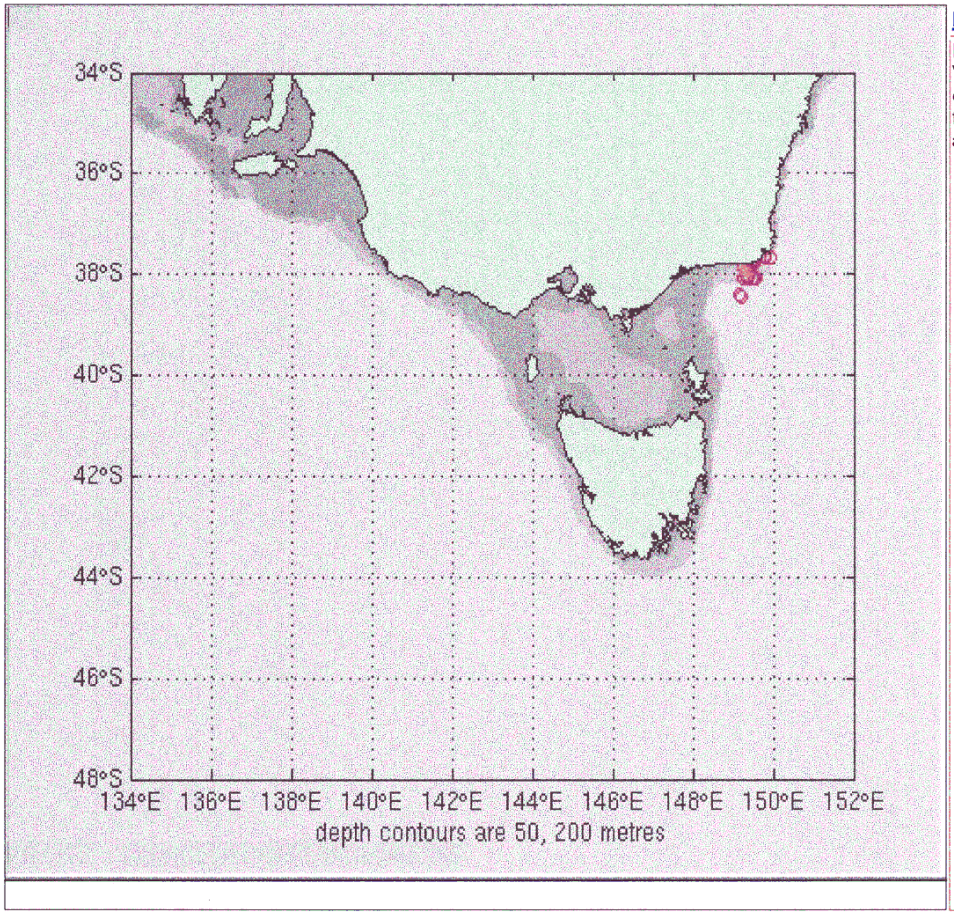
L (inf) = 18.226; k = 0.071; t(0) = 7.028

(R^2 = 0.73; n = 21)

Yellowtail have a protracted larval duration of at least 29 days.

Back-calculated spawning dates ☐
Larval growth ☐
Regional comparison ☐

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34



Larval Dispersal

Model runs are based on larvae aged from eastern Victoria. Modelled source locations are concentrated close to the capture locations. Too few sampling positions with aged larvae are available to fully assess larval dispersal processes.

Trachurus novaezelandiae	Richardson, 1843	
yellowtail scad	CAAB 37337003	34

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Gray, C. A., Otway, N. M., Laurenson, F. A., Miskiewicz, A. G. & Pethebridge, R. L. (1992). Distribution and abundance of marine fish larvae in relation to effluent plumes from sewage outfalls and depth of water. Marine Biology 113: 549 - 559.

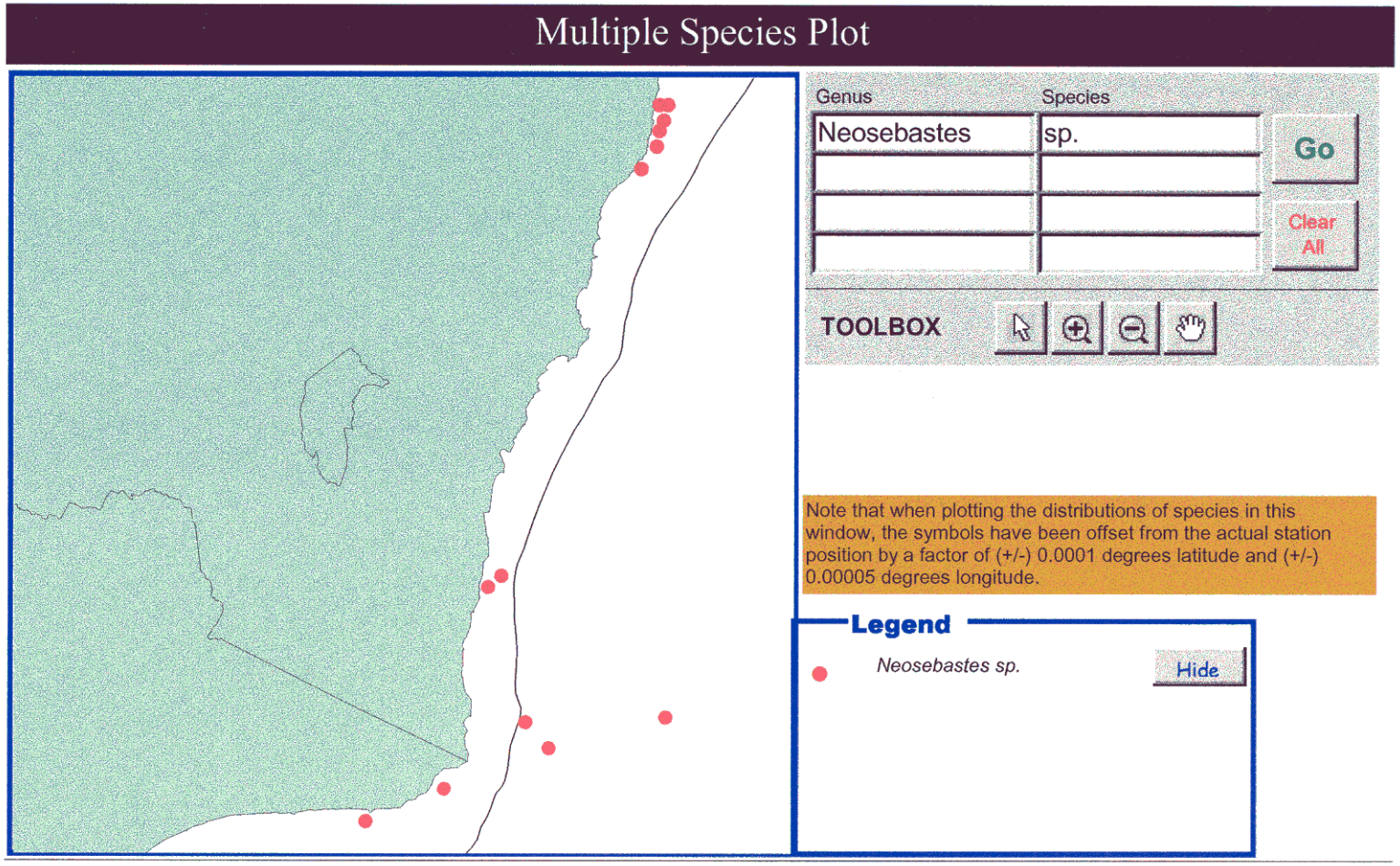
Horn, P. L. (1991). Trawl survey of jack mackerels (Trachurus spp.) off the central west coast, New Zealand, February - March 1990. New Zealand Fisheries Technical Report 28: 1 - 40.

Lindholm, R. & Maxwell, J. G. H. (1988). Stock separation of jack mackerel Trachurus declivis and yellowtail T. novaezelandiae (Richardson 1843) in southern Australian waters, using principal component analysis. CSIRO Marine Laboratories Report 189: 1 - 7.

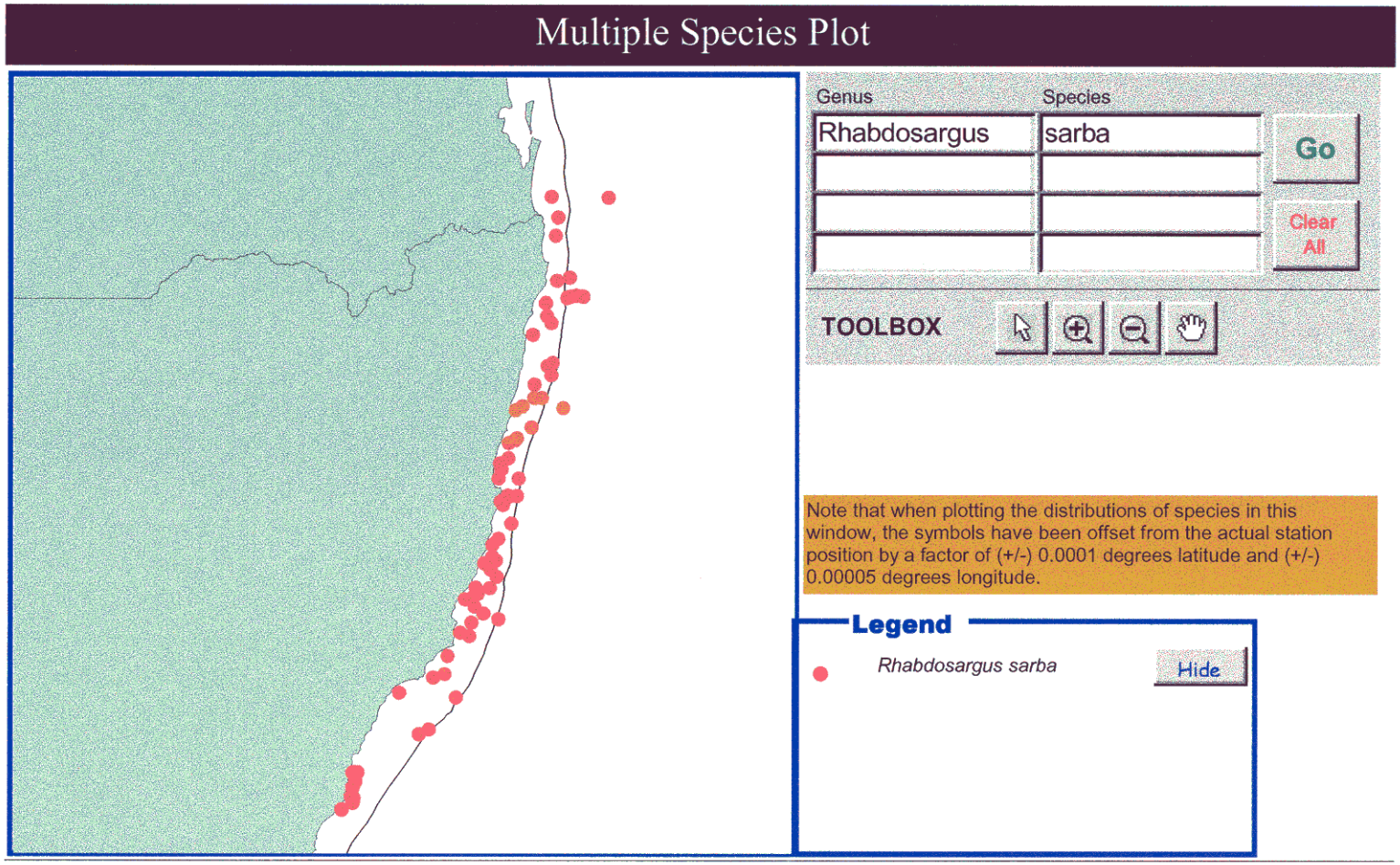
Smith, A. K., Ajani, P. A. & Roberts, D. E. (1999). Spatial and temporal variation in fish assemblages exposed to sewage and implications for management. Marine Environmental Research 47: 241 - 260.

Secondary species

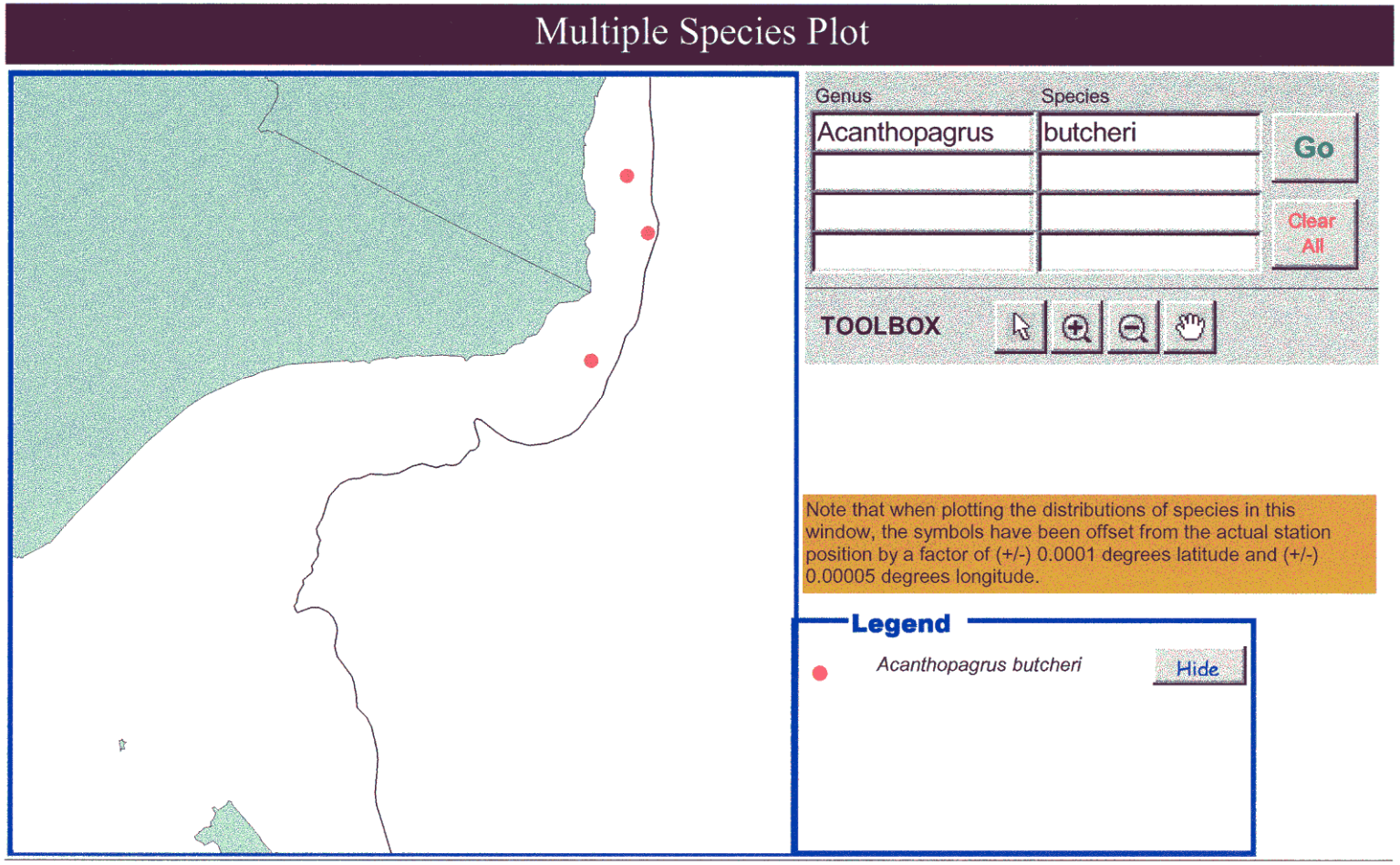
Gurnard perch (*Neosebastes* sp.)



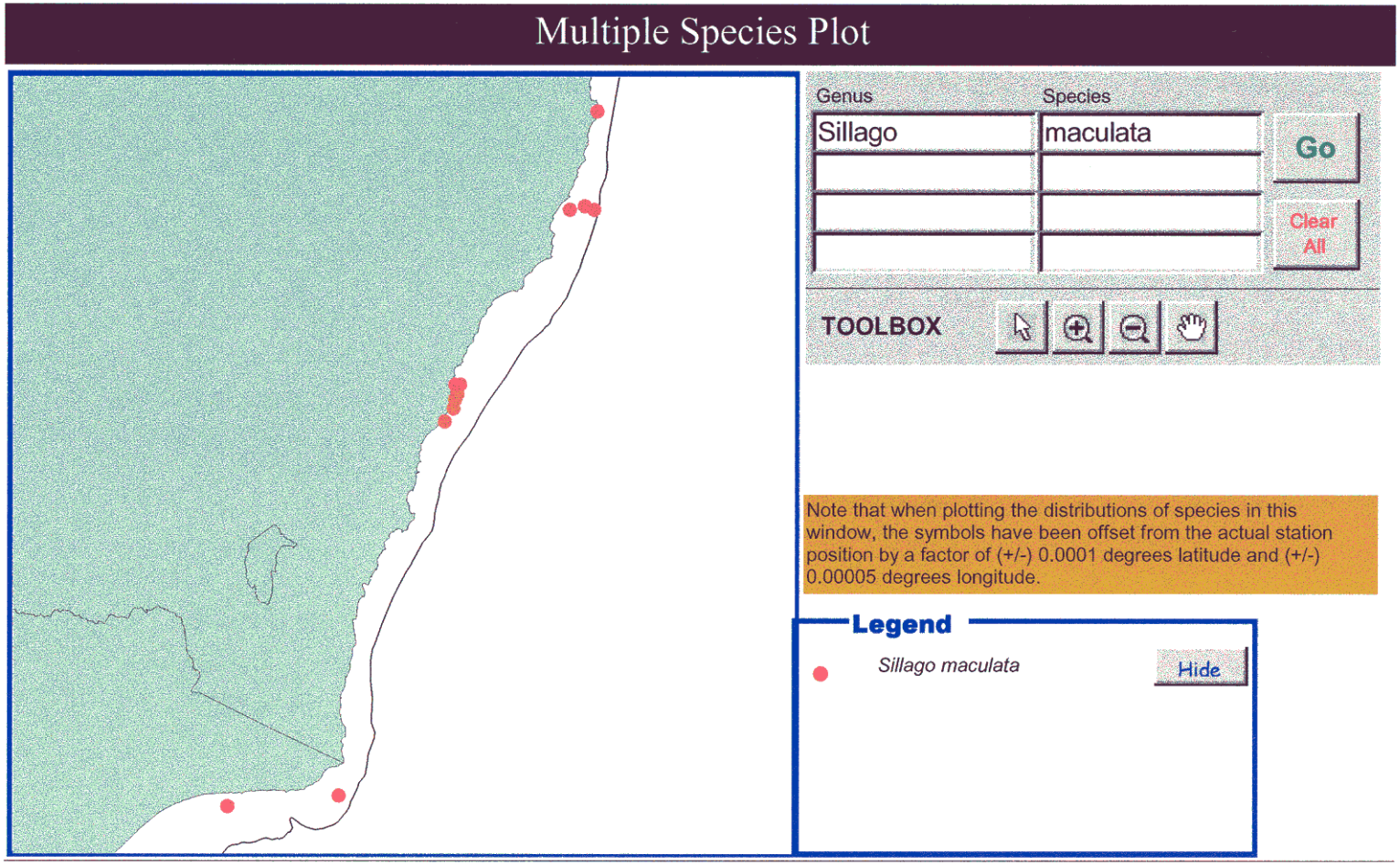
Tarwhine (*Rhabdosargus sarba*)



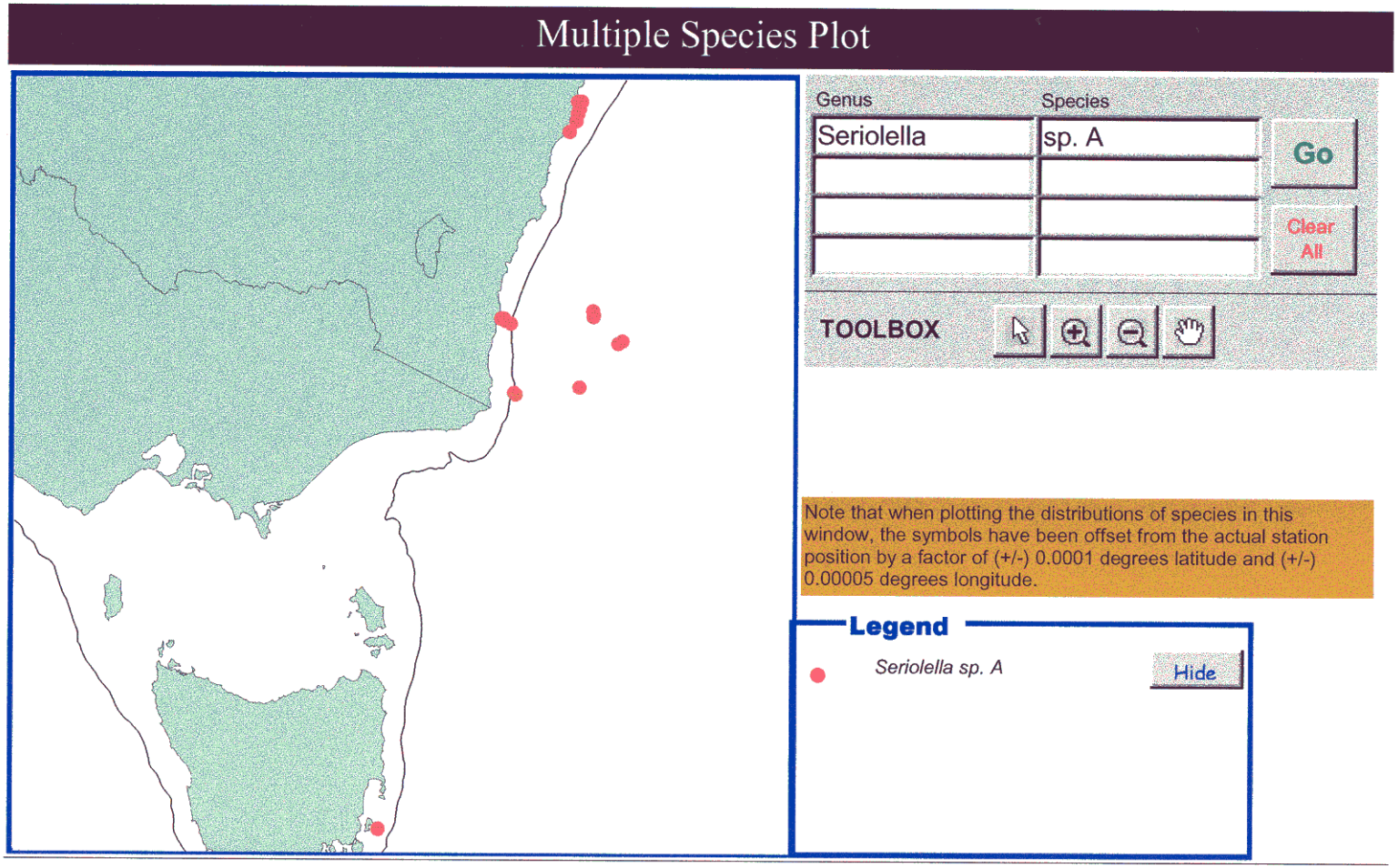
Black bream (*Acanthopagrus butcheri*)



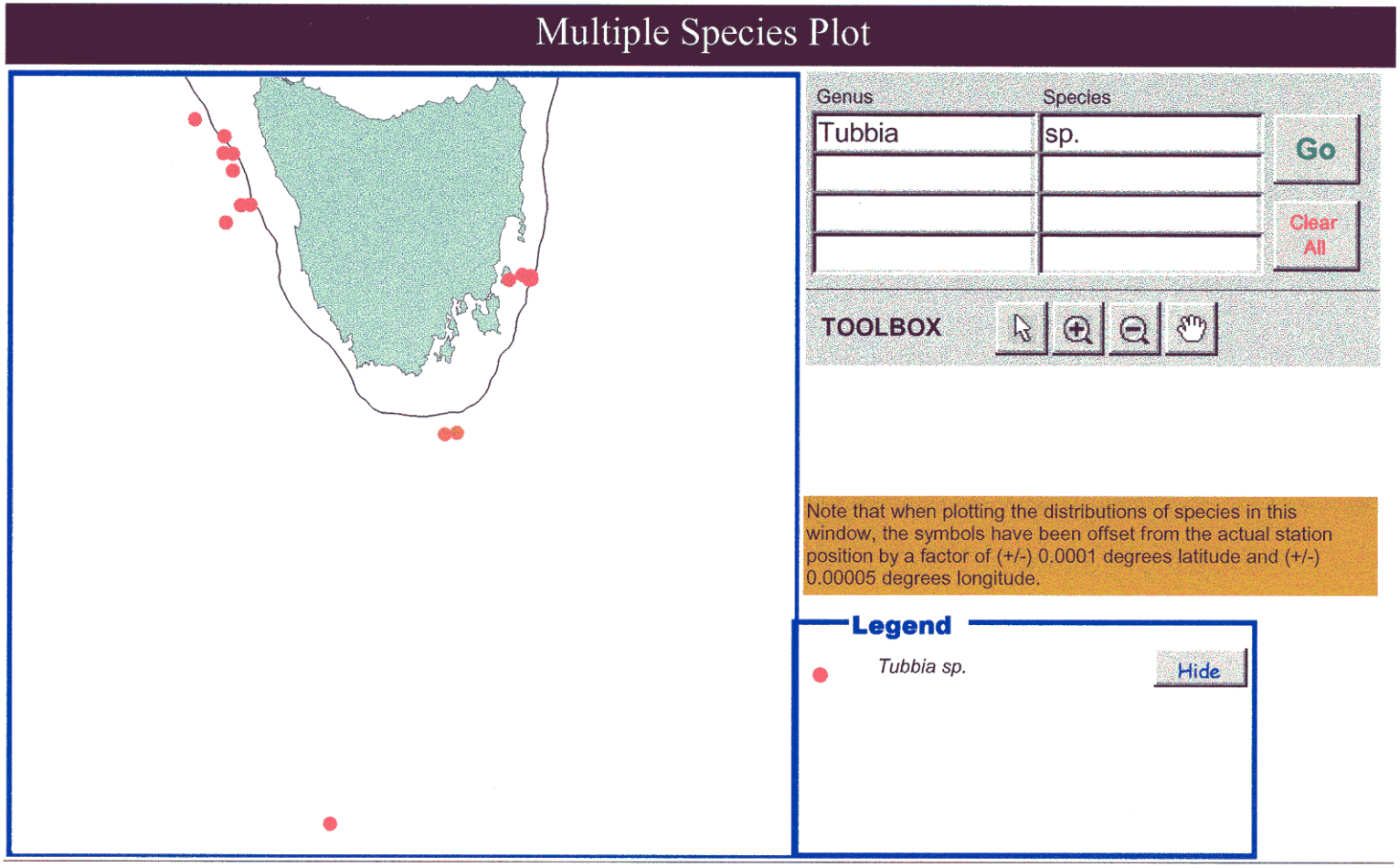
Trumpeter whiting (*Sillago maculata*)



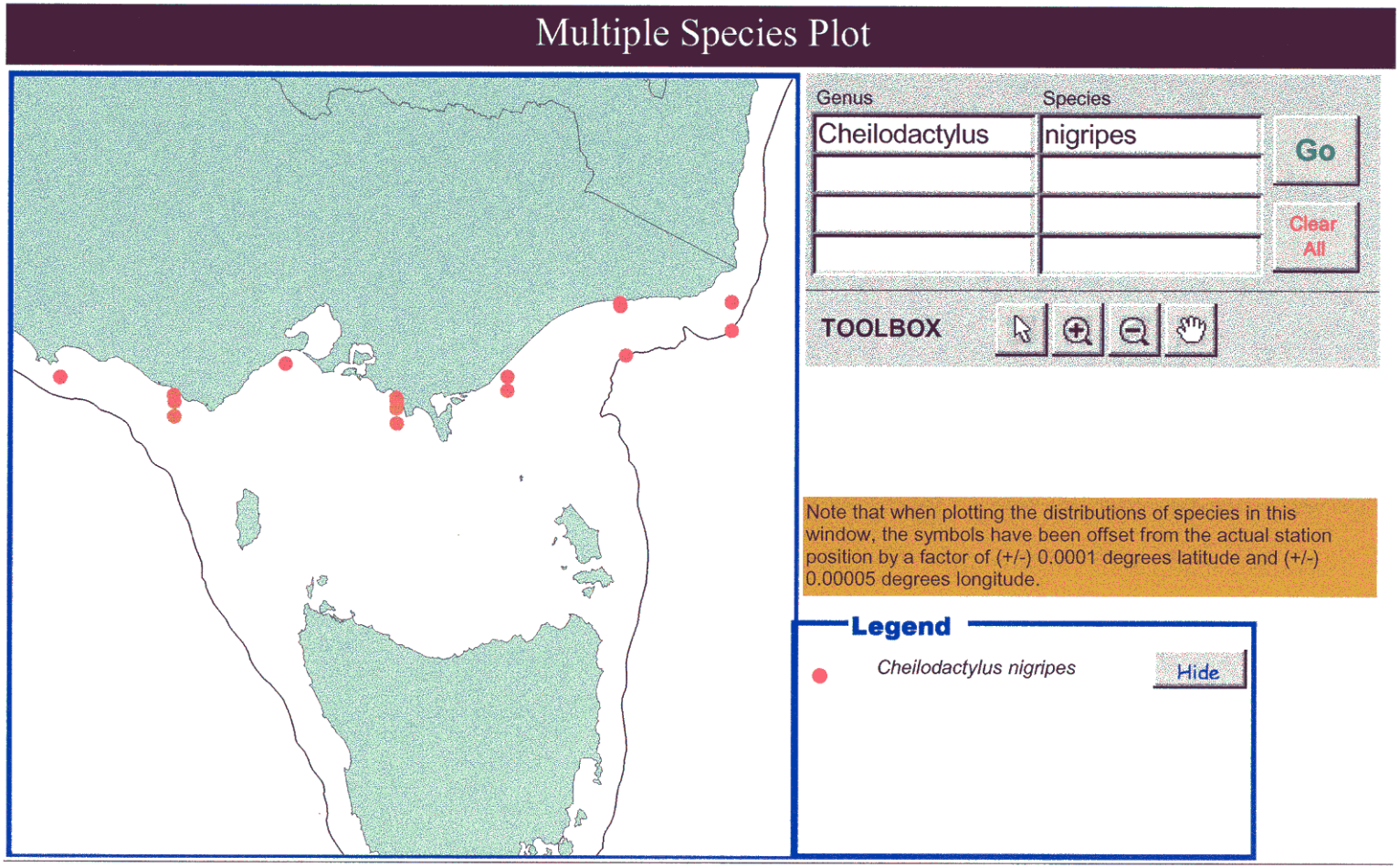
White warehou (?) (*Seriolella* sp.)



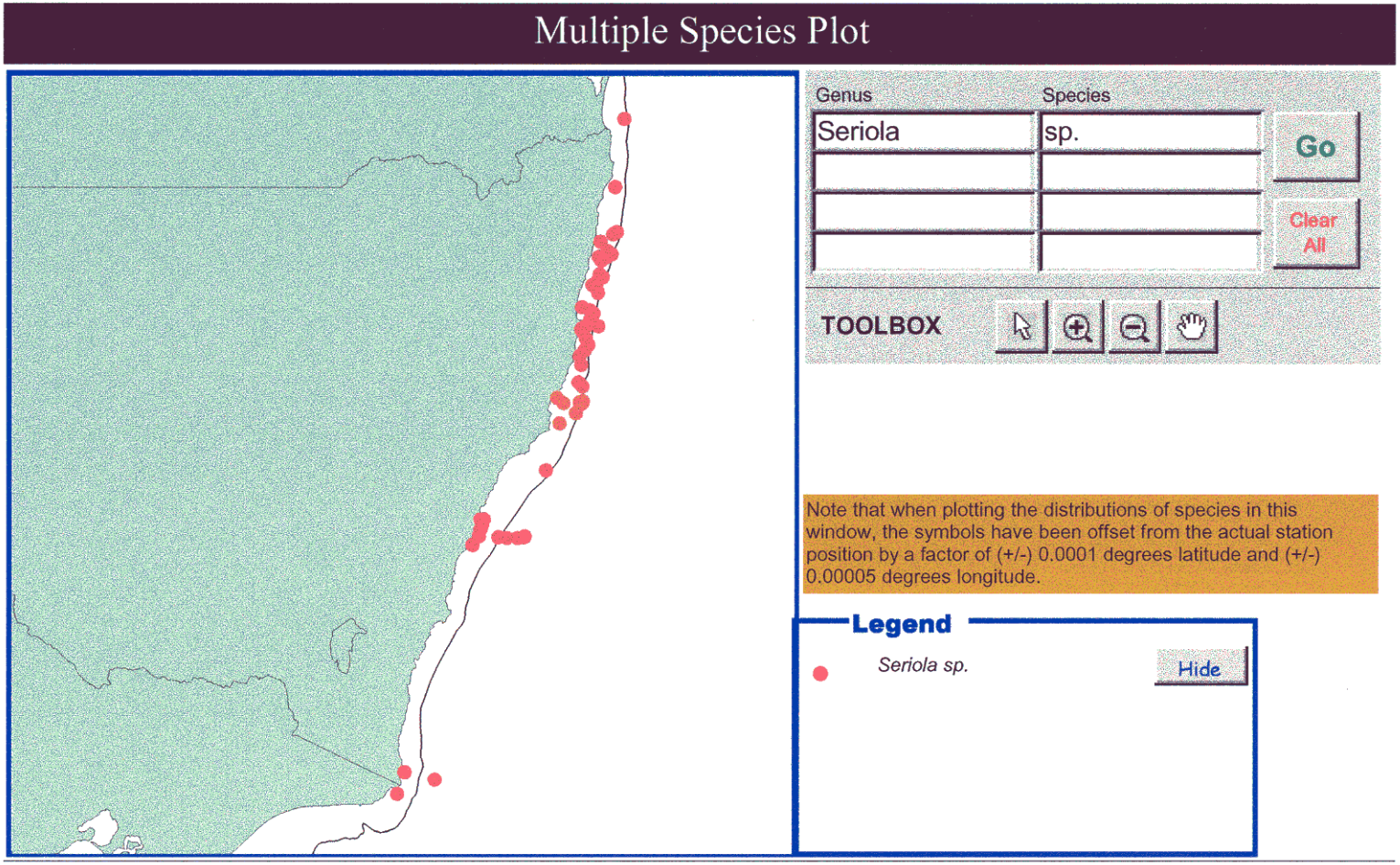
Rudderfish (*Tubbia* sp.)



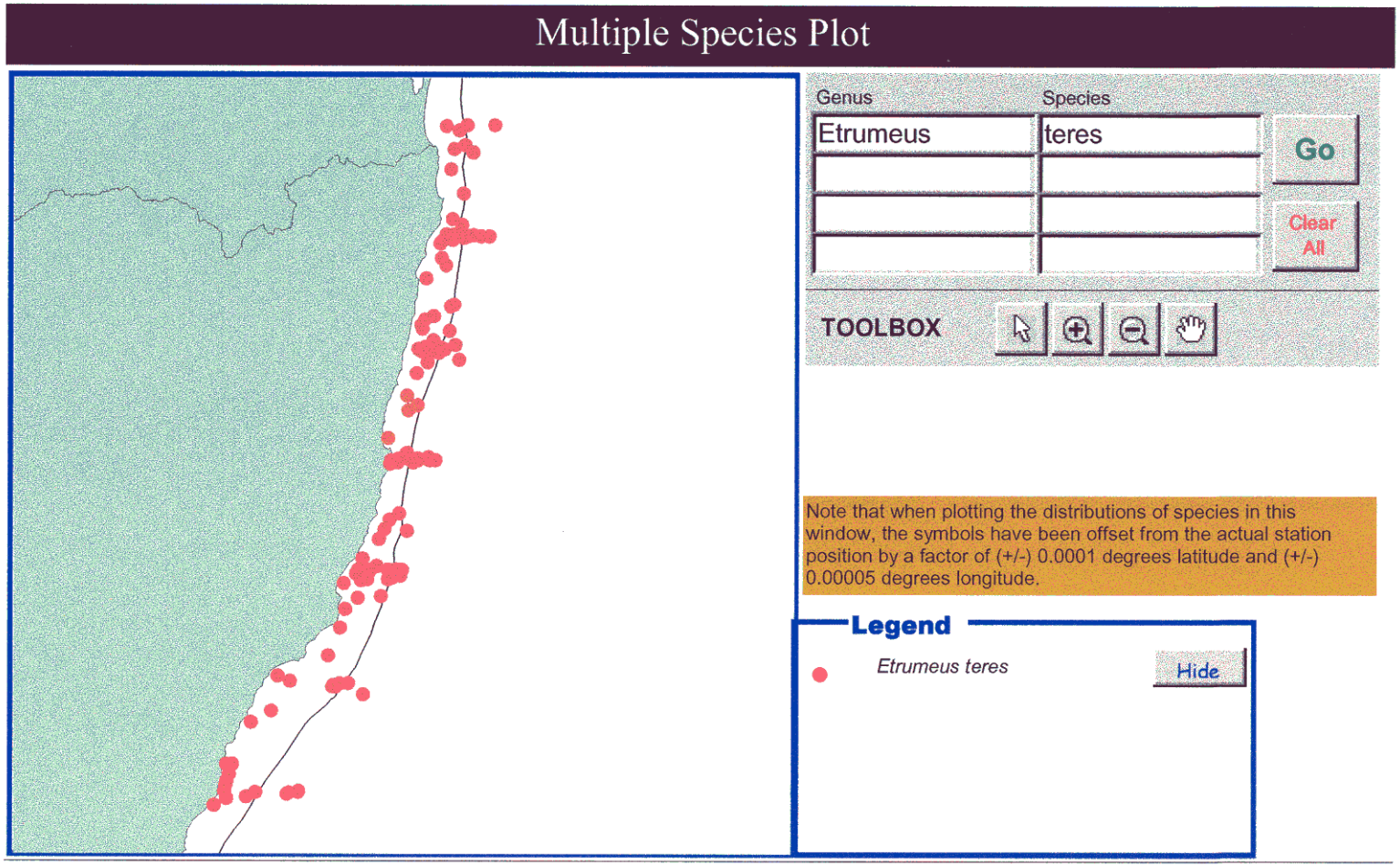
Magpie perch (*Cheilodactylus nigripes*)



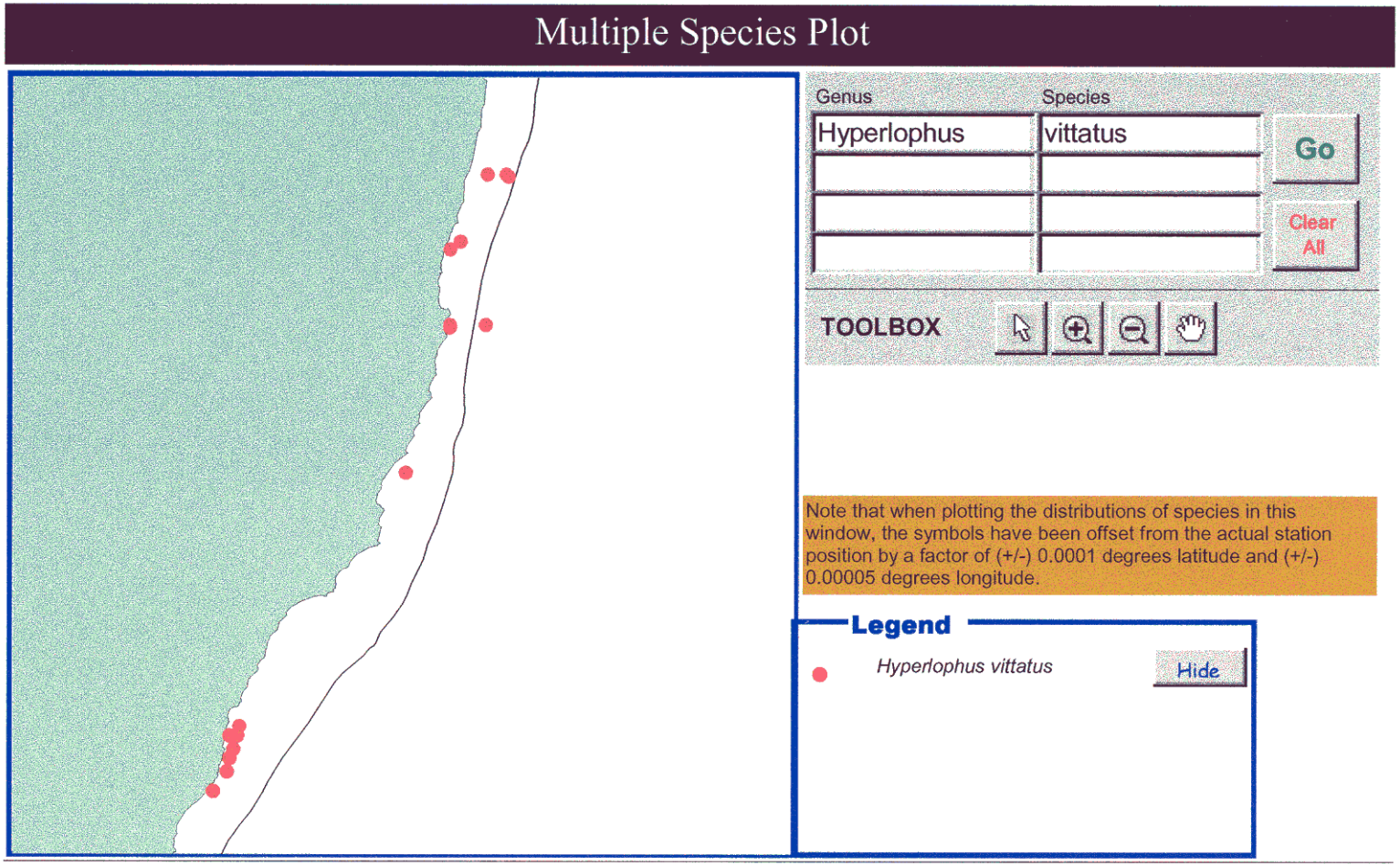
Kingfish/samsonfish (*Seriola* sp.)



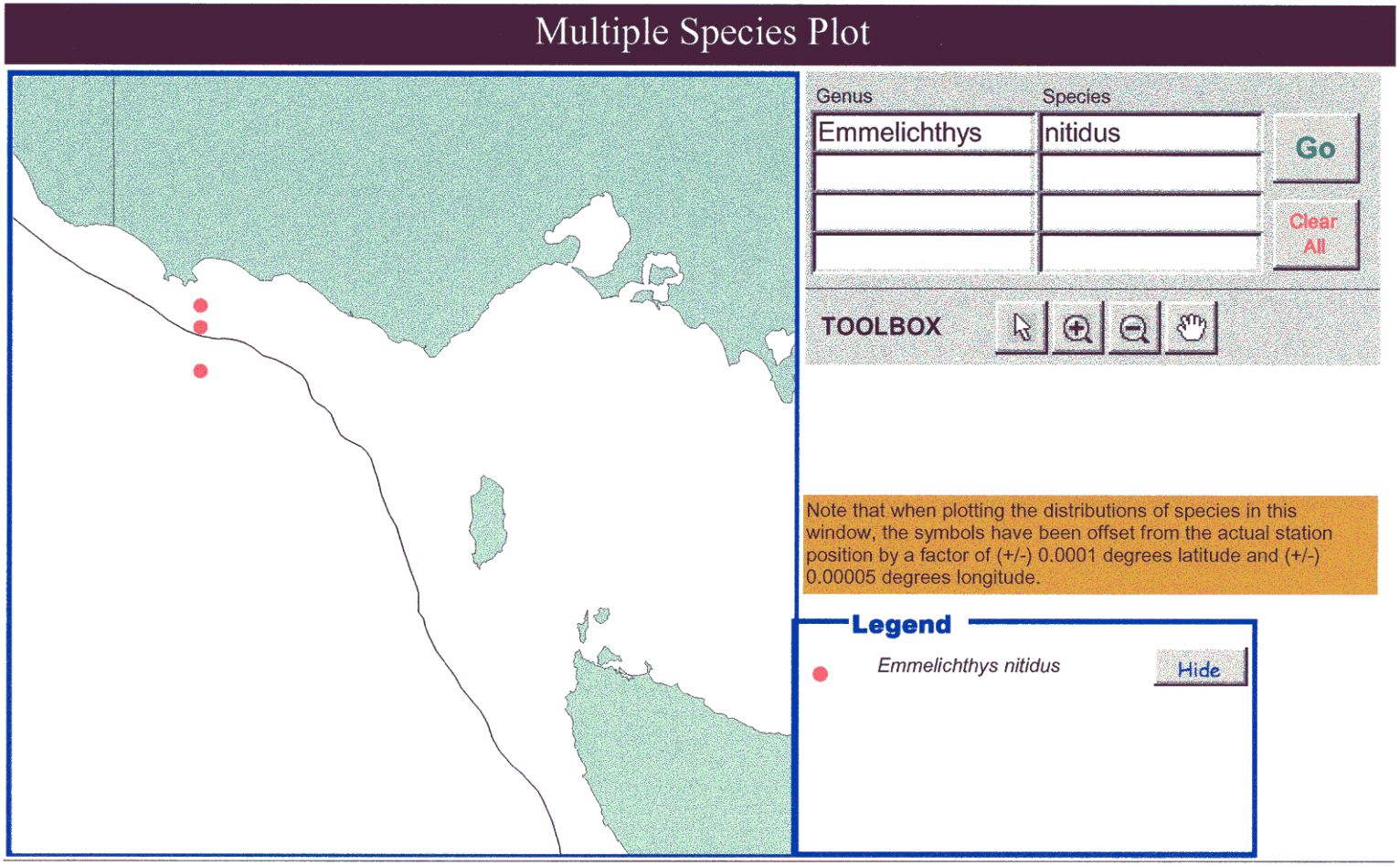
Maray (*Etrumeus teres*)



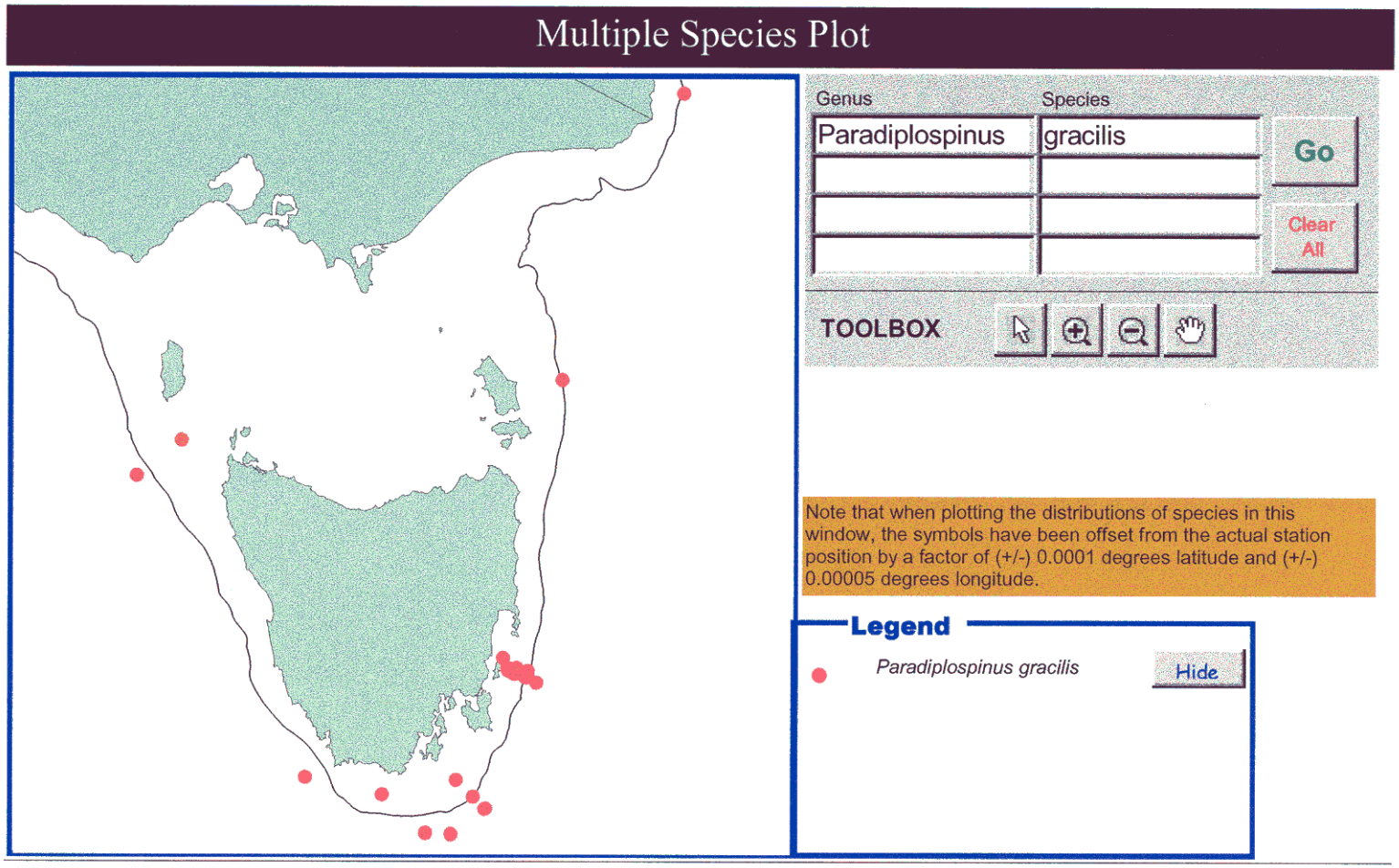
Sandy sprat (*Hyperlophus vittatus*)



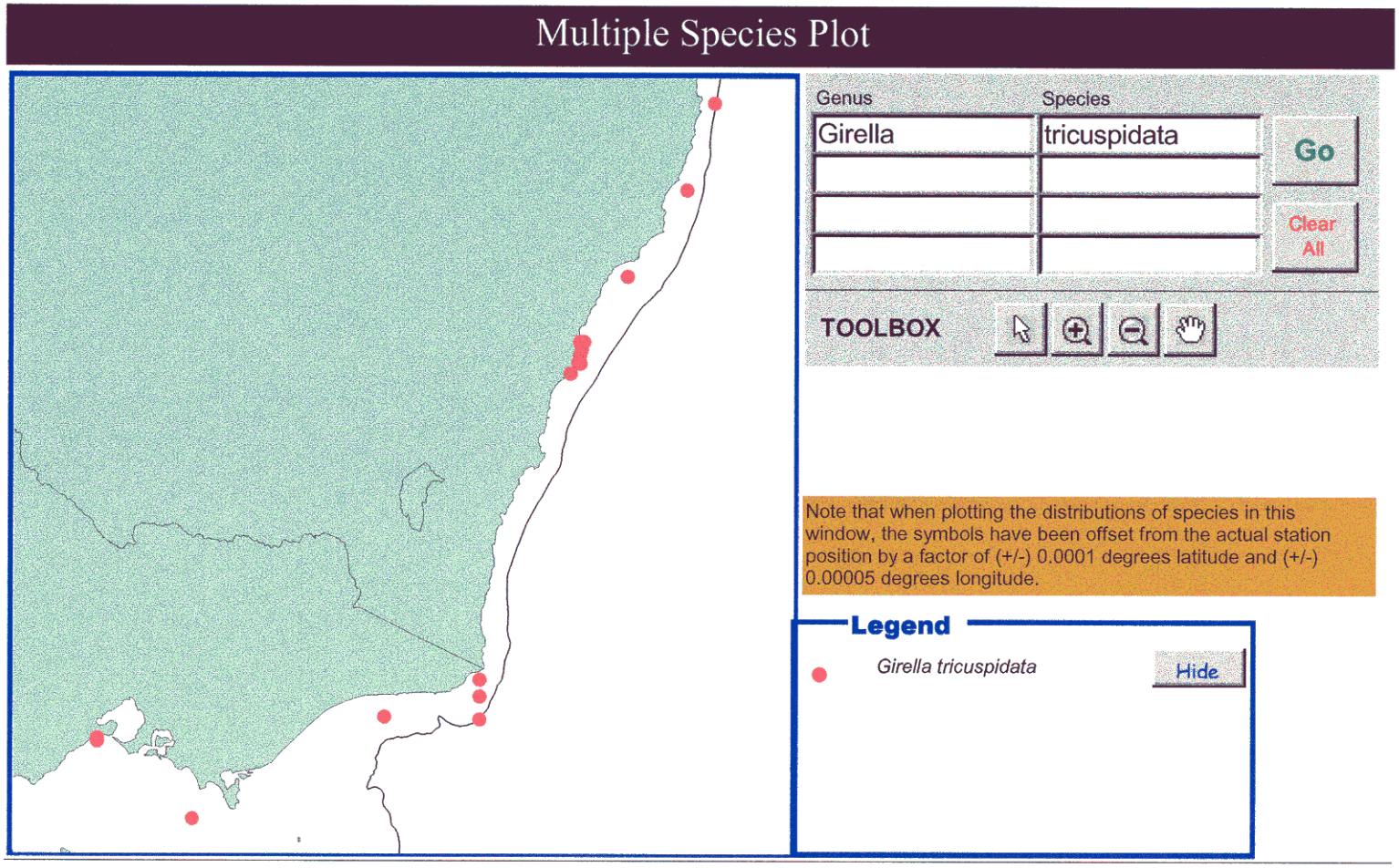
Redbait (*Emmelichthys nitidus*)



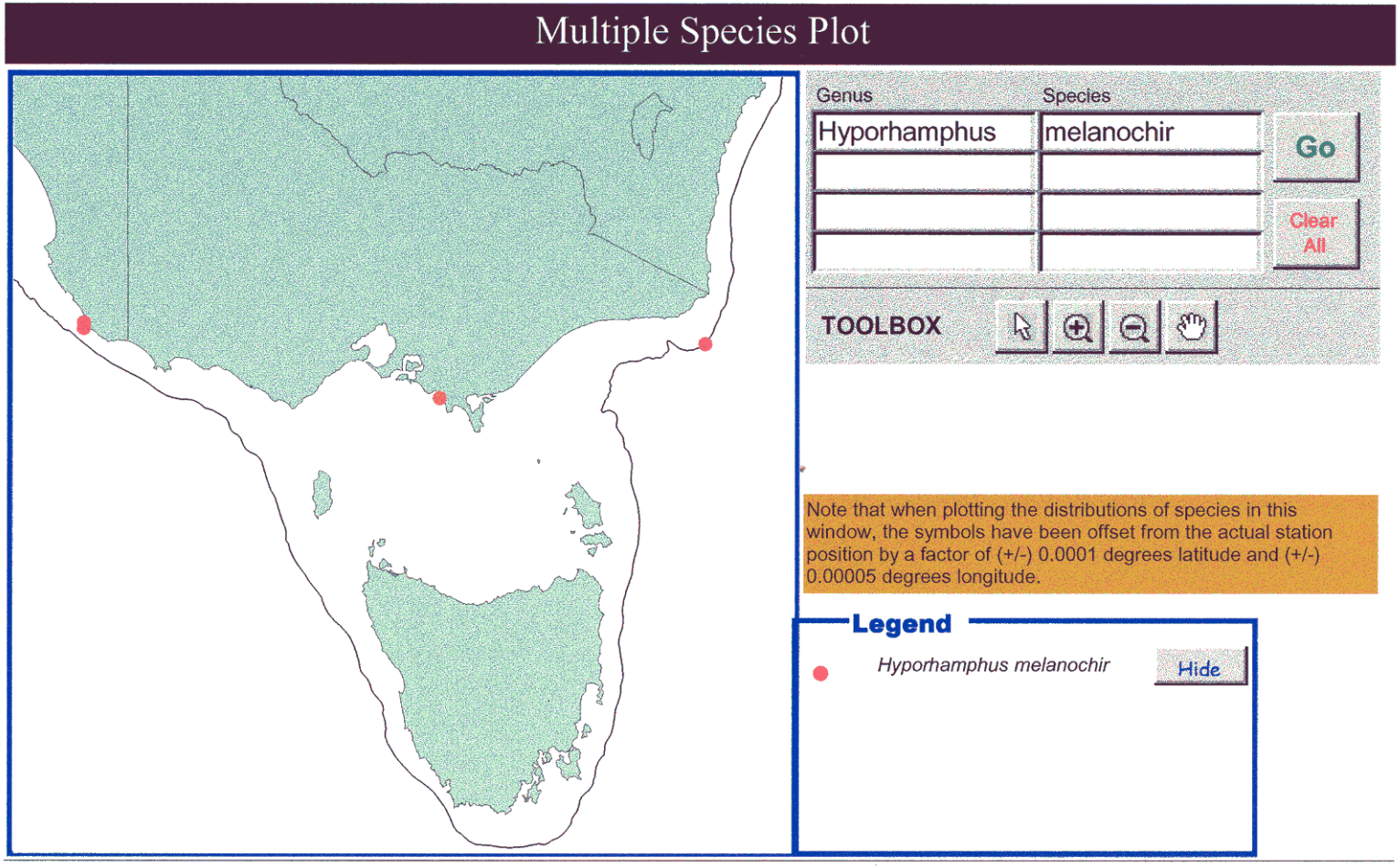
Slender escolar (*Paradiplospinus gracilis*)



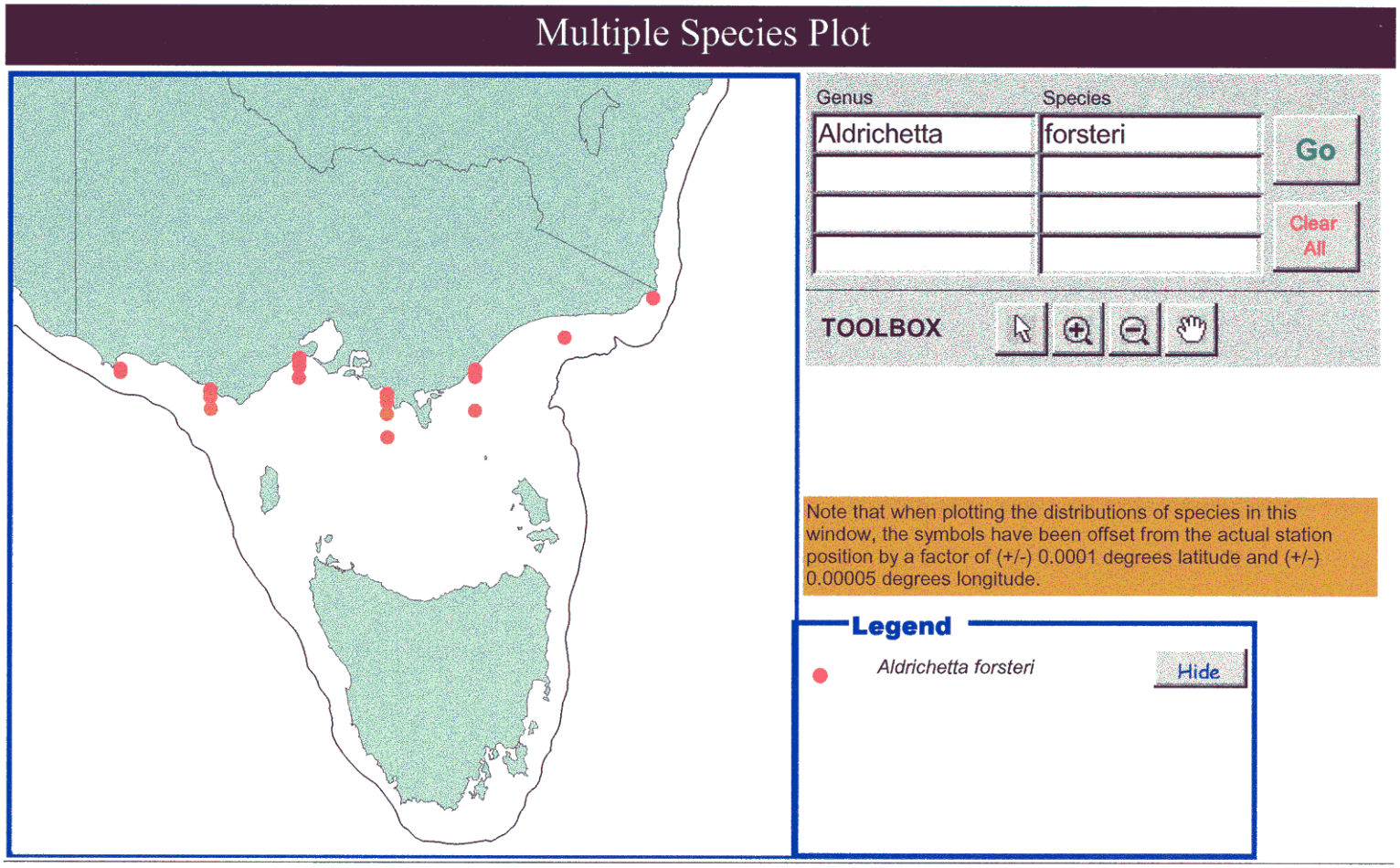
Luderick (*Girella tricuspidata*)



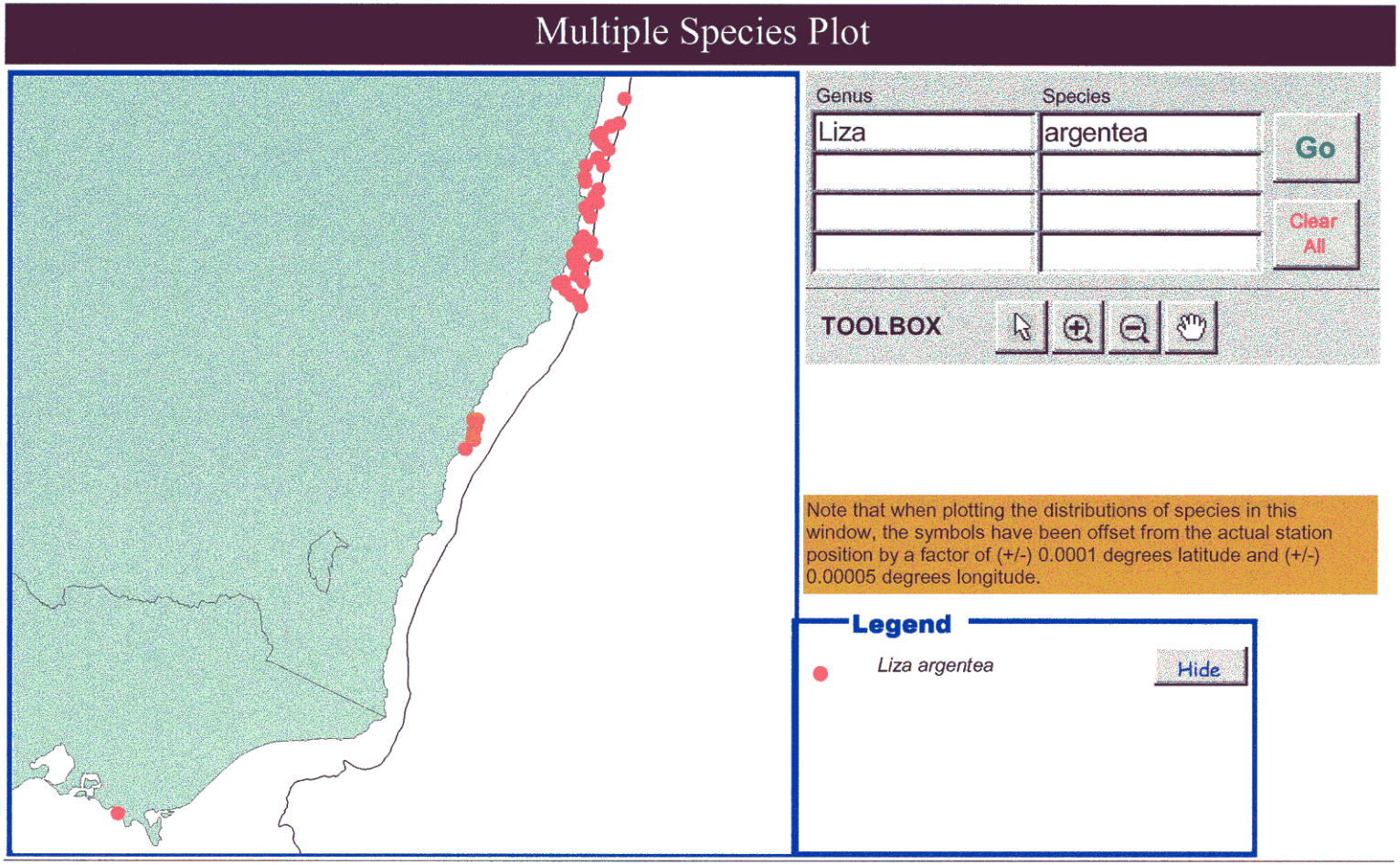
Southern sea garfish (*Hyporhamphus melanochir*)



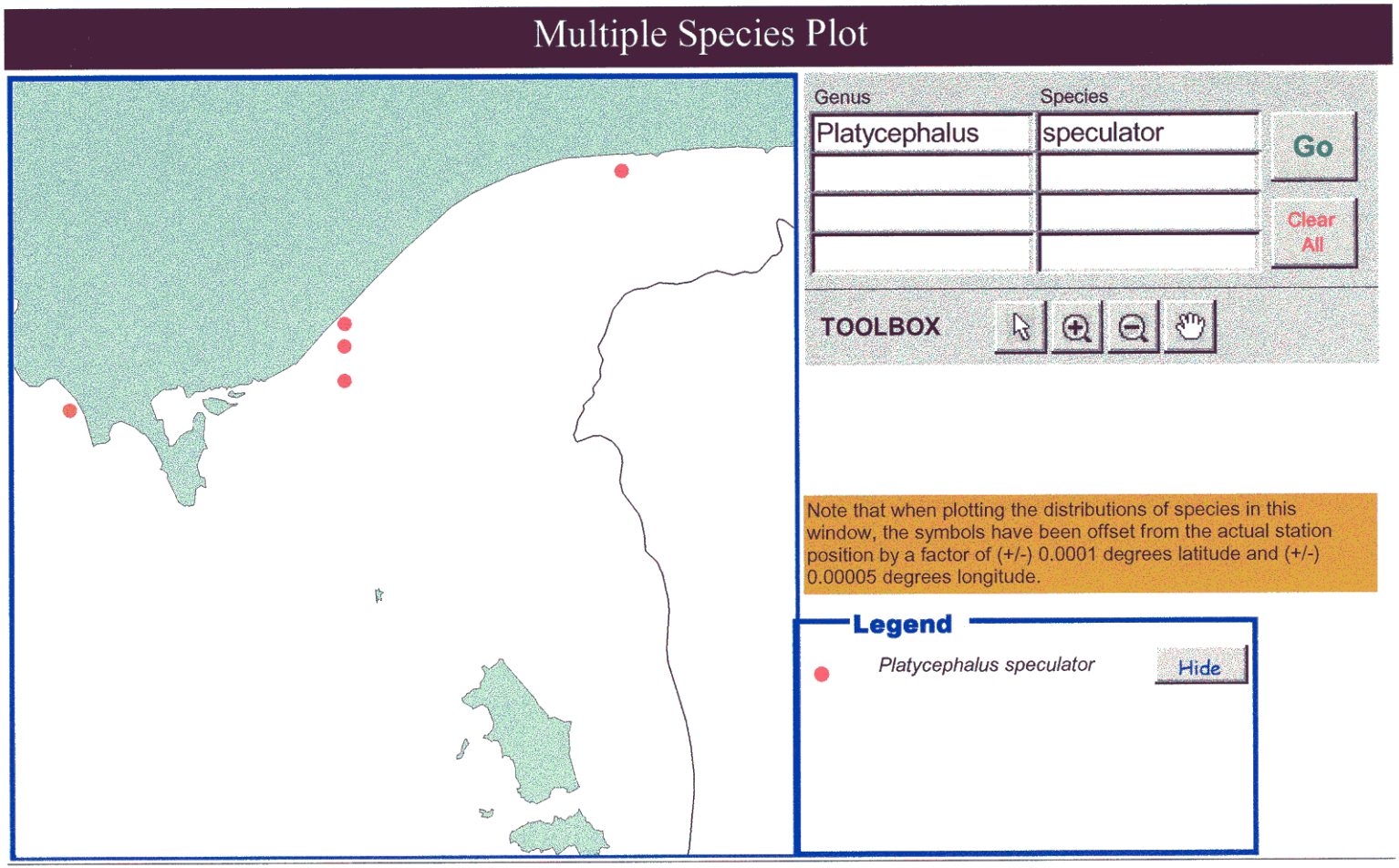
Yelloweye mullet (*Aldrichetta fosteri*)



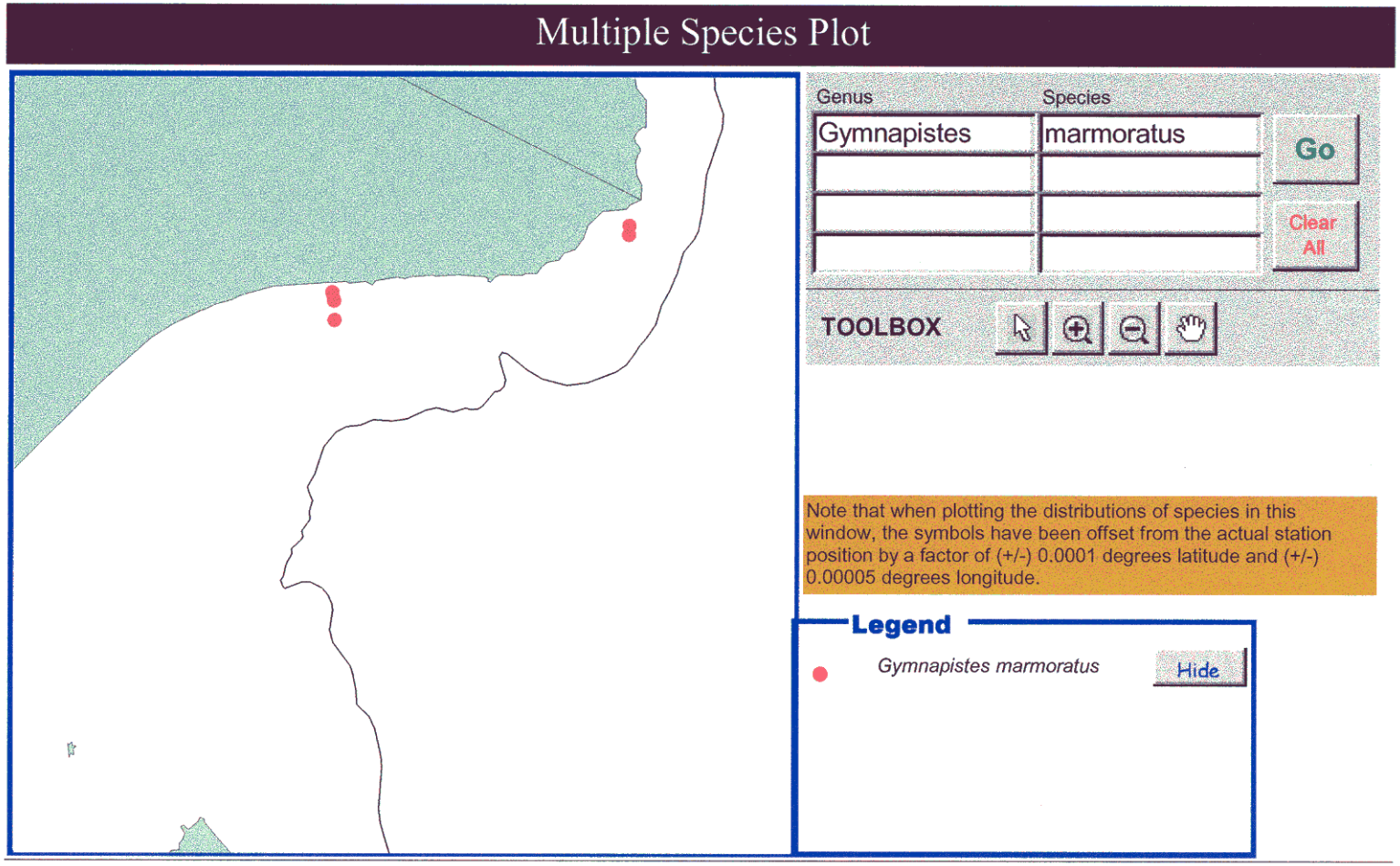
Flat-tail mullet (*Liza argentea*)



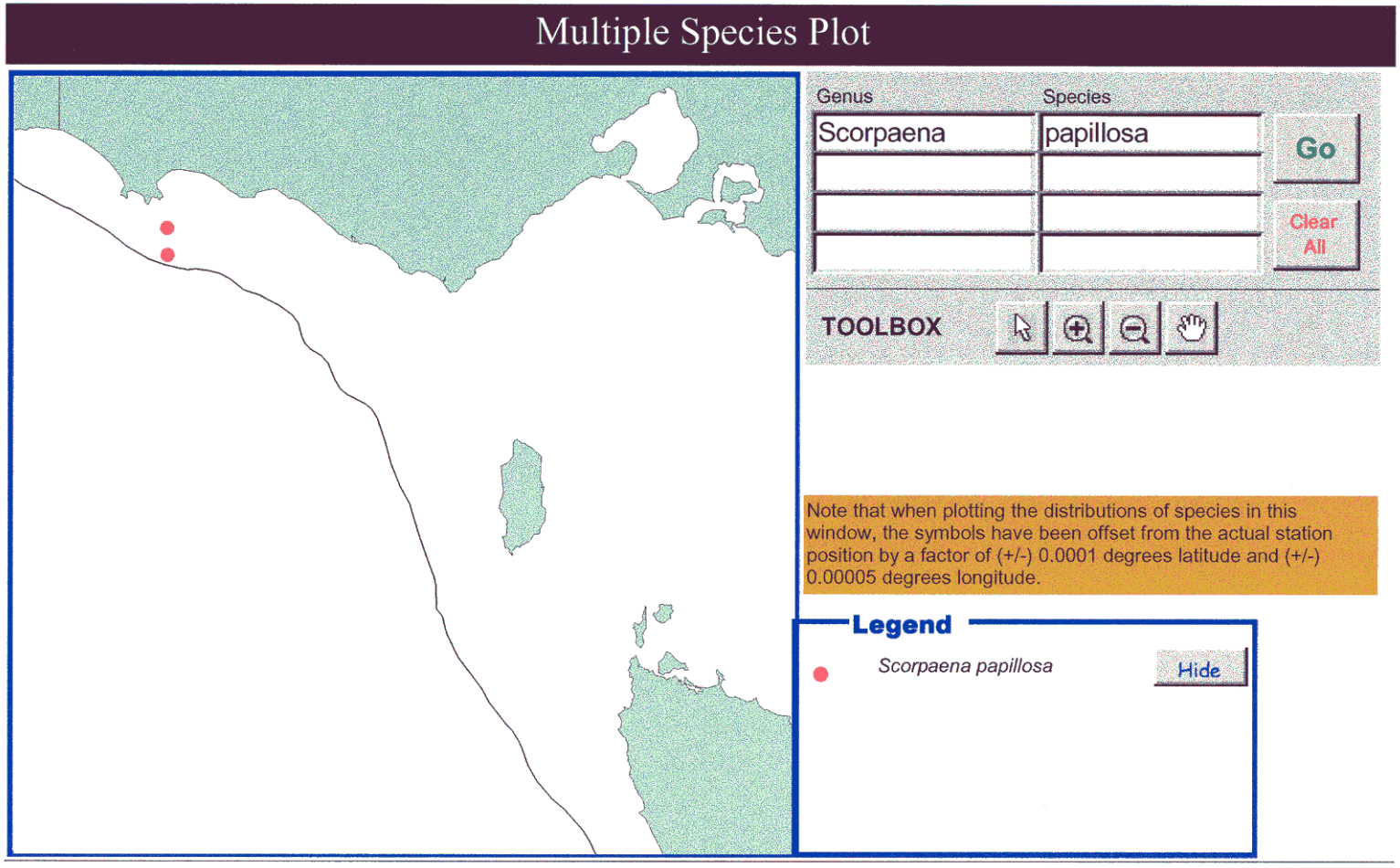
Yank flathead (*Platycephalus speculator*)



Soldierfish (*Gymnapistes marmoratus*)



Red rock cod (*Scorpaena papillosa*)



BENEFITS

The LFD provides a tool to summarise the available information on the early life history of fish in Australian waters and draws together data on 51 species from southeast Australia. Specifically it has drawn together information on several important commercial species in the region.

FURTHER DEVELOPMENT

There have been several recommendations from trial users (listed below) that may be considered for further development of the database.

- Display the stations from a selected cruise and overlay a species' distribution.
- Display species' distribution on a seasonal basis.
- An additional layer displaying the distribution of a species based on published literature.
- The ability to plot distribution and ageing data on a state or regional-basis.
- Incorporate a means of displaying who holds the larval data (e.g. a label feature that displays the cruise and station data as well as data repository when the cursor is situated over a station – SO4/85/24 #CSIRO#).
- Convert all of the MapX components to ESRI's MapObjects (Developers Edition includes ~ 200 runtime licenses allowing greater distribution at a substantially reduced cost).
- Convert the interface to a Visual Basic application (this would allow even greater functionality).
- Convert the database into a web-based document (would possibly result in some slowing down of data retrieval and loss of some functionality – such as the double-click glossary capability).

The most significant issue for the LFD is how best to update it when further details of either existing species or those not yet covered are available.

CONCLUSION

The sampling effort directed at ichthyoplankton in southern Australian waters has produced a significant information base on the early life history of finfish. However, accessing species - specific information has previously been hampered by the scattered nature and varied format of the literature. It has also been hampered by incomplete sample analyses and the lack of a coordinated way to summarise the available data. The Larval Fish Database provides a tool that can house data from ichthyoplankton studies in a single warehouse and give users an

immediate summary of available information on distribution and ecology. It also allows for an assessment of the extent of previous sampling effort in regions of interest and will allow researchers to identify what data is available on target species in specific areas. Data on 51 species are currently held in the database from samples collected over a 17 year period from 1982 – 1999. Current geographic coverage of the data ranges from the great Australian Bight to southern Queensland. This project has highlighted the benefits of archiving samples from projects. The LFD, as it currently stands, provides a significant resource on the early life history of selected Australian finfish. However, such databases only retain their usefulness if they are updated as information becomes available.

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Bruce, B. D., Neira, F. J. and Bradford, R. W. (2001). Larval distribution of blue and spotted warehous (*Seriolella brama* and *Seriolella punctata*: Centrolophidae) in south-east Australia. Marine and Freshwater research 52: 631 – 636.

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.

APPENDIX A: INTELLECTUAL PROPERTY

The intellectual property of this project includes database design. However it is currently provided as a read-only summary of the data it contains.

APPENDIX B: STAFF ENGAGED ON THE PROJECT

Staff	Institution	Role
B. Bruce	CMR	Principal Investigator
R. Bradford	CMR	Database development and data analyses
S. Condie	CMR	Larval transport modelling
J. Mansbridge	CMR	Larval transport modelling
A. Miskiewicz	Wollongong City Council	Larval data
A. Jordan	TAFI	Larval data
F. Neira	AMC	Larval data

APPENDIX C: DATABASE STRUCTURE

Data fields available in the Larval Fish Database.

Unless otherwise noted, all tables have a column containing a unique reference number providing a means of uniquely identifying each record. The layout of the following information is two-tiered such that the table name is flush left and the field names within that table indented.Database linkages are shown in Figure C1.

Table Name and Description
Field Name, Data Type and Description

Books1: Reference details for books or book chapters cited in the Larval Ecology database.

BOK_Publisher	Text	Name of Publisher
BOK_Place	Text	Place of publication
BOK_Title	Text	Title of book or book section
BOK_Editor	Text	Editor(s)
BOK_Volume	Number	Volume or edition
BOK_ISBN	Text	ISBN reference code

Citations1: Used to link specific references to a particular species

TXA_ID	Number	Taxon unique identifier
REF_ID	Number	Link to unique reference identifier
CIT_Desc	Memo	Description of reference type – e.g. book, journal, etc (not used)
CIT_Location	Text	Page numbers of reference (not used)

Codes1: Field names that are used more than once in the design of the database

COD_Type	Text	What area the code will be used in (e.g. TXA for taxonomic tree – Phylum, Subphylum, Class…)
COD_ShortName	Text	Unique 3 to 4 letter code (e.g. PHY, SBP, CLS…)
COD_LongName	Text	Full Name (e.g. Phylum, Subphylum, Class…)
COD_InUse	Yes/No	Indicating if the code is used or not in the current version of the database
COD_Sequence	Number	Order of display if codes are in a list

Collection1: Used for referring to a sample held in a collection.

STX_ID	Number	Sample taxon identifier
SAM_ID	Number	Link to sample table identifier
COL_Type	Number	Type of collection (e.g. external, internal, reference, or voucher)
COL_StorageMedium	Number	Storage medium (e.g. ethanol, formalin)
COL_StorageLocation	Number	Physical location of sample
COL_MuseumRef	Text	Accession number assigned by the relevant museum
COL_CreatedBy	Text	Creation user name
COL_CreatedOn	Date/Time	Creation time stamp
COL_ModifiedBy	Text	Last modified user name
COL_ModifiedOn	Date/Time	Last modified time stamp

EnvironMeasurements: Concurrent environmental parameters collected at the sample station (currently not in use).

RGN_ID	Number	Link to unique station identifier
EMT_ID	Number	Link to type of environmental measurement in 'EnvMeasTypes' table (e.g. salinity, moon phase, dissolved oxygen …)

ENM_MinValue	Number	Minimum value recorded
ENM_MaxValue	Number	Maximum value recorded
ENM_Cycles	Number	The number of measures taken
ENM_Period	Number	Periodicity, as # of cycles, for this measure

EnvMeasTypes: The range of environmental measures possible and the units of measurement.

EMT_ShortName	Text	Abbreviated name (e.g. SAL)
EMT_LongName	Text	Full name for identifier (e.g. Salinity)
EMT_LowerBoundary	Number	Minimum realistic value (used in verification – e.g. 0)
EMT_UpperBoundary	Number	Maximum realistic value (used in verification – e.g. 38)
EMT_Units	Text	Standard units of measurement (e.g. ppt)

Glossary:

GLO_Word	Text	The word to be defined
GLO_Definition	Memo	The definition for the word

Glossary1: Extension of the 'Glossary' table for alternative forms and illustration.

GLO_ID	Number	Link to the word in the 'Glossary' table
GLF_TermType	Text	Type of entry (e.g. plural form, adverb)
GLF_AltForm	Text	The extension used to create the alternative form
GLF_Illustration	OLE Object	Path name to an illustration (.bmp file) that is used to simplify or clarify a definition

Journals1: A list of journal names and their recognised abbreviated form.

JNL_ShortName	Text	Common abbreviated form
JNL_LongName	Text	Full journal name
JNL_Publisher	Text	Journal publisher
JNL_Place	Text	Place of publication

JournArts: An intermediate table linking a journal reference (from 'References1') with a journal name ('Journals1') – the key field for this table is made up from a combination of the unique identifiers for the reference and the journal.

REF_ID	Number	Unique identifier of the reference ('References1')
JNL_ID	Number	Unique identifier of the journal ('Journals1')
JNA_Volume	Number	Volume of the journal containing the specific reference
JNA_Issue	Text	Issue of the journal containing the specific reference

Maps: Not in use in version 1 of the Larval Ecology Database (possible future use for holding reference to published distribution maps – see Future Developments section).

TXA_ID	Number	Link to taxon
MAP_Code	Text	Abbreviated form of map type (e.g. DIST)
MAP_LongName	Text	Type of map (e.g. Species Distribution)
MAP_Path	Text	Path name to a map file

References1: Reference details.

REF_Type	Number	Type of reference (e.g. journal article, book)
REF_Author	Text	Author(s) of article
REF_PubYear	Text	Year of article's publication
REF_Title	Text	Title of the article or book
REF_Location	Text	Page numbers for article
REF_Desc	Memo	Additional information (e.g. In Japanese)
REF_Keywords	Memo	Keywords (used in searching for articles)
REF_Abstract	Memo	Abstract of a journal article
PRCT_ID	Number	Currently not used
PRCT_Type	Number	Currently not used

Regions: List of IMCRA regions (used to position a cruise)

RGN_Code	Text	IMCRA unique 3-letter code (e.g. BAT)

RGN_Number	Number	IMCRA code number (e.g. 53)
RGN_Name	Text	IMCRA-defined region name (e.g. Batemans Shelf)
RGN_State	Text	IMCRA-defined region's state (e.g. NSW)
RGN_Desc	Memo	IMCRA-defined region descriptor (e.g. North of Tuthra to Shell Harbour (34.5833))

Species1: General and specific descriptive information explaining data renditions for each species.

TXA_ID	Number	Unique species identifier
SPC_CommonName	Text	Preferred common name on the basis of the most widely used, descriptive, or taxonomically consistent.
SPC_MinDepth	Number	Currently not in use
SPC_MaxDepth	Number	Currently not in use
SPC_MinTemp	Number	Currently not in use
SPC_MaxTemp	Number	Currently not in use
SPC_MinSalinity	Number	Currently not in use
SPC_MaxSalinity	Number	Currently not in use
SPC_AdJuvDist	Memo	Summary of juvenile and adult distribution based on published accounts
SPC_Spawning	Memo	Summary of spawning information based on both published accounts and additional information in the Larval Ecology database
SPC_StockStructure	Memo	Summary of general stock structure based on published accounts
SPC_OtherTaxa	Memo	List of taxa commonly co-occurring in samples
SPC_AtlasRef	Memo	Reference to a full larval description – default to Larvae of Temperate Australian Fishes where no published description exists
SPC_LarDistribution	Memo	Summary of larval distribution information based on both published accounts and additional information in the Larval Ecology database
SPC_LarDurGrowth	Memo	Summary of larval growth information based on both published accounts and additional information in the Larval Ecology database
SPC_Ageing	Memo	Summary of larval age (derived from otoliths) information based on both published accounts and additional information in the Larval Ecology database
SPC_LarDispersal	Memo	Summary of larval dispersal as illustrated by the model .avi movie clip
SPC_Diagnostics	Memo	Diagnostic features of larvae as in Larvae of Temperate Australian Fishes
SPC_AVI	Text	Path name to .avi file of modelled larval dispersal
SPC_AustSeafood	Memo	Reference to Australian Seafood Handbook: Domestic Species if available
SPC_Extras	Text	Path name to a bitmap image of regional comparison in otolith age data – if available
SPC_Ecology	Memo	Currently not in use
SPC_AtlasPages	Text	Page numbers for the relevant section of Larvae of Temperate Australian Fishes

SpeciesLfStageMeristics: Details of the path names for illustrations of larval developmental stages.

TXA_ID	Number	Unique species identifier
SPL_Stage	Number	A significant stage in the species' development (e.g. preflexion, flexion)
SPM_ImagePath	Text	Path name to bitmap image of developmental stage
SPM_ImageAuthor	Text	Name of illustator

SPM_ImageBL	Number	Body length of the illustrated larva

SpeciesSynonyms1: A listing for synonyms. Currently not in use

TXA_ID	Number	Unique identifier of the accepted taxonomic name (from Taxa1)
ALT_Synonym	Text	Alternative species name
ALT_Author	Text	Name of author to describe this synonym
ALT_Date	Text	Year in which the synonym was described

T_Abundance: Contains raw and standardised abundance for larval species at each station

TXA_ID	Number	Link to taxon table (Taxa1)
SAM_ID	Number	Link to sample table (T-Samples)
STX_TaxaGroup	Number	Species parent group
TXA_cf	Yes/No	Validated species identification
ABN_Abundance	Number	Total species abundance
ABN_StdAbund	Number	Standardised total abundance (# per 1000m^3)
ABN_Preflexion	Number	Total preflexion stage abundance
ABN_StdPRF	Number	Standardised total preflexion stage abundance
ABN_Flexion	Number	Total flexion stage abundance
ABN_StdFLX	Number	Standardised total flexion stage abundance
ABN_Postflexion	Number	Total postflexion stage abundance
ABN_StdPFLX	Number	Standardised total postflexion stage abundance

T_Cruise: Cruise metadata

CRS_ID	Auto	Unique cruise identifier
CRS_Vessel	Text	Vessel name (e.g. FRV Southern Surveyor)
CRS_Code	Text	Recognised unique cruise code (e.g. SS03/97)
CRS_Leader	Text	Cruise leader(s) or contact person(s)
CRS_StartDate	Date/Time	Cruise start time stamp
CRS_EndDate	Date/Time	Cruise end date time stamp

T_Meristics: Meristic data for larval samples

STX_ID	Auto	Unique sample identifier
SAM_ID	Number	Link to sample table (T_Samples)
STX_TaxaGroup	Number	Best level of identification to closest taxonomic group
STX_cf	Yes/No	'Yes' if there is some uncertainty in the classification
STX_TaxaSp	Number	Species identification
OTO_ID	Number	Otolith identifier, if removed from organism
STX_Stage	Number	Developmental stage (e.g. preflexion)
STX_Age	Number	Age (in days) of organism as derived from otolith increment counts
STX_Length	Number	Body length of organism (in mm)
STX_DorsalFSC	Text	Dorsal fin spine count
STX_DorsalFRC	Text	Dorsal fin ray count
STX_AnalFSC	Text	Anal fin spine count
STX_AnalFRC	Text	Anal fin ray count
STX_CaudalFRC	Number	Caudal fin ray count
STX_P1SC	Number	Pectoral fin spine count
STX_P1RC	Number	Pectoral fin ray count
STX_P2SC	Number	Pelvic fin spine count
STX_P2RC	Number	Pelvic fin ray count
STX_MyomerC	Number	Number of myomers (muscle bands)

T_Samples: Sample metadata

STN_ID	Number	Link to station table (T_Stations)
SAM_ID	Auto	Unique sample identifier
SAM_NetType	Text	Type of net used for this sample (e.g. surface net, bongo net)

SAM_Depth	Text	Depth at which the sample was taken (e.g. surface, oblique, 40m, 100m)
SAM_Volume	Number	Volume filtered (in $1000m^3$)
SAM_NetNumber	Text	Net number (e.g. rep1, rep2, A, B, Port, Stbd)

T_Stations: Station metadata

CRS_ID	Number	Link to cruise table (T_Cruise)
STN_ID	Auto	Unique station identifier
STN_Number	Number	Station number
STN_Timestamp	Date/Time	Begin station occupation time stamp
STN_Latitude	Number	Station start latitude
STN_Longitude	Number	Station start longitude
STN_Region	Number	IMCRA region within which the station is located
STN_SurfTemp	Number	Surface water temperature
STN_SurfSal	Number	Surface salinity
STN_MoonPhase	Text	Moon phase (e.g. full, half)

T_StomContents: Summary of major groups found in gut samples of larval fish. Currently not in use

TXA_ID	Number	Link to taxon table (Taxa1)
STM_ID	Auto	Unique stomach sample identifier
STX_Stage	Number	Developmental stage of the larva (e.g. preflexion)
STM_Cladocera	Number	Percentage of cladocerans in gut
STM_Harpacticoida	Number	Percentage of harpacticoids in gut
STM_Cyclopoida	Number	Percentage of cyclopoids in gut
STM_Calanoida	Number	Percentage of calanoids in gut
STM_Caridea	Number	Percentage of carideans in gut
STM_Euphausiacea	Number	Percentage of euphausids in gut
STM_Decapoda	Number	Percentage of decapods in gut
STM_Bivalvia	Number	Percentage of bivalves in gut
STM_Unidentified	Number	Percentage of unidentifiable remains in gut

Taxa1: Taxonomic metadata

TXA_ID	Auto	Unique taxon identifier
TXA_Level	Number	Taxonomic classification level, from Codes table (e.g. Phylum, subphylum)
TXA_Name	Text	Name of taxon
TXA_Parent	Number	Identifier of the parent taxon
TXA_Author	Text	Taxon author and year
TXA_CAAB	Text	CSIRO CAAB code (Codes for Aquatic Biota)
TXA_Validated	Yes/No	'Yes' if verified
TXA_ValidatedBy	Text	Validation username
TXA_ValidatedOn	Date/Time	Validation time stamp
TXA_CreatedBy	Text	Creation username
TXA_CreatedOn	Date/Time	Creation time stamp
TXA_ModifiedBy	Text	Last modified username
TXA_ModifiedOn	Date/Time	Last modified time stamp

TaxonLinks1: Intermediate table to house links between parent and sibling entries in Taxa1 table

PathLength	Number	Number of nodes
Start	Number	Upper level (e.g. Macruronus)
End	Number	Lower level (e.g. novaezelandiae)

T-Coverage: List of species for which there is a sufficient amount of data in the database

CVG_ID	Auto	Unique identifier
CVG_Genus	Text	Genus name
CVG_Species	Text	Species name
CVG_Completion	Text	Extent of information available in the database
CVG_Notes	Memo	Explanatory notes

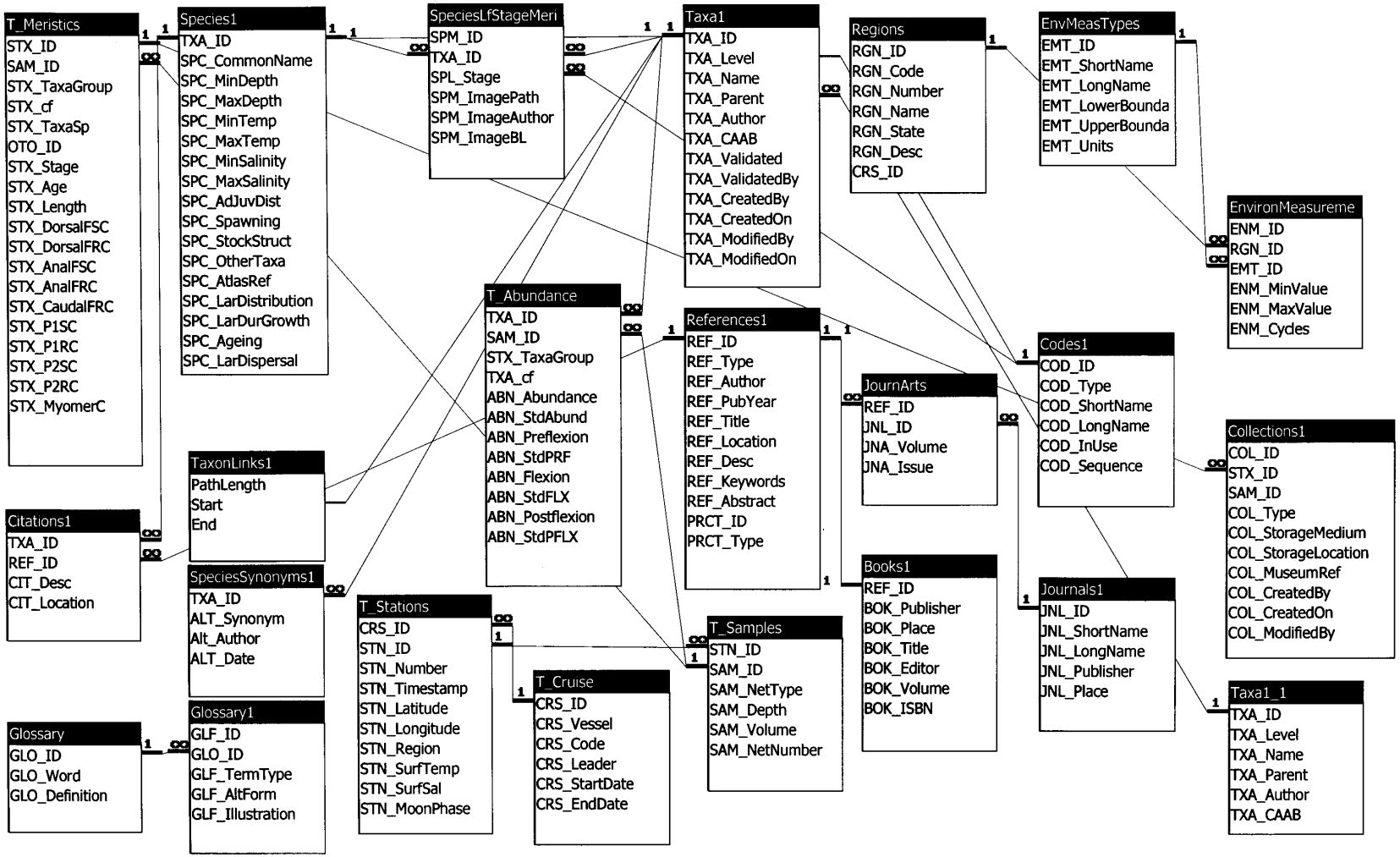


Figure C1: Database relationships

APPENDIX D: DETAILS OF DISPERSAL MODEL AND LARVAL TRAJECTORY ANIMATIONS

(by S. Condie and J. Mansbridge)

Ocean circulation

Circulation of waters for the dispersal sections given in the species accounts was simulated using the three-dimensional non-linear hydrodynamic model referred to as MECO (Model of Estuaries and Coastal Oceans). This model has previously been applied to a range of estuarine and shelf systems, the most thoroughly documented being Port Philip Bay in Victoria (Walker 1996, Walker 1999). It has also been used specifically for larval advection studies in the Gulf of Carpentaria (Condie *et al*. 1998) and southeast Australia (Bruce *et al.* 2001a).

Numerical solutions were computed on a latitude-longitude grid, which had been rotated through a false pole to cover a region from Albany in the west, across the Great Australian Bight and Tasmania, to a few hundred kilometres east of the coast at the Victoria/New South Wales border. There were 136 by 47 grid cells in the horizontal and 37 in the vertical. The horizontal resolution was approximately 20 km, while the vertical resolution expanded from 3 m near the surface to 200 m at the maximum model depth of 2000 m (interfaces at depths of 0, 3, 6, 9, 12, 15, 18, 22, 27, 33, 40, 48, 57, 67, 78, 90, 102, 116, 132, 150, 170, 195, 225, 260, 300, 350, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800 and 2000 m).

Since larvae are advected for periods much longer than a tidal cycle, high frequency tidal motions were neglected. Model forcing was provided by seasonal climatologies of wind, sea level, temperature and salinity with the focus on sub-inertial motions. The use of climatologies rather than data from a specific time–period, provides the subsurface temperature and salinity fields needed for open boundary forcing and interior data assimilation. The output of such a model provides “typical” seasonal flow patterns, while effectively removing any influences associated with interannual variability. Thus model runs represent a “typical” year rather than the variation associated with an individual year.

Climatological winds were computed by vector averaging winds from the National Center for Environmental Prediction (NCEP) reanalysis data set (Kalnay *et al.* 1996) over the 12 years from 1976 to 1997. This process gave 12 months of six hourly climatological fields with a spatial resolution of approximately 200 km. Sea level, temperature and salinity fields were taken directly from the CSIRO Atlas of Regional Seas (CARS) seasonal climatology, which resolves the annual and semiannual harmonics on a 0.5 degree geographical grid (Dunn and Ridgway 2002, Ridgway and Dunn 2002). The flow was forced by climatological winds over the surface, while sea level, temperature and salinity were specified at the open boundaries. Within the interior, sea level, temperature and salinity climatologies were assimilated through relaxation of the model values toward the climatological values. The relaxation time was set at 20 days for each field. The climatological fields were also used to initialize the model, which was first run for 20 days to allow transient effects associated with the initialization to dissipate.

Larval advection

Larvae were represented in the model by neutrally buoyant particles, which were advected by the circulation while also being dispersed through a random walk process. The model domain was seeded with 500,000 particles whose positions and depths were randomly chosen and the model was run over an annual cycle. Each particle was tracked individually so that movements could be traced.

Trajectory plots – predicted spawning locations and recruitment envelops

The capture date and location of larvae, for which ages were available, were used to build larval trajectory profiles for each species. Species–specific larval trajectory plots were generated from the model by initially determining the position of all modelled particles in the upper 100 m of the water column on the date that each individual larva was caught (e.g. 13 August). The ten model particles nearest the position of the captured larva were then identified. All ten particles were required to be within 0.1 degrees of the capture location. Provided this requirement was satisfied, the trajectories of these ten particles were then traced back in time to the spawning date inferred by the estimated age of the captured larva. All of the trajectories associated with captures of larvae of a particular species were combined and are displayed to estimate both there source (potential spawning locations) and the geographic range over which they were likely to be advected during their larval period (recruitment envelop). The spread of predicted source locations reflect not only the potential extent of spawning grounds, but also uncertainties associated with the sensitivity of trajectories to the initial particle position. Additional errors may be associated with factors such as interannual variability in circulation and larval behaviour. The trajectory modelling thus encompasses a range of predicted source locations and advection endpoints of larvae given their capture location and age.

Larval duration

Larval duration is still poorly documented in most species and is likely to be variable. For the purpose of the modeling exercise we selected a default value of 60 days for all taxa except jackass morwong. Sixty days was selected because it was either close to, or exceeded the maximum recorded pre-settlement age of larvae based on otolith microstructure. In the case of jackass morwong, existing data suggest a pelagic early life history of up to 9 – 10 months (Bruce *et al*. 2001b, Jordan 2001) and for this reason, 270 days was selected for the model period.

References

Bruce, B.D., Sutton, C.A. and Condie, S.A. (2001). Larval distribution of blue grenadier (*Macruronus novaezelandiae*) in south eastern Australia: Further evidence for a second spawning area. Marine and Freshwater Research 52: 603-610.

Bruce, B. D., Young, J. W. Evans, K.; Sutton, C. A. and Furlani, D. M. (2001). The influence of mesoscale physical oceanographic processes on larval distribution and stock structure in jackass morwong (*Nemadactylus macropterus*). ICES J. Mar. Sci. 58: 1072-1080.

Dunn J.R., and K.R. Ridgway (2002). Mapping ocean properties in regions of complex topography. *Deep-Sea Res*. I, 49, 591-604.

Jordan, A. R. (2001). Spatial and temporal variations in abundance and distribution of juvenile and adult jackass morwong, *Nemadactylus macropterus*, in south-eastern Tasmania. Marine and Freshwater Research 52: 661 – 670.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., *et al.* (1996). The NCEP/NCAR 40 – year reanalysis project. Bulletin of the American Meteorological Society 77: 437 – 471.

Ridgway K.R. and J.R. Dunn (2002). Ocean interpolation by four-dimensional weighted least-squares - application to the waters around Australia. J. Atm. and Ocean. Tech., 19, 1357-1375.

Walker, S. J. (1996). Hydrodynamic models of Port Phillip Bay. Technical Report No. 38, CSIRO Port Phillip Bay Environmental Study, Melbourne, Australia.

Walker, S. J. (1999). Coupled hydrodynamic and transport models of Port Phillip Bay, a semi-closed bay in south-eastern Australia. Marine and Freshwater Research 50: 469 – 481.

APPENDIX E: CRUISES COVERED WITHIN THE DATABASE

This appendix provides summary details of the cruises from which data has been collated for the LFD.

Cruise details identify the vessel used for sampling, the institution responsible for the original sampling, a contact person for the data (where available), the area of coverage given by cruise bounds (see below) and a reference to the methodologies used in sampling where available.

The cruise bounds are defined by a rectangle around the area covered by each cruise in the database. The northwest corner of the rectangle is defined by the minimum latitude (S) – minimum longitude (E) of all stations positions within the cruise; the northeast corner, by the minimum latitude (S) – maximum longitude (E); the southeast corner by the maximum latitude (S) – maximum longitude (E) and the southwest cornet by the maximum latitude (S) minimum longitude (E).

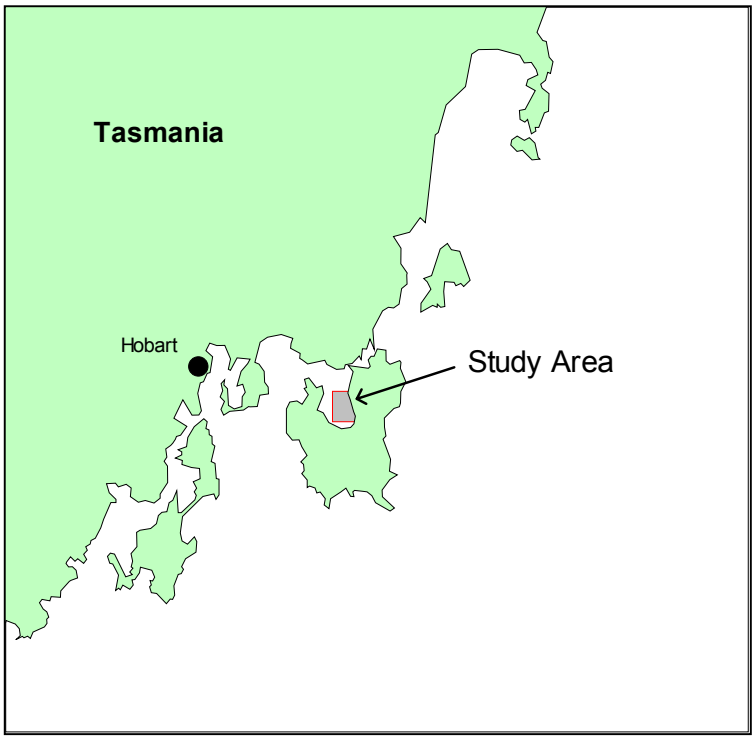
Cruise Details

Vessel: TAFI Sharkcat

Contact: A. Jordan (TAFI)

Cruise Code	**Month**
AJ7/96	November

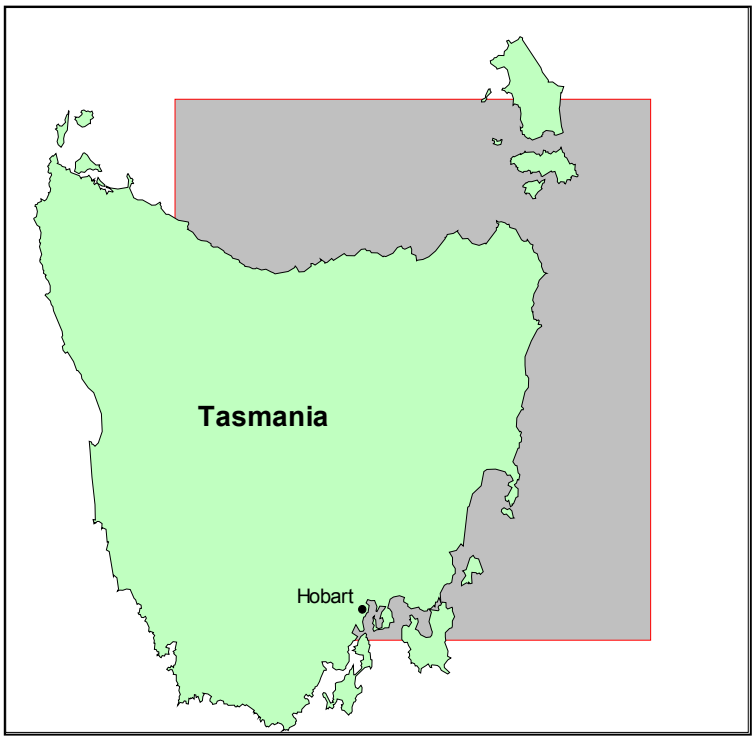
Methods: Jordan (2001)



Vessel: Challenger

Contact: A. Jordan (TAFI)

Cruise Code	Month
CH179	December
CH190	January
CH193	February/March
CH197	April
CH198	April
CH215	November
CH217	December
CH218	January
CH219	January
CH221	February
CH222	February
CH224	March
CH225	March
CH226	April
CH247	December
CH248	January
CH249	January
CH250	January
CH252	February
CH253	February
CH254	March
CH256	April
CH258	May



Methods: Jordan *et al*. (1995)

Vessel: Dell Richie

Contact: M. Lewis (CSIRO)

Cruise Code	Month
DR1/95	June
DR2/95	July
DR3/95	August

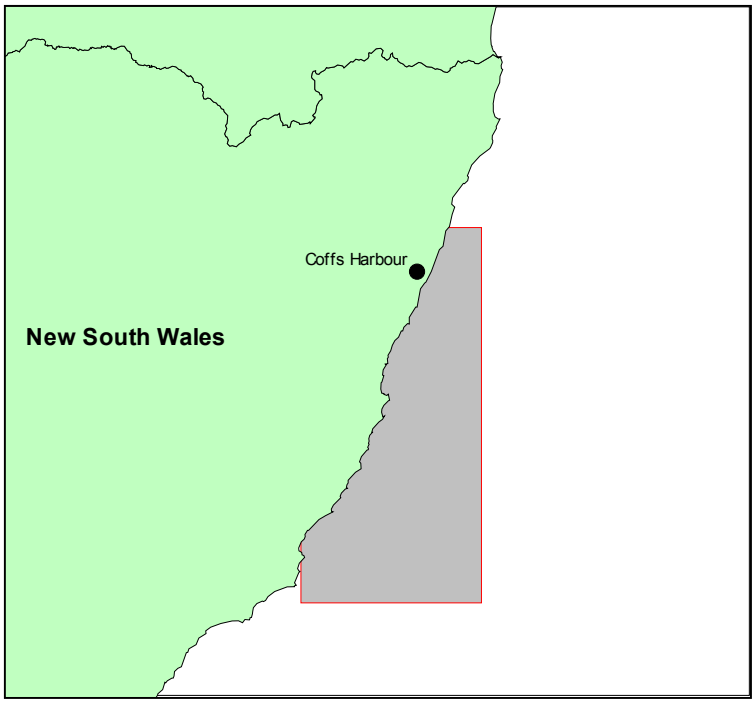
Methods: Bulman *et al*. 1999

Vessel: Franklin

Contact: A. Misckiewicz

Cruise Code	Month
FR6/89	May

Methods: Miskiewicz *et al*. (1996)



Vessel: Franklin

Contact: F. Neira (AMC)

Cruise Code	Month
FR2/97	January
FR11/97	December
FR7/98	May/June
FR9/98	July

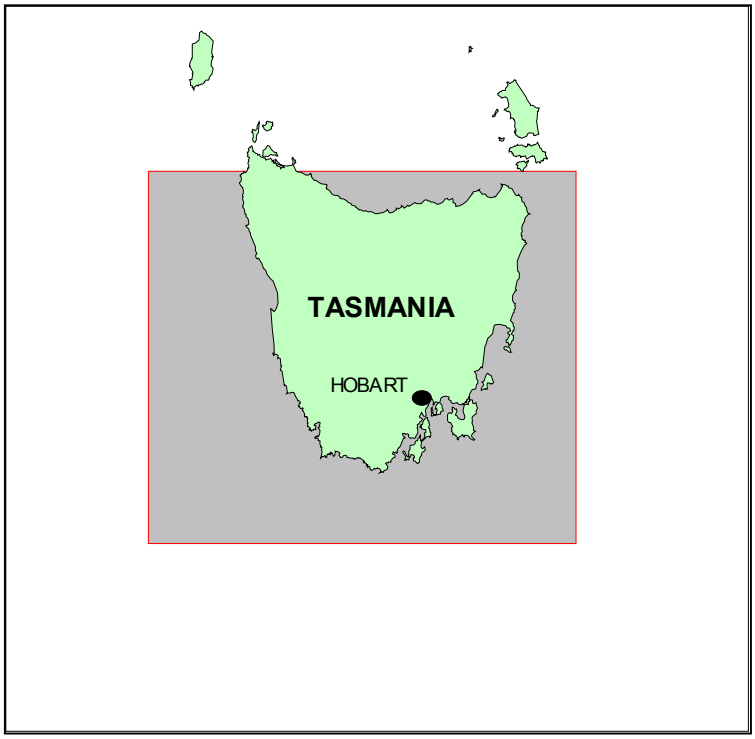
Methods: Neira *et al*. (2000)

Vessel: Franklin

Contact: G. Cresswell (CSIRO)

Cruise Code	**Month**
FR3/97	March

Methods: Bruce *et al*. (2000)

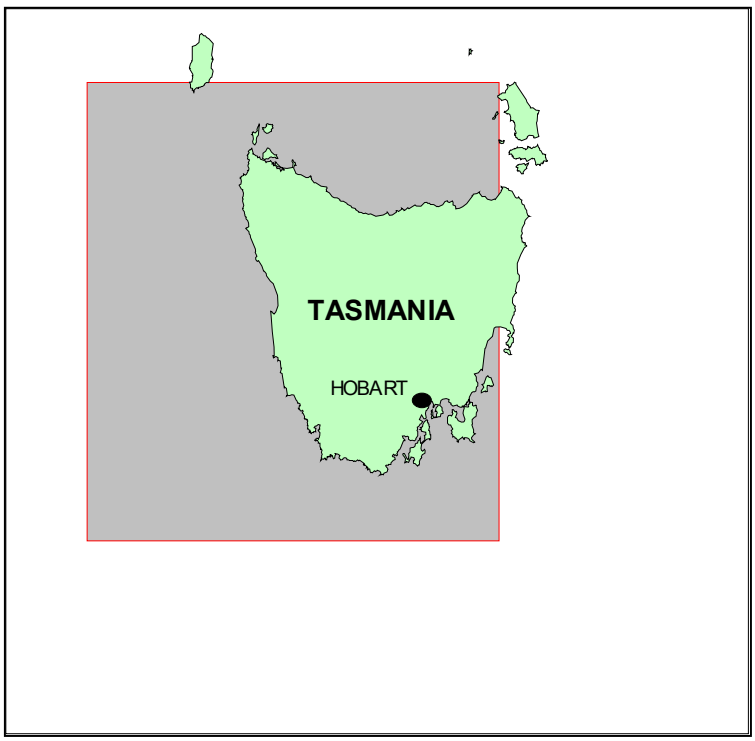


Vessel: Franklin

Contact: G. Cresswell (CSIRO)

Cruise Code	**Month**
FR10/97	December

Methods: Bruce *et al*. (2000)

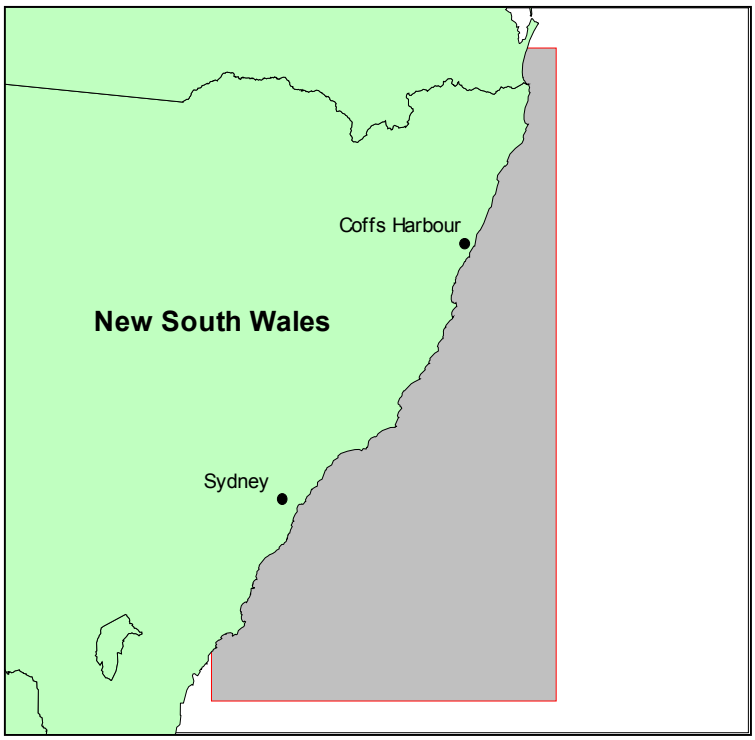


Vessel: Kamala

Contact: A. Miskiewicz

Cruise Code	Month
KM17/86	July
KM18/86	July
KM19/86	August
KM20/86	August
KM21/86	August
KM22/86	September

Methods: Miskiewicz at al (1987)

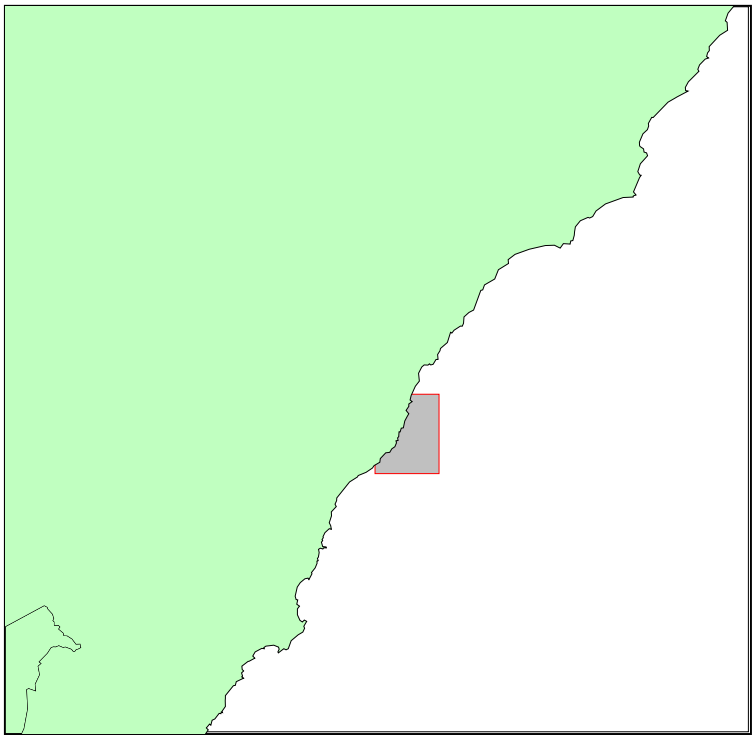


Vessel: Kamala

Contact: A. Miskiewicz

Cruise Code	Month
KM1/89	December
KM2/90	April/May
KM3/90	August/September
KM4/90	November
KM5/90	November
KM6/91	April/May
KM7/91	July
KM8/91	October
KM9/92	January/February
KM10/92	April/May
KM11/92	July
KM12/92	September
KM13/92	December
KM14/93	February

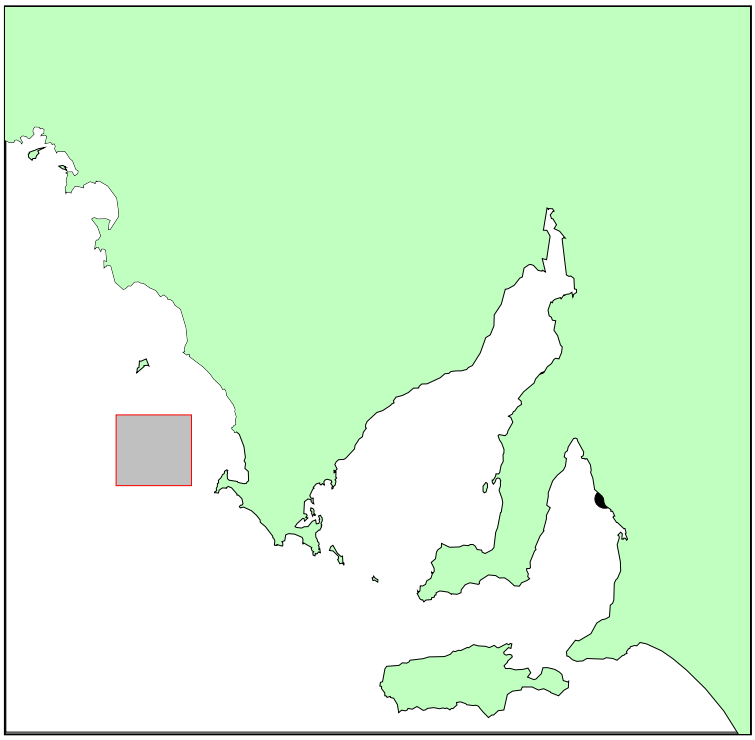
Methods: Gray and Miskiewicz (2000)



Vessel: Ngerin

Contact: B. Bruce (CSIRO)

Cruise Code	Month
LJ89	May



Vessel: Ngerin

Contact: T. Ward (SARDI)

Cruise Code	Month
NG1/86	March
NG2/86	April
NG3/86	June
NG4/86	September
NG5/86	November
NG1/87	January
NG2/87	March
NG3/87	April
NG4/87	May
NG5/87	June
NG6/87	August
NG1/88	July
NG2/88	August
NG3/88	September
NG4/88	October
NG1/89	January
NG2/89	March
NG3/89	June
NG1/90	May
NG2/90	December
NG1/95	January
NG2/95	March
NG1/96	January
NG2/96	February
NG1/97	February

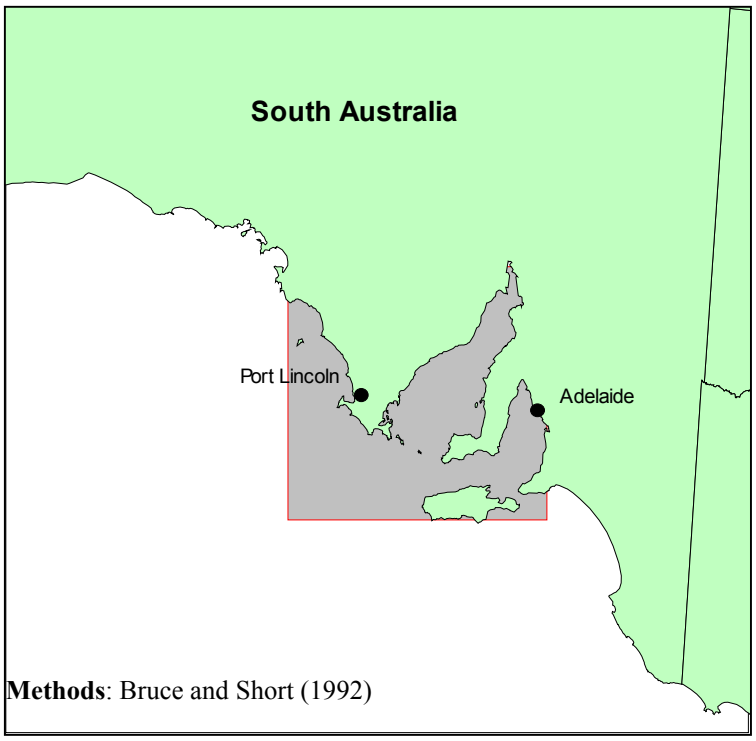
NG2/97	March
NG3/97	March
NG1/98	January
NG2/98	February/March
NG3/98	March
NG4/98	April
NG1/99	February
NG2/99	March
NG3/99	April
NG4/99	July

Methods: Ward *et al.* (2001)

Vessel: Ngerin

Contact: B. Bruce (CSIRO)

Cruise Code	**Month**
PL86/1	March
PL86/2	April
PL86/3	June
PL86/4	September
PL86/5	November
PL87/1	January
PL87/2	March
PL87/3	April
PL87/4	May
PL87/5	June
PL87/6	August
PL88/1	July
PL88/2	August
PL88/3	September
PL88/4	October
PL89/1	January
PL89/2	March
PL89/3	June
PL90/2	May

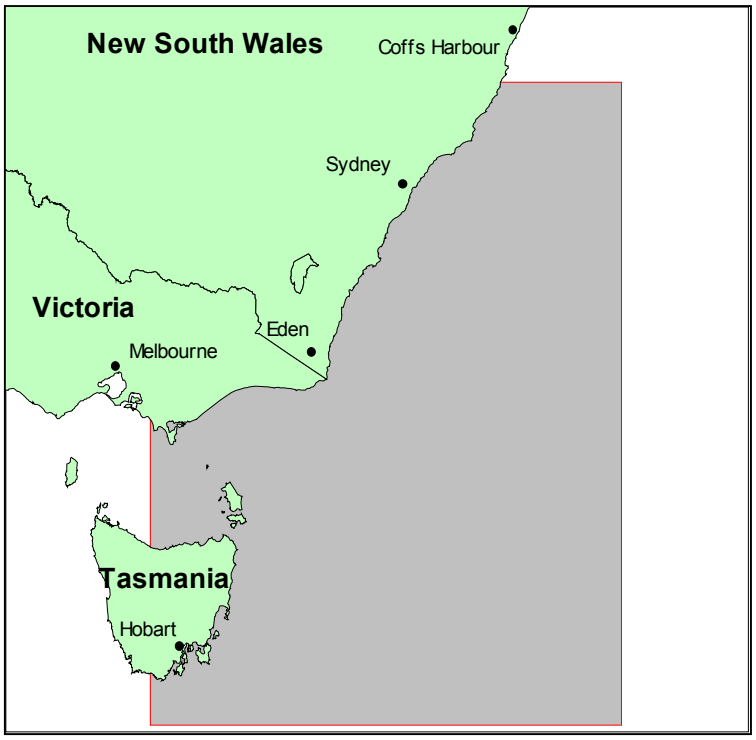


Methods: Bruce and Short (1992)

Vessel: Soela

Contact: CSIRO

Cruise Code	**Month**
SO1/82	January/February

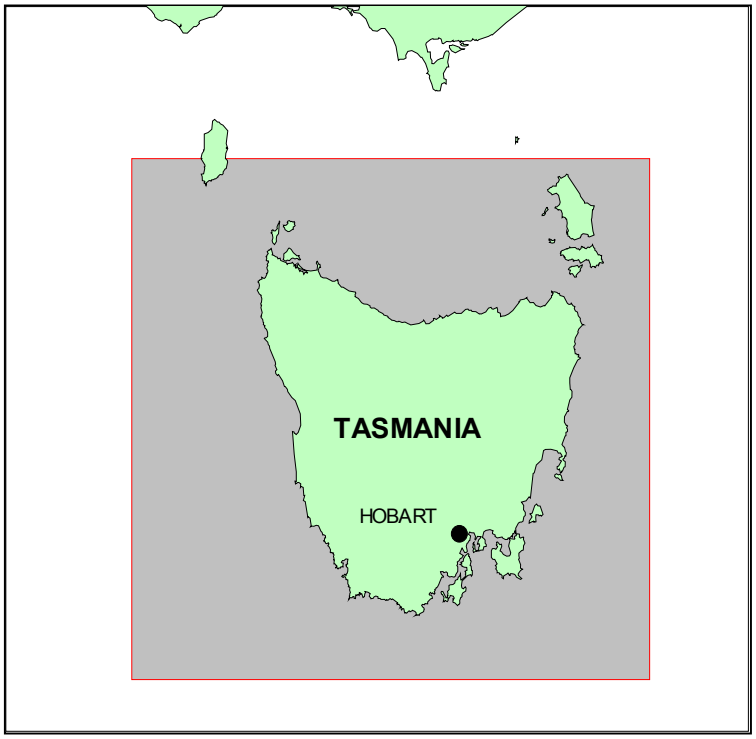


Vessel: Soela

Contact: CSIRO

Cruise Code	**Month**
SO2/84	May
SO3/84	June/July
SO5/84	October/November
SO6/84	November/December
S01/85	January/February
SO2/85	March/April

Methods: Thresher *et al*. (1988)



Vessel: Soela

Contact: CSIRO

Cruise Code	**Month**
SO4/84	August

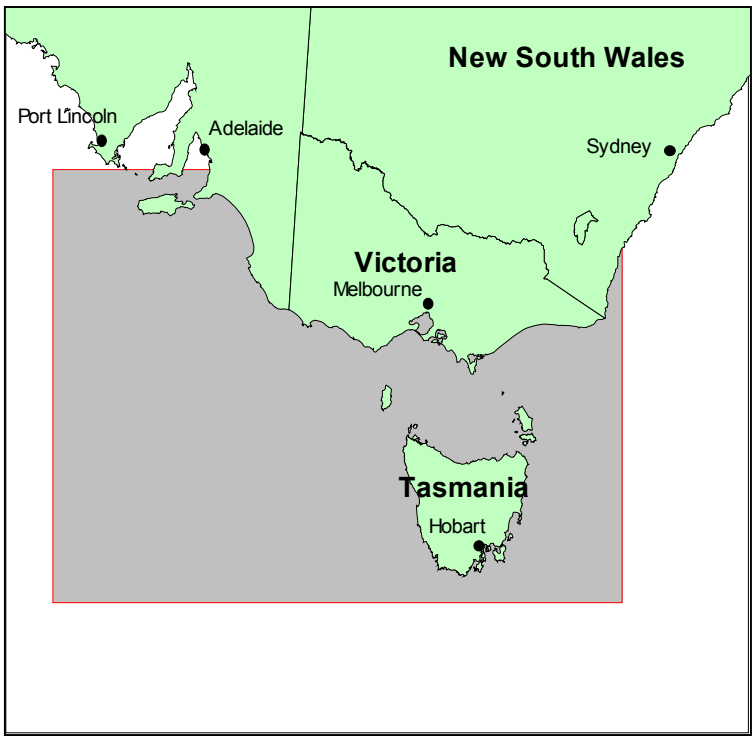
Methods: Thresher *et al*. (1988)

Vessel: Soela

Contact: R. Thresher (CSIRO)

Cruise Code	**Month**
SO4/85	July/August

Methods: Thresher *et al*. 1988

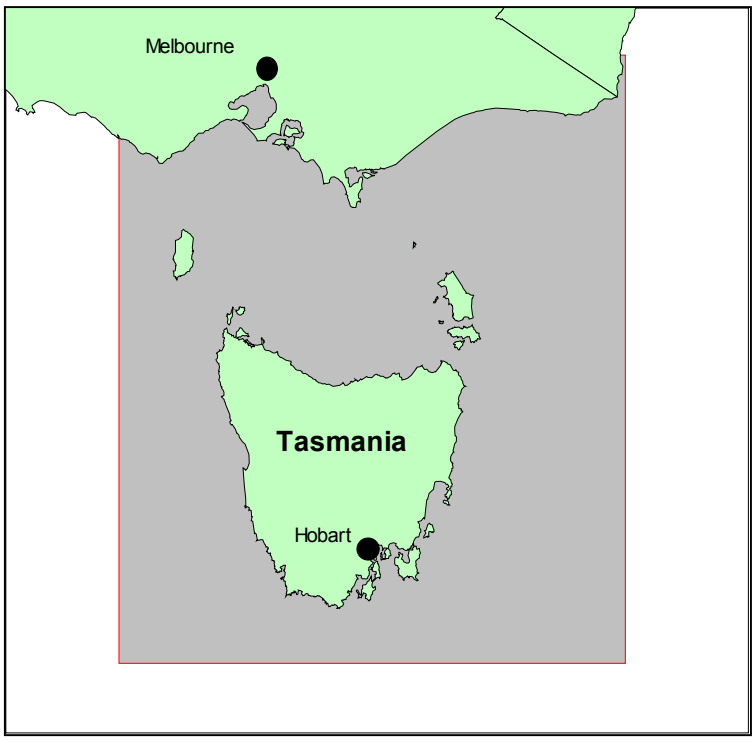


Vessel: Soela

Contact: CSIRO

Cruise Code	**Month**
SO5/85	September

Methods: Thresher *et al*. (1988)

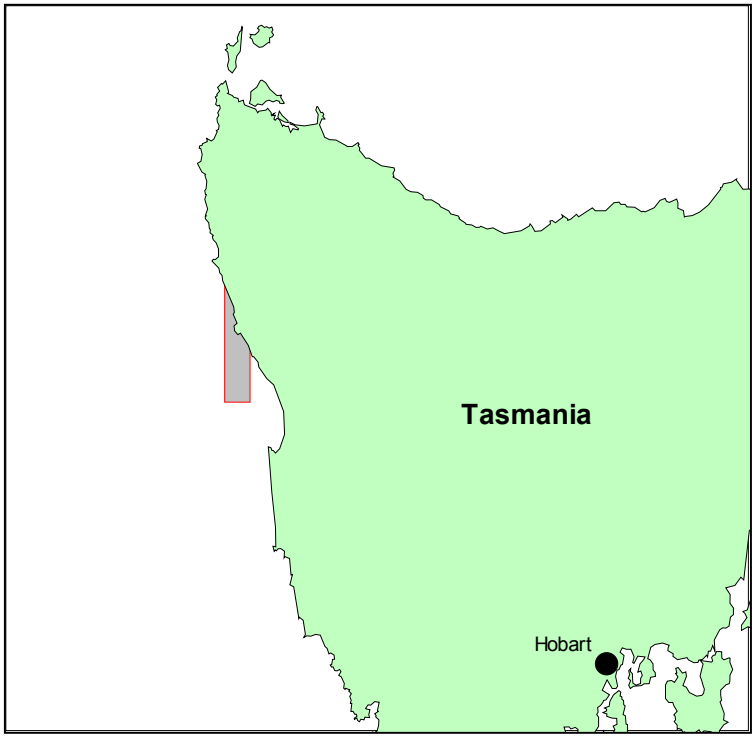


Vessel: Soela

Contact: CSIRO

Cruise Code	**Month**
SO4/86	June

Methods: Thresher *et al*. (1988)

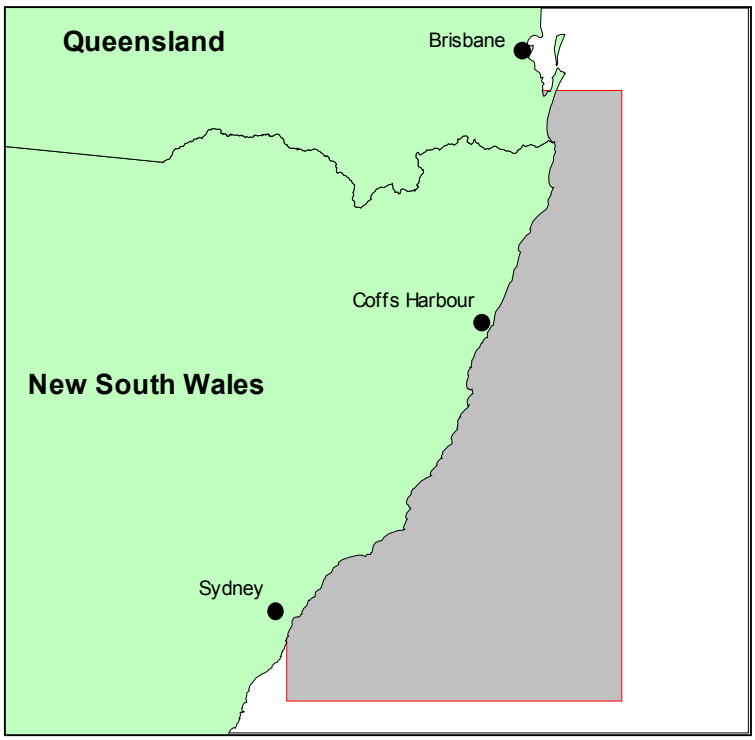


Vessel: Sprightly

Contact: CSIRO

Cruise Code	**Month**
SP1/83	January
SP6/83	March
SP9/83	May

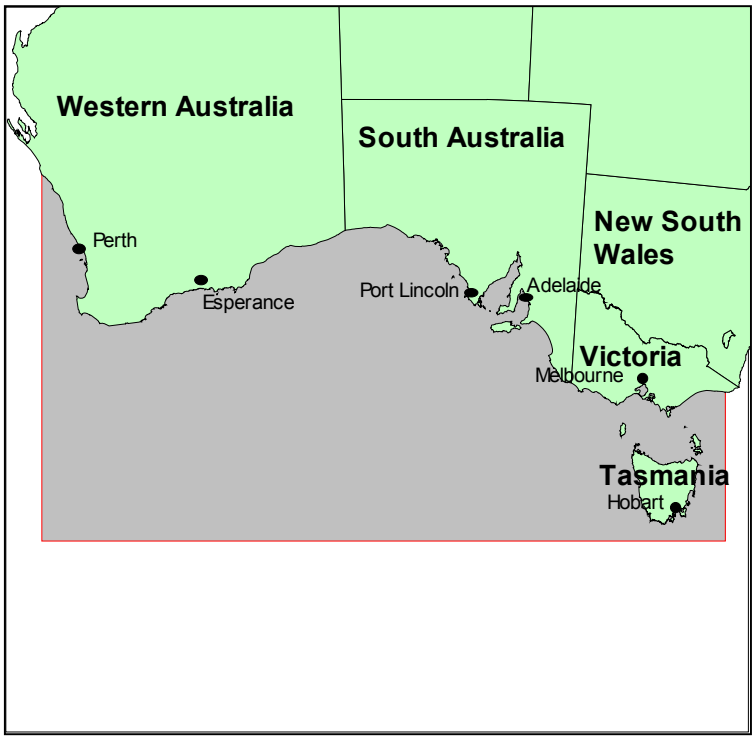
Methods: Miskiewicz *et al.* (1996)



Vessel: Southern Surveyor

Contact: D. McKenzie (CSIRO)

Cruise Code	**Month**
SS3/91	August/September

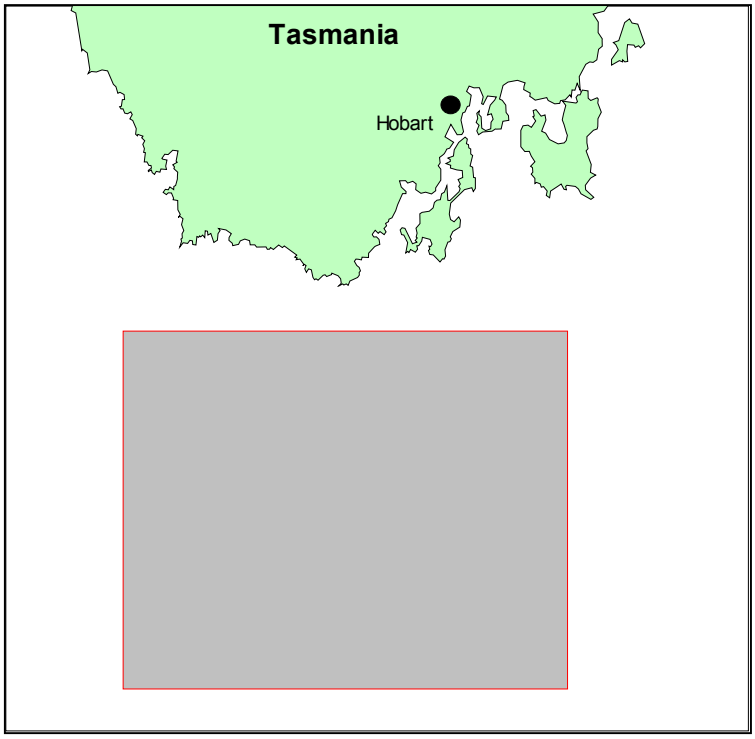


Vessel: Southern Surveyor

Contact: T. Koslow (CSIRO)

Cruise Code	**Month**
SS1/92	February

Methods: Bruce *et al*. (2000)

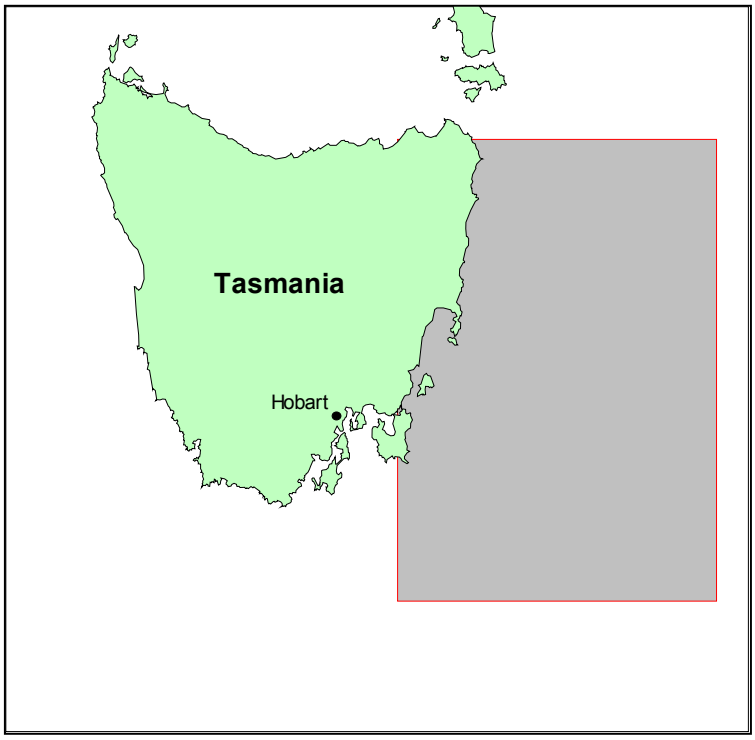


Vessel: Southern Surveyor

Contact: J. Young (CSIRO)

Cruise Code	**Month**
SS2/92	May/June

Methods: Young *et al*. (1996)

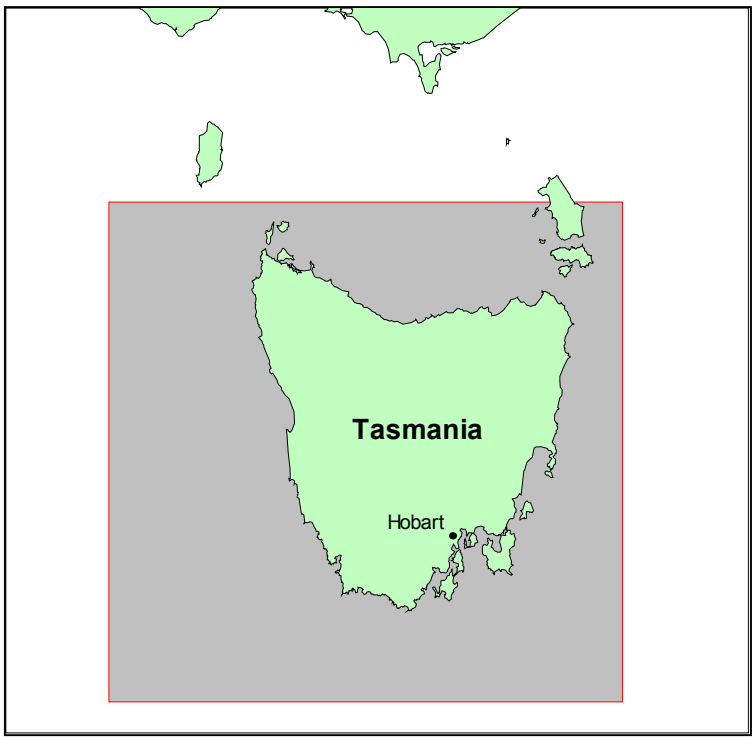


Vessel: Southern Surveyor

Contact: T. Koslow (CSIRO)

Cruise Code	**Month**
SS3/92	July/August

Methods: Bruce *et al*. (2000)

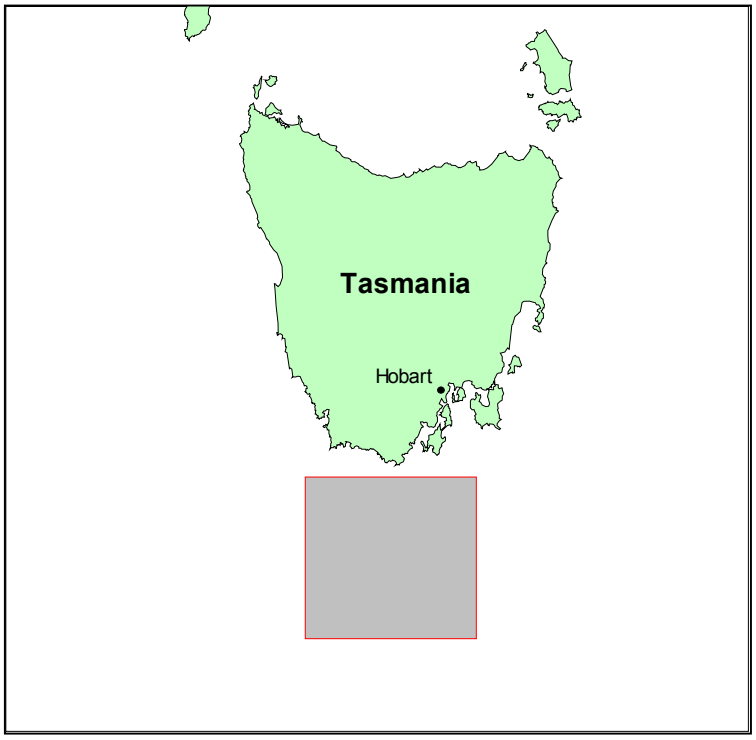


Vessel: Southern Surveyor

Contact: T. Koslow (CSIRO)

Cruise Code	**Month**
SS4/92	November/December

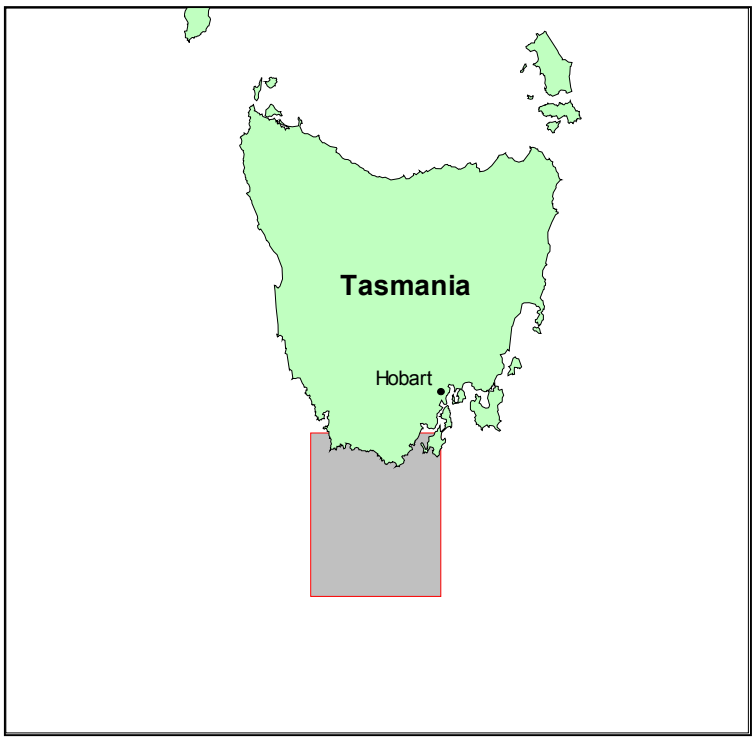
Methods: Bruce *et al*. (2000)



Vessel: Southern Surveyor

Contact: B. Griffiths (CSIRO)

Cruise Code	**Month**
SS3/93	April

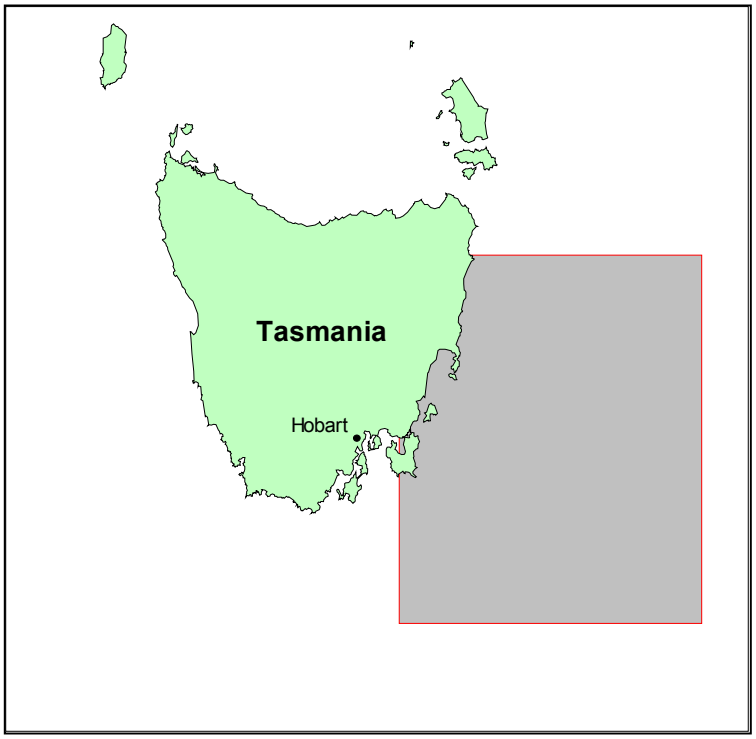


Vessel: Southern Surveyor

Contact: J. Young (CSIRO)

Cruise Code	**Month**
SS4/93	June

Methods: Young *et al*. (1996)

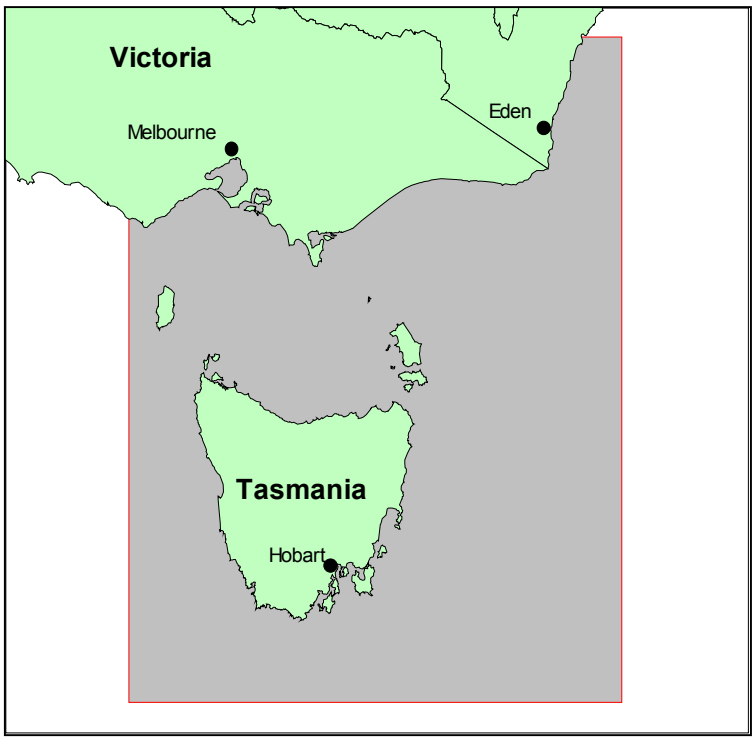


Vessel: Southern Surveyor

Contact: T. Koslow (CSIRO)

Cruise Code	**Month**
SS5/93	July/August

Methods: Bruce *et al*. 2001

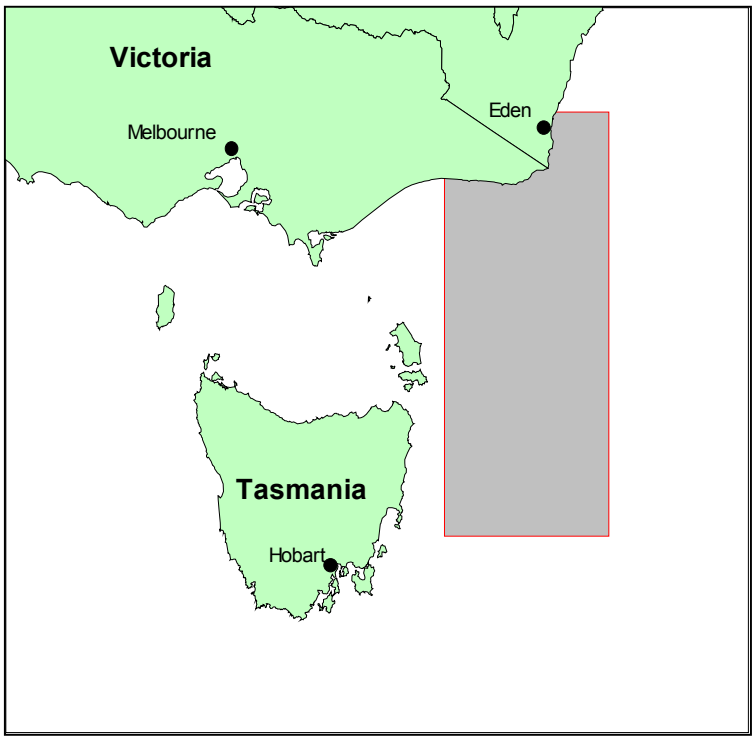


Vessel: Southern Surveyor

Contact: B. Bruce (CSIRO)

Cruise Code	**Month**
SS2/94	February

Methods: Bruce et al. (2000)

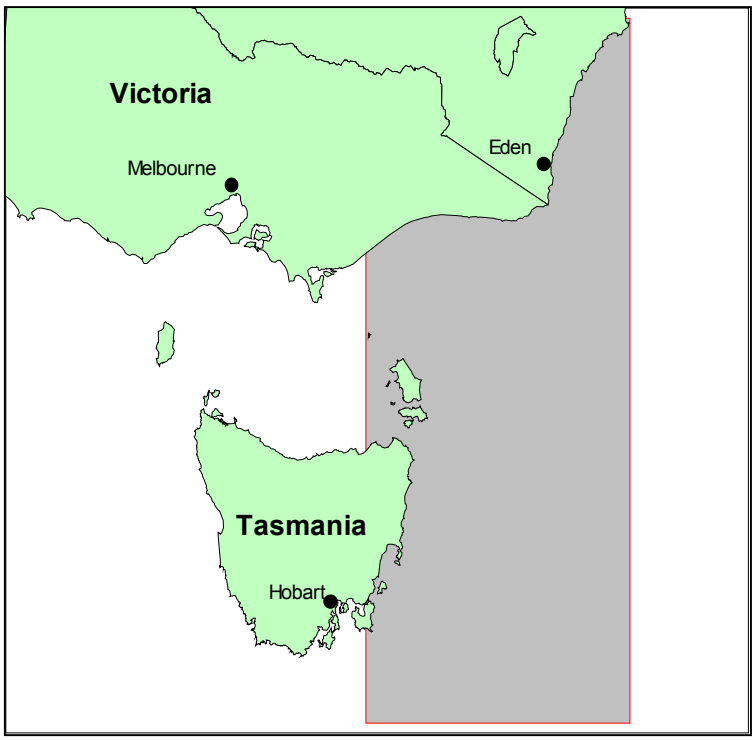


Vessel: Southern Surveyor

Contact: J. Young (CSIRO)

Cruise Code	**Month**
SS3/94	May

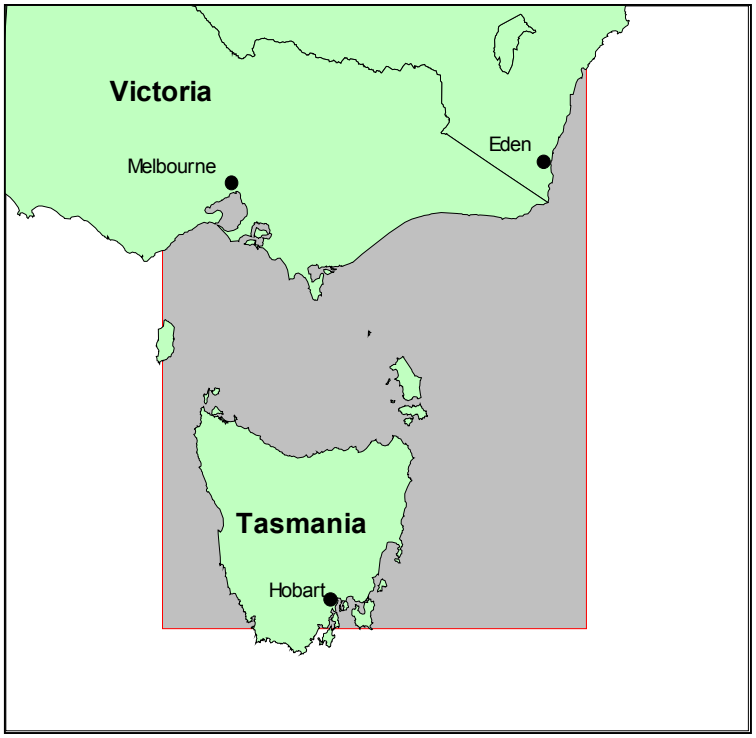
Methods: Young *et al*. (1996)



Vessel: Southern Surveyor

Contact: T. Koslow (CSIRO)

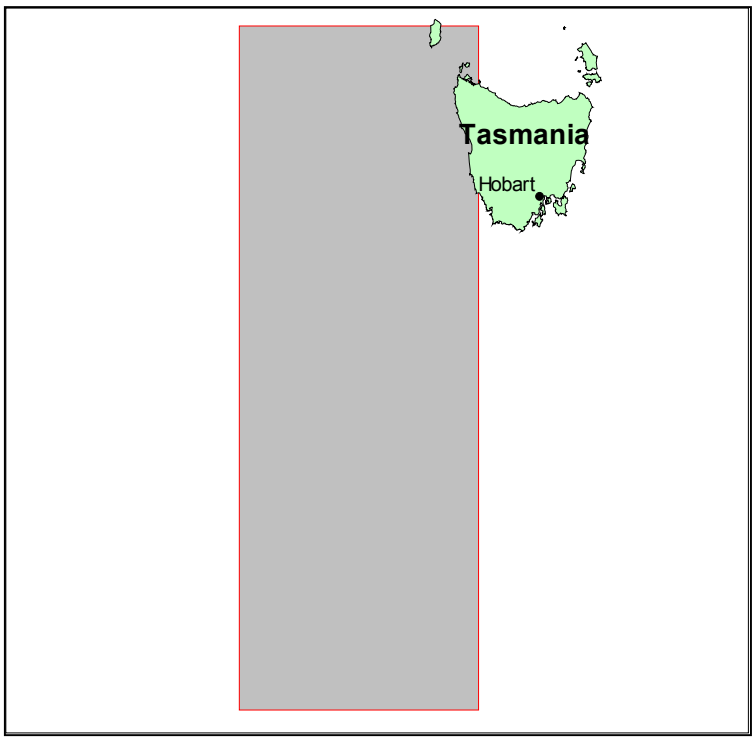
Cruise Code	**Month**
SS5/94	August/September



Vessel: Southern Surveyor

Contact: J. Parslow (CSIRO)

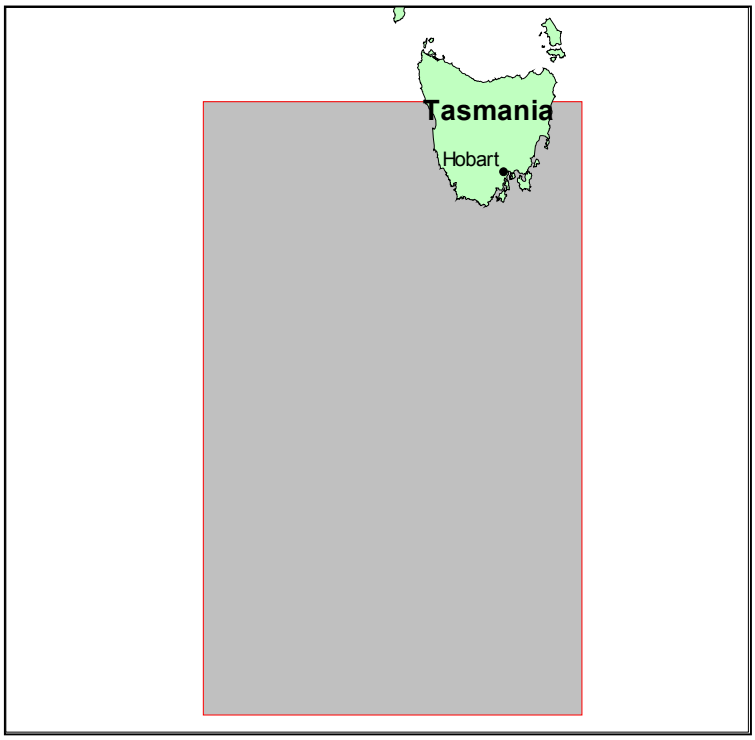
Cruise Code	**Month**
SS1/95	January/February



Vessel: Southern Surveyor

Contact: B. Tilbrook (CSIRO)

Cruise Code	**Month**
SS11/95	November/December



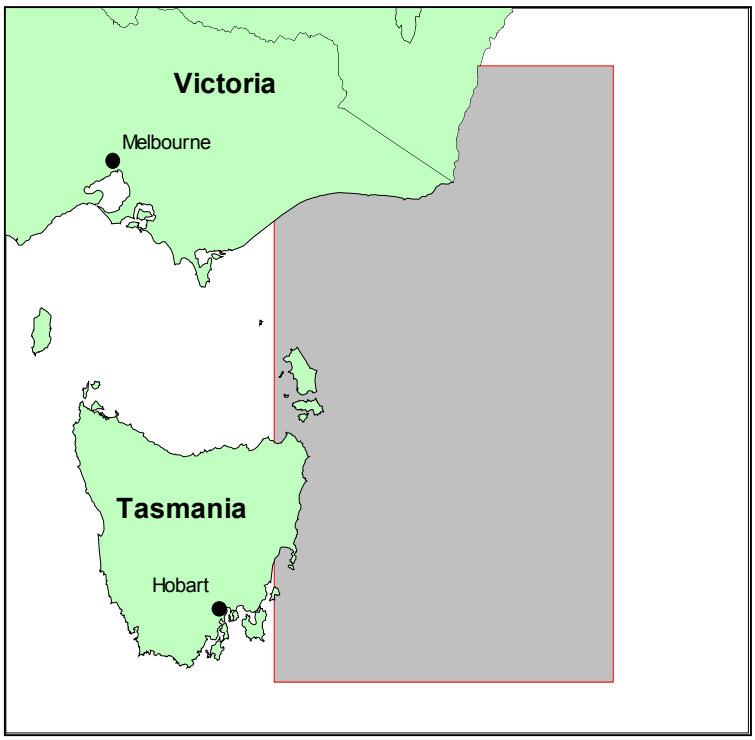
Methods: Bruce *et al*. (2000)

Vessel: Southern Surveyor

Contact: J. Young (CSIRO)

Cruise Code	**Month**
SS3/96	May

Methods: Young *et al*. (1996)



Vessel: Southern Surveyor

Contact: R. Kloser (CSIRO)

Cruise Code	**Month**
SS1/00	April/May

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APPENDIX F: SCIENTIFIC OUTPUTS

This appendix provides details of manuscripts published during the project period.

The influence of mesoscale oceanographic processes on larval distribution and stock structure in jackass morwong (*Nemadactylus macropterus*: Cheilodactylidae)

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ICES Journal of Marine Science 2001 58: 1072-1080

Abstract

The distribution of morwong larvae in the south-west Tasman Sea was investigated during autumn/early winter over three consecutive years (1992-94). Larvae were confined to surface tows and large numbers (6-30 mm in length) were captured up to 250 km east of Tasmania (the limit of sampling). The jackass morwong (*Nemadactylus macropterus*) dominated samples, although larvae of the banded morwong (*Cheilodactylus spectabilis*) were also recorded. *N. macropterus* larvae were found both north and south of a major frontal zone within water masses derived from the East Australian Current (EAC) and Sub-Antarctic Water (SAW). Back calculated spawning dates, significant differences in otolith microstructure and inferred current patterns suggest that larvae from within each water mass originate from different spawning regions - herein termed “northern” (probably southern New South Wales and eastern Victoria) and “southern” (probably western and southern Tasmania). There was a significant positive relationship between larval age and distance offshore. Trajectories of satellite tracked surface drifters suggested that larvae could be passively transported offshore within surface waters. Once offshore, satellite tracked drifters moved in a complex pattern but were generally retained within 300-500 km of the coast for periods up to 18 months, which exceeds the pelagic duration of morwong. Seasonal movements of these major water masses in the south west Tasman Sea provide mechanisms that may facilitate regionally self recruiting populations in northern and southern regions with an area of recruitment derived from both regions covering eastern Tasmania and Bass Strait. Larval distribution and advection processes suggest spatially variable levels of mixing between spawning regions. These data provide an explanation for both the lack of previously detected population sub-structuring from genetics studies and the multiple spawning population scenario suggested by otolith microchemistry studies.

Introduction

Physical oceanographic processes influence the distribution of larval fish and invertebrates on a variety of scales ranging from a few metres (eg langmuir circulation and tidally generated slicks - Kingsford 1990) to thousands of kilometres (Sherman *et al*. 1984, Cowan 1985, Lobel and Robinson 1986). The interactions between such processes and larval biology are generally regarded as some of the primary determining factors in larval fish survival, supply at settlement and hence, contribute to the recruitment dynamics of a species (Myers and Drinkwater 1989, Jenkins and May 1994, Shenker *et al*. 1993, Sale 1990). Successful completion of the planktonic stage in many marine species requires early life history stages to be transported to specific nursery areas (Hare and Cowan 1993). Where spawning areas and nursery areas are within the same geographic region, the retention of larvae within that region is generally believed to maximise survival (Iles and Sinclair 1982). Such "retention areas" may also play a role in structuring populations by limiting genetic exchange between regions and thus maintaining stock integrity (Iles and Sinclair 1982, O'Boyle *et al*. 1984). Physical circulation processes combined with larval behaviour play a dominant role in establishing the nature and extent of larval dispersal/retention.

The jackass morwong *Nemadactylus macropterus* is a commercially important temperate ground fish that is common in coastal and continental shelf waters of southern Australia and New Zealand (Last *et al*. 1983, Ayling and Cox 1982). Despite a number of studies, the population structure of the species remains contentious (Thresher *et al*. 1994). Genetic analyses suggest little population sub-structuring across southern Australia, but a distinct separation between Australia and New Zealand (Richardson 1982, Elliott and Ward 1994, Grewe *et al*. 1994). Otolith microchemistry analyses, however, suggest a far more complex population structure with up to four distinct groupings within southern Australia and a link between southern and western Tasmanian populations and those of the South Island of New Zealand (Thresher *et al*. 1994). This discrepancy has been ascribed to the relative sensitivities of the two techniques to the rates of exchange between populations (Thresher *et al*. 1994, Elliott and Ward 1994). The multiple population scenario for *N. macropterus* in southern Australia is consistent with observed regional declines in abundance (Thresher *et al*. 1994) and work in New Zealand where three geographically discrete populations of this species have been identified (Gauldie and Nathan 1977). It does, however, suggest regional self recruiting populations which seems at odds with the species extended offshore pelagic early life history (Vooren 1972, 1975, Tong and Saito 1977) that presumably implies a high potential for larval mixing and dispersal.

The early life history of *N. macropterus* is poorly documented due largely to the paucity of specimens collected during previous ichthyoplankton sampling. Between 1992 and 1994, over two thousand *N. macropterus* larvae were collected in the south-west Tasman Sea. Our purpose here is to examine the distribution, water mass affinities and advection processes of *N. macropterus* larvae in order to further clarify the stock structure of the species in south eastern Australia.

Materials and methods

Sample collection and laboratory details

Larvae were sorted from samples collected primarily off the east coast of Tasmania during three research cruises of the *RV Southern Surveyor* between 1992 and 1994, one in May/June each year (Figure 1). Cruises were designed to study zooplankton and micronekton within the region of a seasonal long-line fishery for southern bluefin tuna (see Young *et al*. 1996 for full sampling details). These collections were supplemented with larvae collected from various other cruises within Tasmanian waters and southern New South Wales during the 1993-1994 period. Larvae were collected using two main net systems: a 1 m^2 (1000 µm mesh) net towed at the surface adjacent to the vessel and a multiple opening closing EZ (BIONESS) net. Young *et al*. (1996) provide a full description of gear and sampling protocols. All samples from 1992 were fixed in a 10% unbuffered formaldehyde/seawater solution. Samples from 1993 and 1994 were fixed in either 10% unbuffered formaldehyde/seawater or 95% ethanol. On occasions, samples were rough sorted on-board and all observed cheilodactylid larvae were removed and fixed in ethanol while the remaining material was fixed in formaldehyde. Volume filtered was calculated using calibrated General Oceanics flowmeters. Reported catch rates of larvae are standardised to number per 1000 m^3.

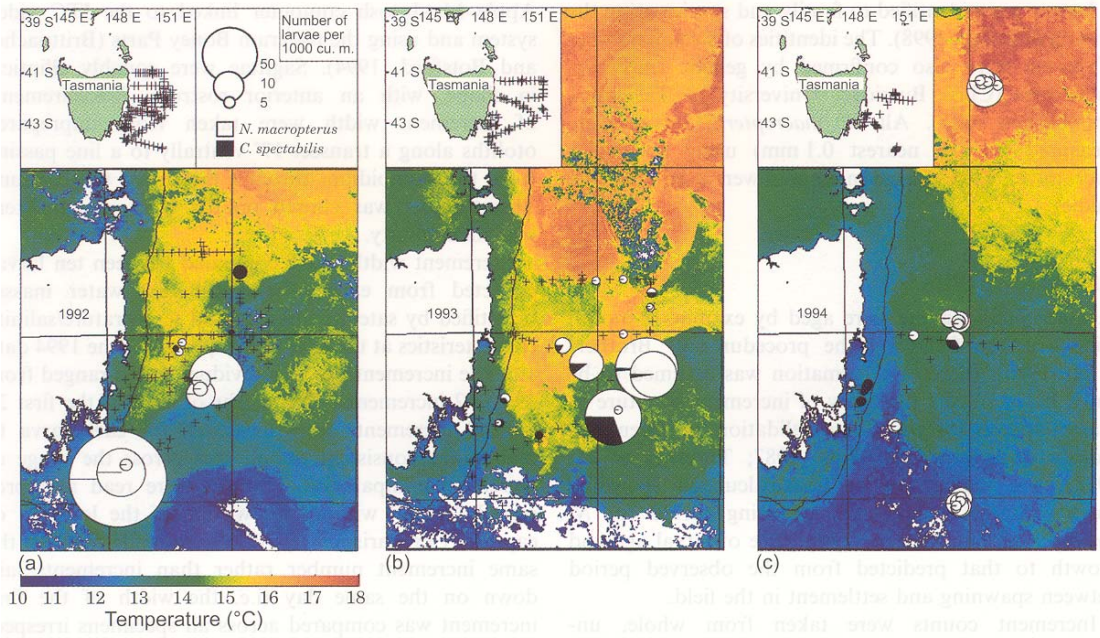


Figure 1: The study area off south eastern Australia including Advanced Very High Resolution Radiometer (AVHRR) images of sea surface temperature and larval distribution for each sampling period. Warm EAC water is light grey in colour. White areas to the south east of Tasmania are clouds. Stations where larvae were not recorded are denoted "+".

Larvae were identified to family and species using the criteria of Bruce (1998). The identities of a small number of larvae were also confirmed by genetic (mtDNA) techniques (Chris Burridge, University of Tasmania unpublished data). All *N. macropterus* larvae were measured (to the nearest 0.1 mm) using an ocular micrometer. Larvae fixed in ethanol were used in ageing studies.

Ageing

N. macropterus larvae were aged by examining otolith microstructure following the procedures of Brothers *et al*. (1976). Increment formation was assumed to be daily, based on the similarity of increment structure to that in species for which age validation has been previously documented (eg Thresher *et al*. 1988, Jenkins 1987), the coincidence of back calculated spawning dates with the documented spawning period for *N. macropterus*, and the correspondence of larval age and growth to that predicted from the observed period between spawning and settlement in the field.

Increment counts were taken from whole, unprocessed otoliths mounted in a drop of lens immersion oil. Otoliths were examined under transmitted light at 1200-2500x using a Leitz Orthoplan microscope fitted with a high resolution television camera (Ikegami CTC-6000) and linked to a high resolution monitor. Counts were made from a single sagitta and lapillus removed from the same side of the head. The remaining otoliths were left intact within the specimen. Increment age was estimated by averaging counts between the sagitta and lapillus (where counts from a respective otolith set did not differ by 5% for larvae ≤ 40 d or 10% - larvae ≥41 d). Otolith pairs not satisfying these criteria were rejected from subsequent analyses (4.2%). Increment age (ie number of increments) was used in all calculations of growth rate and in back calculating spawning dates. Increment age differs from true age by the number of days between spawning and the formation of the first increment. The timing of first increment formation varies between species from prior to hatching (eg Radtke and Dean 1982, Neilson and Green 1985) to the commencement of exogenous feeding (eg Brothers *et al*. 1976, Thresher *et al*. 1988). No information exists regarding the time to first feeding in *N. macropterus*, however, Robertson (1978) reported that yolk sac absorption was complete after "1 week" in larvae reared at 18-20^{o}C. Thus reported ages may underestimate true age by up to 7 days. Use of increment age rather than true age has little influence on either the calculation of growth rates or rates of advection from otolith data, although it will result in a minor shift in back calculated spawning dates.

Measurement of increment widths and otolith radius

The radius to the first increment and total otolith radius were measured on sagittae from 40 larvae via an Apple MacIntosh computer linked to the ITC video system and using the program Boney Parts (Brittnacher and Botsford 1994). Sagittae were roughly elliptical in shape with an anterior rostrum. Measurements of increment width were taken from unprepared otoliths along a transect 17 degrees ventrally to a line passing from the primoidium through the tip of the rostrum. This transect was chosen on the basis of consistent increment clarity.

Increment widths were compared between 10 larvae collected from each of two different water masses (identified by satellite imagery and temperature/salinity characteristics at the time of sampling) for the 1994 data set. The increment age of individual larvae ranged from 29 - 42 increments. The widths of each of the first 29 sagittal increments were measured for each larva to maintain a consistent sample size across the range of increment comparisons. Otoliths were read and processed "blind" without knowledge of the location of capture. Comparisons of width were made between the same increment number rather than increments layed down on the same day (ie the width of the first increment was compared across all specimens irrespective of total age, then the second and so on). This was necessary to avoid confounding effects of ontogenetic changes in increment widths.

Physical Oceanography

Three data sets were used to examine circulation patterns and water mass structure in the sampling region; cruise data, satellite images of sea surface temperature and satellite tracked surface drifters. Each cruise sampled along a series of transects covering the two dominant water masses; East Australian Current (EAC) T>15^{o}C, Sub-Antarctic water (SAW) T< 14^{o}C and the sub-tropical convergence (STC) 14 □ T □ 15^{o}C (Young *et al*. 1996). Temperature and salinity profiles to a depth of 1000 m were recorded on each transect using a Neil Brown CTD. These data were used to ground truth concurrently collected satellite data. Satellite images of sea surface temperature were obtained for each sampling period and were used to identify the position of the EAC, SAW and STC prior to sampling.

The trajectories of 10 satellite tracked drifters released at various positions on the Tasmanian continental shelf between 1992 and 1994 (Cresswell *et al*. 1994) were compared to the distribution of *N. macropterus* larvae and the position of large scale oceanographic features.

Results

Physical Oceanography

The physical and biological oceanography of the study region has been described in detail by Young *et al*. (1996). Briefly, in 1992, the EAC extended southwards in a broad wedge, bounded by the shelf break, to approximately 43^{o}S (Figure 1). The STC, separating cooler SAW to the south, extended along a NE/SW axis and was characterised by a change in surface temperature of approximately 2^{o}C over a distance of 40 km. A cell of warm water, probably of EAC origin, was located between 150-152^{o}E and 42-43^{o}S. In 1993, the EAC was located slightly further offshore and extended further south than in 1992 (Figure 1). The STC was much broader and less intense with a surface temperature gradient of 2^{o}C over a distance of some 190 km. In 1994, EAC water was located even further offshore and only extended to approximately 42^{0}S during the period of sampling (Figure 1). The STC was well defined with a surface temperature gradient of approximately 4^{o}C over 95 km.

Vertical profiles in all three years identified EAC water within the sampling region as a relatively shallow (0-150 m) tongue overlying cooler SAW (Young *et al*. 1996).

Ageing

N. macropterus larvae had a series of unambiguous bipartite increments extending from a central core to the edge in both sagitta and lapilli. The first increment was regularly located at 10.0 - 13.2 μm from the primoidium in sagitta (mean = 12.0, sd = 1.23, n = 40) and 10.0 - 14.4 μm (mean = 12.7, sd = 1.23, n = 40) in lapilli.

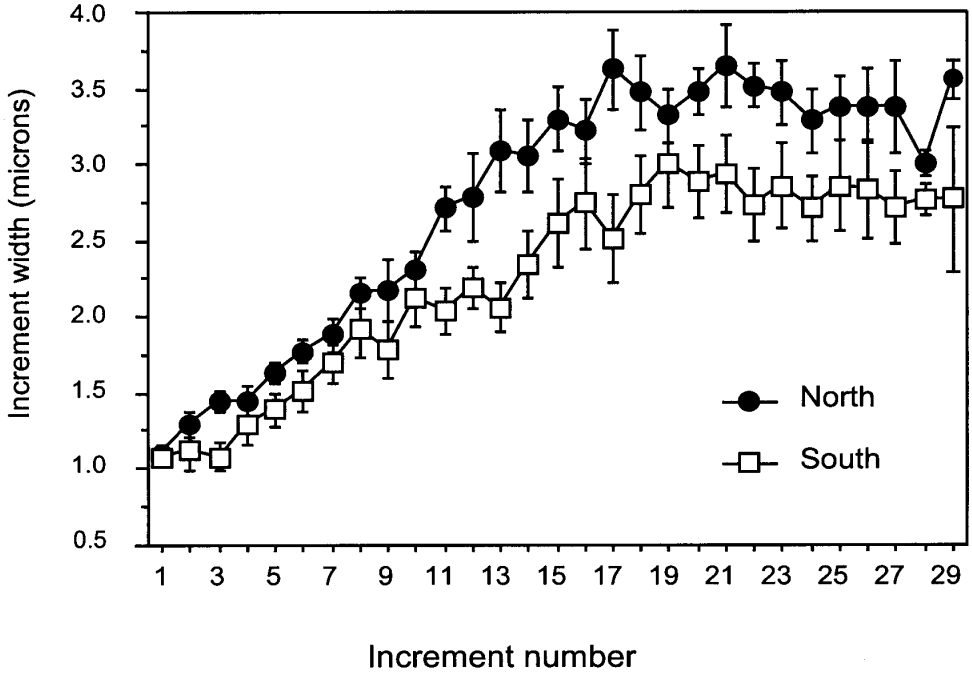
Sagittal increments increased steadily in width from approximately 1 μm at increment 1 to approximately 3 μm by increment 17-18 (6-8 mm total length) in wild caught larvae. This length corresponds to the size at notochord flexion (Bruce 1998). Increment width remained relatively constant thereafter (Figure 2).

Increment widths varied between larvae from different water masses (Figure 2). To test the significance of these differences, otolith increments prior to flexion (during the period of

gradually increasing increment width, ie ≤ increment 17) and after flexion (when increment widths remained relatively constant) were tested separately. For the increment period prior to flexion, intercepts (α) and slopes (β) were calculated for growth trajectories of individual larva by regression analyses. These derived parameters were then compared between regions using a two sample t-test. A significant difference in the calculated slopes (β) would signify a significant difference in increment widths (growth rate). For the period after flexion, mean increment widths were calculated for each larva and then similarly compared between regions using a two sample t-test.

Figure 2. Mean increment widths for *N. macropterus* larvae collected north and south of the frontal zone separating the EAC and SAW off eastern Tasmania. Bars denote one standard deviation.

Increment widths were significantly wider in larvae captured north of the frontal zone for both



increment periods tested (increments ≤17, α -intercept- t=-0.06, p=0.953, β -slope- t=2.216, p=0.043; increments >17, t=2.799, p=0.015).

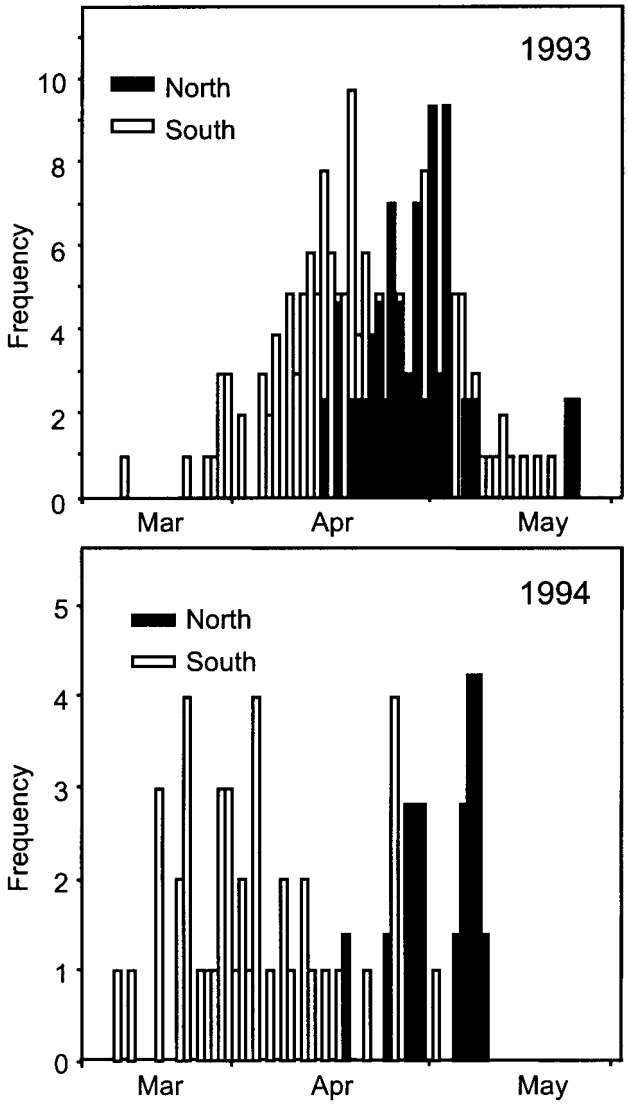
Back calculated spawning dates

Spawning dates were calculated for larvae aged from 1993 and 1994 (Figure 3). The timing of spawning was consistent between years. In 1993, spawning was recorded on 49 days over a 65 d period between 17 March and 21 May. A peak in spawning dates occurred in mid to late April. In 1994, spawning was recorded on 34 days over a 53 d period between 16 March and 8 May. Insufficient specimens were available to delineate a peak in back calculated spawning dates for the 1994 set.

Back calculated spawning dates varied with location of capture. There was a tendency in both years for larvae north of the front to have been spawned later than those south (Figure 3). In 1993, back calculated spawning dates from larvae south of the front were recorded on 45 d over a 62 period from 17 March to 18 May, with a peak around the 19 April. North of the front, spawning dates were recorded on 16 d over a 37 d period from 14 April to 21 May, with

a peak around 30 April. In 1994, back calculated spawning dates from larvae south of the front were recorded on 24 d over a 46 d period from 16 March to 1 May. North of the front, spawning dates were recorded on 11 d over a 20 d period from 18 April to 8 May.

Figure 3: Back calculated spawning dates for *N. macropterus* larvae collected within EAC



(North) and SAW (South) in 1993 and 1994.

Distribution of larvae

A total of 2,432 *Nemadactylus macropterus* larvae (5.9 - 30.4 mm) were recorded. Larvae of the banded morwong (*Cheilodactylus spectabilis*) were also, though less commonly, encountered.

Both *N. macropterus* and *C. spectabilis* larvae were caught only in surface tows or in depth stratified sampling that included the surface layer. No cheilodactylid larvae were recorded from either oblique tows or sub-surface strata sampled with opening closing gear.

Nemadactylus macropterus larvae were widely distributed in all three years and were recorded up to the limit of sampling, 250 km offshore (see Figure 1). Larvae were

predominantly distributed in cooler waters south of the major frontal zone. Larvae decreased in abundance with distance north of the frontal zone in 1992 and 1993. Sampling was extended further north in 1994 than previous years. Samples at these northern stations also contained significant numbers of *N. macropterus* larvae.

Age vs distance offshore

There was a significant increase in increment age with distance offshore (Figure 4, r^2=0.538 p=0.0001 n=280). The largest/oldest specimens were collected at the limit of offshore sampling (250 km) suggesting that the distribution of *N. macropterus* larvae extended beyond the sampling region.

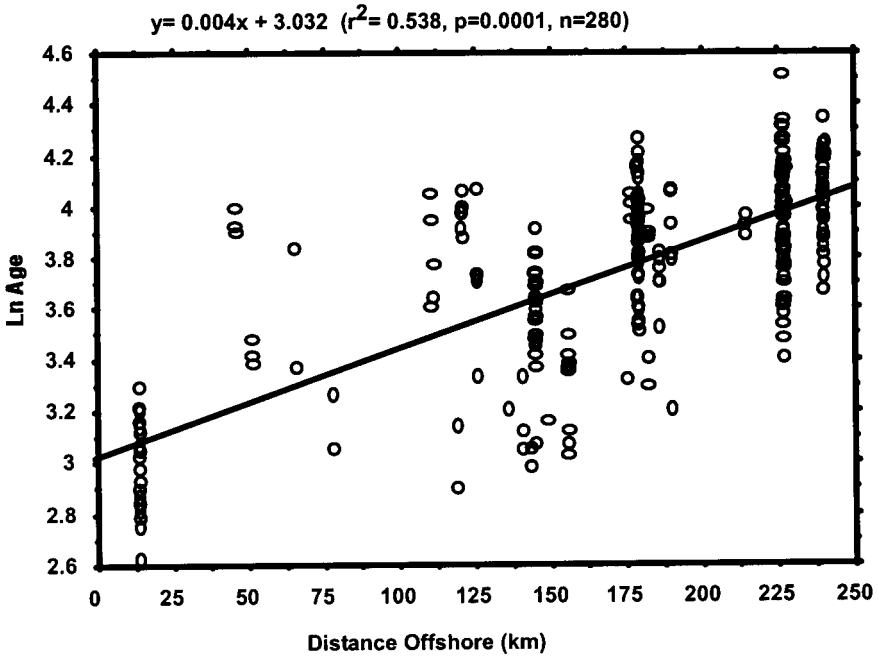


Figure 4: Relationship between increment age and distance offshore.

Discussion and conclusions

Previous data on cheilodactylids, although sparse, suggest that an extended, neustonic, offshore larval phase is widespread within the group (Nielson 1963, Barnard 1927, Vooren 1973, 1975, Tong and Saito 1977, Bruce 1998). These early life history characteristics, combined with presettlement stages attaining a large size (40 - 90 mm), and hence presumably enhanced swimming and net avoidance capabilities, have no doubt contributed to the lack of cheilodactylid material from conventional ichthyoplankton sampling in shelf and slope waters. While such offshore early life history strategies have been reported for several tropical taxa (Sale, 1970; Leis, 1991), there are relatively few temperate examples. Of these, most have been associated with particular oceanographic features (eg separation of the Gulf Stream from the coast (Hare and Cowan, 1993) or regarded as transport events leading to the loss or expatriation of larvae (Nelson *et al*., 1977).

The consistent pattern of offshore larval distribution for *N. macropterus* off south east Australia, the significant relationship between age and distance from shore and the lack of

larvae > 6 mm in shelf waters suggests that this is a regular strategy and does not represent an anomalous transport of early life history stages.

Spawning in *N. macropterus* occurs over a protracted period from February to June (Lyle and Ford, 1993, Kailola *et al*., 1993). Back calculated spawning dates, from larvae captured during 1993 and 1994, consistently recorded spawning between mid March and May. This narrower range in spawning may be due to a combination of the timing and spatial extent of sampling. Sampling at a different time of the year and/or outside of the survey region should provide larvae with back calculated spawning dates further covering the range of the reported spawning period. This is supported by the capture of larvae at the edge of the continental shelf on an earlier, separate cruise in March 1994. These specimens were 6.7 - 9.6 mm in length, with an increment age of 19 - 28 and had back calculated spawning dates ranging between 10-24 February.

The only known Australian nursery areas for *N. macropterus* occur in bays and estuaries of southern Tasmania and in Bass Strait (Tilzey *et al*., 1990). Settlement in southern Tasmanian waters occurs between September and December at a size of 70 - 90 mm (A. Jordan, pers. comm.) thus supporting Vooren's (1972) conclusion of a minimum 8 - 10 month pelagic phase for the species.

Surface circulation patterns, based on the trajectories of satellite-tracked drifters, provide an offshore transport mechanism for *N. macropterus* larvae. Once offshore, the behaviour of these drifters suggests that surface circulation patterns may also facilitate the retention of early life history stages within the Tasmanian region and may provide a mechanism for return of larvae towards the coast. The trajectories of satellite tracked surface drifters show a complex pattern of movement (Cresswell *et al*., 1994). The predominant trend is for drifters to, eventually, move eastwards into the South Tasman Sea towards New Zealand. However, two major patterns were observed. First, some drifters headed quickly offshore from eastern Tasmania but then spent a considerable period (up to 8 months) in a complex circulation pattern between 148^0E and 155^0E (Figure 5). Second, some drifters headed offshore south or south east of Tasmania and either remained in that vicinity or tracked west for up to 18 months before being entrained in an eastward flowing coastal current following the Tasmanian continental shelf (Figure 5). The periods over which these drifters were within offshore Tasmanian waters are consistent with or exceed the pelagic duration of *N. macropterus* and thus offer a possible mechanism for retention of larvae within the region. Remarkably, the circulation of several drifters brought them back to within 10's of kilometres of the shelf edge after 5-18 months offshore. The actual process whereby settlement stage *N. macropterus* move back inshore is unknown. However, given their size and presumed swimming capabilities, active orientation and movement may play a role. Directed swimming towards coral reefs by settlement stage larvae has been described by Leis *et al*. (1996) and Stobutzki and Bellwood (1994). These observations have, however, generally been made within a few kilometres from reefs. At this range, acoustic or chemical cues may assist larvae orienting towards the reef (Leis *et al.* 1996). It is unclear what cues a presettlement fish tens of kilometres from the coast may use to locate inshore nursery areas.

Implications for stock structure

There are conflicting interpretations of the structure and number of *N. macropterus* stocks in southern Australia. Results from genetic studies suggest that *N. macropterus* is represented by a single population in Australian waters that is distinct from New Zealand (west coast South

Island) populations (Elliott and Ward, 1993, Richardson, 1982). Analyses of otolith microchemistry provide a more complex picture. Thresher *et al*. (1994) suggested that there are possibly four stocks of *N. macropterus* within southern Australia (Western Australia, Great Australian Bight, New South Wales/Victoria and southern Tasmania. Furthermore, their otolith analyses could not separate the southern Tasmanian population from that of New Zealand (west coast South Island). The extended offshore pelagic phase of *N. macropterus* offers ample opportunity for widespread dispersal (and presumably mixing between populations of at least some larvae) thus it is not surprising that genetic analyses suggest little sub-structuring across southern Australia. Otolith microchemistry techniques are believed to be less sensitive to mixing rates and hence, able to provide a finer level of stock resolution (Thresher *et al*., 1994).

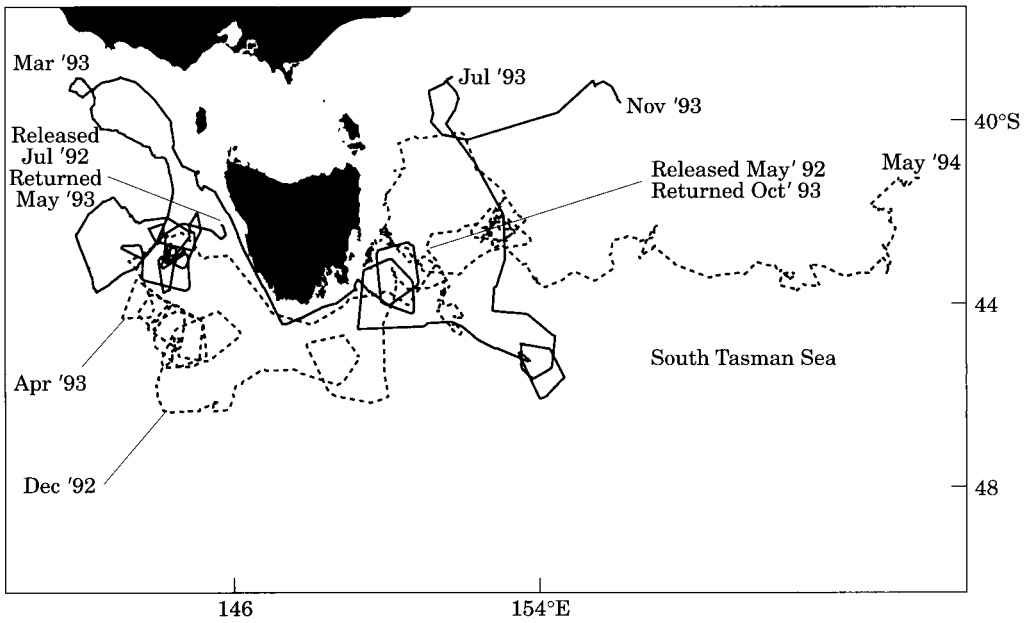


Figure 5: Trajectories of four satellite tracked surface drifters in the south western Tasman Sea (after Cresswell *et al.* 1994).

The maintenance of separate stocks of *N macropterus* in southern Australia requires that offspring recruit back to their source population and that mixing between stocks is restricted. The similarity of otolith microchemistry signals between juveniles and adults in each area suggests that this occurs during their pelagic early life history (Thresher *et al*., 1994). The stock structure proposed by Thresher *et al*. (1994) for the SE Australian region, comprised two populations (southern Tasmania and NSW/Vic) with an area of overlapping population signals between the south east Tasmanian coast and Bass Strait.

The dominant physical oceanographic features of the southern Tasman Sea are the EAC derived and SAW water masses (Harris *et al*., 1987). The location of these water masses is both seasonally and inter-annually variable. The maximum southerly extension of the EAC reaches to the south of Tasmania and occurs between February and April. The EAC then retreats progressively northwards to eastern Bass Strait by August. *N. macropterus* larvae were present in both EAC and SAW water. Differences in widths of otolith increments were consistent with larvae being in their respective water masses for their entire early life history. *N. macropterus* spawn across their adult range, but do so progressively later during the season at lower latitudes. Back calculated spawning dates were consistently later in larvae from EAC

water thus suggesting that these were of a different, and more northerly origin to the SAW larvae. EAC water travels predominantly southwards in a series of complex eddies and loop currents (Cresswell and Legeckis 1986). Thus *N. macropterus* larvae originating from NSW and Victoria would be expected, once offshore, to be advected southwards. Given this, it is reasonable to expect that the maximum southerly extent of advection would be south eastern Tasmania. Similarly, *N. macropterus* larvae from Tasmanian spawning might be advected as far north as eastern Bass Strait. The seasonal cycling of the water masses, combined with some mixing along the frontal zone, provides a possible mechanism to explain the mixed recruitment signal detected from otolith microchemistry between SE Tasmania and Bass Strait (Figure 6). Populations outside these areas, specifically south-western Tasmania and eastern Victoria/southern NSW, would be less likely to receive larvae from either further north or south respectively. In addition, circulation patterns from satellite tracked surface drifters (Cresswell *et al*., 1994) suggest self recruitment is possible to both these regions.

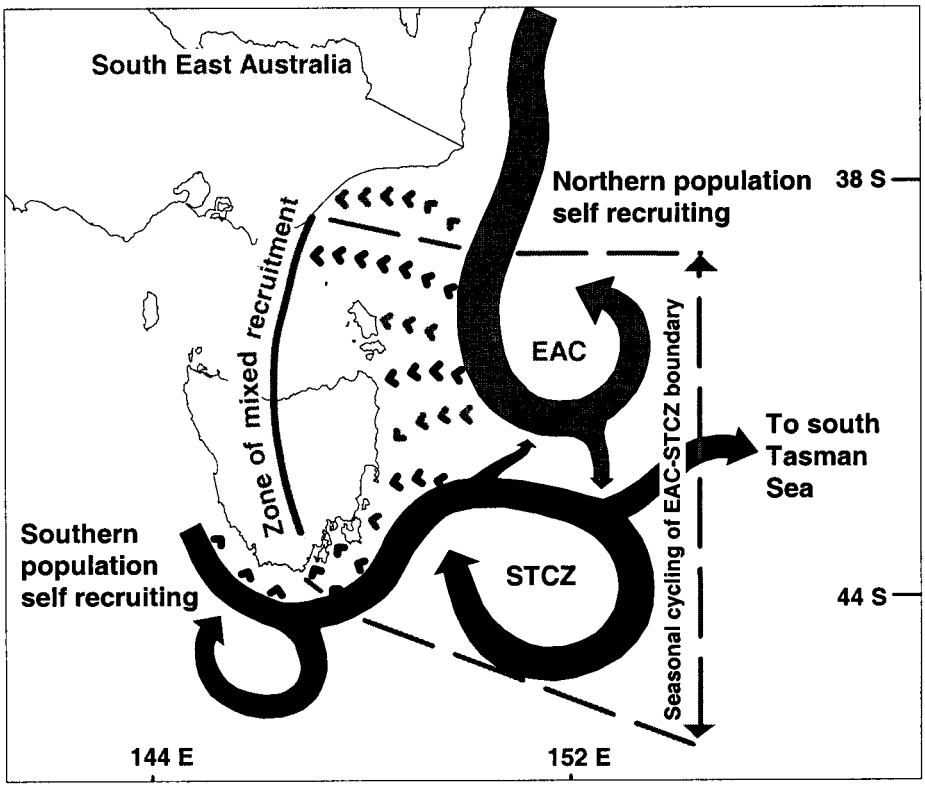


Figure 6: Summary of larval advection processes for *N. macropterus* in the south west Tasman Sea.

The trans-Tasman movement of satellite tracked drifters south of the frontal zone suggests a physical transport link between southern Tasmania and New Zealand's South Island. A link between southern Tasmanian and NZ populations of *N. macropterus* was also suggested by otolith microchemistry data, although it was not resolved whether this was due to mixing of larvae or the similarity of environmental signals between the two regions (Thresher *et al*., 1994). The time frame for drifter movement between southern Tasmania and New Zealand (approximately 15 -24 months, Cresswell *et al*., 1994) exceeds the estimated larval duration of *N. macropterus*. However, given that drifters are drogued at 15 m and larvae are at the surface, it is possible that some larvae may be subjected to much higher transport rates. In addition the maximum possible larval duration of *N. macropterus* is yet to be established and may well facilitate the cross-Tasman dispersal of some individuals.

In summary, the dispersal of *N. macropterus* larvae in SE Australian waters appears to be linked to mesoscale oceanographic processes within the region. Furthermore, the distribution of larvae and the seasonal variability in the movement of major water masses off the SE Australian coast provide mechanisms facilitating regionally self recruiting populations in western and southern Tasmania as well as southern NSW, with a region of mixed recruitment covering eastern Tasmania and eastern Victoria. Larval distribution and advection processes thus support the multiple population scenario suggested by otolith microchemistry analyses. The degree of population mixing suggested by both these studies, particularly off eastern Tasmania, is undoubtedly sufficient to eliminate distinct genetic heterogeneity. Whether populations remain sufficiently distinct to be managed separately remains unresolved. This depends on the extent of larval mixing and post-settlement movement patterns.

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

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Abstract

Blue and spotted warehous (*Seriolella brama* and *S. punctata*) are important commercial species within the South East Fishery, yet very little is known regarding their early life histories. Several thousand archived ichthyoplankton samples, collected across broad areas of southern Australia, were analysed for the occurrence of larvae of both species in order to examine their early life history and the timing and location of spawning. Larvae of both species were widely distributed within shelf and slope waters. They and were most commonly encountered during winter-spring and frequently co-occurred in samples. Larvae of *S. brama* were recorded from Kangaroo Island, South Australia (SA) to southern New South Wales (NSW), whereas *S. punctata* larvae were recorded from western Tasmania to southern NSW. Back calculated spawning dates, based on otolith microstructure, indicated spawning predominantly occurs during late July and August but that the timing of spawning varies between regions. Spawning times were approximately one month later for *S. brama* in Tasmanian waters compared to southern NSW. The abundances of small larvae (< 5.0 mm body length) were highest for both species off western Tasmania suggesting that this area is a major spawning ground. Large numbers of small *S. brama* and *S. punctata* larvae were also found off southern NSW suggesting that this is also a spawning area. Small *S. brama* larvae were not 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 there are separate spawning areas for *S. brama* in western and eastern regions of SEF, with the primary spawning ground off western Tasmania. The pattern for *S. punctata* is less clear, but the data suggests a more continuous link between populations in south-eastern Australia compared to *S. brama*.

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 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 effect 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 impacts 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 (Ian Knuckey, MAFRI, 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 1999).

A recent study by Knuckey and Sivakumaran (1999) 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.

We report herein, the distribution and occurrence of *Seriolella 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

A total of 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 (Figure 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*. (*in press*, 1996), Young *et al*. (1996) and Gunn *et al*. (1989). Net systems are briefly described below.

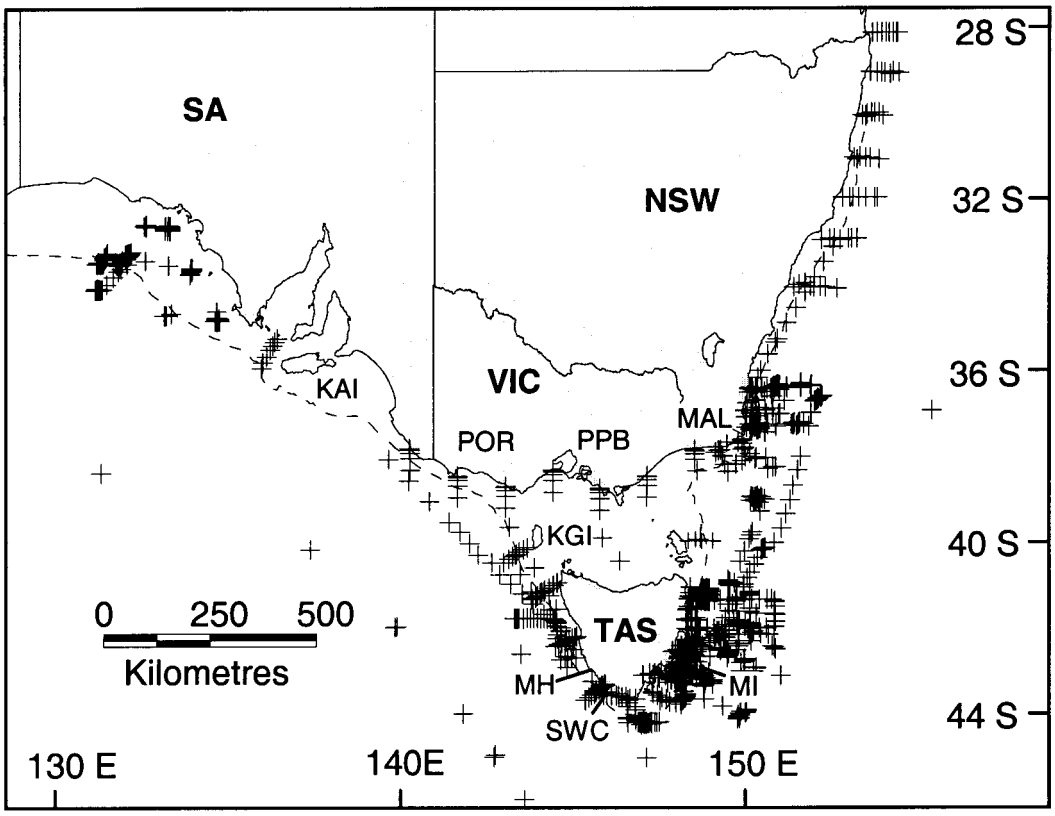


Figure 1. The distribution of samples available for analyses of larval distribution in south-eastern Australia. NSW – New South Wales, VIC – Victoria, TAS – Tasmania, SA – South Australia, MAL – Mallacoota, PPB Port Phillip Bay, POR – Portland, MI – Maria Island, SWC – South West Cape, MH – Macquarie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

Surface net

The surface net consisted of a square frame with a mouth area of $1m^2$ 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 knots for 10–15 minutes.

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 knots, the latter from within 10 m of the bottom (maximum depth 200 m) to the surface.

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 knots. 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 minute 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 (nm) apart, and each contained five sampling stations located at 2, 4, 8, 16 and 32 nm offshore. Sampling was conducted mostly during daylight hours. In stations where bottom depth was $\geq$ 100 m, discrete samples were obtained in the strata 100-75, 75-50, 50-25 and 25-0 m using four 500 µm mesh nets. Each net was opened for 15 min while towing the BIONESS system obliquely at a speed of 1-2 knots. In stations <30 m deep, a 15 min oblique tow in the strata 25-0 m was carried out using the bongo sampler instead of the BIONESS net. Surface samples were also collected at each station using 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 using 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 standardised to numbers of larvae per 1000 m^3 for comparison.

Samples were fixed in either 10% formaldehyde 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) using 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 examining otolith microstructure following 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 (Knuckey and Sivakumaran 1999, Smith 1989), 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 1200-2500x using 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 + six (based on the estimated period between fertilisation 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 specimens being stored 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 less than 7 mm BL and are best described by the following equations:

S. brama:	[age] = 6.321[BL] – 18.71	R^2=0.86
S. punctata:	[age] = 5.814[BL] – 17.32	R^2=0.81

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

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

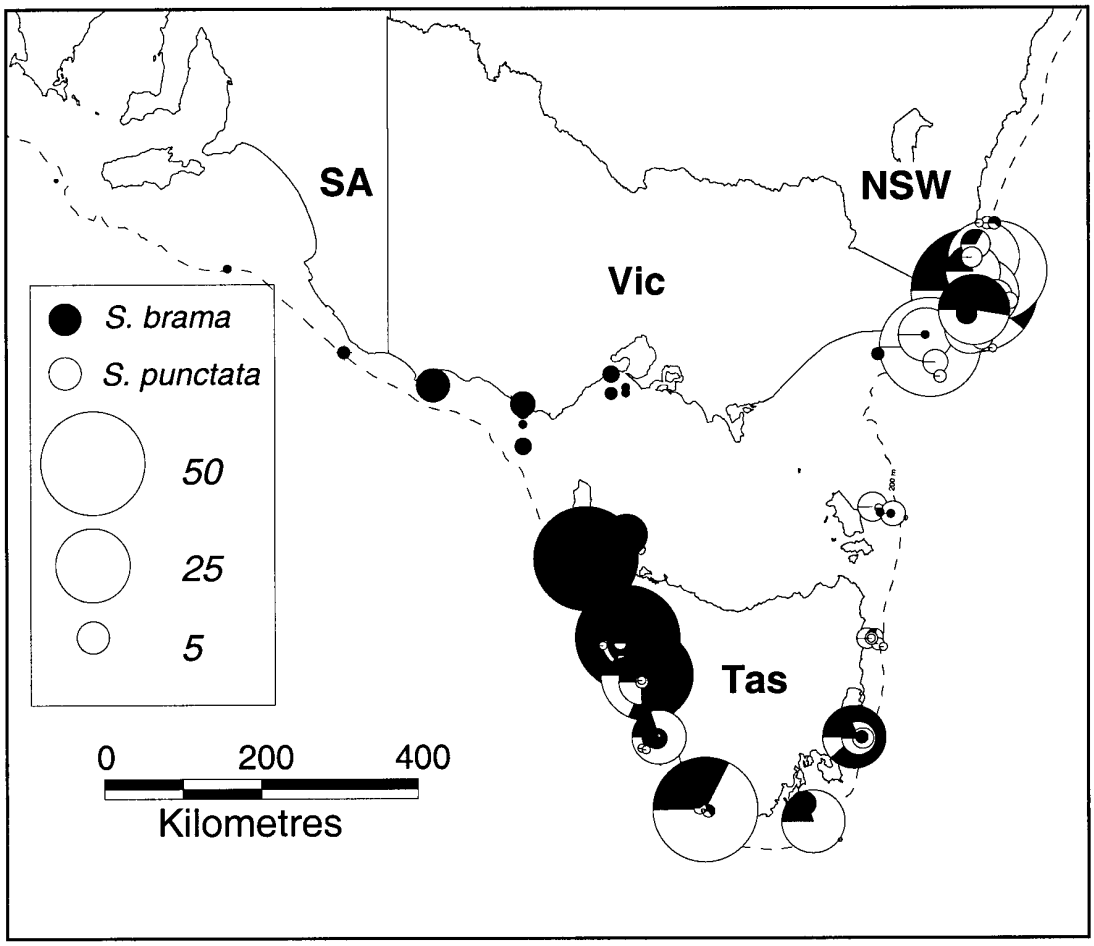
Results

Regional Distribution

A total of 695 *Seriolella 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 were recorded from samples more than 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 (Figure 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.

Figure 2. The distribution of *Seriolella brama* larvae and *S. punctata* larvae in southern Australia (all sizes combined). Scale = numbers of larvae/1000 m^3.

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.

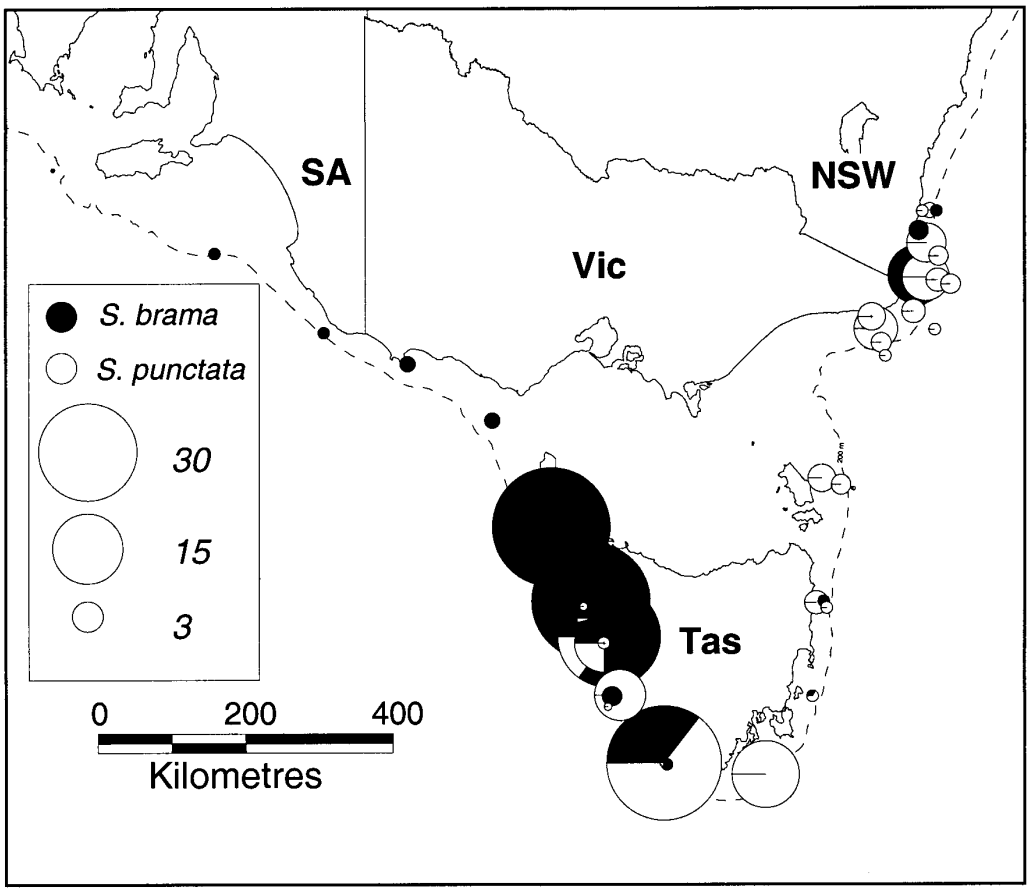


Figure 3. The distribution of *Seriolella brama* larvae and *S. punctata* larvae less than 5 mm BL. Scale = numbers of larvae/1000 m^3.

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 the75-100 m stratum, with the highest abundances in the upper 50 m (Fig. 4).

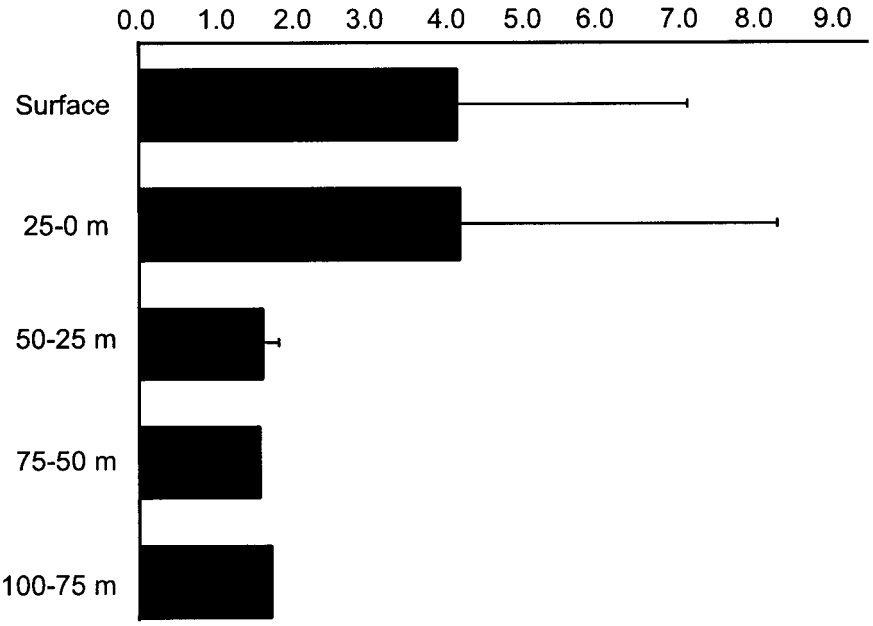


Figure 4. The vertical distribution of *Seriolella brama* larvae in Bass Strait (all records combined). Bars denote one standard deviation. Number in parentheses = number of tows that collected *S. brama* larvae within the specified depth strata.

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 2.9-18.6 mm (n=34) and 2.8-12.0 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 – 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 Victoria/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.

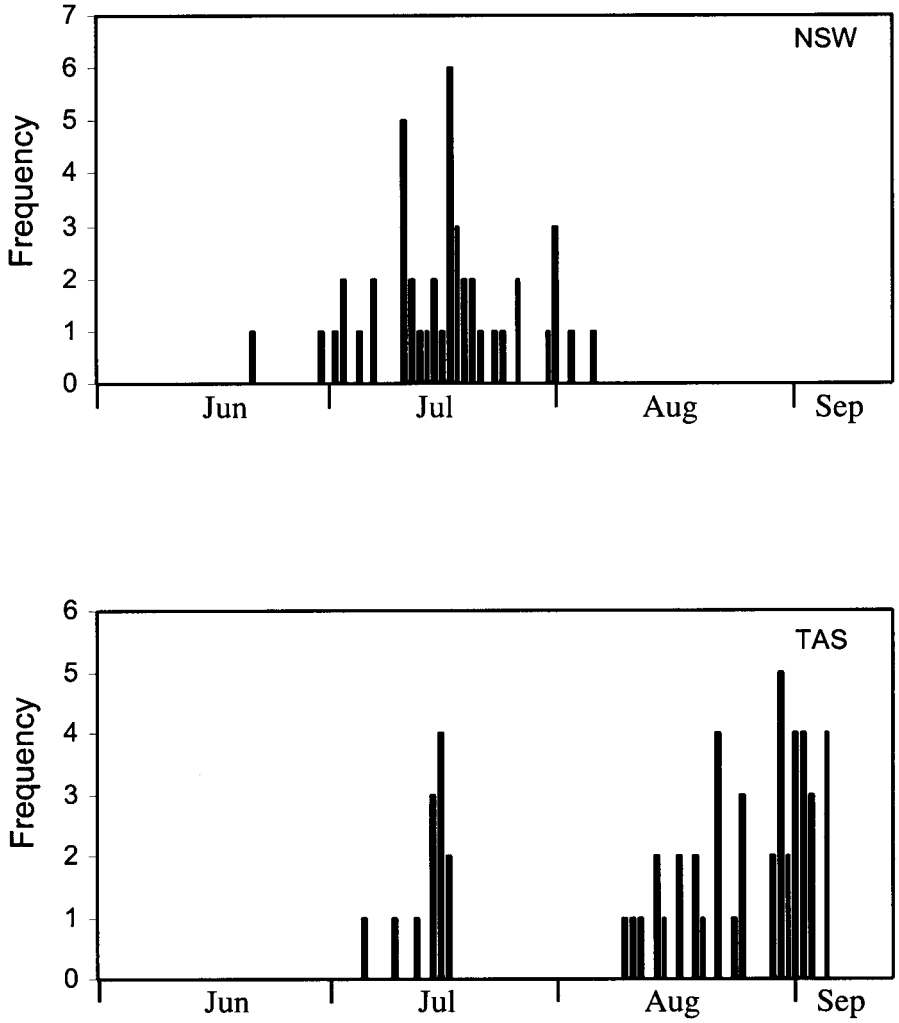


Figure 5. Back-calculated spawning dates for *Seriolella brama* larvae in southern Australia.

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 Victoria/southern NSW ranged from 1 July to 11 August, with a spawning peak in late July-early August.

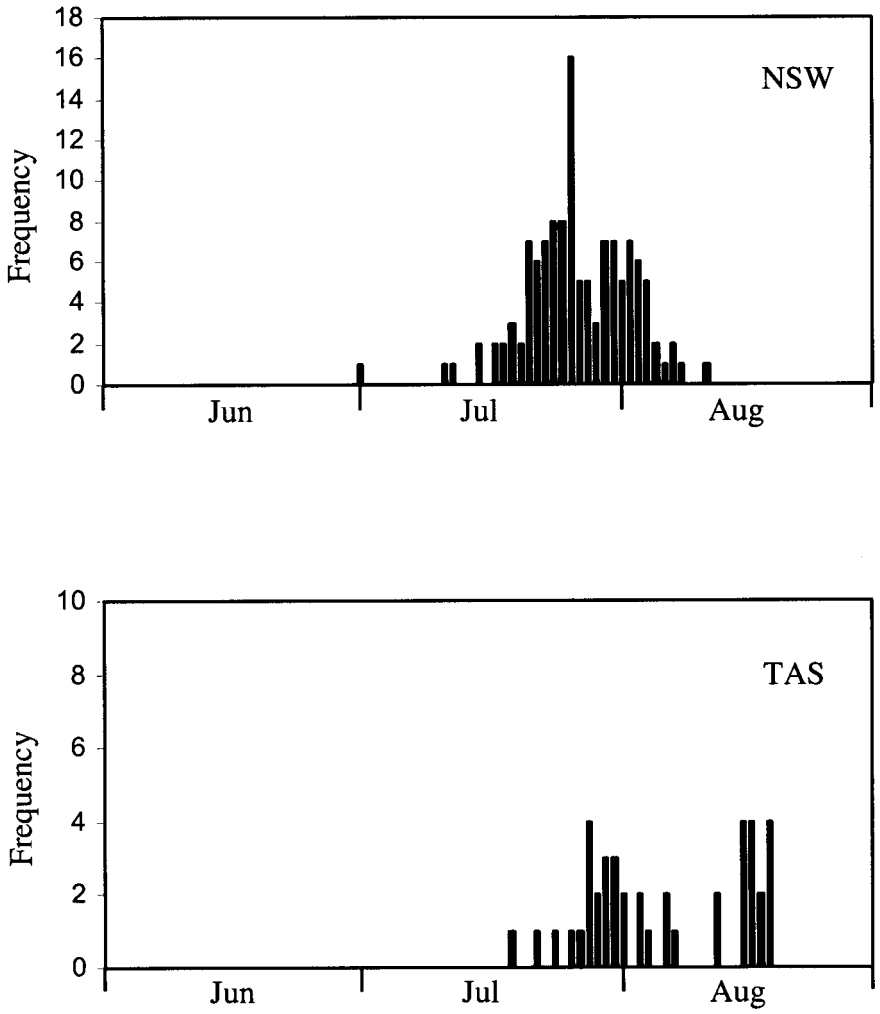


Figure 6. Back-calculated spawning dates for *Seriolella punctata* larvae in southern Australia.

Discussion

Our 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 (Knuckey and Sivakumaran 1999, Smith 1989). 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) which 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 1999). 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 (Mark Lewis and Cathy Bulman, CSIRO Marine Research, personal communication).

The location of large concentrations of small *S. brama* larvae off eastern Victoria/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 Victoria/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 (1999) 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 *Seriolella 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 for both 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, Victoria (F. J. Neira, unpublished data). 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 Suvakumaran (1999) 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 *Seriollela brama* and *S. punctata* in south-eastern Australia. Although spawning is widespread in both species, our data suggests that there are separate spawning grounds off the west coast of Tasmania and north-eastern Victoria/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 this larval data alone and will depend on the extent of mixing in sub-adult and adult fish as well as spawning site fidelity. However, our data is not inconsistent with this hypothesis. The pattern for *S. punctata* is less clear, but our data suggests a more continuous link between populations in south-eastern Australia compared to that of *S. brama*.

Acknowledgments

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Larval distribution of blue grenadier (*Macruronus novaezelandiae* Hector) in south-eastern Australia: Further evidence for a second spawning area

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Abstract

Small numbers of blue grenadier, *Macruronus novaezelandiae*, larvae were found in coastal waters off eastern Victoria and southern New South Wales in August 1993. This is the first record of larval blue grenadier from mainland Australian waters. It is considerably further north than previous records of larvae and remote from the single known spawning ground off western Tasmania. Larvae were aged between 17 and 36 days and were largely confined to an inshore northward flowing water mass. Back calculated spawning dates indicated that larvae from eastern Victoria/southern NSW were spawned earlier than larvae collected during the same period off western and southern Tasmania. Otolith increment widths were significantly wider in larvae caught in eastern Victoria/southern NSW suggesting that they experienced faster growth and development conditions than the Tasmanian larvae. Three-dimensional modelling of circulation and particle advection suggested that the source of eastern Victoria/southern NSW larvae was most likely eastern Bass Strait. These data suggest that there is a second, albeit limited, spawning area for blue grenadier in south-eastern Australia.

Introduction

The blue grenadier, *Macruronus novaezelandiae*, is a large, southern temperate gadoid that supports commercial trawl fisheries in both Australia and New Zealand (Gunn *et al*. 1989). In Australian waters, blue grenadier are thought to be a single stock which is genetically distinct from New Zealand stocks (Kailola *et al.* 1993). This is supported by (i) the existence of a single known spawning ground for the species off western Tasmania (Gunn *et al.* 1989), (ii) the presence of coastal currents able to transport larvae from west coast spawning grounds to nursery areas on the east coast of Tasmania (Thresher *et al.* 1989; Lyne and Thresher 1995), and (iii) a general pattern of genetic homogeneity (Milton and Shacklee 1987). However, some data regarding stock structure of blue grenadier in southern Australia are more ambiguous. Milton and Shacklee (1987) also noted that although there was no overall genetic pattern to suggest geographically distinct populations, there was a high degree of microspatial heterogeneity. They suggested that this may be due to the existence of two or more stocks of blue grenadier overlapping in time and space. A preliminary examination of long-lived endo-parasites by Lester (reported in Milton and Shacklee 1987) also did not support extensive movement of blue grenadier between east and west coasts of Tasmania.

Although only a single spawning ground for blue grenadier has been located in southern Australia, the occurrence of multiple spawning areas would be consistent with the species' behaviour in New Zealand. Blue grenadier (= hoki) spawn in two main areas in New Zealand, one off the Westland region of the South Island and also in Cook Strait (Murdoch and Chapman 1989; Livingston 1990; Zeldis *et al*. 1998). Blue grenadier from these two spawning areas are considered to be different stocks (Livingston and Schofield 1996) and this has led to the establishment of separate management zones between east and west coasts (Livingston 1990; Annala 1995).

A second spawning ground for blue grenadier in Australian waters was suggested by Thresher *et al.* (1988) based on their collection of small numbers of small larvae from north-east Tasmania. Subsequent intensive sampling, however, failed to locate any further concentrations of blue grenadier larvae either in that area or outside of Tasmanian waters, leading to the conclusion that if spawning did occur off north-east Tasmania, it was both minor and intermittent (Gunn *et al.* 1989). There are also persistent (but unconfirmed) reports of ripe blue grenadier in areas other than western Tasmanian waters (eg western Victoria and eastern Bass Strait) and juveniles (<20 cm) are sometimes reported from eastern Victoria and southern New South Wales (J. Garvey, Bureau of Resource Sciences, Canberra personal communication; CSIRO unpublished data). These data suggest that some level of spawning may occur in areas of southern Australia other than the west coast of Tasmania despite there being no reports by commercial fishers of blue grenadier aggregations outside of the western Tasmanian spawning ground.

We report herein, the first discovery of blue grenadier larvae from southern New South Wales and eastern Victoria. These data combined with the output from a new advection model, further supports the existence of a second spawning area for blue grenadier in eastern Bass Strait.

Materials and methods

Sampling procedures and laboratory details

Larvae were sorted from ichthyoplankton samples collected on 5 transects spaced roughly equidistantly between Bermagui (NSW) and Pt Hicks (Vic), a series of additional stations in shelf waters in the vicinity of Eden (NSW) and stations along the west and south coasts of Tasmania (Fig. 1). Sampling was designed to study the distribution of larvae of commercial fin-fish species in south eastern Australian waters (Bruce *et al*. 1996). Each transect consisted of 4 stations (nearshore, 40–50 m bottom depth), midshelf (100–120 m), shelf edge (180–200 m) and offshore (10 nautical miles seaward of the shelf edge). Sampling in Tasmanian waters targeted mid-shelf locations where previous sampling had recorded large numbers of blue grenadier larvae (Thresher *et al.* 1988). Samples were collected from *RV Southern Surveyor* between 16–25 August 1993. Stations were occupied on arrival, regardless of the time of day. At each station, temperature and salinity profiles were recorded using a Neil Brown CTD. Satellite images of sea surface temperature were obtained for the region during the period of sampling to determine the location of major oceanographic features.

Surface and oblique tows were taken at each station using bongo nets (70 cm dia., 500 µm mesh). Oblique tows were taken to a maximum depth of 200 m or to within 10 m of the bottom. Depth and tow profiles were monitored in real time using either a submersible data

logger attached to the frame of the bongo net (see Davis *et al.* (1990) for details) or a SCANMAR depth sensing unit. Surface nets were towed for 15 minutes from the side of the vessel. Volume filtered was calculated for each net using calibrated General Oceanics flowmeters. Numbers of larvae are standardised to 1000 m^3 volume filtered. For each tow, a sample from one side of the bongo was fixed in 10% formalin (for identification) and the other in 95% ethanol (the latter for ageing). Larvae were identified using the descriptions of Bruce (1988, 1998).

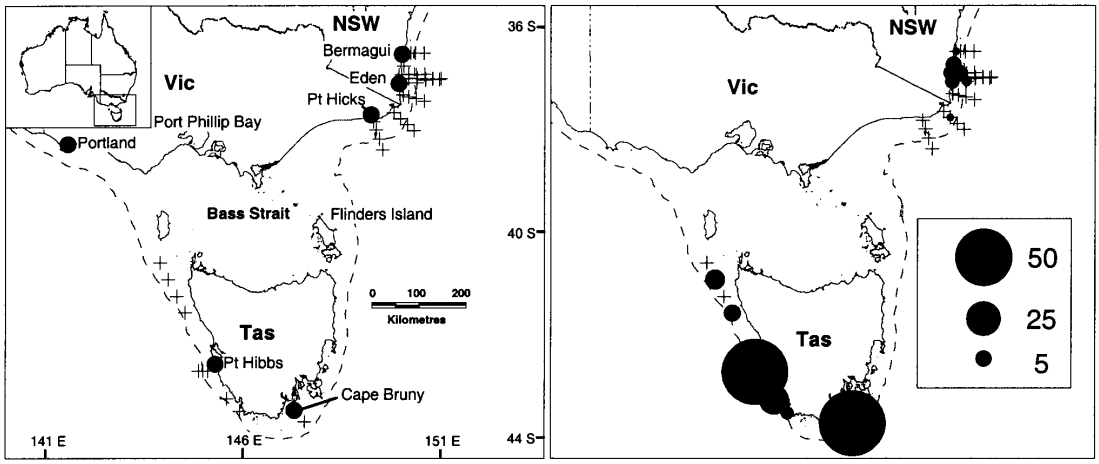


Figure 1: Sampling sites and the distribution of blue grenadier larvae in southeast Australia, August 1993. Larval abundance is expressed in numbers per 1000 m^3.

Otolith analyses

The total age (ie. increment number + 6) of blue grenadier larvae were determined from otolith microstructure following the procedures of Thresher *et al*. (1988). Growth rates were calculated using body length (Leis and Trnski 1989) and are uncorrected for shrinkage. Statistical analyses were done using Statview FPU 4.02.

Increment widths were measured on the lapilli of 20 specimens via a computer linked video system using the program Bony Parts (Brittnacher and Botsford 1994). Measurement protocols followed those of Thresher *et al.* (1988). Increment widths were compared between larvae collected from the eastern Victoria/southern NSW and Tasmanian waters. Ten larvae were selected from each area for analysis. Ages of larvae analysed ranged from 23–31 d (17–25 increments). Otoliths were read and processed "blind" without knowledge of the location of capture. Comparisons of increment widths were made between the same increment number rather than increments formed on the same day (i.e. the width of the first increment was compared across all specimens irrespective of total age, then the second and so on). This was necessary to avoid the confounding effects of ontogenetic differences in increment widths (Bruce *et al*. in press).

Advection modelling

Circulation of the waters surrounding Tasmania and the southeast mainland was simulated using the three-dimensional non-linear hydrodynamic model referred to as MECO (Model of Estuaries and Coastal Oceans). This model has previously been applied to a range of estuarine and shelf systems, the most thoroughly documented being Port Philip Bay in Victoria (Walker

1996, Walker 1999). It has also been used specifically for larval advection studies in the Gulf of Carpentaria (Condie *et al*. 1998).

Numerical solutions were computed on a latitude-longitude grid, which had been rotated through a false pole to cover a region from Albany in the west, across the Great Australian Bight and Tasmania, to a few hundred kilometres east of the Victorian coastline. There were 136 by 47 grid cells in the horizontal and 37 in the vertical. The horizontal resolution was approximately 20 km, while the vertical resolution expanded from 3 m near the surface to 200 m at the maximum model depth of 2000 m (interfaces at depths of 0, 3, 6, 9, 12, 15, 18, 22, 27, 33, 40, 48, 57, 67, 78, 90, 102, 116, 132, 150, 170, 195, 225, 260, 300, 350, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800 and 2000 m).

Since the larvae tend to be found in regions of significant mean flow and are advected for periods much longer than a tidal cycle, high frequency tidal motions were neglected. Model forcing was provided by seasonal climatologies of wind, sea level, temperature and salinity with the focus on sub-inertial motions. The use of climatologies rather than data from a specific time period, provides the subsurface temperature and salinity fields needed for open boundary forcing and interior data assimilation. The output of such a model provides "typical" seasonal flow patterns, while effectively removing any influences associated with interannual variability.

Climatological winds were computed by vector averaging winds from the National Center for Environmental Prediction (NCEP) reanalysis data set (Kalnay *et al.* 1996) over the 12 years from 1976 to 1997. This process gave 12 months of six hourly climatological fields with a spatial resolution of approximately 200 km. Sea level, temperature and salinity fields were taken directly from the Climatology of Australian Regional Seas (CARS) seasonal climatology, which resolves the annual and semiannual harmonics on a 0.5 degree geographical grid (CSIRO Marine Research unpublished). The flow was forced by climatological winds over the surface, while sea level, temperature and salinity were specified at the open boundaries. Within the interior, sea level, temperature and salinity climatologies were assimilated through relaxation of the model values toward the climatological values. The relaxation time was set at 20 days for each field. The climatological fields were also used to initialize the model, which was first run for 20 days to allow transient effects associated with the initialization to dissipate.

Blue grenadier larvae were represented in the model by neutrally buoyant particles, which were advected by the flow while also being dispersed through a random walk process. The entire model domain to a depth of 300 m was randomly seeded with 500,000 particles. Each particle was tracked individually, so that particle movements could be traced back in time. This allowed spawning sites to be estimated from the observed location of capture and age of the larvae. No attempt was made to model the period between spawning at depth and eggs/larvae first reaching the surface mixed layer, which we estimate may take 1-2 days.

Results

Larval distribution

Blue grenadier larvae were most commonly collected off the west and south coast of Tasmania between Pt Hibbs and Cape Bruny (Figure 1), where sampling at similar times of the year had previously recorded large numbers of larvae (Gunn *et al.* 1989).

Small numbers of larvae were also collected off southern NSW and eastern Victoria (referred to below as the mainland). Larvae recorded within this area were located at either inshore or mid-shelf stations, the single exception being a larva collected at the shelf edge off Eden. Blue grenadier larvae were largely confined to a cool water region bounded by a marked frontal feature located on the shelf. The structure of plumes associated with this frontal feature (identified from satellite images of sea surface temperature, Figure 2) suggested that this cooler water was part of an inshore northerly flow extending from eastern Bass Strait to just north of the Bermagui transect. Seaward of the frontal zone was a southerly flowing warm water mass of East Australian Current origin extending as far south as central Tasmania.

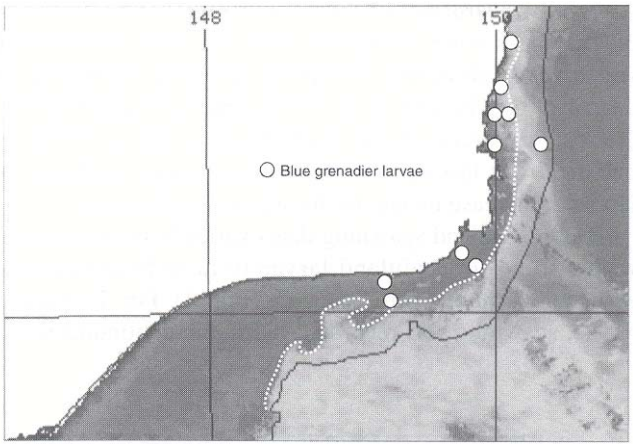


Figure 2: Satellite image of sea surface temperature, August 1993. White dotted line denotes approximate position of frontal boundary between cool inshore northward flowing water mass and warm East Australian Current derived water.

Aging

Otolith microstructure was similar to that described for blue grenadier larvae by Thresher *et al*. (1988). Blue grenadier larvae collected from western and southern Tasmanian coast ranged from 3.1 - 8.6 mm BL and 9 - 31 days (total age). Larvae from the mainland were, on average, both larger and older than those from Tasmanian waters (5.3 - 14.5 mm and 17 - 36 days respectively - Figure 3). Age and size structure of larvae on the west and south coast of Tasmania were consistent with the well documented southward advection of larvae around Tasmania as described by Thresher *et al*. (1988) and Lyne and Thresher (1995). A pattern of age distribution in larvae from the mainland was less clear, although there was a tendency for larvae to increase in age northwards along the coast.

Back calculated spawning dates varied between regions with a trend for mainland larvae to have been spawned earlier than those from Tasmania (Figure 4). For Tasmanian larvae, spawning was recorded essentially continuously (21 d over a 22 d period) from 24 June to 15

July, with no defined peak in spawning activity. Back calculated spawning dates from mainland larvae were recorded on 14 d over a 22 d period between 13 June and 4 July.

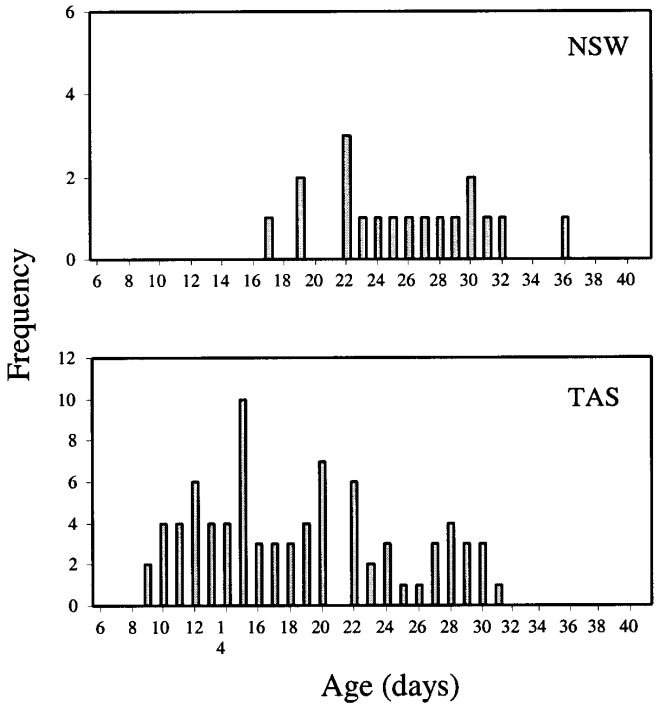


Figure 3: Age distribution of blue grenadier larvae by area.

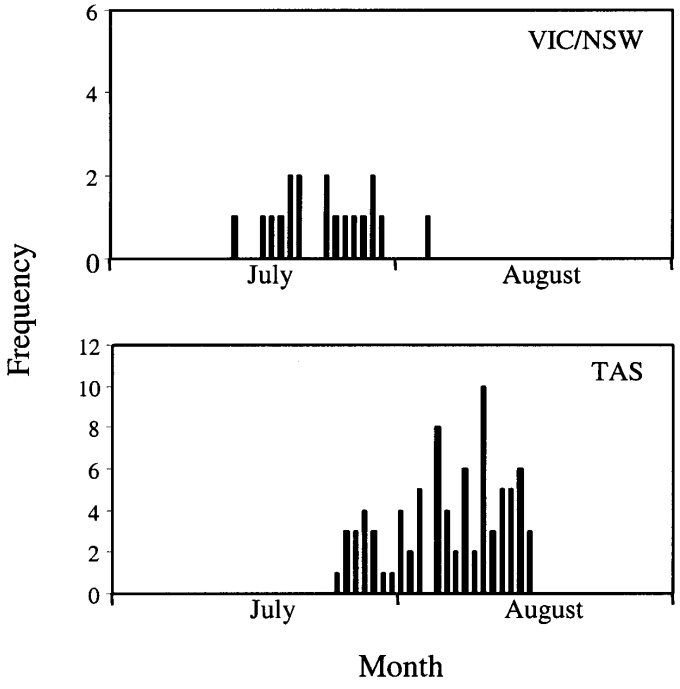


Figure 4: Back calculated spawning dates of blue grenadier larvae by area.

Widths of the first 7–9 increments were similar in larvae from both areas, but rapidly diverged thereafter (Figure 5). Subsequent increment widths were significantly larger in larvae from the mainland (paired *t*-test: t=8.749, $p<0.0001$). Larvae from both areas had the same pattern of

increasing increment widths up until approximately increment 16, with widths then oscillated around means of approximately 3.6 µm (mainland) and 2.8 µm (Tasmania) respectively.

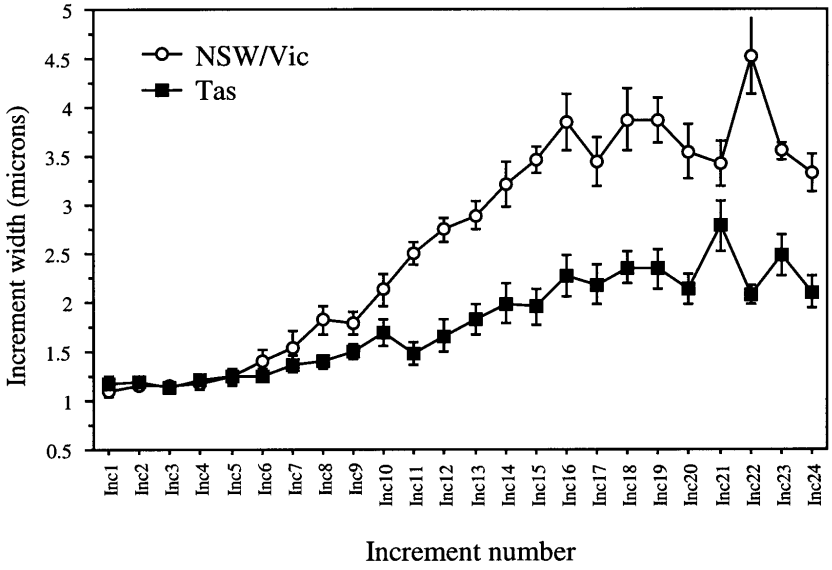


Figure 5: Increment widths of blue grenadier larvae by area. Bars = 1 standard deviation.

Advection modelling

Model flows during the blue grenadier spawning period reveal strong coastal currents extending along the western flank of Bass Strait and around southern and eastern Tasmania (Figure 6). This flow, known as the Zeehan Current (Baines *et al.* 1983), is a persistent feature on the west coast, but it's effects are more seasonal in the east due to the encroachment of the East Australian Current during summer. The model currents off the west coast are consistent with long term current meter mooring data with average current speeds of 0.3 m s^{-1} (Lyne and Thresher 1995). The recirculating patterns further offshore to the west are also evident in satellite drifter tracks (Cresswell, in press). After the model current passes around the south coast, it separates from the northeast coast of Tasmania and moves eastward towards New Zealand (Figure 6). Ocean drifter tracks confirm this separation, although it tends to occur on the central east coast, with current speeds rarely exceeding 0.3 ms^{-1} (Cresswell, *in press*).

The model currents within Bass Strait and along the southeastern mainland shelf are generally much weaker than the Zeehan Current flows. Most of the eastward transport is initially concentrated in the southern half of the strait, before crossing to the north and exiting along the southeast mainland shelf. This current distribution is very similar to that obtained by Middleton and Black (1994) using a depth-averaged model with realistic wind and sea level forcing and is consistent with satellite images of seas surface temperature for this time of year. The flow in offshore waters immediately east of Bass Strait is dominated by an anticlockwise circulation in the model. Further offshore there is weak southward flow associated with the East Australian Current, whose core is much further to the north at this time of the year. These model outputs are also consistent with circulation features observed at this time of year.

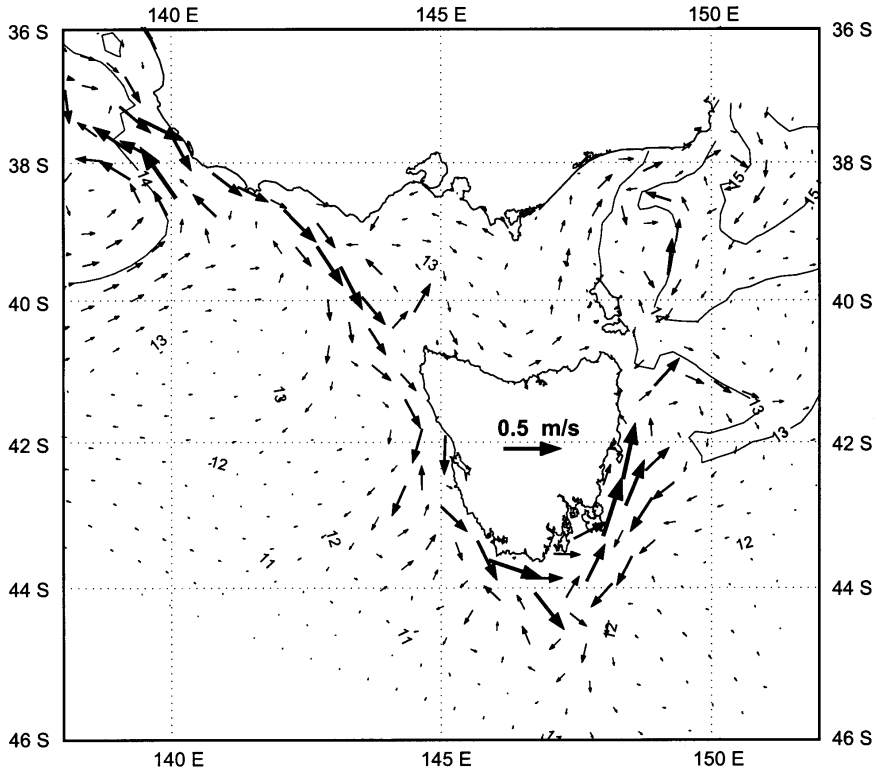


Figure 6: Model current vectors and temperature contours (°C) at a depth of 20 m on the 20th of July.

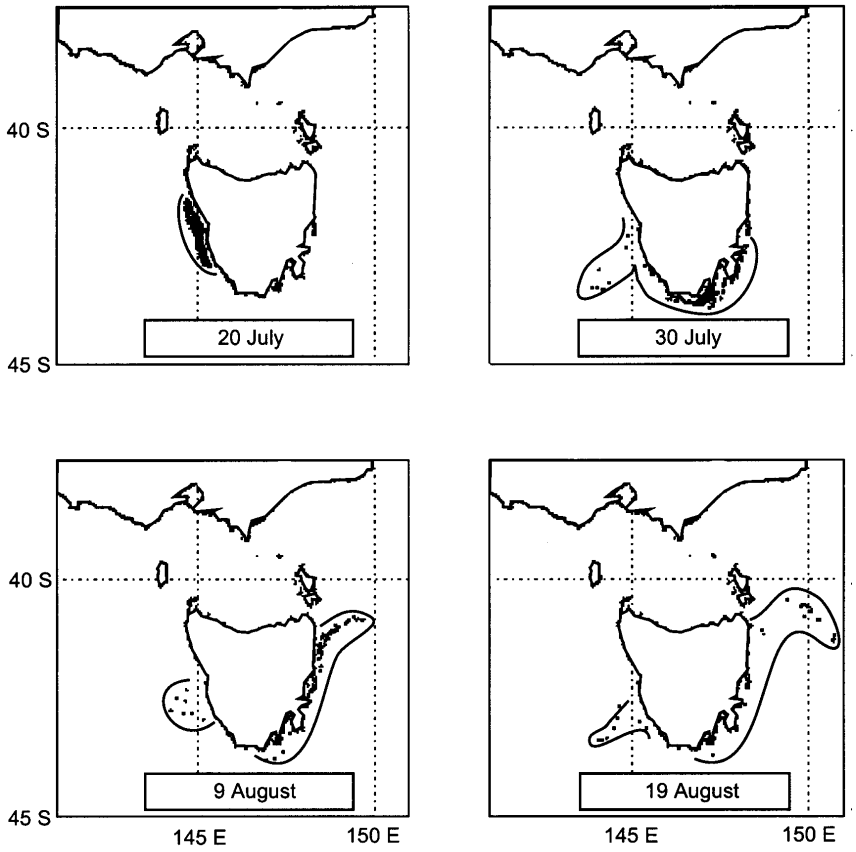
The potential for larvae from the known spawning grounds off western Tasmania to reach the southeast region was first tested by tracking particles which were over these grounds at the mean spawning date (20 July). Particles starting within the top 100 m of this region were tracked for a month and their dispersion is shown at 10 day intervals (Figure 7). A one month period was selected because it covered the ages of most larvae collected from the south east region and thus the time period required for transport to that area. Particles from the northern end of the spawning ground moved up to 100 km offshore to the southwest, before most returned to the west coast shelf waters. However, the majority of particles followed the strong coastal current around southern Tasmania, then tracked north along the east coast before turning offshore into the Tasman Sea. There was no evidence of particles from the Tasmanian west coast approaching the mainland region where blue grenadier larvae were caught.

A more systematic approach to identifying potential spawning grounds is to identify particles approximately coincident in time and location with the capture of each larva and track them back in time to the spawning date estimated from the otolith analysis. The closest 20 particles to each blue grenadier larva caught in mainland waters were identified and tracked back in time to the back-calculated spawning date. The region defined by this cluster of particles at the spawning date then provided an estimate of the potential spawning location. The particle clusters derived from all of the mainland larval catches are shown in Figure 8. The potential spawning region forms a tight band along the southeastern Victorian shelf, then spreads south across eastern Bass Strait. The complex flow patterns east of Bass Strait also entrain a smaller number of particles from further offshore over the continental slope and deep ocean.

The points in Figure 8 are not necessarily representative of actual spawning sites. Blue grenadier are known to spawn over the upper slope in 400 to 600 m of water. This is followed by a short period (estimated by us to be about 1-2 days) in which the eggs and young larvae

rise up into the surface mixed layer (presumably due to their positive buoyancy) where they usually first appear over the shelf. This initial vertical migration is not represented in the model. However, the horizontal advection during this period is expected to be small and primarily from the upper slope onto the shelf. Figure 8 therefore suggests that larvae caught off the mainland are consistent with either spawning on the nearby slope, or spawning further south on the slopes of eastern Bass Strait.

Figure 7: Modeled dispersion of particles seeded off the west coast of Tasmania on the 20th



of July. Lines denote the range of particle clouds and their distribution is shown 10, 20 and 30 days after seeding.

Discussion

Our discovery of blue grenadier larvae off the southern NSW and eastern Victoria supports the hypothesis of Thresher *et al.* (1988) that the species may have more than one spawning ground in southern Australia. Their study reported finding small numbers of blue grenadier larvae east of Flinders Island, however they failed to record any blue grenadier larvae off southern NSW or eastern Victoria. The survey by Thresher *et al*. (1988) in these latter areas was restricted to the shelf edge which, based on our observations, would fail to sample the cooler inshore water where we found larvae. Examination of satellite records (1988–1994) indicates that this cooler inshore water mass is a consistent feature of the inner shelf region during the June–August period.

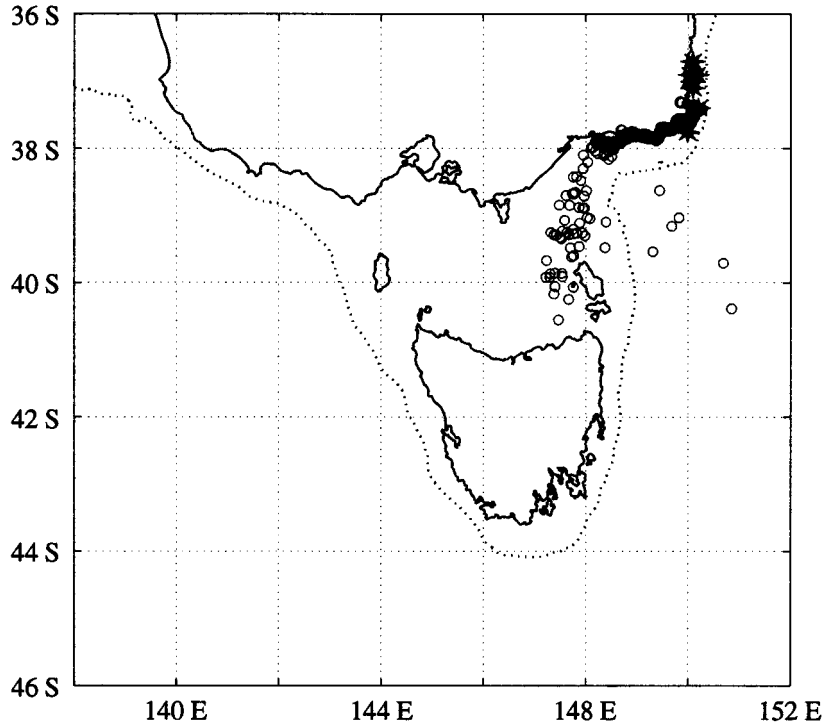


Figure 8: Locations of particles approximately coincident in space and time with the capture of blue grenadier larvae, after tracking back in time to the spawning date (hollow circles). The capture locations of blue grenadier larvae used in the analyses (asterisk) and 500 m depth contour (dotted line) are also shown.

Comparison of back calculated spawning dates for larvae from both Tasmania and the mainland indicate a trend towards earlier spawning in the latter. A pattern of earlier spawning in larvae from the mainland compared to Tasmanian waters has been reported for several other species (Bruce *et al*. in press, Bruce *et al*. – this volume). However, both spawning date ranges fall well within the spawning period previously documented for blue grenadier on western Tasmanian grounds (Gunn *et al.* 1989). Thus, if the mainland larvae originated from a second spawning ground, it is likely that this spawning is roughly simultaneous with western Tasmania. Simultaneous spawning at different spawning grounds is also a feature of blue grenadier populations in New Zealand (Livingston, 1990).

There are three potential scenarios regarding the source of the mainland blue grenadier larvae. First, larvae may have originated from the area where they were caught. Second, larvae may have originated from the well documented western Tasmanian spawning grounds and advected from there to the sampling area. Third, larvae may have originated from a second, as yet unidentified, spawning area separate to either of the above.

The absence of either eggs or small larvae< 10 d of age, the location of larvae within an inshore northward flowing water mass, and the pattern of increasing age with distance north along the coast, all suggest that the mainland larvae were not from local spawning but from a more southerly source. Only a single larva was captured outside the cool inshore water. This specimen, from near the shelf break off Eden, was the largest and oldest (14.5 mm, 36 d) collected and most likely had become entrained in the southward flowing East Australian Current after originally being part of the northward flow.

The similarity of increment widths between specimens from Tasmania and the mainland for the first 6 to 10 days post first feeding, suggests that (i) larvae originated from the same locality and subsequently moved into separate water masses, (ii) larvae were spawned in different areas but experienced similar initial growth conditions or (iii) that increment widths are initially ontogenetically determined and poorly reflect growth characteristics for the first 6–10 days post-first feeding. Our data cannot distinguish between these possibilities. However, increment widths in other species have been shown to correlate well with somatic growth (Mugiya and Oka 1991, Fowler and Short 1996) and have been used to identify larvae of different sources within south-eastern Australia (Bruce *et al*. in press).

The normal advection pathway for blue grenadier larvae from western Tasmania spawning grounds is southwards to nursery areas on the south and east coasts of Tasmania (Thresher *et al.* 1988). The mean rate of advection previously observed (0.1 – 0.2 ms^{-1}) falls within the range of our advection model (0.1 – 0.5 ms^{-1}) and is consistent with previous empirical and modelled longshore currents (Lyne and Thresher, 1995). This implies a largely passive transport mechanism. Indeed our observations, based on ages of larvae collected during sampling of the west and south coasts of Tasmania, support such southerly transport. However, the advection rate required to transport larvae via this southerly route around Tasmania and then north to southern NSW (a distance of 1050–1250 km) in 17 - 36 days is 0.5 – 0.7 m s^{-1}. This is well in excess of that previously recorded and is not reflected in the model particle advection rates (Figure 7). This suggests that if the mainland larvae had originated from western Tasmania then they could not have been transported via the normal southern Tasmanian route.

The shortest distance between western Tasmania and southern NSW is through Bass Strait. Recent ichthyoplankton sampling in Bass Strait, however, failed to locate any blue grenadier larvae (F. J. Neira, Australian Maritime College, Launceston, personal communication). Given the age of blue grenadier larvae collected from the mainland and the distance from the western Tasmanian spawning grounds (650–850 km), a mean advection rate of 0.3 – 0.4 ms^{-1} would be required to transport larvae to the southeast region. Thresher *et al.* (1988) did note that a small number of drift cards released over west coast spawning grounds tracked north and were returned from King Island, western Victoria and Western Port Bay. One card was also returned from southeast mainland Australia, although this was after several months and it was unclear whether it had followed a path around southern Tasmania or through Bass Strait.

Winds are a major influence on the circulation in Bass Strait and during the month leading up to the larval sampling these were very similar to the climatological fields used to force the advection model (5 – 8 ms^{-1} from west-north-west). The circulation within Bass Strait generated by the model at this time of the year consisted of a meandering current stretching from northwest Tasmania across to the mainland where the sampling occurred (Fig. 6). Very similar flow patterns have also been obtained with a depth-averaged model with real-time wind data and sea level forcing (Middleton and Black 1994). However, in both models the current speeds are well below those required to carry larvae from western Tasmania to the mainland within the age period of the larvae. When particles were tracked in our model from northwestern Tasmania, they were carried northeast into Bass Strait, but after 30 days had only moved approximately half way across the Strait.

There are unconfirmed observations, by commercial fishers, of ripe blue grenadier from two areas outside of the west Tasmanian spawning ground - south of Portland (western Victoria) and eastern Bass Strait. These areas provide possible sources for the mainland larvae. Using

similar calculations to the above, advection rates of 0.3–0.4 ms^{-1} would be required to transport larvae the 750-950 km from Portland to our sampling area, again well exceeding observed and modelled rates.

Advection rates required to transport larvae from eastern Bass Strait are far more realistic. The advection modelling, combined with the observed continuity of water properties (from SST), suggests that the mainland larvae were likely to originate somewhere along the slope between the sampling region and eastern Bass Strait/Flinders Island. The latter is the same region where Thresher *et al*. (1988) reported small numbers of blue grenadier larvae and thus our data further supports their conclusions regarding spawning in the area. Neither the annual regularity nor the exact location of this spawning event can yet be determined. Juvenile blue grenadier (<30 cm) have been recorded, in some years, from outer shelf and slope waters of southern NSW and eastern Victoria (J. Garvey Bureau of Resource Sciences, Canberra, personal communication) suggesting either irregular spawning in, or irregular recruitment to, the area.

In summary, our data further support the presence of a second spawning area for blue grenadier in southeastern Australia. Based on the age of larvae and modelled advection patterns, this spawning area is most likely located off eastern Bass Strait as originally hypothesised by Thresher *et al.* (1988). The exact location, annual regularity and magnitude of this spawning event, and whether spawning in this area may represent a separate stock or represents a satellite spawning ground for adults that do not always migrate to the western Tasmanian grounds, are all yet to be determined. That no significant aggregations of blue grenadier have been reported from eastern Bass Strait by commercial fishers suggests that spawning in the area is of a minor scale relative to the western Tasmanian grounds. These questions provide potential areas for future research.

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