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Estimating the spawning fraction of Blue Mackerel off eastern Australia:

Stage 1: Developing sampling methods and identifying sampling locations.

Report to the Australian Fisheries Management Authority

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Executive Summary

Background and Need

Blue Mackerel (*Scomber australasicus*) is a target species of the Commonwealth Small Pelagic Fishery (SPF). Catches from the Eastern sub-area reached 10,050 tonnes in 2021/22, which is 87% of the Total Allowable Catch (TAC) of 11,440 tonnes. Estimates of spawning biomass obtained using the Daily Egg Production Method (DEPM) are used to set TACs. Limited understanding of spawning fraction (i.e., the proportion of females that spawn each night during the spawning season) off eastern Australia is a major contributor to uncertainty in estimates of spawning biomass. In December 2020, the SPF Resource Assessment Group (RAG) identified that robust estimates of the spawning fraction of Blue Mackerel off eastern Australia were needed to provide more robust and accurate estimates of spawning biomass and ensure confidence in the setting of TACs.

Objectives

The objectives of this project are to:

1. Establish reliable methods for sampling large adult Blue Mackerel in offshore waters of the east coast of Australia.
2. Identify several locations (at different latitudes) where large adult Blue Mackerel can be sampled during the spawning season.
3. Develop preliminary estimates of the spawning fraction (and other adult reproductive parameters) of Blue Mackerel off eastern Australia.
4. Investigate whether, or not, large Blue Mackerel spawn off southern NSW during summer. (Additional objective added at request of industry.)

Methods

*S*ampling was undertaken during 2022-23 between Coffs Harbour and Eden using a variety of approaches, including catch sampling from commercial mid-water trawlers and purse-seine vessels, and targeted fishery-independent sampling from commercial line-fishing vessels. Sampling focused on the latter half of the spawning season from September-October 2022 at known spawning locations such as Coffs Harbour and Port Stephens. However, sampling was also undertaken off southern NSW from September 2022 to March 2023 to determine if Blue Mackerel also spawn in this region. A variety of line fishing techniques were trialled. Standard techniques (e.g., Ward et al.

2009) were used to macroscopically stage ovaries (Stage I-V), microscopically stage oocytes (1-5), determine the presence/absence of post-ovulatory follicles (POFs) and estimate spawning fraction.

Results, Discussion and Recommendations for Stage 2

Methods for sampling large adult Blue Mackerel

Blue Mackerel above the size at maturity were collected by mid-water trawling, purse-seining and line-fishing. However, only samples taken by purse-seining off Wollongong and line-fishing off Coffs Harbour and Port Stephens included mature fish. The most effective baits for catching large mature Blue Mackerel varied among locations and fishing trips and was best determined at each site by trial and error. However, the consistently most efficient baits were fish-strips (~4 cm x 1 cm x 1 cm).

Sampling locations and timing of spawning

Mature females were collected from Coffs Harbour, Port Stephens and Wollongong during September and October 2022. POFs indicative of recent spawning were abundant in samples collected from Port Stephens in early October (present in ~24.85% of females) but rare in samples collected from Coffs Harbour (0.87%) and Wollongong (3.26%). Results are consistent with the current understanding that the main spawning season off eastern Australia extends from July to October and the main spawning area extends from Sandy Cape to about Wollongong. No evidence was collected to suggest that Blue Mackerel spawning occurs south of Wollongong.

Preliminary estimates of spawning fraction

Based on the assumption that POFs persist for two days, the mean spawning fraction at Port Stephens in October was 0.124, which is similar to the overall estimate for South Australia (i.e., 0.135) that was obtained using the same assumption (Ward et al. 2009). Determining how long POFs persist in the ovaries of Blue Mackerel off eastern Australia is a high priority.

Recommendations for Stage 2

Stage 2 of this study should involve sampling multiple locations throughout the main spawning area and spawning season using both commercial purse-seine vessels and targeted line-fishing. Several additional sampling sites should be established. Conducting around the clock sampling over multiple days to determine how long POFs persist in ovaries is a high priority.

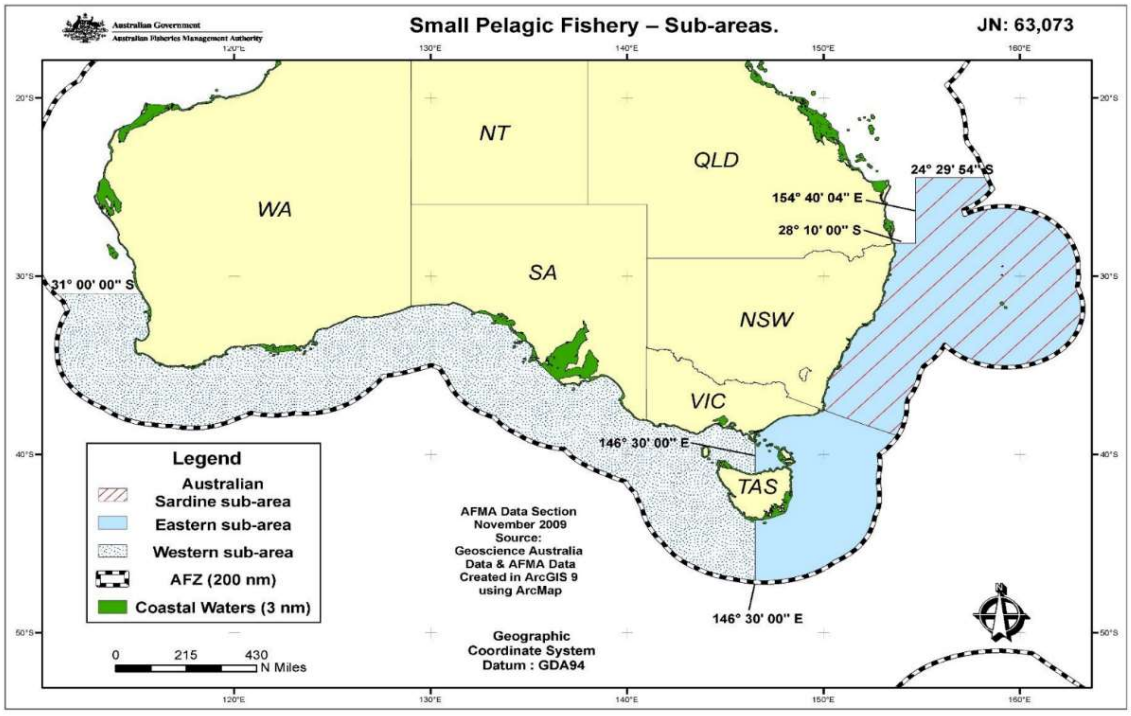
Keywords: Daily Egg production Method, pelagic fishes, *Scomber australasicus*

1 Introduction

1.1 Background

Blue Mackerel (*Scomber australasicus*) is a key target species of the mid-water trawl sector of the Commonwealth Small Pelagic Fishery (SPF). Catches of Blue Mackerel from the Eastern sub-area of the SPF (Figure 1) have grown rapidly since 2016 and reached 10,050 tonnes in 2021/22, which is over 87% of the Total Allowable Catch (TAC) of 11,440 tonnes (e.g. Noriega et al. 2022). Most of the recent catch has been taken from three catch grids off southern New South Wales, near Ulladulla and Eden (Figure 2). Blue Mackerel is also a target species within the NSW Ocean Hauling Purse-Seine Fishery, currently managed under an annual TAC of 758 t.

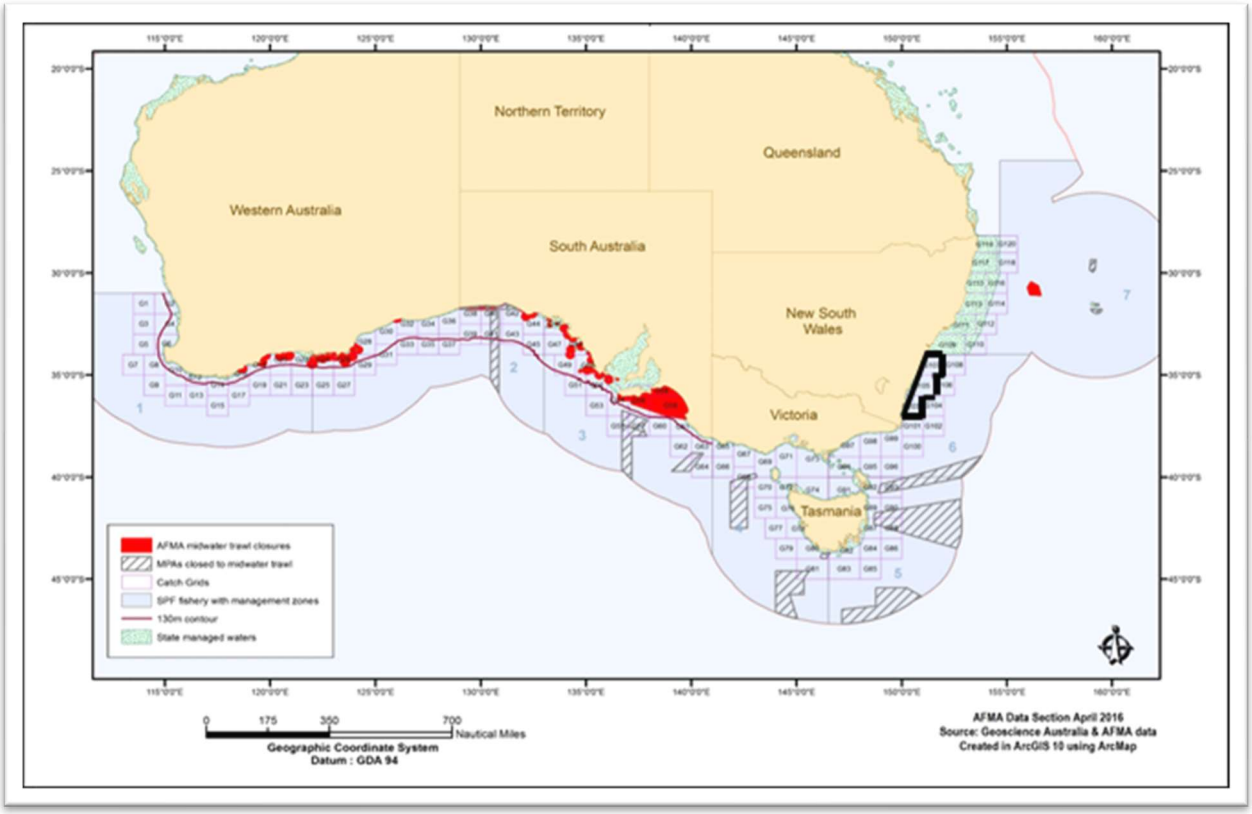
Figure 1.1 Sub-areas of the Commonwealth Small Pelagic Fishery. Source: SPF-Harvest-Strategy_April-2017_FINAL.pdf (afma.gov.au))



Blue Mackerel, also known as Slimy Mackerel, is a key target species for recreational fishers off eastern Australia (e.g., Murphy et al 2020), especially game fishers, who consider "slimies" to be the premier bait for a range of large pelagic fishes, including tunas and marlin. Recreational fishers have expressed concerns about the ecological sustainability of commercial fishing for Blue Mackerel and

potential impacts of disturbance of bait schools on the availability of game fish in key recreational fishing hotspot (spf_panel_meeting_minutes_17_january_2019_final.pdf(afma.gov.au)).

Figure 1.2. Areas open and closed to fishing in the mid-water trawl sector of the Small Pelagic Fishery. The catch grids (G101, G103 and G105) where most catches have been taken are marked in black. (Source: Small Pelagic Fishery | Australian Fisheries Management Authority (afma.gov.au))



Like other species in the SPF (AFMA 2008, 2009), the primary source of information used to determine Recommended Biological Catches (RBCs) and set TACs for Blue Mackerel are estimates of spawning biomass obtained using the Daily Egg Production Method (DEPM, Parker 1980, Lasker 1985, AFMA 2008). The premise of the DEPM is that spawning biomass can be estimated by dividing the mean number of pelagic eggs produced per day throughout the spawning area (i.e., total daily egg production) by the mean number of eggs produced per unit mass of adult fish (i.e., mean daily fecundity) (Parker 1980, Lasker, 1985). Total daily egg production is calculated from estimates of mean daily egg production and spawning area obtained from broad-scale plankton surveys. Mean daily fecundity is calculated from samples of adult fish collected during the spawning season.

Ward (2021 a, b) showed that mean daily fecundity can be calculated most precisely from three adult parameters (Parker 1980), i.e. sex ratio, relative fecundity and spawning fraction, rather than

the four parameters identified by Lasker (1985). Under this formulation, variation in mean daily fecundity is driven almost entirely by variation in spawning fraction because sex ratio (by weight) is usually close to 0.5 (1:1 males versus females by number) and relative fecundity is virtually constant across a wide range of female weights because the relationship between female weight and batch fecundity is linear. Ward (2021 a, b) also showed that for Australian Sardine (and perhaps Blue Mackerel) spawning fraction can be relatively stable among years in comparison to sampling error and may not need to be estimated annually. This finding has the potential to substantially reduce survey costs by potentially eliminating and at least reducing the need for ongoing adult sampling once reliable estimates of spawning fraction are established.

The DEPM has been applied to Blue Mackerel in the East sub-area three times (Ward et al. 2009, 2015, 2021b). The initial application of the method in 2003 and 2004 suggested that the spawning biomass was at least 30,000 t (Ward et al. 2009). The estimates of spawning biomass obtained in 2014 and 2019 were ~83,300 (95% CI = 35,100–165,000 t) and 88,265 t (95% CI = 33,320–143,209), respectively (Ward et al. 2015, 2021b). The authors of all these studies suggested that the results should be interpreted with caution because of the lack of data available to estimate key adult reproductive parameters. The similarity of the estimates of spawning biomass obtained in 2014 and 2019 reflects, at least in part, the fact that both estimates were based on adult reproductive data (especially spawning fraction) obtained from samples collected off South Australia. The use of the estimate of spawning fraction obtained from these samples (i.e., 0.135 (0.102–0.167 95% CI)) was justified by its relative similarity to the mean spawning fractions of 0.08 and 0.169 reported for a closely related species, i.e., Chub Mackerel (*Scomber japonicus*) off Japan (Shiraishi et al. 2009) and California (Dickerson et al. 1992), respectively. There was also no alternative but to use the South Australian data because no other estimates of spawning fraction are available of Blue Mackerel.

The lack of information available on the spawning fraction of Blue Mackerel off eastern Australia is important because uncertainty in this parameter has a strong effect on the reliability of estimates of spawning biomass obtained using the DEPM, especially for species with low spawning fractions (e.g., Stratoudakis et al. 2006). Sensitivity analyses presented in Ward et al. (2021a) showed that varying spawning fraction across the range of values that have been reported for Chub Mackerel (*Scomber japonicus*) off Japan (i.e., 0.087 to 0.386) resulted in a more than threefold variation in estimates of spawning biomass, i.e., from approximately 140,000 t to 40,000 t. If the actual

spawning fraction of Blue Mackerel off eastern Australia during the previous surveys was higher than the assumed value of 0.135, then the spawning biomass would have been lower than the estimates provided by Ward et al. (2015, 2021b), and vice versa.

The lack of information available on the reproductive biology of Blue Mackerel off eastern Australia reflects the limitations of previous sampling programs. Blue Mackerel in Australian waters can attain lengths up to 650 mm (Hutchins and Swainston 1986) and ages of 8+ years (Stevens et al. 1984; Ward and Grammer 2016). Blue Mackerel in New Zealand have been reported to attain more than 20 years of age (Marriott and Manning 2011). However, samples collected from the east coast of Australia have been obtained mainly from vessels operating in inshore waters and dominated by small (<300 mm FL, Ward et al. 2015, 2021), young (≤2 years old, Stewart and Ferrell 2001; Ward and Rogers 2007) fish. Larger, older fish may occur in offshore waters where only a few specimens have been collected through opportunistic sampling by commercial fishers (John Stewart, NSW DPI, unpublished data). The lack of data available from larger, older fish constrains our knowledge of the growth rates, longevity, reproductive biology and spawning biomass of Blue Mackerel off eastern Australia.

Samples collected from inshore waters off New South Wales by Ward et al. (2021) included female fish that were around the mean size at maturity in waters off South Australia (i.e., ~287 mm, Rogers et al 2009) and macroscopically mature (i.e., ovaries with yolked oocytes), but their ovaries displayed no histological signs of recent spawning (i.e., post-ovulatory follicles, POFs), so the spawning fraction was zero. Low spawning rates inshore and high spawning rates offshore have been observed in other species in the genus *Scomber*. For example, the spawning fraction of the western stock of Atlantic Mackerel (*Scomber scombrus*) has been shown to vary from 0.1 in inshore waters to 1.0 offshore (Priede et al. 1995). The spawning rates of *Scomber* species also vary with latitude. For example, the spawning fraction of Atlantic Mackerel varies from 0.18 in the (cool) north, through 0.34 in the central region to 0.62 in the (warmer) south (Priede and Watson 1993). This suggests that the spawning fraction of Blue Mackerel off eastern Australia (25-34^{o}S) could be higher than off South Australia (32-36^{o}S).

Estimates of spawning fraction are strongly influenced by assumptions about how long POFs persist in ovaries (e.g., Ganias 2012). The estimate of spawning fraction provided by Ward et al. (2009) was based on the assumption that POFs persist in ovaries of Blue Mackerel for two days. However, in

some scombrids, such as Skipjack Tuna, *Katsuwonus pelamis*, (Hunter et al., 1986) and Yellowfin Tuna*, Thunnus albacares*, (Schaefer, 1996), POFs can degenerate in one day or less.

A dedicated adult sampling program is required to investigate spatio-temporal variability in the spawning fraction of Blue Mackerel off eastern Australia. However, a reliable method(s) for sampling adult Blue Mackerel in offshore waters of the east coast has not been established. Locations where actively spawning adults can be collected reliably have not been identified. The aim of this initial study (Stage 1) is to address these limitations. If sampling methods are established and sampling locations are identified, and if larger samples are required, a follow up project (Stage 2) will be conducted to evaluate whether or not the spawning fraction of Blue Mackerel of eastern Australia is similar to that reported for South Australia (i.e. 0.135) and if adult sampling programs need to be undertaken each time that the DEPM is applied to Blue Mackerel off eastern Australia.

1.2 Need

At its meeting in December 2020, the SPF RAG highlighted the need "to collect adult Blue Mackerel in order to obtain parameters used to calculate stock biomass" and listed this a high research priority (July 2021 SPF Resource Assessment Group Meeting 03). The RAG considered that this project was needed to provide a more robust and accurate stock assessment and ensure confidence in setting of TACs for Blue Mackerel East.

Historically, most of the Blue Mackerel that have been taken in the mid-water trawling operation off southern New South Wales have predominately been below the size at maturity (e.g., Grammer et al. 2022). However, large (>40 cm FL) Blue Mackerel have been recently caught by mid-water trawlers operating in this region during summer (Figure 1.3). At the request of industry, the focus of this project was expanded to include an investigation of whether, or not, Blue Mackerel spawn in southern New South Wales during summer.

1.3 Objectives

The objectives of this project are to:

1. Establish a reliable method(s) for sampling large adult Blue Mackerel in offshore waters of the east coast of Australia.

2. Identify several locations (at different latitudes) where large adult Blue Mackerel can be sampled during the spawning season.
3. Develop preliminary estimates of the spawning fraction (and other adult reproductive parameters) of Blue Mackerel off eastern Australia.
4. Investigate whether, or not, large Blue Mackerel spawn off southern NSW during summer. (Additional objective added at request of industry.)

Figure 1.3. Large Blue Mackerel taken off Eden, southern New South Wales during summer 2021. Source: Jeffrey Afflick, Proteins Australia

We use the results of this project (i.e., Stage 1) to develop recommendations to inform the design of Stage 2 "*Spatio-temporal variability in spawning patterns and implications for future DEPM surveys*" which was approved by the AFMA Research Committee in February 2023 (Appendix 1) and will be conducted from 1 July 2023 to 24 May 2025. Data collected in the Stage 1 will also be incorporated into the final report for Stage 2.

2 Methods

2.1 Adult sampling

Sampling of adult Blue Mackerel was undertaken during 2022-23 between Coffs Harbour and Eden using a variety of approaches, including catch sampling from commercial mid-water trawlers and purse-seine vessels, and targeted sampling from commercial line fishing vessels. Sampling included the peak spawning season in August-September (Rogers et al. 2009) and focused on known spawning grounds such as Coffs Harbour (e.g., Ward et al. 2009, 2015, 2021). However, due to the late start of the project sampling was also conducted off Port Stephens in October. To address the question of whether, or not, spawning occurs off southern NSW during summer, samples were also collected from Wollongong, Narooma, Ulladulla and Eden where spawning had not previously been recorded.

Sampling Program

The sampling program consisted of three targeted field trips.

Field trip 1 was undertaken from 12 September to 30 October 2022 between Eden and Coffs Harbour. Samples were collected from a mid-water trawler operating off Eden and line fishing vessels operating out of Coffs Harbour and Port Stephens (Figure 2.1).

Field trip 2 was undertaken between 6 December and 12 December 2022. Sampling was undertaken from both a commercial mid-water trawler and line-fishing vessel operating off Eden (Figure 2.1).

Field trip 3 was undertaken between 16 January to 25 January 2023, Samples were collected from a mid-water trawler operating off Eden and a line fishing vessel off Narooma (Figure 2.1).

Between August and November samples were also collected from NSW state-based NSW state-based purse-seine vessels that operated out of Wollongong through a catch sampling program done at Sydney Fish Markets by NSW Department of Primary Industries, Fisheries.

From December 2022 to March 2023, the skipper of a mid-water trawler operating out of Ulladulla and Eden provided images of dissected Blue Mackerel taken in trawls.

Sample collection and processing

All mature-sized Blue Mackerel taken by line-fishing were euthanised (Animal Ethics Project Number A27624) and placed in a seawater-ice slurry. Fish were dissected at the end of each sampling trip to determine their sex and reproductive status. Gonads were removed from mature females (Stage III-V ovaries) and fixed in 5% buffered formaldehyde solution (Figure 2.2).

Males, immature females and carcasses of dissected (individually labelled) females were frozen and transported to the Australian Institute of Marine and Antarctic Studies (IMAS, Hobart, Tasmania) for further processing. All fish were measured (Fork Length, nearest mm) and weighed (nearest g) and gonads were staged (Figure 2.1) and weighed (±0.01 g).

Fish taken by the commercial mid-water trawler were stored on ice and processed when the vessel returned to Eden. As dissections showed that fish were not actively spawning, each sample was labelled, frozen and transported to IMAS for subsequent processing.

Fish taken by the purse-seine vessels were placed on ice and transported to Sydney Fish Markets. Samples taken from the markets were processed at Sydney Institute of Marine Science. Gonads were removed from mature females (Stage III-V ovaries) and fixed in 5% buffered formaldehyde solution (Figure 2.2). Males and immature females were processed as described above. Otoliths were removed from selected larger fish and stored for age-determination in future projects.

2.2 Histological and statistical analyses

Preserved ovaries were embedded in wax, sectioned using a microtome, stained with haematoxylin and eosin and fixed to microscope slides (e.g., Rogers et al. 2009, Ward et al. 2009). Microscopic characteristics were described based on the standard histological terminology and staging criteria for small pelagic fishes used by Rogers et al (2009) and Ward et al. (2009). The main criteria used to evaluate the ovarian sections were oocyte stages (unyolked, partially yolked, fully yolked, hydrated), post-ovulatory follicles (POFs) and percentage atresia (Figure 2.2).

Sections from each ovary were examined to determine the presence/absence of POFs (Figure 2.2). POFs were initially assigned to stages (i.e., day 0, day 1) based on the criteria of Rogers et al. (2009) and Ward et al. (2009) but were subsequently pooled due to: 1) uncertainties in assigning each POF to a stage; and 2) limited understanding of how long POFs persist in the ovaries of Blue Mackerel off eastern Australia.

The number of females in each sample that spawned each night was first estimated by dividing the number of fish with ovaries containing POFs by two. This approach reflected the assumption that POFs persist for two days and followed the method used by Ward et al. (2009). However, to examine the effects on estimates of spawning fraction of uncertainty about how long POFs persist, the number of fish with ovaries containing POFs was also used as an estimate of the number of fish that spawned each night, based on the assumption that POFs only persist for one day. Estimates of spawning fraction, i.e., SF POFs 2 days and SF POFs 1 day, were then calculated by dividing each of the estimates of the number of fish that spawned each night by the total number of mature females in each sample. This approach provided a sensitivity analysis of the effects on estimates of spawning fraction of uncertainty associated with how long POFs persist in the ovaries of Blue Mackerel off eastern Australia.

Figure 2.1. Map showing sampling locations mentioned in the text.

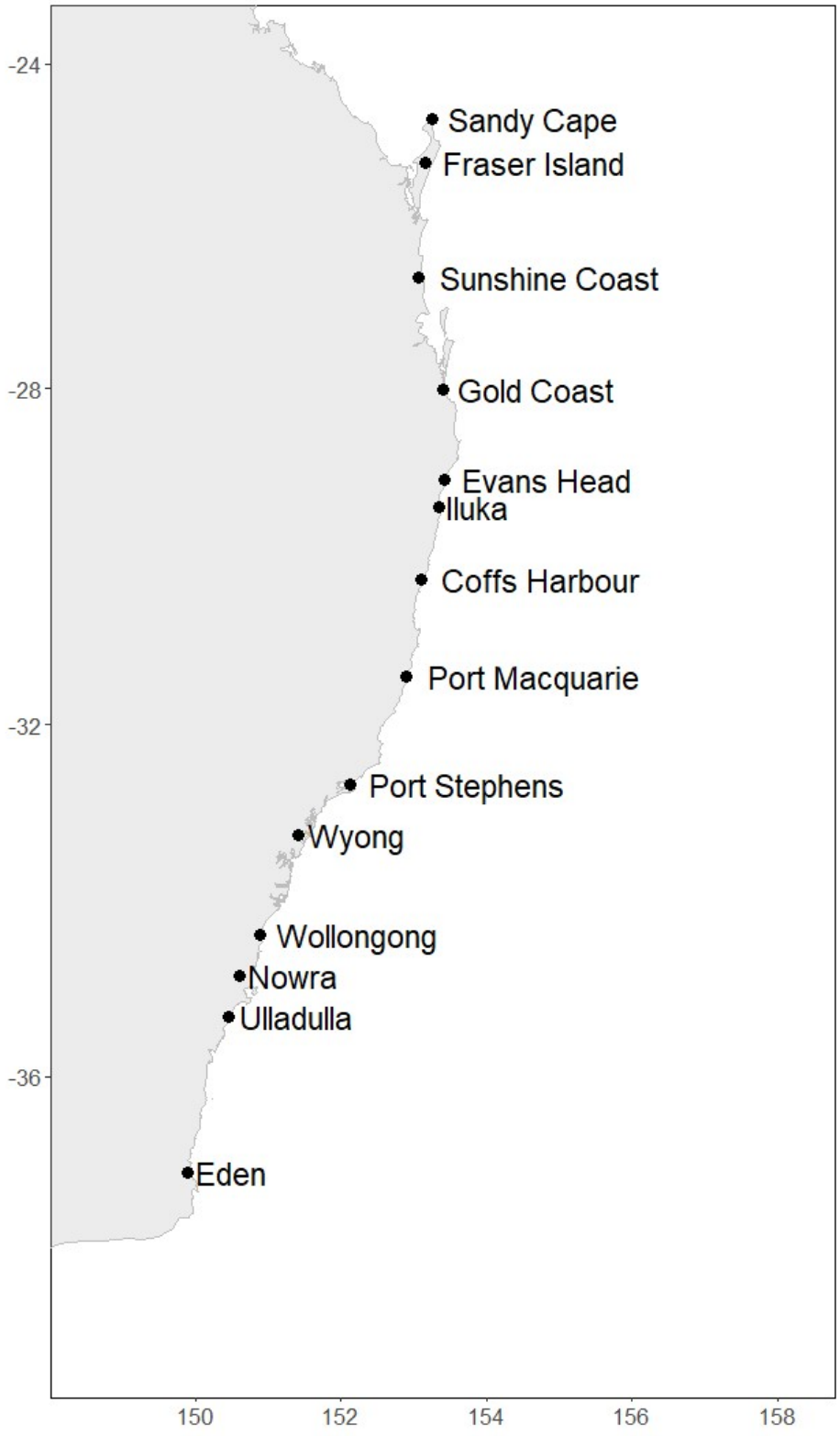
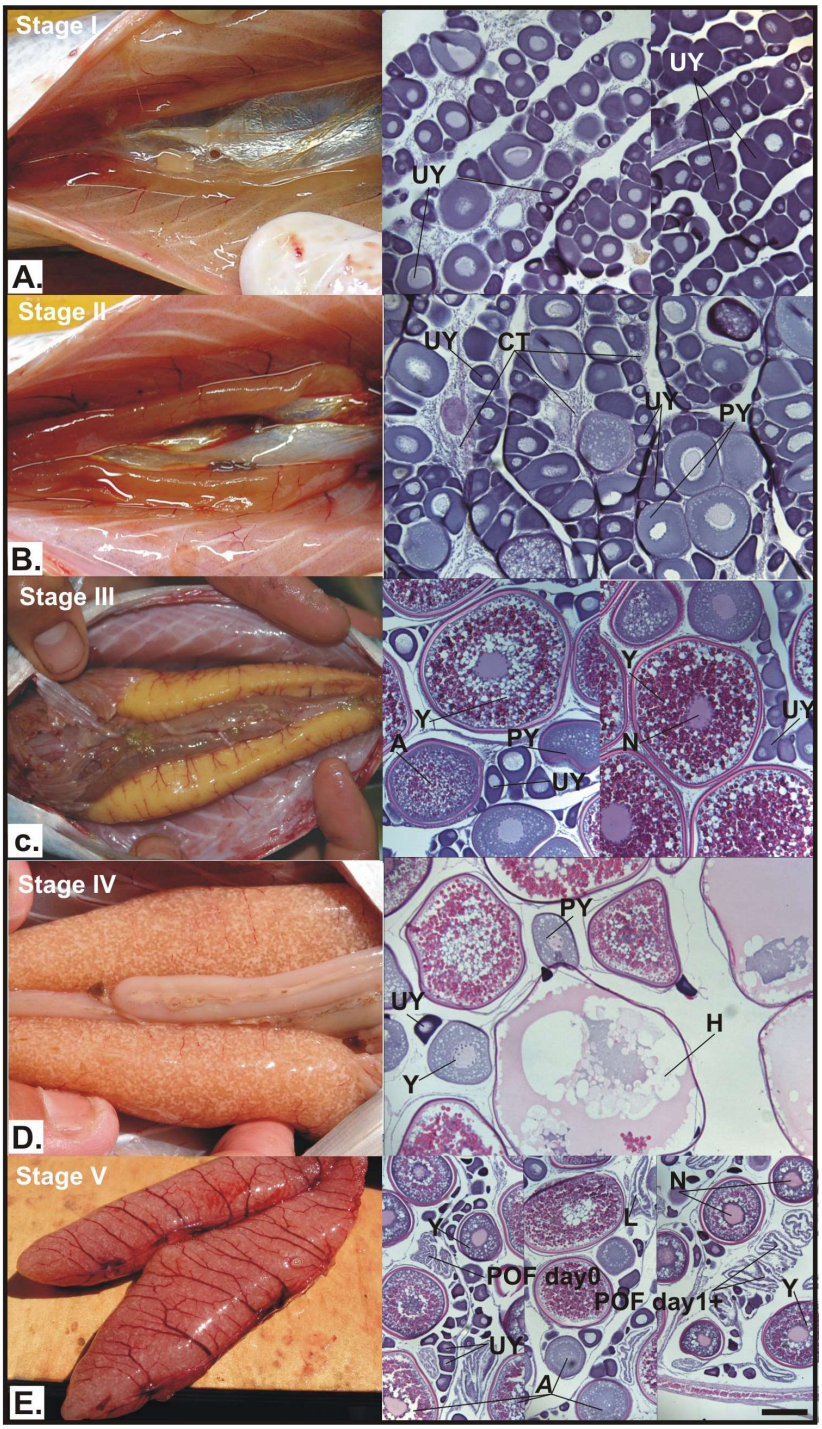


Figure 2.2. Macroscopic stages I–V and their microscopic characteristics. A: Immature Stage I ovary with developing unyolked (UY) oocytes. B: Maturing Stage II ovary with UY and partially yolked (PY) oocytes. C: Mature Stage III ovary with UY, PY and fully yolked oocytes (Y). D. Hydrated Stage IV ovary with UY, PY and partially hydrated oocytes (H). E: Spent Stage V ovary with day 0 and day 1+ post-ovulatory follicles (POFs). Scale bar = 150µm. Source: Rogers et al. (2009), *Marine and Freshwater Research*.



3 Results and Discussion

3.1 Methods for sampling large adult Blue Mackerel

Blue Mackerel above the size at maturity were at times collected by mid-water trawling, purse-seining and line-fishing. Samples taken by purse-seining off Wollongong and line-fishing off Coffs Harbour and Port Stephens included mature females (Stage III-V ovaries). In contrast, samples collected off southern New South Wales (i.e., south of Wollongong) by mid-water trawling and line fishing did not include mature females (Table 3.1).

Off Coffs Harbour, samples containing mature females were collected at two sites, i.e., the "Wide Bait Grounds" (east of Coffs Harbour) and "The Patch" (South-east of Coffs Harbour). Samples collected at several other sites in the region were comprised mainly (often entirely) of immature Blue Mackerel. Similarly, off Port Stephens large mature Blue Mackerel were only collected at one site, i.e., "Gibber Reef" (southeast of Seal Rocks), and samples from numerous sites closer to Port Stephens were comprised entirely of immature Blue Mackerel. All sites where large mature Blue Mackerel were collected were located in depths of 35-40 m.

The most effective baits for catching large mature Blue Mackerel varied among locations and fishing trips and was best determined by trial error. However, the consistently most efficient bait for catching large Blue Mackerel were fish-strips (~4 cm x 1 cm x 1 cm), although cubes (~1.5 cm) were sometime more effective. *Sabeki* jigs were consistently effective for catching small Blue Mackerel and were sometimes effective for catching larger fish. On some occasions, very large fish (> 35 cm) were caught on lures by fishers targeting Australian Bonito (*Sarda australis*).

3.2 Locations where large mature Blue Mackerel were sampled

Large, mature fish (Stage III-V ovaries) with fully yolked oocytes (Table 3.1) were collected from Coffs Harbour, Port Stephens and Wollongong in September and October, but were not present in samples collected from southern NSW (i.e., south of Wollongong) at any time of the year. Post ovulatory follicles (POFs) indicative of recent spawning activity were relatively abundant in samples collected from Port Stephens in early October (i.e., present in 24.85% of females) but were rare or absent in samples collected from Coffs Harbour and Wollongong. These findings are consistent with

current understanding (e.g., Ward et al. 2009, 2015, 2020) that the main spawning season is July to October and that the main spawning ground extends from Sandy Cape to about Wollongong.

3.2 Preliminary estimates of the spawning fraction

POFs were present in between 0.00% and 49.28% of females obtained in individual samples collected off Coffs Harbour, Port Stephens and Wollongong (Table 3.1). Estimates of spawning fraction ranged from 0.00 in several samples taken off Coffs Harbour and Wollongong to 0.246 and 0.493 in one sample taken off Port Stephens in early October, assuming that POFs persist for two days (SF POFs 2 days) and one day (SF POFs 1 day), respectively (Table 3.1).

Port Stephens was the only location where all the samples collected included females with POFs. The overall mean spawning fractions for Port Stephens were 0.124 (SPF POFs 2 days) and 0.248 (SPF POFs 1 day). The estimates of spawning fraction for Port Stephens obtained by assuming POFs persist for two days was similar to the overall estimate obtained for South Australia of 0.135, which was also based on the assumption that POFs last for two days (Ward et al. 2009). Because estimates of spawning fraction have a strong influence on estimates of spawning biomass (e.g., Stratoudakis et al. 2006) determining how long POFs persist in the ovaries of Blue Mackerel off eastern Australia is a high priority for Stage 2 of this project.

Figure 3.1 Locations where adult Blue Mackerel were collected in 2022 (pink stars) are shown in relation to distributions of eggs (circles), adult sampling locations (red dots) and Sea Surface Temperatures recorded in DEPM surveys in 2014 and 2019. (Source: Ward et al. 2015, 2021b).

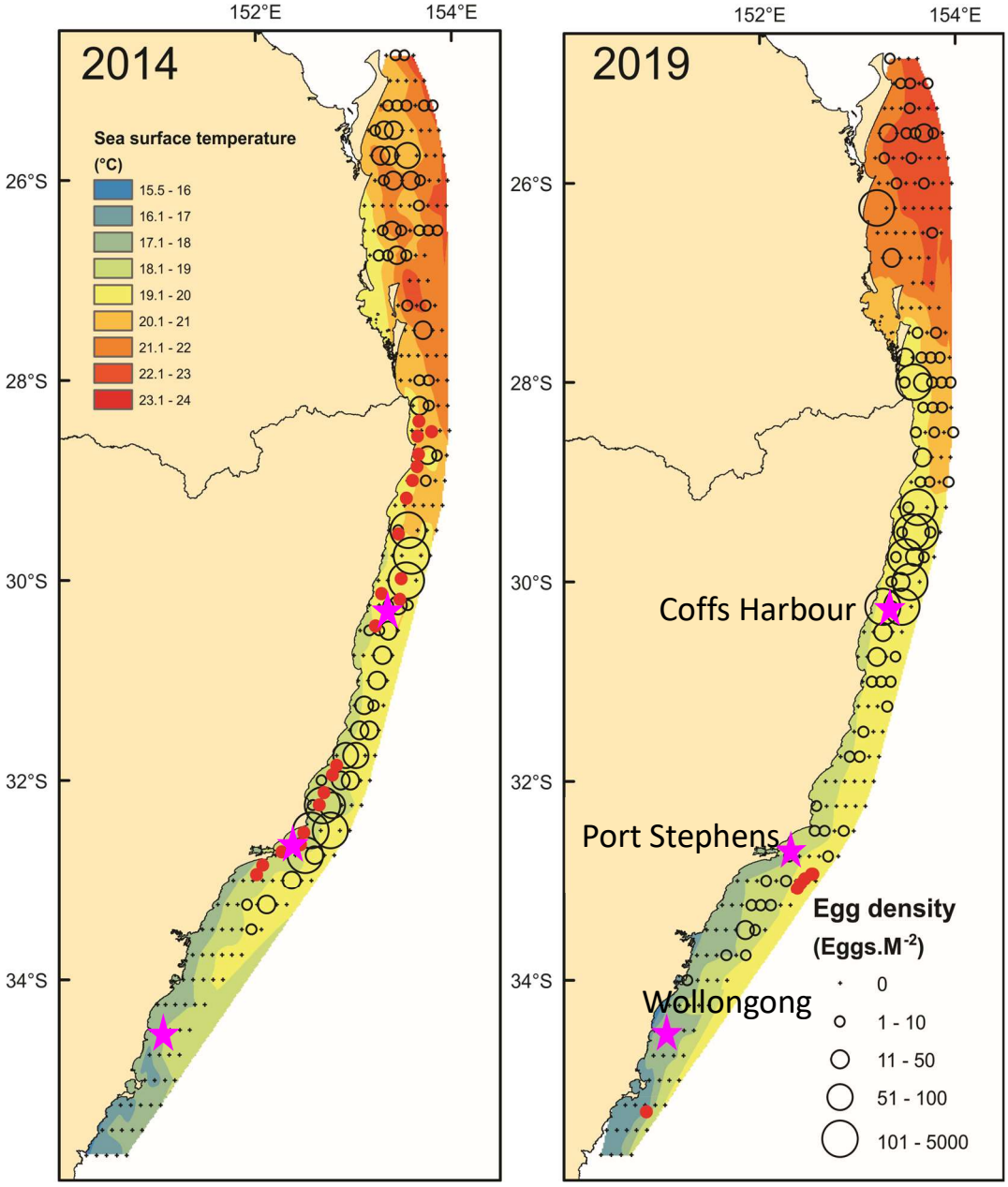


Table 3.1. Locations and dates where Blue Mackerel were sampled in 2022, including a summary of reproductive data for mature females. Definitions of macroscopic (macro) ovary and microscopic (micro) oocyte stages are provided in Figure 2.1. % POFs is the percentage of females with post-ovulatory follicles. SF POFs 2 days and SPF POFs 1 day are estimates of spawning fraction obtained by assuming POFs last for 2 days and 1 day, respectively.

Location	Date 2022	Sampling Method	Highest Macro Ovary Stage	Number Ovaries Fixed	Highest Micro Oocyte Stage	Number POFs	% POFS	SF POFs 2 days	SF POFs 1 day
Eden	12, 24 Sept	Trawling	II	0					
Coffs Harbour (Bait ground)	17 Sept	Line	III	18	Y	0	0.00	0.000	0.000
Coffs Harbour (Bait ground)	18 Sept	Line	III	69	Y	0	0.00	0.000	0.000
Coffs Harbour (Bait ground)	19 Sept	Line	III	69	Y	0	0.00	0.000	0.000
Coffs Harbour (The Patch)	19 Sept	Line	III	25	Y	0	0.00	0.000	0.000
Coffs Harbour (The Patch)	20 Sept	Line	V	48	Y	2	4.17	0.021	0.042
Sub-total (Coffs)				**229**		**2**	**0.87**	**0.004**	**0.009**
Port Stephens (Gibber)	04 Oct	Line	III	16	H	3	18.75	0.094	0.188
Port Stephens (Gibber)	05 Oct	Line	IV	69	Y	34	49.28	0.246	0.493
Port Stephens (Gibber	11 Oct	Line	III	41	Y	1	2.44	0.012	0.024
Port Stephens (Gibber)	12 Oct	Line	III	35	H	2	5.71	0.029	0.057
Sub-total (Port St)				**161**		**40**	**24.85**	**0.124**	**0.248**
Wollongong	25 Aug	Purse	III	6	Y	0	0.00	0.000	0.000
Wollongong	06 Sep	Purse	III	4	Y	0	0.00	0.000	0.000
Wollongong	14 Sep	Purse	III	26	H	2	7.69	0.038	0.077
Wollongong	21 Sep	Purse	III	13	Y	1	7.69	0.038	0.077
Wollongong	28 Sep	Purse	III	31	Y	0	0.00	0.000	0.000
Wollongong	26 Oct	Purse	III	4	Y	0	0.00	0.000	0.000
Wollongong	18 Nov	Purse	V	8	Y	0	0.00	0.000	0.000
Sub-total (W'gong)				**92**		**3**	**3.26**	**0.016**	**0.033**
Eden	26 27, Oct	Trawling	II	0					
Eden	9, 10 Dec	Line	Nil catch	0					
Narooma	25 Jan	Line	II	0					

Recommendations for Stage 2

The sampling program established for Stage 2 of this project should involve collecting samples at multiple locations between Sandy Cape and Wollongong during early July to late October. Samples should be collected from both commercial purse-seine vessels that operate in the region (e.g., off Iluka and Wollongong) and by targeted line-fishing at selected locations, including Coffs Harbour, Port Stephens and Wollongong. Targeted line fishing should also be conducted at additional locations such as the Sunshine Coast, Gold Coast, Evans Head, Yamba, Port Macquarie and Wyong. Samples should be collected repeatedly throughout the entire spawning season from both Coffs Harbour and Port Stephens. Around the clock sampling should be conducted over multiple days at Port Stephens to determine how long POFs persist in ovaries.

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Appendix 1: Approval letter Stage 2

Australian Government
Australian Fisheries Management Authority

14 February 2023

Dr Tim Ward
Associate Professor in Fisheries Science
University of Tasmania
Private Bag 49
HOBART TAS 7001
Email: timothy.ward@utas.edu.au

Dear Dr Ward

Re: Full proposal submitted for potential 2023/24 AFMA research funding

Thank you for submitting a full proposal, *Estimating spawning fraction of Blue Mackerel off eastern Australia: Stage 2. Spatio-temporal variability in spawning patterns and implications for future DEPM surveys*, in response to AFMA's September 2022 call for research.

I am writing to advise that at its 79th meeting held on 8 February 2023, the AFMA Research Committee (ARC) considered and endorsed your proposal for funding. As your proposal has been endorsed, the next step is the development of a research contract.

Ms Kerrie Bennetts, AFMA Research Section will be in touch prior to the proposed start date to prepare a draft research contract for your consideration. She can be contacted on telephone (02) 6225 5558 or by email: Research.Secretary@afma.gov.au.

Yours sincerely

Ryan Murphy

Ryan Murphy

Senior Manager, Policy, Environment, Economics and Research

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