# The Sustainable Oyster Assessment Program (SOAP) A cooperative monitoring program quantifying oyster performance and relationships with estuarine health

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## Abstract

Oysters are a key indicator of the condition of our catchments. Monitoring the performance of the NSW oyster industry not only increases our knowledge of the factors influencing the performance of this important industry, but also leads to an appreciation of the role oyster farming plays in managing catchment health. Two data sets vital to the oyster industry are oyster performance and estuary health. Since this data is scarce and in some instances confidential, there is a need to establish estuary-wide long-term monitoring programs that facilitate collective monitoring within and across key oyster growing estuaries. This information can be used to improve husbandry operations leading to efficiencies in management techniques, increasing the industry's viability into the future.

In this project three types of oysters (Sydney rock oysters, SRO, wild and hatchery and triploid Pacific oysters, TPO) commonly cultivated in NSW estuaries were monitored using an innovative approach by South East Local Land Services, and oyster researchers in direct partnership with the NSW oyster industry. Commercial automated oyster graders (already in use in the industry and tested as potential monitoring tools) were used to quantify oyster performance in terms of growth and mortality at a total of 28 different locations within seven NSW South Coast estuaries between May 2014 and November 2015. Oysters used in the monitoring program belonged to specific cohorts that shared the same origin and husbandry. These oysters were then split among the 28 different growing areas and were graded and measured every 6-8 weeks. This report collates the information gathered throughout the monitoring program, compares oyster performance at locations within estuaries, among estuaries and between oyster groups.

Through the surveillance of growth and mortality in different growing areas of an estuary, sites were characterised and changes in performance identified. Defined patterns in overall mortality levels were found across the estuaries and by oyster type. Overall TPOs showed significantly lower mortalities than SROs. Within SROs, cumulative mortality levels for hatchery oysters ranged between 7-17% (excluding Wonboyn's unexplained mortalities) and for wild ranged between 16-40%. The highest mortalities were recorded in Wonboyn Lake (42%) followed by the Clyde (20%). Wapengo and Wagonga Inlet (12%) recorded the lowest SRO mortalities levels. Overall 2014/15 oyster mortality levels dropped in all estuaries in comparison with levels recorded in the previous two years of the monitoring program. SROs at the Corner Channel (wild) and Broadwater (hatchery) locations within Wonboyn had the highest annual mortalities (average of 4.5% per grading every 2months). The lowest wild SRO mortalities (<1.1%) were recorded at Golden Mile location in Wagonga Inlet and at Mid Lake in Wapengo. The lowest mortalities in hatchery stock were recorded in Mid Lake in Merimbula, Crookhaven in the Shoalhaven and Armstrongs in Wapengo Lake. Throughout the program, mortalities increased from 10 to 12 months into the program (autumn-winter).

Growth rates at the end of each monitoring program showed distinct patterns across estuaries and oyster types too. TPO growth rates were 40% faster than hatchery SROs and

75% faster than wild SROs. At all locations, hatchery SROs showed faster growth than wild stock. Overall SROs grew the fastest at Wapengo Lake followed by Pambula Lake. SROs grew the least at the Shoalhaven and Wonboyn. TPOs grew equally well at the two estuaries monitored in this program: Clyde and Shoalhaven. Across all sites, included in the monitoring program, wild oysters cultivated at Broadwater in Wonboyn, Lavender Point in Wagonga, Berry's in the Shoalhaven and the Entrance in Pambula showed the lowest growth rates (on average 7mm/month). Hatchery oysters at Broadwater and Berry's also resulted in the poorest performance (on average 18mm/month), although overall levels were close to the best growing performance of wild SROs. Alternatively, highest wild oyster growth was recorded at Mid Lake in Wapengo (20.2mm/month) and at Moonlight in the Clyde (17mm/month). Hatchery oysters also performed at its best at Moonlight and at Armstrong Bay at Wapengo (on average 40mm/month).

SRO condition index was monitored as part of this program. Overall oyster condition responded to the seasonal cycle and heavy rainfall events. Overall condition levels were the lowest at the Clyde locations for both types of SROs. Best oyster condition levels were seen at Wagonga. However, the rest of the estuaries followed closely with very good condition levels. In all estuaries except the Clyde, wild oysters scored overall better condition levels than hatchery oysters. It was noted that condition levels among hatchery stock was more variable than among wild stock.

Through time, at most locations, oyster performance increased dramatically between the warmer months of November to January, in correlation with increased water temperatures. During this period high algae activity was also observed resulting in increased levels of phytoplankton productivity. Wapengo and Wonboyn had a larger percentage of small microalgae species than in Pambula and Merimbula. Wapengo and Wonboyn also had a larger number of benthic diatoms while Pambula and Merimbula had more planktonic diatoms. The percentage of toxic species from a human food safety point of view was low ranging from 0.5%-5%. The algal species contributing to the %harmful levels is consistent among lakes with regard to species type; the difference is based on the cell levels. Typical toxic algae correspond to the groups: *Pseudo-Nizchia, Alexandrium, Dinophysis* and *Prorocentrum*. However in Wonboyn Lake, a larger number of other toxic dinoflagellates were present.

While the South East LLS' Sustainable Oyster Assessment Program (SOAP) is an example of a cooperative partnership between industry, researchers and catchment managers where minimal effort and cost can be maximised to achieve estuary-wide benefits; its continuation is vital in identifying and establishing long term performance baselines. Continuation will only further enhance oyster grower's ability to manage their practices based on known characteristics of an estuary and its relationship with environmental influences, the product of which will be a more robust and viable industry into the future.

## Contents

# Introduction

## 1.1 Oysters and their ecological role in our catchments

The natural resources of the catchment and waterways, as well as the local biological, physical and chemical characteristics of the oyster growing areas determine the make-up of the food components available to oysters and subsequent cultivation (rearing) conditions. Oysters not only trap suspended material but also regenerate and mineralise materials back into the water column, resulting in nutrient recycling. It is for this reason that oysters play a major part in many of the ecological processes taking place in estuarine systems (Ruesink et al. 2005) and are widely recognised for their important role in the biological and chemical dynamics of coastal areas (Officer et al. 1982; Dame et al. 1989; Songsangjinda et al. 2000). The performance of the oyster industry can reflect the health of the catchment in which it lies.

In NSW, there are 32 commercial oyster growing areas (Figure 1), between Wonboyn in the south and Tweed Heads in the north, with around 274 oyster permit holders producing 5.1 million dozen oysters in a $35 million industry (NSW Department of Primary Industries 2014). Oyster growers in NSW primarily farm Sydney rock oyster (SRO) *(Saccostrea glomerata)*. In some estuaries growers have diversified by also cultivating the Pacific oyster (PO) *(Crassostrea gigas),* and to a lesser extent the native Flat oyster *(Ostrea angasi)*. SRO production is economically and culturally important, accounting for 77% of the total aquaculture production in NSW. SRO production has, however, been in a state of decline since the mid-1970s. This reduction has been attributed to many different factors such as disease outbreaks; degradation of water quality as a result of catchment development; depressed market price of oysters and/or competition by the PO market. Over the last decade, however, SRO production levels have stabilised as a result of progressive action towards new technologies and new management systems. This has led to significant improvements in oyster supply, environmental and disease management, and the coordination of stakeholders within catchments to protect water quality and environmental systems.

This report is focused on the Southern Rivers region of the far south coast of New South Wales with seven oyster growing estuaries between Shoalhaven and Wonboyn engaged in the Sustainable Oyster Assessment Program (SOAP).

## 1.2 Overview of international and national oyster monitoring programs

Through sustained monitoring, baseline information can be established that allows for the identification of unusual events (e.g. high mortalities, extreme changes in water conditions) and the identification of long-term trends as well as the potential causes attributing to these patterns. Building and sharing knowledge about the characteristics of certain growing areas and the drivers potentially affecting oyster performance across different environments, can lead to improvements in management techniques and decisions.

Oyster monitoring programs are, however, rare in Australia and limited across the world. In Australia, oyster monitoring programs are mainly focused on water quality and oyster testing to address food health safety as a result of oyster's ability to bioaccumulate pathogens and toxins present at times in the surrounding waters. Managed by the NSW Food Authority, as part of the Australian Shellfish Quality Assurance Program (SQAP), NSW oyster growers are required to routinely test water quality and oysters in their harvest areas prior to market (valued at $17,000 - $43,000 depending on the estuary). Unlike in a few countries, Australia's monitoring programs do not collect information on oyster performance. This information has however been highlighted by NSW oyster industry members as being particularly important.

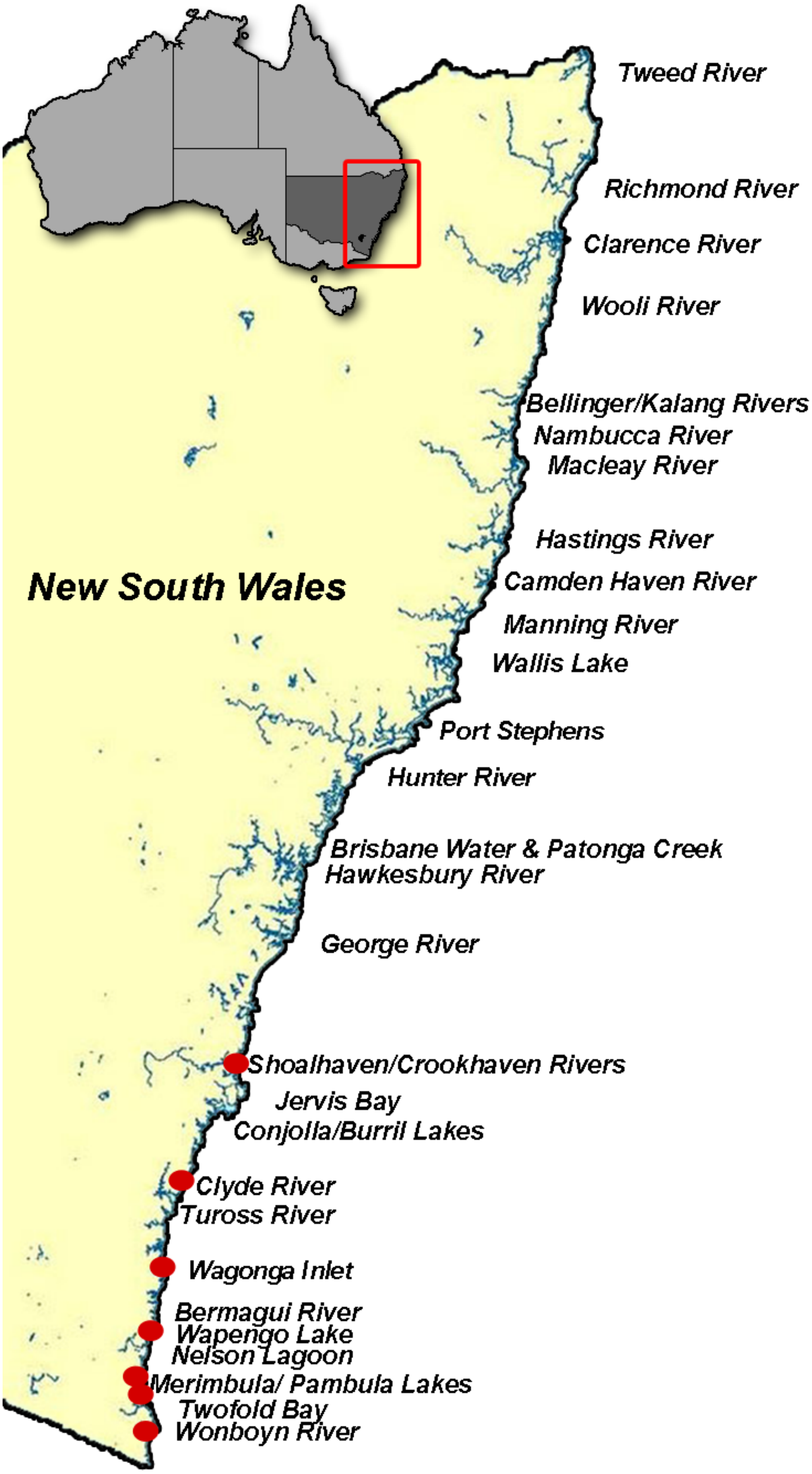



**Figure 1: Map showing the geographical location of the seven estuaries involved in the Southern Rivers estuary-wide oyster monitoring program. Maps of each estuary included in Appendix 1.**

### 1.3 SOAP

To increase handling efficiency, many growers in NSW are investing in automated commercial oyster graders that sort oysters photographically for pre-market. While these graders are primarily used for sorting they have the potential to be used to assist in monitoring the performance of oyster cohorts and the different growing areas of an estuary (Rubio 2010). Using oyster graders is an innovative method that overcomes the laborious effort of traditional methods used to track oysters (i.e. weighing and measuring oysters one by one). As demonstrated in pilot studies (Rubio 2010, Nash et al. 2013), these graders have the capacity to deal with large volumes of oysters, store data efficiently and operate under predetermined protocols, all at a consistent performance level.

By monitoring oysters through the years a baseline or 'the norm' can be established (i.e. an average yearly performance) that can be used as a reference point by industry and managers. Shifts away from this norm will help to identify potential problems that growers/managers/researchers can quickly act upon. Through the implementation of this simple baseline monitoring a wide range of important information can be collected and collated, contributing towards:

- a standard and simple annual assessment of oyster performance and mortalities;
- an assessment of trends over time;
- spatial differences across leases or estuaries (i.e. characterisation of sites);
- identification of periods of high mortalities and/or high growth; and
- correlations to climatological or hydrological data in order to determine factors limiting growth or conditions exacerbating mortality levels.

Quantifying the capacity and performance of cultivating areas (i.e. oyster leases) will assist growers in managing their cultivation space in a more sustainable and productive way. This oyster monitoring program has attempted to fill this knowledge gap and provide important information in addition to that derived from the SQAP. The collation and accessibility of SQAP and other information (e.g. local councils) can be used to great advantage by government and industry in planning and deciding upon future management strategies.

The SOAP was designed and set-up to cause as little interference as possible with the day-to-day husbandry and production protocols that growers are currently undertaking. The less the experiments differ from normal growers' practices, the more likely oyster farmers will be able to integrate these monitoring methods into their daily routines. The current program has been developed so that each estuary uses the same oyster cohorts, which allows for comparisons to be made across estuaries.

## 2 Aims

The two primary goals for the program were; (1) Collect baseline information on growth and mortality to categorise productive capacity of oyster growing areas. (2) Better understand the relationship between water quality and environmental stresses relating back to catchment health.
By collating a long-term data set for oyster performance across each of the estuaries industry should be able to better manage their leases and maximize business profitability.

In addition to oyster performance and condition data, the SOAP was designed to collect (where possible) environmental data including water temperature and phytoplankton community composition and abundance. The inclusion of these parameters allows for exploration into the environmental conditions characterising different estuaries and growing areas. A greater understanding of oyster performance and environmental variability was considered important in order to gauge the effectiveness of management decisions based on how different growing areas respond to different influences.

We also received feedback from oyster growers in regards to their involvement, whether the data was useful for them to compare sites for productivity, if they had used the data to modify their farm management, and whether we were providing the right data to help their business.

# 3 Methods

In July 2014, Program 3 of the Southern Coast NSW LLS Oyster Monitoring Program (SOAP) was established at the seven main oyster producing estuaries in the Southern Rivers region; Shoalhaven River, Clyde River, Wagonga Lake, Wapengo Lake, Merimbula Lake, Pambula Lake and Wonboyn Lake. A summary of the set-up information by oyster type and estuary is provided in Table 1. Refer to Appendix 1 for maps of the seven estuaries which includes the locations of the monitoring sites within each estuary.

The SOAP required access to an automated grader (here Shellquip SED oyster graders were used http://shellquip.com.au/ ) to count live oysters and to measure shell length. These graders are common in NSW with a third of the oyster producing estuaries having access to one. It is also frequently used among the oyster growers in South Australia and Tasmania. These graders can accurately grade oysters of 30mm shell length (approximately one year old) and above. Other similar automated graders can be used in similar monitoring programs.

In order to minimise inherent genetic variability across estuaries, oysters were selected from a unique batch and estuary. Pre-defined computer proforma (referred to as a ‘recipe’) was used to keep grading size and oyster density consistent throughout the monitoring program so that growth assessments are comparable through time. The methodology used in the current SOAP follows previous pilot studies (Rubio 2010) and is outlined in Appendix 2.

Previous studies have focused on oyster performance by infrastructure type and/or density levels. SOAP Program 3 this year has focused on oyster performance across estuaries and across locations within estuaries. It has also included performance between hatchery-produced and wild-sourced oysters. Source of oysters and oyster size at set-up has been tabulated in Table 1.

The 2014/15 SOAP monitored wild and hatchery SRO, and Triploid Pacific oysters (TPO), see Woodford (2015) for separate TPO final report. The sampling sites within an estuary were chosen by industry with the aim of targeting a range of growing areas that are known to perform differently.

Oysters were graded approximately every 7-10 weeks. This involved growers bringing oysters in from the lease for grading by the SOAP coordinator following a standard process (note that where data is missing in the figures means oysters were not brought on time to be graded).

Oyster farmers were responsible for the husbandry of the cultivation units to reduce fouling and by-catch. Units were replaced if too heavily covered in foul or when damaged.

At each grading event (Appendix 3), mortality rates were calculated by counting the number of dead oysters per oyster batch by hand. While the assessment of mortality levels did not include the determination of the cause of the mortality, we contacted the biosecurity branch of NSW DPI if mortality levels were found to be higher than 10%. Oyster size was determined photographically by the grader based on shell dimensions. Overall batch growth rates were calculated by taking into account the number of oysters, the shell length and mortality rates per grade and integrating this information into an oyster performance indicator, (referred to as weighted average shell length) that was compared through time.

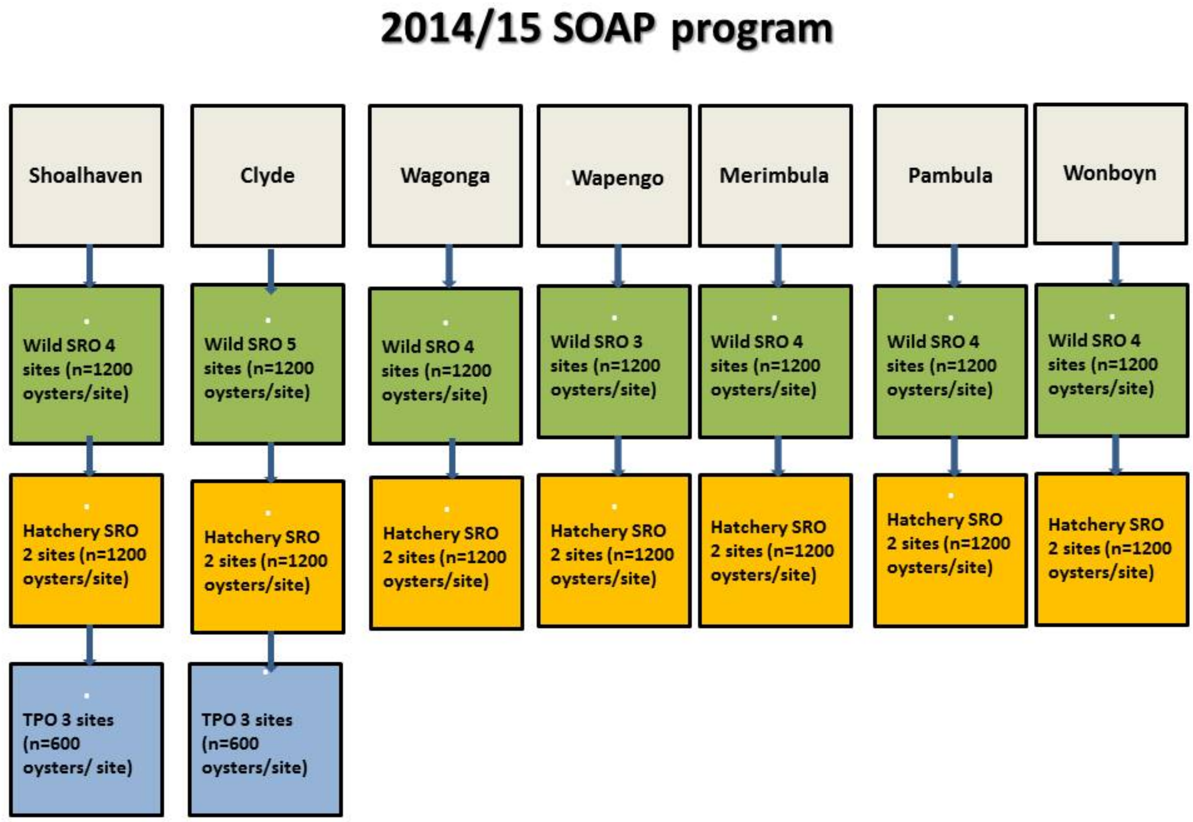



**Figure 2. SOAP estuaries and oyster types used**

Incremental increases in shell length (expressed as mm/month) were calculated based on the initial and final shell length measurement proportioned across the days for that program. 40 wild SRO were collected from each estuary and frozen for disease monitoring if required. Condition assessment was conducted by randomly sampling 6 oysters from the wild and hatchery sites. Oysters were then opened, photographed and rated according to the SRO grading guide (Australian Seafood CRC). Wild oysters were then stored in formalin for future research programs.

Temperature was monitored hourly as each sampling oyster lease (refer to Appendix 1 for site locations) using DS1921G Thermochron iButton attached to a yellow fob sealed in canisters and attached to the inside of the cultivation unit (e.g. to a floating basket, static basket or tray). The loggers were downloaded at each grading between May 2014 and November 2015.

Full counts and taxonomical identification of phytoplankton were monitored at one of the pre-defined SQAP sites representing a harvest area per estuary. The presence of harmful algae is identified using a 300ml water sample collected to obtain counts per algae type. The sample is sent to a NATA-certified laboratory where it is concentrated by 100 times using membrane filtration (ie. the 300ml sample is concentrated down to 3ml). A 1ml sample of the concentrated matter is counted in a Sedgwick glass chamber using Zeiss Axiolab or Zeiss Standard microscopes, equipped with phase-contrast. A second algal sample is also collected using a phytoplankton net that is dragged for a certain amount of time at the same site. This sample is used for qualitative purposes only, to identify the presence of any organisms in low numbers. As part of the SOAP, algal analysis included identification of harmful and non-harmful species of phytoplankton between August 2014 and June 2015.

Reports for each estuary were sent to each grower and uploaded in http://www.southcoastoysterindustry.com.au/. A summary report was also produced for the Steering Committee.

**Table 1: Set-up of SOAP by Southern NSW Estuaries (refer to estuary maps in Appendix 1).**

| Estuary | Program duration | Sampling Sites | Species | Oyster origin | Initial shell length |
|---|---|---|---|---|---|
| Shoalhaven River | May 2014-December 2015 | Berry's Bay<br>Crookhaven<br>Goodnight<br>Comerong | SRO<br>Wild | Port Macquarie (Oysters caught during spawning session Dec12-Feb13) | 59±3mm |
| | May 2014-December 2015 | Berry's Bay<br>Crookhaven | SRO<br>Hatchery | Select Oyster Company (Camden Haven Oyster Hatchery Winter Mortality – spawned 28/5/13) | 61±2mm |
| | May 2014-Match 2015 | Crookhaven<br>Goodnight<br>Curleys | TPO | Shellfish Culture, Tasmania Batch (SPL13C spawned 4/11/2013) | 46mm |
| Clyde River | May 2014-December 2015 | Big Island<br>Moonlight<br>Mogo<br>Snapper<br>Paddock | SRO<br>Wild | Port Macquarie<br>As above | 59±3mm |
| | May 2014-December 2015 | Big Island<br>Moonlight | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |
| | May 2014 – March 2015 | Big Island<br>Moonlight<br>Snapper | TPO | Shellfish Culture, Tasmania As above | 50mm |
| Wagonga Lake | May 2014-December 2015 | Punkally Creek<br>Lower Honeymoon<br>Golden Mile<br>Lower Lavender Point | SRO<br>Wild | Port Macquarie As above | 59±3mm |
| | May 2014-December 2015 | Punkally Creek<br>Lower Honeymoon | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |
| Wapengo Lagoon | May 2014-December 2015 | Mid Lake<br>Spiros<br>Armstrong Bay | SRO<br>Wild | Port Macquarie As above | 59±3mm |
| | May 2014-December 2015 | Mid Lake<br>Spiros | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |
| Pambula Lake | May 2014-December 2015 | Front Lake<br>Mid Lake<br>Back Lake<br>Entrance | SRO<br>Wild | Port Macquarie As above | 59±3mm |
| | May 2014-December 2015 | Front Lake<br>Mid Lake | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |
| Merimbula Lake | May 2014-December 2015 | Top Lake<br>Golf Lake<br>Boggy Creek<br>Mid Lake | SRO<br>Wild | Port Macquarie As above | 59±3mm |
| | May 2014-December 2015 | Boggy Creek<br>Mid Lake | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |
| Wonboyn Lake | May 2014-December 2015 | Broadwater<br>Corner Channel<br>Red Rock<br>Mid Lake | SRO<br>Wild | Port Macquarie As above | 59±3mm |
| | July 2014-December 2015 | Broadwater<br>Red Rock | SRO<br>Hatchery | Select Oyster Company As above | 61±2mm |

# 4 Results

## 4.1 Performance by estuary

### 4.1.1 Shoalhaven River

#### 4.1.1.1 Mortality

Highest wild mortalities >5% were recorded at Comerong during the 10 month grading and in Berry at 12 months. A peak in mortality was recorded in the first grading after deployment for all wild oysters. Cumulative wild SRO mortality levels at Shoalhaven ranged from 15-22% and for hatchery oysters cumulative mortality ranged from 4-8% (Figure 3). TPO oyster mortality levels were very low for the majority of the program, reaching cumulative mortality levels of 0.3% at Curleys and Crookhaven and 1.7% at Goodnight after 10 months.

| | % Mortality/grading | | | Shell growth increment (mm/month) | | |
|---|---|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **TPO*** | **SRO-Wild** | **SRO-Hatchery** | **TPO*** |
| **Goodnight** | 2.77 | - | 0.32 | 0.57 | - | 5.08 |
| **Curleys** | - | - | 0.05 | - | - | 2.7 |
| **Crookhaven** | 1.95 | 0.61 | 0.06 | 0.65 | 1.12 | 4.42 |
| **Comerong** | 2.50 | - | - | 0.60 | - | - |
| **Berry's** | 1.91 | 0.80 | - | 0.44 | 1.13 | - |

(*) program stopped at 10 months, calculation based on 10 months. In contrast SRO program is 16 months

**Table 2. % Mortality per grading and shell growth increment (mm/month) for wild and hatchery SROs and TPOs at Shoalhaven's locations.**

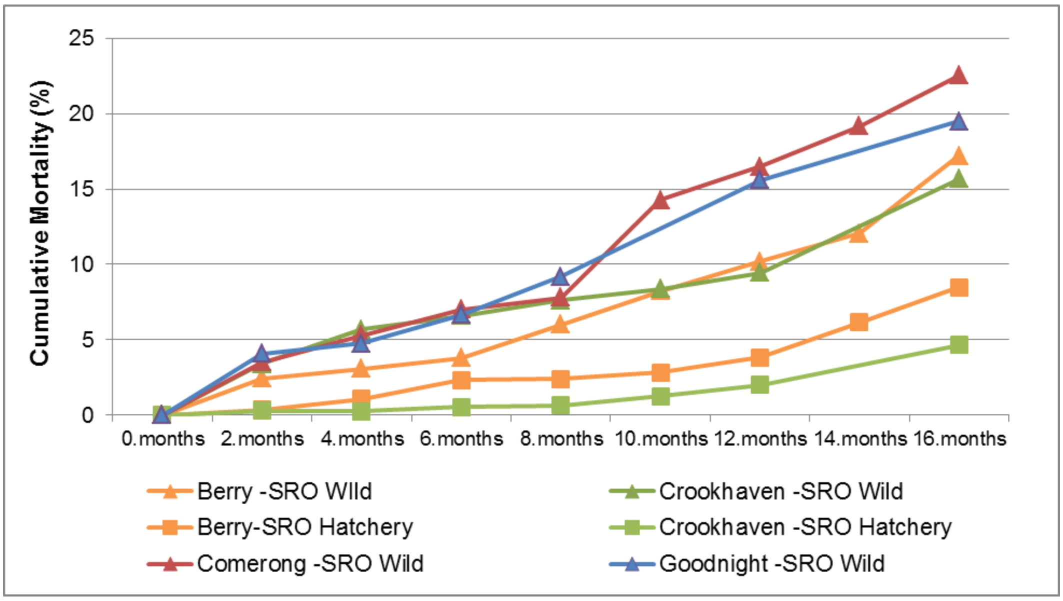
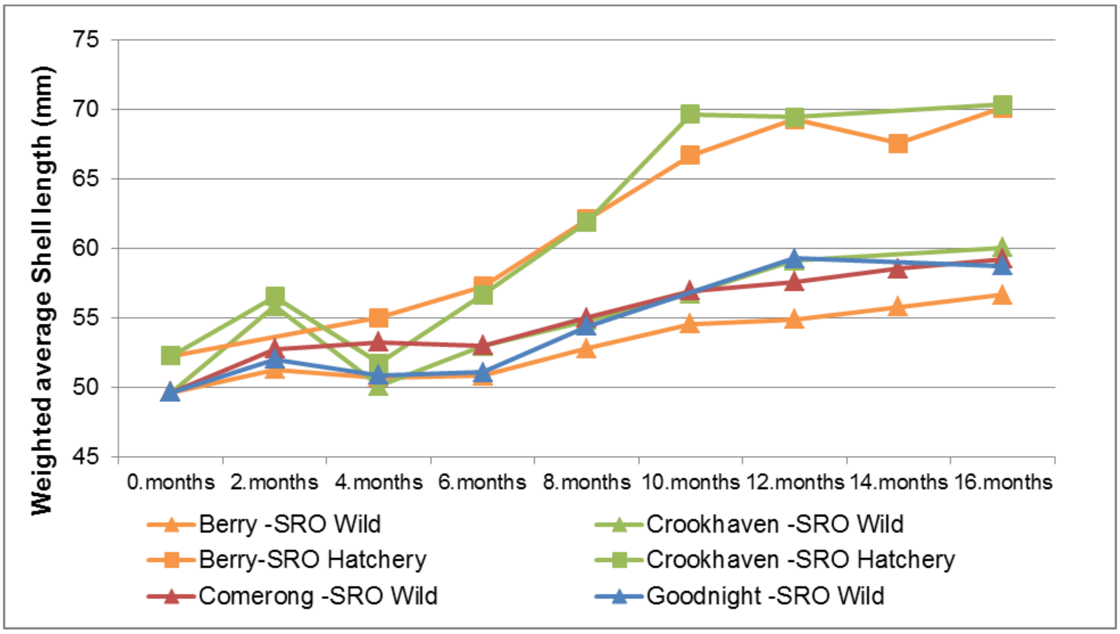



**Figure 3. Cumulative mortality for wild and hatchery oysters at each grading for all Shoalhaven sites.**

#### 4.1.1.2 Growth

Shell growth increments by month are displayed in Table 2. Hatchery oysters grew more than wild oyster and performance within species was very similar at all locations. The smallest wild oyster growth was recorded at Berry's Bay (upstream site). Greatest wild oyster growth was recorded at Crookhaven and Goodnight with similar final lengths. Hatchery oysters at Berry's Bay outperformed Crookhaven oysters for the first 6 months of grading, however after summer, Crookhaven oysters reached the size of Berry's Bay oysters (Figure 4a). TPO growth rates were very similar at Goodnight and Crookhaven reaching shell lengths at the end of the program (10 months) of 97mm at Goodnight and 90mm at Crookhaven, (Fig.4b). Curley TPOs reached 73mm at the end of the program.

a)




b)

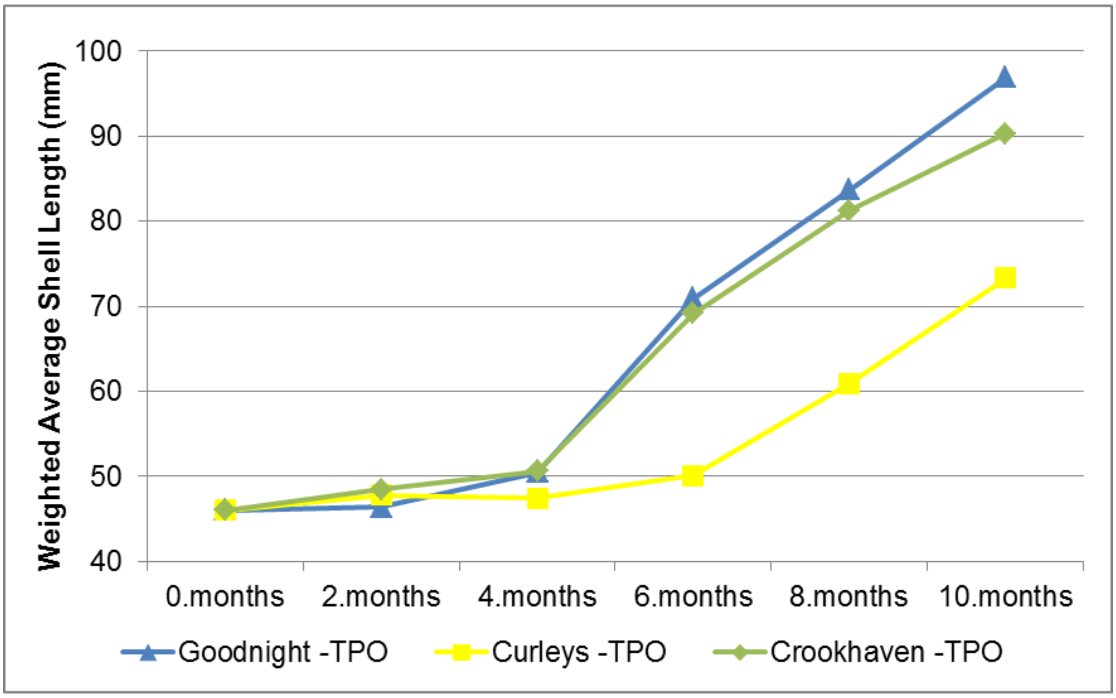



**Figure 4. Weighted average shell length of a) wild and hatchery, and b) TPO oysters, at Shoalhaven over time.**

#### 4.1.1.3 Condition

Oyster condition was assessed at two sites Crookhaven and Berry's Bay for both wild and hatchery stock (Figure 5). At the start of the program during Spring 2014 the condition of hatchery oysters was lower than wild oysters at Berry's. At all gradings except one, condition of wild oysters at Berry was very good. Condition at Crookhaven for hatchery oysters was quite stable through time. Overall condition levels during autumn-winter 2015 was more variable. Condition for both oyster types at both locations improved to very good in Spring towards Summer 2015.

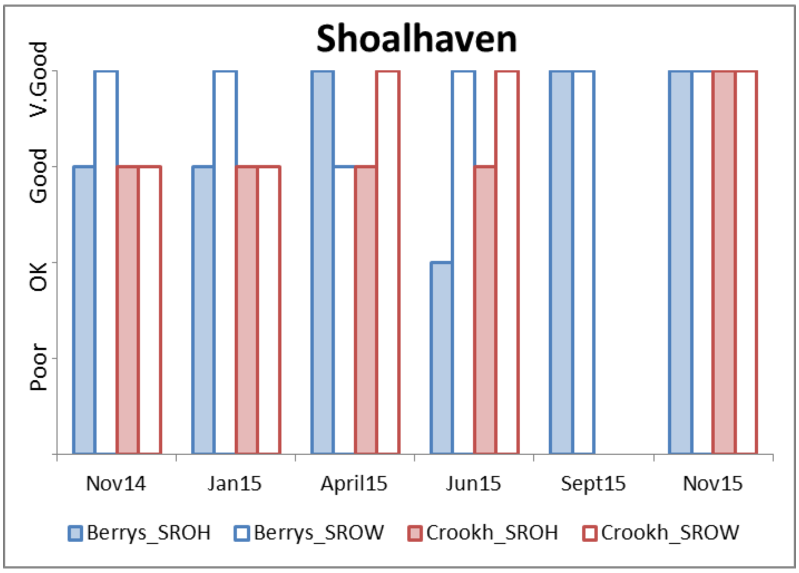



**Figure 5. Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters.**

#### 4.1.1.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Crookhaven, Berry's Bay, Comerong and Goodnight, Figure 6). At the start of the program in mid May 2014, water temperatures for all sites were between 15-20°C, over the two month period towards winter, water temperatures dropped to 10-15°C. Crookhaven site recorded the lowest temperatures and Goodnight the highest. This pattern continued throughout winter, where large rainfall events >20mm were recorded between the start of June and mid-end August. During Spring 2014, water temperatures fluctuated between 13-18°C until the end of September, when Tallowa Dam released water following large rainfall events >70mm during mid-October. Over summer, Berrys Bay recorded the highest temperatures and Goodnight and Comerong the lowest with all sites fluctuating between 18-27°C. Temperatures when dropped again over summer, autumn and winter to reach a low of between 10-14°C and then the cycle continued. There was a large rainfall event at the end of August with 200mm of rain.

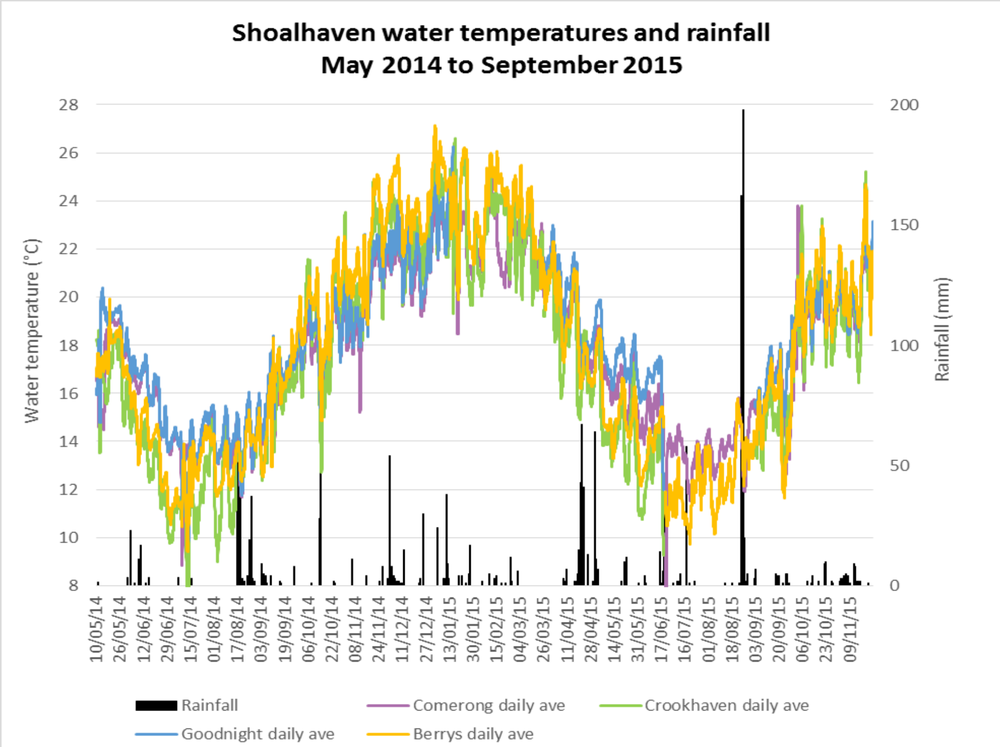



**Figure 6. Time series of temperature and rainfall for four monitoring sites within the Shoalhaven.**

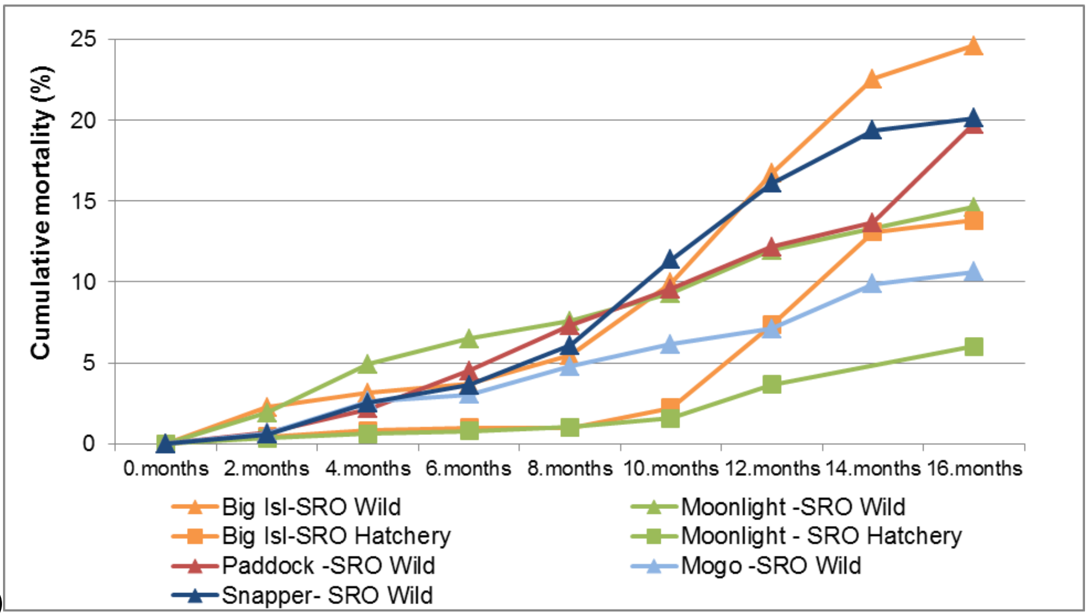
### 4.1.2 Clyde River

#### 4.1.2.1 Mortality

Highest wild mortalities >5% occurred at Snapper during the 10 month grading, at Big Island at 12 and 14 months and at Paddock at 16 months. Moonlight and Mogo remained lower than all other sites, although data is missing for Moonlight at 14months. Hatchery mortalities were low for Moonlight whereas Big Island mortalities increased after 12 months (Table 3). Overall cumulative wild SRO mortality levels at Clyde ranged from 10-24% and for hatchery oysters from 6-14% at the conclusion of the Program (
Figure 7a).TPO oyster mortality levels were very low after the program finished at 10 months and ranged from 6-9% (
Figure 7b).

**Table 3. % Mortality per grading and shell growth increment (mm/month) for wild, hatchery and TPO oysters at Clyde.**

| | % Mortality/grading | | | Shell growth increment (mm/month) | | |
|---|---|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **TPO*** | **SRO-Wild** | **SRO-Hatchery** | **TPO*** |
| **Snapper** | 2.16 | - | 1.00 | 0.76 | - | 5.26 |
| **Big Island** | 2.73 | 1.53 | 1.11 | 0.74 | 1.27 | 3.19 |
| **Moonlight** | 1.77 | 0.75 | 1.47 | 1.1 | 2.50 | 5.13 |
| **Mogo** | 1.18 | - | - | 0.95 | - | - |
| **Paddock** | 2.19 | - | - | 0.90 | - | - |

a) 

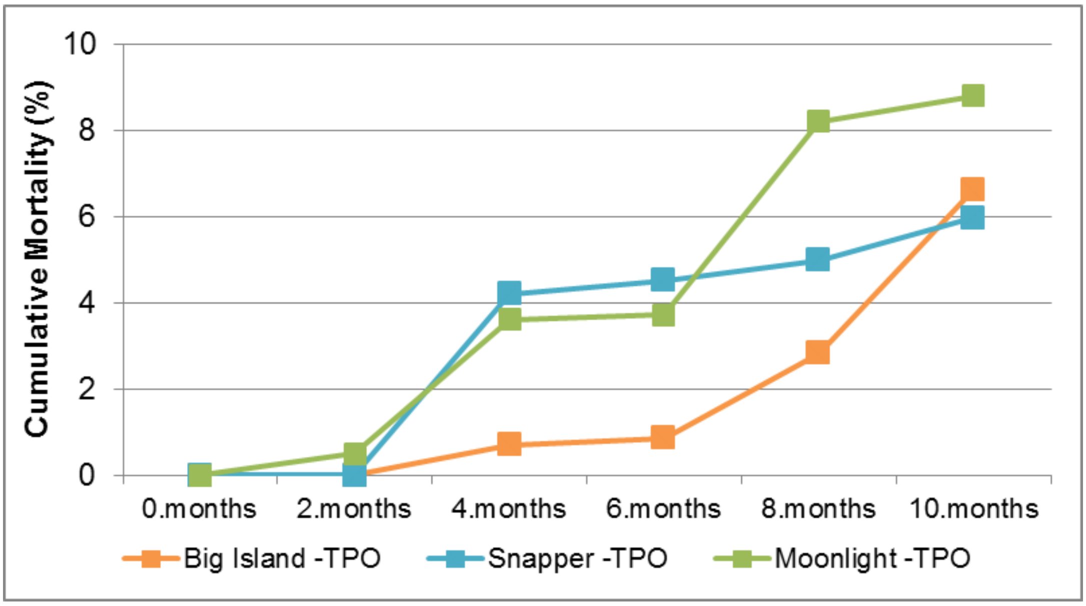
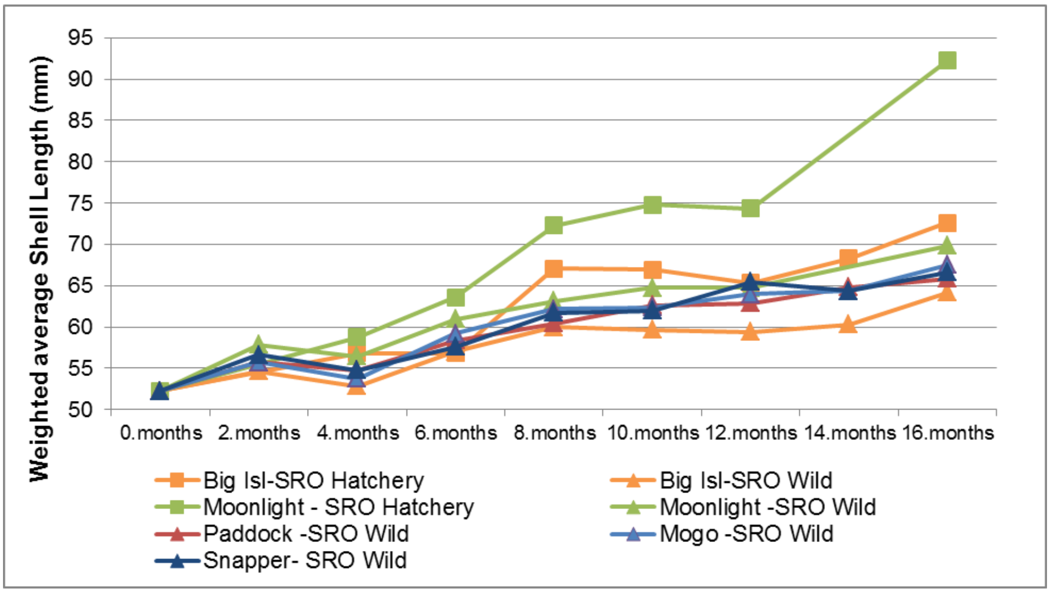

b) 

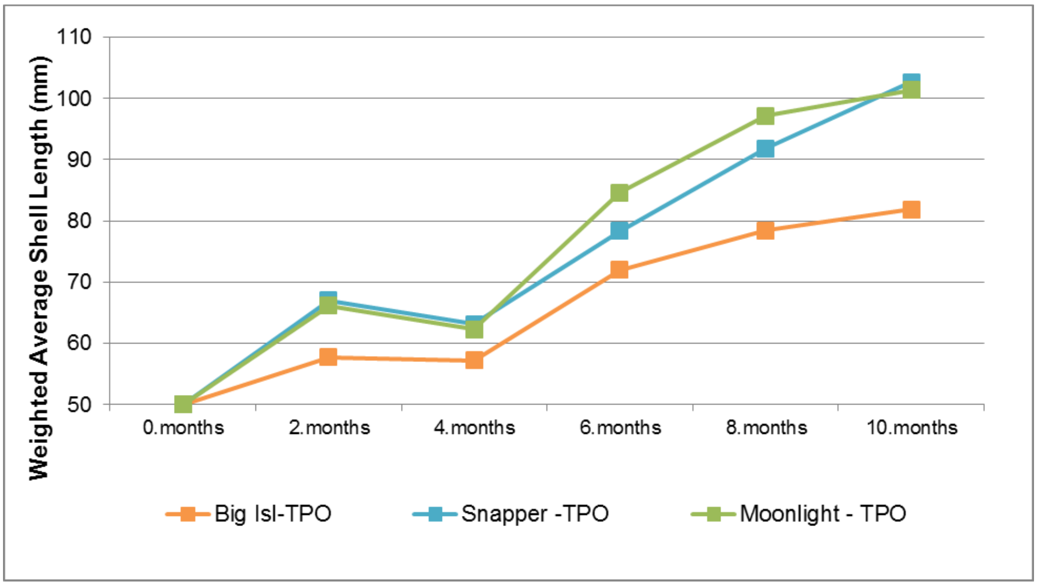

**Figure 7. Cumulative mortality of a) wild and hatchery and b) TPO oysters at each grading for all Clyde sites.**

### 4.1.2.2 Growth

Shell growth increments (mm/month) are displayed in Table 3.Hatchery oysters grew more than wild oysters. Big Island wild oysters displayed the smallest growth (located upstream). Greatest wild oyster growth was seen at Moonlight (furthest downstream). Hatchery oysters at Moonlight outperformed Big Island oysters for the entire program and displayed a 20mm greater growth increment by the final grading (
Figure 8a). TPO growth rates were very similar for Snapper and Moonlight which remained ahead of Big Island oysters for the duration of the program. At the end of the program at 10 months, Snapper and Moonlight oysters were 101mm and Big Island oysters 81mm (
Figure 8b).




a)




b)

**Figure 8. Weighted average shell length of a) wild and hatchery oysters and b) TPO oysters at Clyde over time.**

#### 4.1.2.3 Condition

Oyster condition was assessed at two sites, Moonlight and Big Island, for both wild and hatchery oysters (Figure 9). At the start of the program during Spring 2014, condition assessments showed that wild oysters were in good condition and hatchery oysters were still developing condition. By Summer 2014-15, wild oysters retained their condition, however they were impacted by large rainfall events towards the end of the season. Condition dropped in both oyster types at Big Island after the rainfall events and with the start of winter. By the end of winter 2015, wild oysters at Big Island improved in condition, whereas hatchery oysters stayed very poor. No oysters were available for grading at the Moonlight site at this point in time. By Spring 2015, both oyster types at both locations showed very good condition.

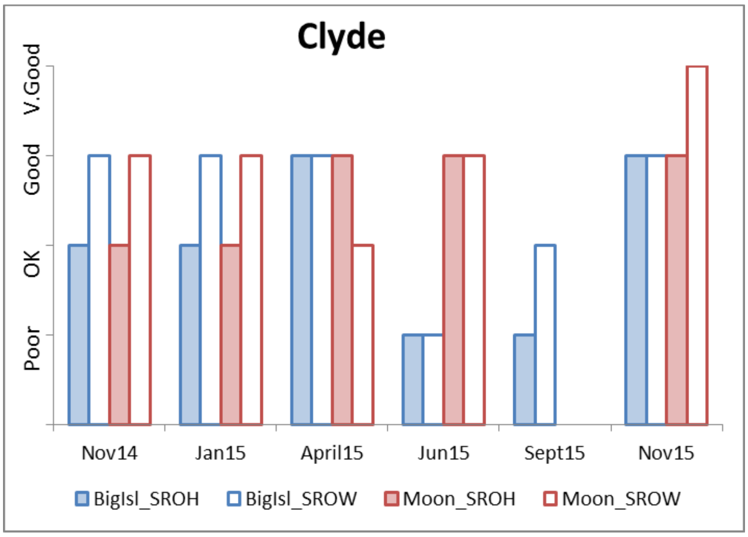



**Figure 9: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

#### 4.1.2.4 Water temperatures

Water temperatures were recorded hourly at all five sites (Paddock, Big Island, Moonlight Mogo and Snapper). At the start of the program in mid-May 2014, water temperatures for all sites remained between 17-18°C for the following two month period, then dropped to 12-13°C over winter. Big Island recorded the lowest temperatures and Paddock, the highest, this continued throughout winter, where large rainfall events >50mm were recorded between the start of June and mid-end August. During Spring 2014, water temperatures fluctuated between 14-18°C until the end of September when temperatures increased to between 18-28°C. From this point until the end of summer, Big Island recorded the highest temperatures and Paddock the lowest. There were only three large rainfall events >50mm in mid-October at the start of December, and January. At the start of autumn, water temperatures were between 22-26°C with Moonlight displaying the lowest temperatures and Mogo and Snapper displaying the highest. Over autumn, temperatures then dropped from 22 to16°C and Paddock displayed the highest temperatures and Snapper the lowest. Large rainfall events occurred again in mid-May, July, August and November 2015. Over winter temperatures fluctuated between 9-14°C, increasing to 18-24°C over spring 2015, with Moonlight displaying the lowest temperatures and Big Island the highest (Figure 10).

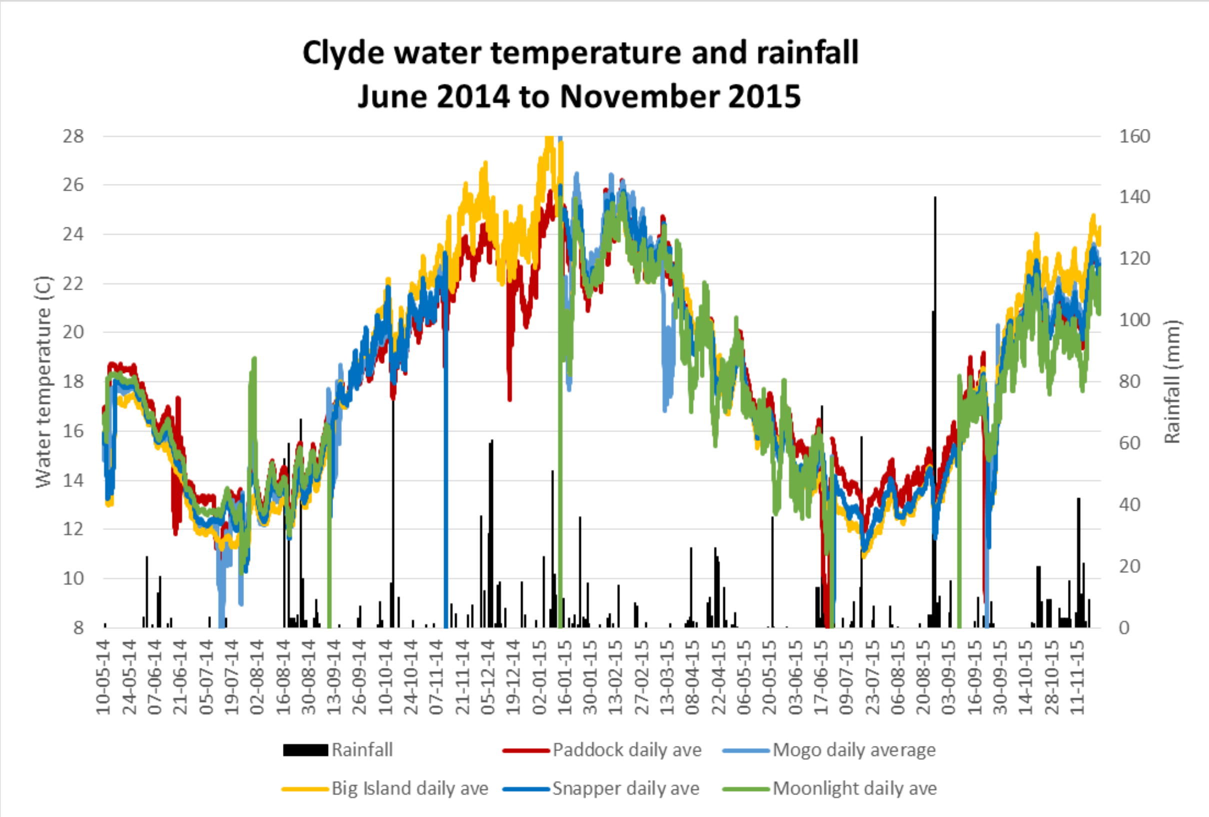



**Figure 10. Time series of temperature and rainfall for four monitoring sites within the Clyde.**

### 4.1.3 Wagonga Inlet

#### 4.1.3.1 Mortality

No wild or hatchery mortalities were greater than 5% during the whole program. Lower Honeymoon remained the site with the lowest mortality overall for wild oysters (Figure 11). Cumulative wild SRO mortality levels at Wagonga ranged from 8-12% and for hatchery oysters both sites were very similar at around 7% by the end of the Program.

**Table 4. % Mortality/grading and shell growth increment (mm/month) for wild, hatchery and TPO oysters at Wagonga.**

| | % Mortality/grading | | Shell growth increment (mm/month) | |
|---|---|---|---|---|
| Location | SRO-Wild | SRO-Hatchery | SRO-Wild | SRO-Hatchery |
| Punkally Ck | 1.83 | 0.75 | 0.65 | 1.59 |
| Lower Honeymoon | 1.25 | 0.78 | 0.85 | 1.75 |
| Lavender Point | 1.81 | - | 0.42 | - |
| Golden Mile* | 0.54* | - | 1.04* | - |

*grading stopped at 8 months

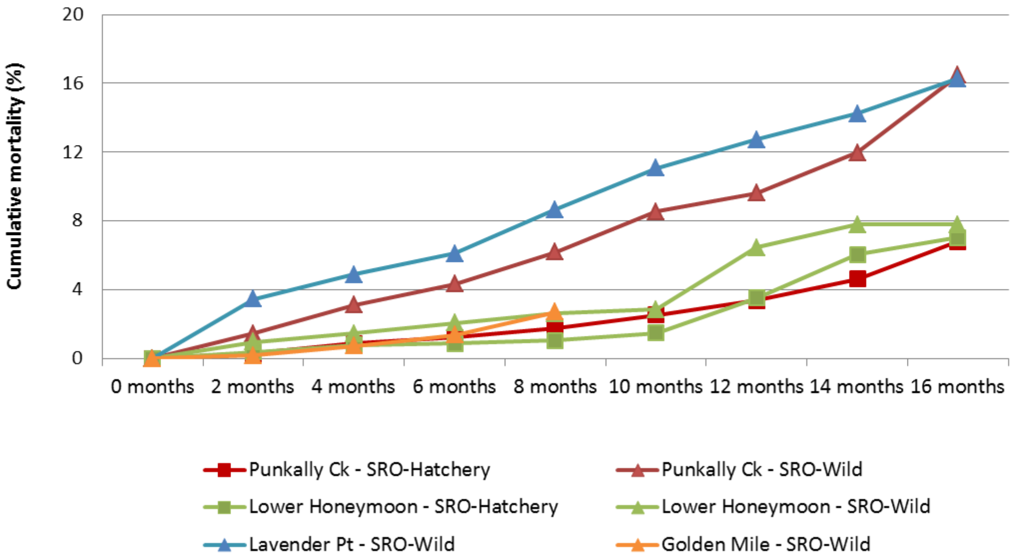



**Figure 11. Cumulative mortality of wild and hatchery oysters at each grading for all Wagonga sites.**

#### 4.1.3.2 Growth

Shell growth increments (mm/month) are displayed in Table 4. Hatchery oysters grew more than wild oysters. Lavender Point wild oysters displayed the smallest growth (located downstream). Greatest wild oyster growth was recorded at Lower Honeymoon (furthest upstream). Hatchery oysters at Lower Honeymoon outperformed Punkally Creek oysters by mid-summer (8 and 10 months), however final growth rates were fairly similar with Lower Honeymoon oysters having 3mm greater growth than Punkally Creek (Figure 12)

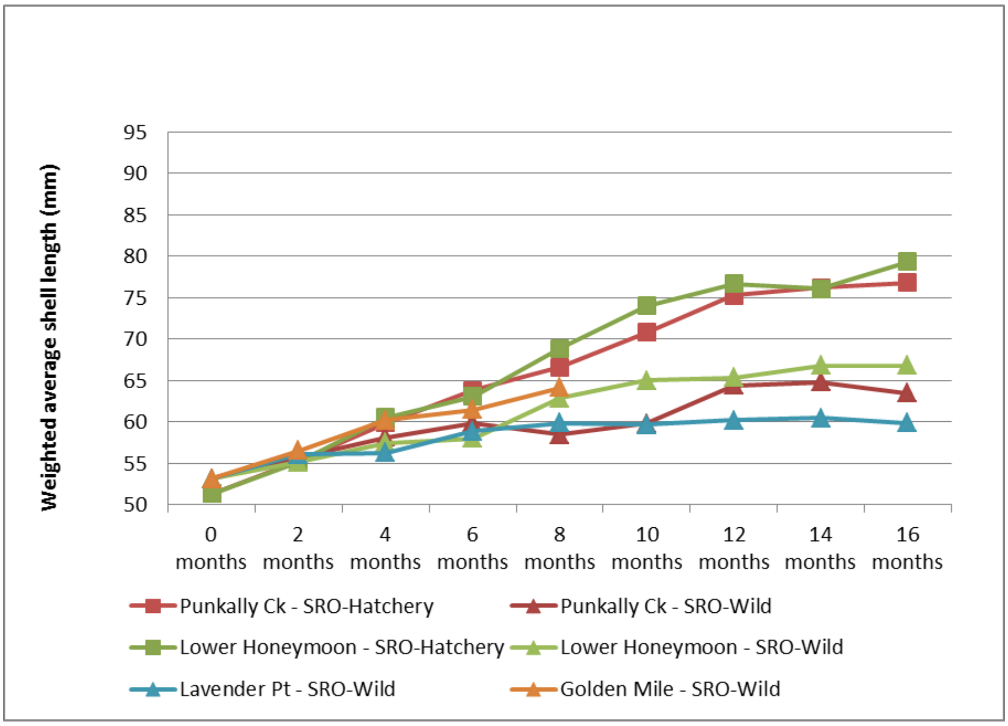



**Figure 12. Weighted average shell length of wild and hatchery oysters at Wagonga Inlet over time.**

#### 4.1.3.3 Condition

Oyster condition was assessed at two sites, Punkally Creek and Lower Honeymoon, for both wild and hatchery oysters (Figure 13). At the start of the program during Spring 2014, condition assessments showed that wild and hatchery oysters were in good condition. By Summer 2014-15, wild oysters at both sites improved condition to ‘very good’ and hatchery oysters stayed the same in ‘good’ condition. During late summer, wild and hatchery oysters both recorded very good to good condition. During Autumn and Winter 2015, oysters lost condition whereas only wild oysters at Punkally remained in good condition. Condition was regained at both sites for all oysters by Spring with the majority scoring as ‘very-good’. These conditions remained until November2015. Wagonga was the estuary in which both type of oysters had the best condition all year around.

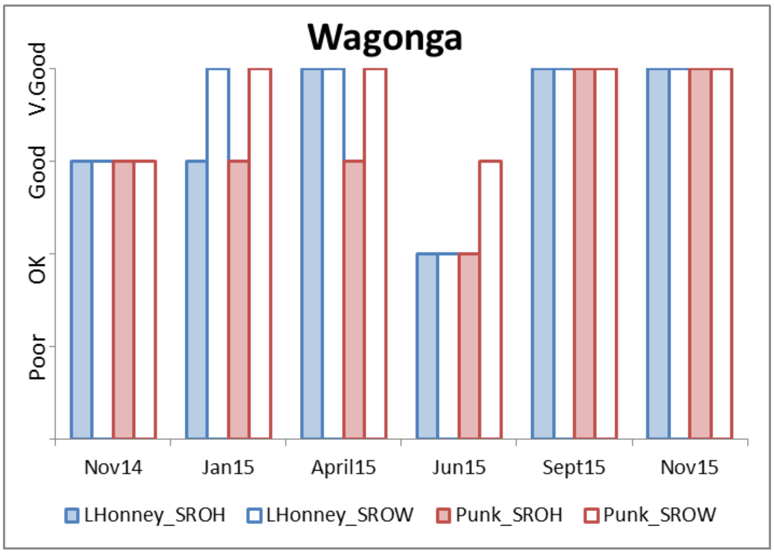



**Figure 13: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

### 4.1.3.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Punkally Creek, Lower Honeymoon, Golden Mile, Lower Lavender Point). At the start of the program in mid-May 2014, water temperatures for all sites were between 16-19°C dropping by 5°C, over winter and increasing to 17-20°C by Spring. Lower Honeymoon recorded the lowest temperatures and Lower Lavender, the highest, this continued throughout winter, where large rainfall events >50mm were recorded between the end of May and mid-June, the end of August and mid-October 2014. During Spring 2014, water temperatures fluctuated between 15-22°C until the end of September when temperatures increased to between 18-28°C. From this point until the end of spring, Lower Honeymoon recorded the highest temperatures and Lower Lavender the lowest. Over summer, temperatures remained between 18-28°C and Golden Mile and Punkally Creek recorded the highest temperatures and Lower Lavender the lowest. There were only three large rainfall events >50mm, in December 2014, January, April, May and August 2015. At the start of autumn, water temperatures were between 16-22°C with Lower Honeymoon displaying the lowest temperatures and Lower Lavender displaying the highest. Over winter 2015, temperatures fluctuated between 9-14°C, increasing to 17-23°C, over spring 2015 with Lower Lavender displaying the lowest temperatures and Lower Honeymoon the highest (Figure 14).

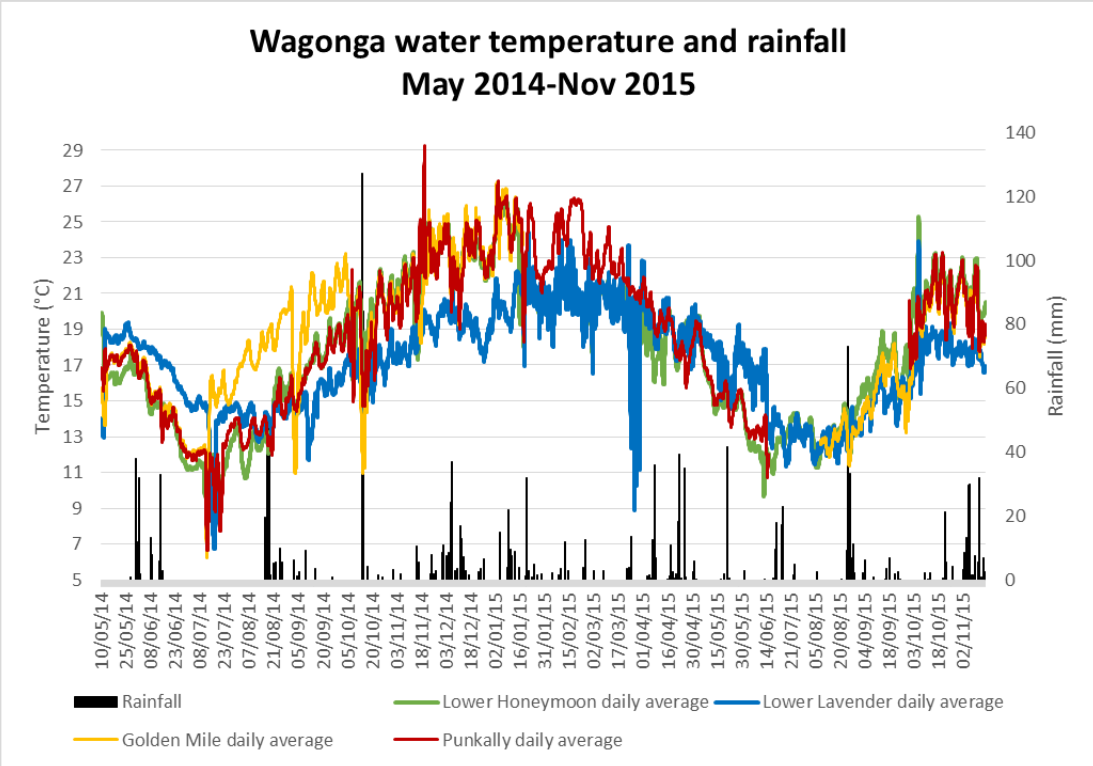



**Figure 14. Time series of temperature and rainfall for four monitoring sites within Wagonga.**

### 4.1.4 Wapengo Lake

#### 4.1.4.1 Mortality

There were no individual mortalities >5% during the program. The highest wild mortalities were at Spiros followed by a very similar oyster performance by the rest of the locations and oyster types (Figure 15). Hatchery mortalities were fairly similar for both sites. Cumulative wild SRO mortality levels at Wapengo ranged from 10-17% and for hatchery oysters from 11-12% at the conclusion of the Program.

**Table 5. % Mortality/grading and shell growth increment (mm/month) for wild, hatchery and TPO oysters at Wapengo.**

| | % Mortality/grading | | Shell growth increment (mm/month) | |
|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **SRO-Wild** | **SRO-Hatchery** |
| **Armstrong Bay** | 1.27 | 0.64 | 0.99 | 2.62 |
| **Mid Lake** | 1.16 | - | 1.27 | - |
| **Spiros** | 1.94 | 1.32 | 1.03 | 1.81 |

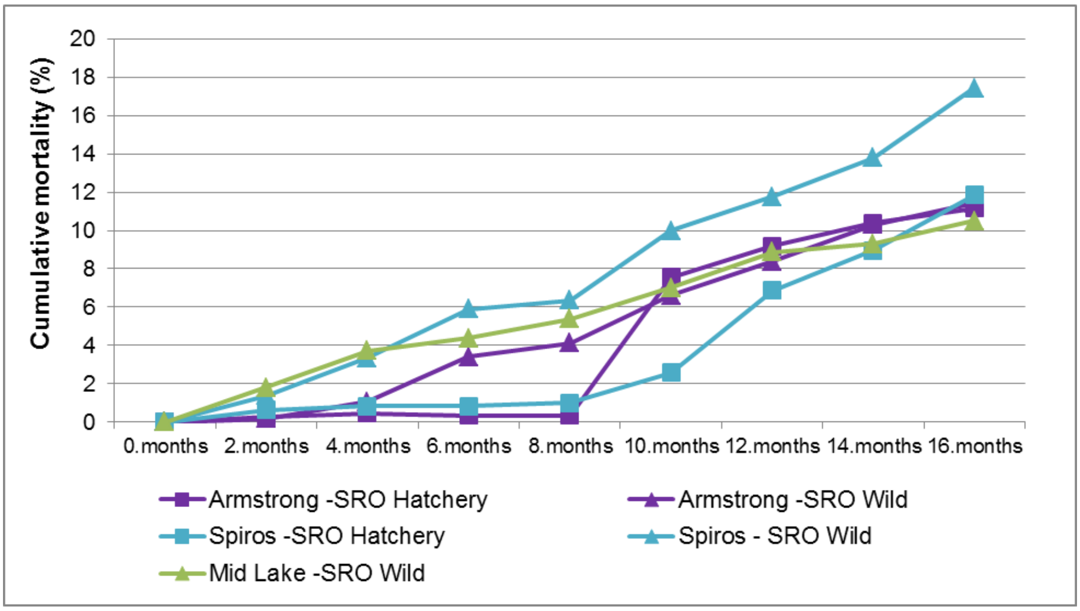



**Figure 15. Cumulative mortality of wild and hatchery oysters at each grading for all Wapengo sites**

#### 4.1.4.2 Growth

Shell growth increments (mm/month) are displayed in Table 5. Mid Lake (furthest downstream) wild oysters grew larger than the other two sites (Figure 16). Armstrong Bay hatchery oysters were larger than Spiros oysters and were 13mm bigger at the end of the program.

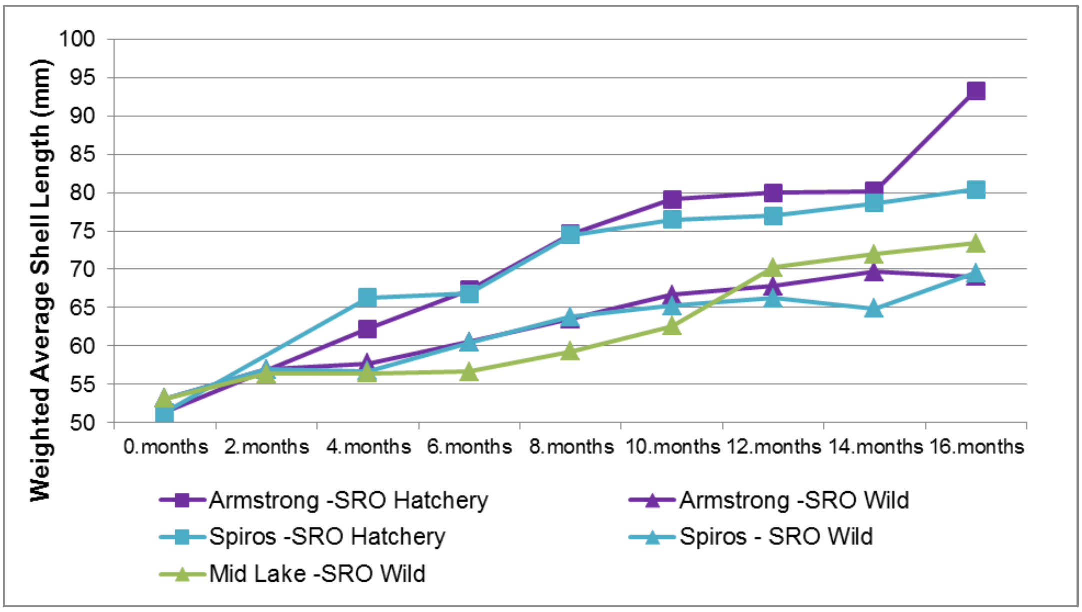



**Figure 16. Weighted average shell length of wild and hatchery oysters at Wapengo Lake over time.**

#### 4.1.4.3 Condition

Oyster condition was assessed at two sites Armstrong Bay and Spiros for both wild and hatchery stock (Figure 17). At the start of the program during Spring 2014, wild oysters were in good condition, whereas hatchery oysters were in a slightly worse condition respectively. Towards the end of summer 2014-15 Armstrong Bay oysters had improved and kept this condition throughout winter, whereas Spiros oysters lost condition. By the final grading in Spring 2015, wild and hatchery oysters at both sites were all in very good-good condition. Overall oysters at Armstrongs had significantly better condition than oysters at Spiros.

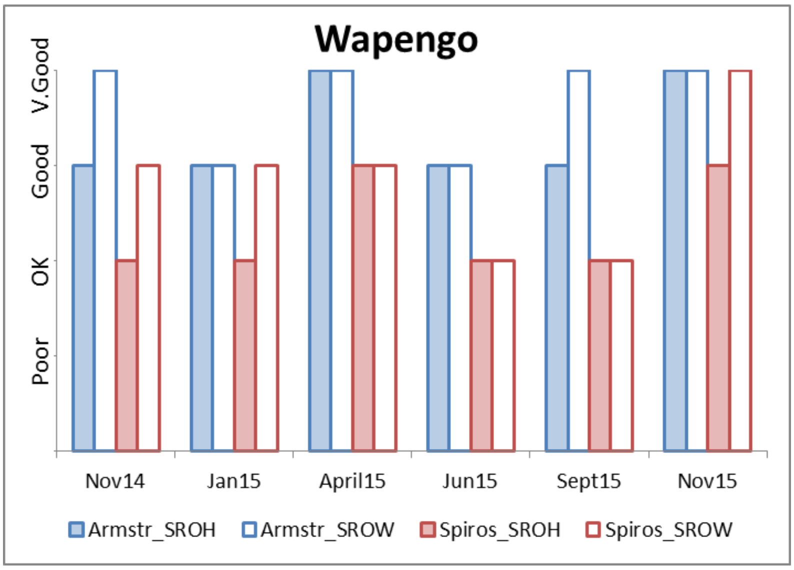



**Figure 17: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

#### 4.1.4.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Spiros, Armstrong Bay and Mid Lake). At the start of the program in mid May 2014, water temperatures for all sites were between 13-19°C, over the following two month period, water temperatures dropped to 9-15°C. Spiros recorded the lowest temperatures and Mid Lake the highest, this continued throughout winter. Water temperatures increased over spring 2014 and summer 2015 to fluctuate between 19-26°C until the end of March 2015 when temperatures started to decline. Over summer, Mid Lake had the highest temperature and Spiros the lowest. Temperatures then dropped to reach a low over winter and increase again during spring 2015. There were a few notable rainfall spikes >50mm in December 2014, and March and August 2015 (Figure 18).

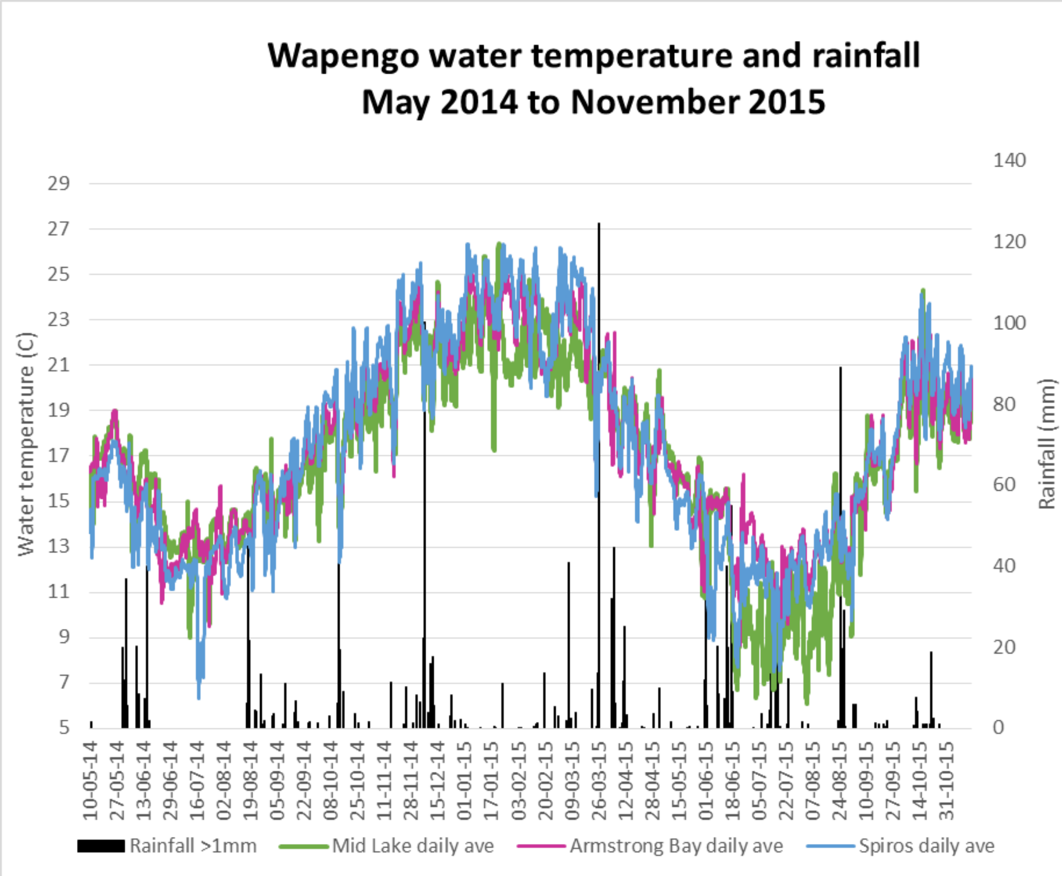



**Figure 18. Time Series of temperature and rainfall for four monitoring sites within Wapengo.**

#### 4.1.4.5 Phytoplankton

The phytoplankton community present most of the times at Site #2 (in the middle of the lake close to monitoring site called Mid Lake) is a well-mixed sample with a variety of small flagellates present in high levels. The breakdown of phytoplankton groups are approximately 40% diatoms; 9% dinoflagellates and 50% corresponds to small flagellates and ‘other plankton’ groups. The level of small flagellates is higher than what was found in close by estuaries. Species of harmful algal species were extremely low (1%).

Water temperatures in the middle of the lake were the lowest during most of the year with increased difference in mid-summer and from May to September. All algal groups were significantly positive correlated to water temperatures and presence of Dinoflagellates is positive correlation to salinity levels. Percentage of harmful algal levels was positively correlated to dinoflagellates, salinity and temperatures, indicating that toxic dinoflagellates species did not appear as a result of rainfall events.

Full phytoplankton report included in Appendix 4

### 4.1.5 Merimbula Lake

#### 4.1.5.1 Mortality

There were high mortalities >5% during the fourth grading (8 months) at Boggy Creek when high rainfall events were suggested to have affected the wild oysters. At the fifth grading (10 months), handling problems resulted in Mid Lake oysters being left out of the water too long and 20% of wild and 40% of hatchery oysters died (data for these mortalities have not been included in the statistical summary as they were not natural mortalities). There was a peak in mortality for Golf Lake at the end of the program, however the cause is unknown. Cumulative wild SRO mortality levels ranged from 12-24% and for hatchery oysters ranged from 4-10% at the end of the program (Figure 19).

**Table 6. % Mortality/grading and shell growth increment (mm/month) for wild and hatchery SRO oysters at Merimbula**

| | % Mortality/grading | | Shell growth increment (mm/month) | |
|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **SRO-Wild** | **SRO-Hatchery** |
| **Boggy Creek** | 1.35 | 1.11 | 0.72 | 1.63 |
| **Mid Lake (*)** | 1.51 | 0.51 | 0.55 | 1.59 |
| **Golf Lake** | 2.70 | - | 0.69 | - |
| **Front Lake** | 1.83 | - | 0.63 | - |

(*) Mortalities in oysters for Mid Lake during grading for 10months were excluded from this table as were not a result of natural mortalities but mishandling of the stock after being graded

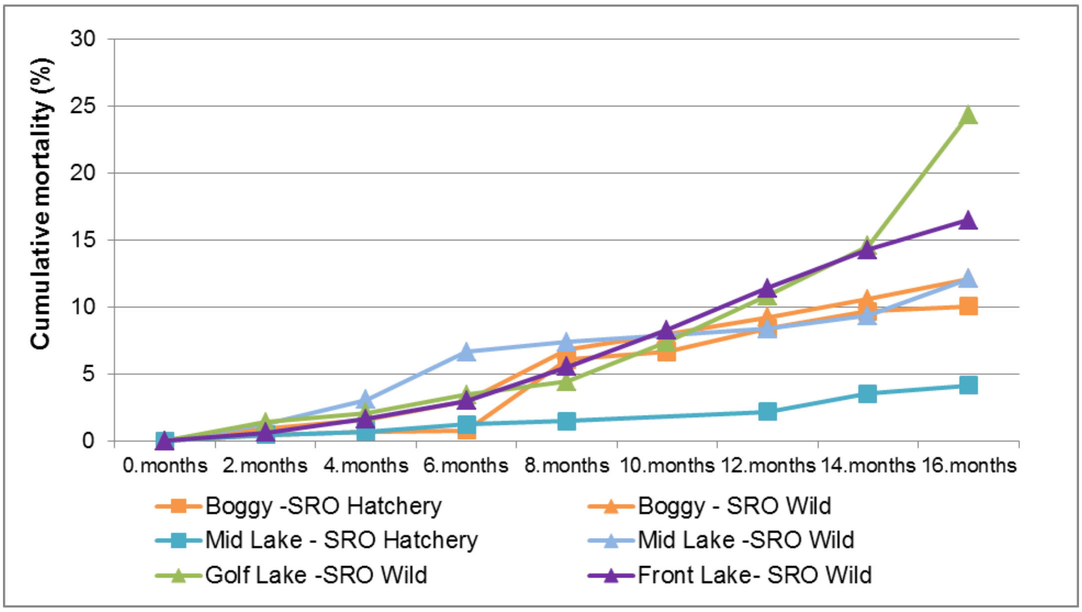



**Figure 19. Cumulative mortality of wild and hatchery oysters at each grading for all Merimbula sites**

N.B. Mortalities in oysters for Mid Lake during grading for 10months were excluded from this table as were not a result of natural mortalities but mishandling of the stock after being graded

#### 4.1.5.2 Growth

Shell growth increments (mm/month) are displayed in Table 6. All wild oysters performed similarly independent of site, they were within 1mm of each other (Figure 20). By the end of the program both hatchery oyster groups were similar in length and showed a shell growth increment of 26mm compared with the wild oysters that grew on average 12mm.

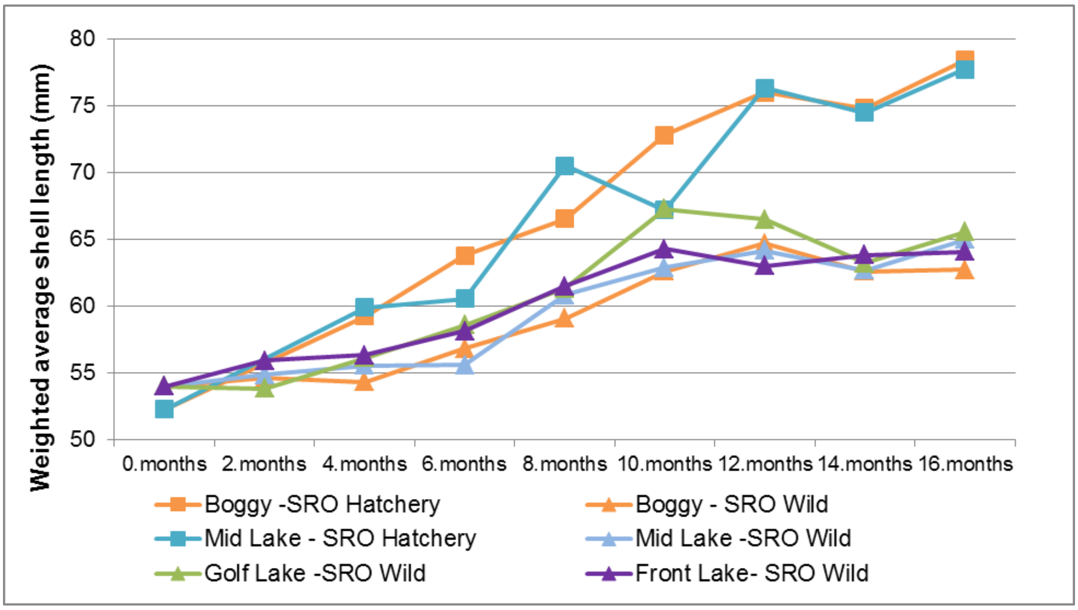



**Figure 20. Weighted average shell length of wild and hatchery oysters at Merimbula Lake over time.**

#### 4.1.5.3 Condition

Oyster condition was assessed at two sites Boggy Creek and Mid Lake for both wild and hatchery stock. At the start of the program during Spring 2014, wild oysters at both sites were in good-developing condition, whereas hatchery oysters were in a slightly worse condition. During summer 2014-15 wild and hatchery stock at both sites started to improve in condition. During Autumn, Boggy Creek oysters started to lose condition, receiving a poor score in both type of oysters. Oyster condition in all oyster batches improved or kept good level of condition, increasing gradually towards Spring 2015. Overall hatchery oysters showed a more variable condition than wild oysters (Figure 21).

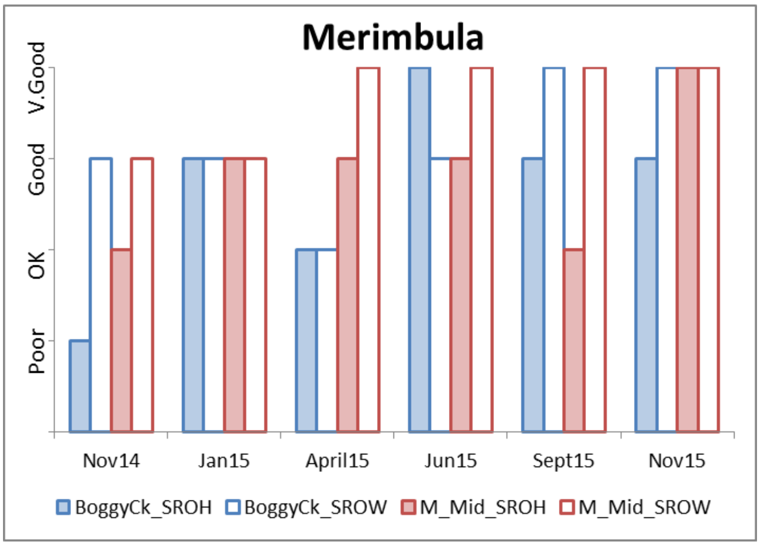



**Figure 21: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

#### 4.1.5.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Top Lake, Golf Lake, Boggy Creek, Mid Lake). At the start of the program in mid May 2014, water temperatures for all sites were between 11-18°C, over the following two month period, water temperatures dropped to 9-15°C. Golf Lake recorded the lowest temperatures and Front Lake the highest, this continued throughout winter, where four large rainfall events >20mm were recorded between at the start of June and mid-end August. Water temperatures increased over spring 2014 and summer 2015 to fluctuate between 21-28°C until the end of March 2015 when temperatures started to decline. Over summer, Golf Lake had the highest temperature and Front Lake the lowest. Temperatures then dropped to reach a low over winter and increase again during spring 2015 (Figure 22).

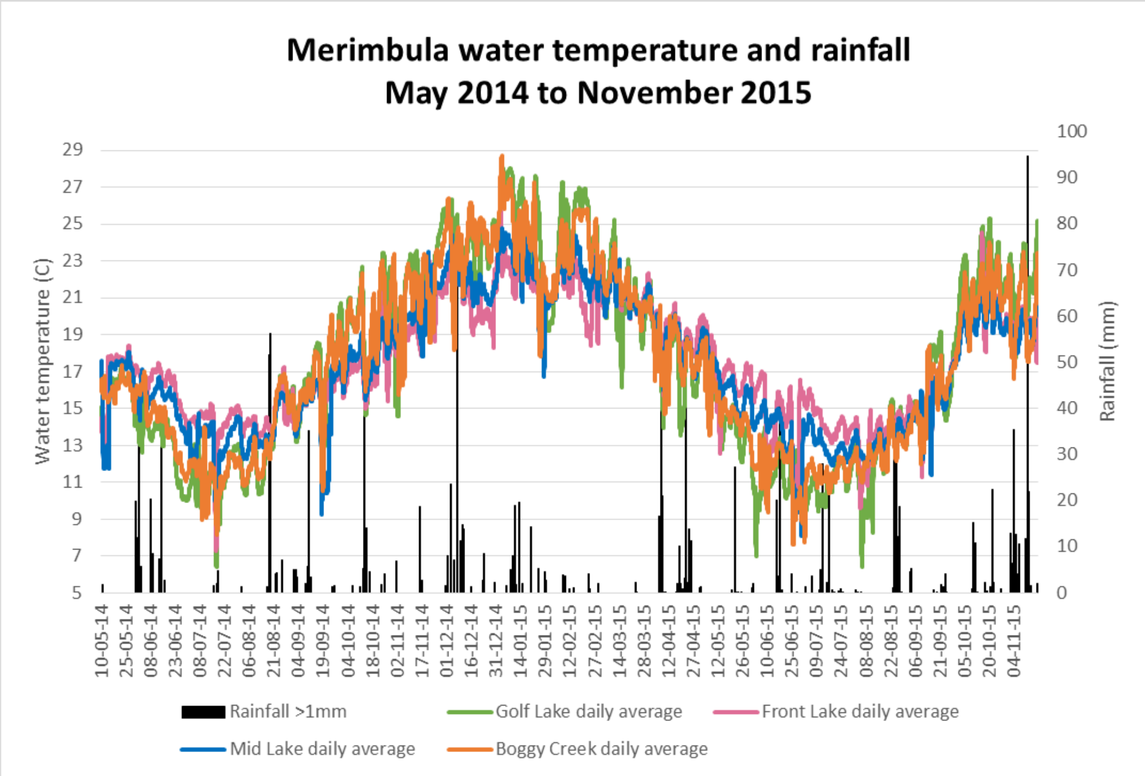



**Figure 22. Time series of temperature and rainfall for four monitoring sites within Merimbula Lake.**

#### 4.1.5.5 Phytoplankton

The phytoplankton community at the Merimbula site #2 (middle of the lake) is normally represented by a well-mixed with a good diversity of diatoms and flagellates. The breakdown of phytoplankton groups are approximately 71% diatoms; 6% dinoflagellates and 22% corresponds to small flagellates and 'other plankton' groups. The diatom group is dominated by planktonic species rather than benthic species. Levels of harmful species per sample were very low (4%) except that in occasions the levels increased to 20%. No link to rainfall events was found and diatoms species dominated the harmful species. All algal groups were found negatively correlated with oyster mortality levels meaning that periods of higher than usual mortalities occur when algal levels for all groups were lower than average.

During the colder months water temperature at sites closer to the mouth/ocean were warmer than inside of the lake. During summer the situation reverses. High levels of dinoflagellates and small flagellates were present during high levels of salinity and water temperature. Significant correlation was found between levels of Dinoflagellates and growth of wild Sydney Rock Oysters.

Full phytoplankton report included in Appendix 4

### 4.1.6 Pambula Lake

#### 4.1.6.1 Mortality

There were no high mortalities >5% during the program however Wild oysters at the Entrance location experienced consistently 3.5-4% every grading from 8 month onwards resulting in the highest cumulative mortality (~23%). Lowest mortalities were seen at Mid Lake for hatchery oysters and at Back Lake for wild oysters (Figure 23). Cumulative wild SRO mortality levels at Pambula ranged from 13-23% and for hatchery oysters from 10-16% at the conclusion of the Program.

**Table 7: % Mortality/grading and shell growth increment (mm/month) for wild, hatchery and TPO oysters at Pambula**

| | % Mortality/grading | | Shell growth increment (mm/month) | |
|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **SRO-Wild** | **SRO-Hatchery** |
| **Entrance** | 2.60 | - | 0.49 | - |
| **Mid Lake** | 1.79 | 1.34 | 0.74 | 1.57 |
| **Back Lake** | 1.54 | - | 0.77 | - |
| **Front Lake** | 1.82 | 2.01 | 0.66 | 2.04 |

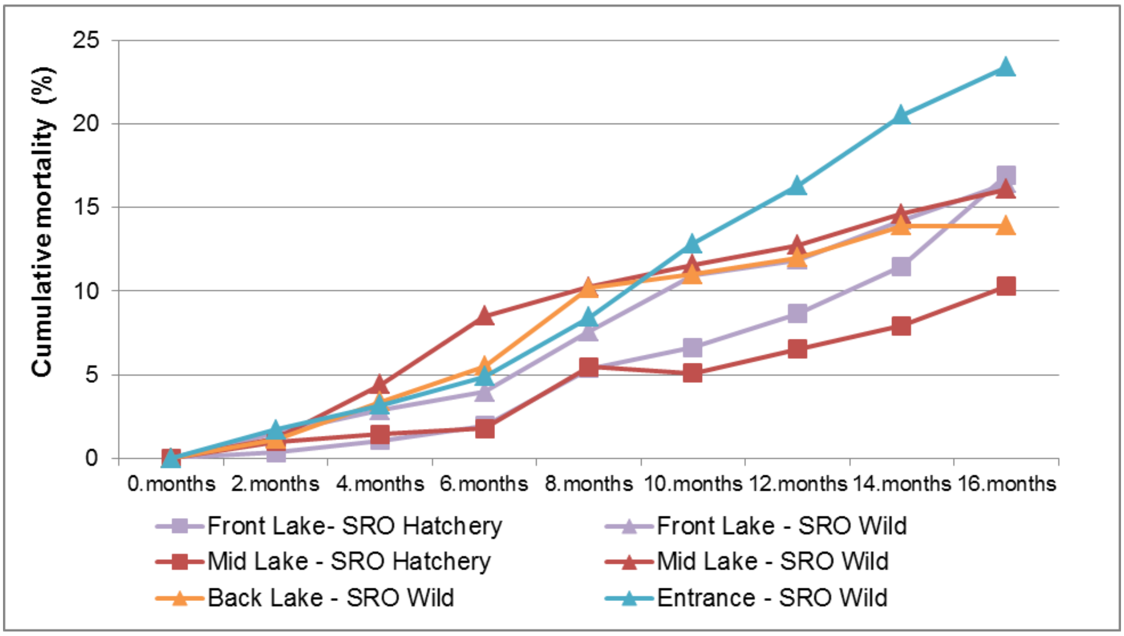



**Figure 23. Cumulative mortality of wild and hatchery oysters at each grading for all Pambula sites**

#### 4.1.6.2 Growth

Shell growth increments (mm/month) are displayed in Table 7. By the end of the program both Front Lake wild oysters and Mid Lake hatchery oysters reached significantly larger sizes that the rest of the oyster batches. These two groups of oysters grew 10-15mm more than the rest (Figure 24). During the 6-month grading (end of November) hatchery oysters recorded a quick increase in growth. Shell lengths recorded for wild oysters at 14months showed a significant reduction in growth compared with the grading during the 12-months. This might have been a result of grader settings or a slight increase in mortalities of large oysters only.

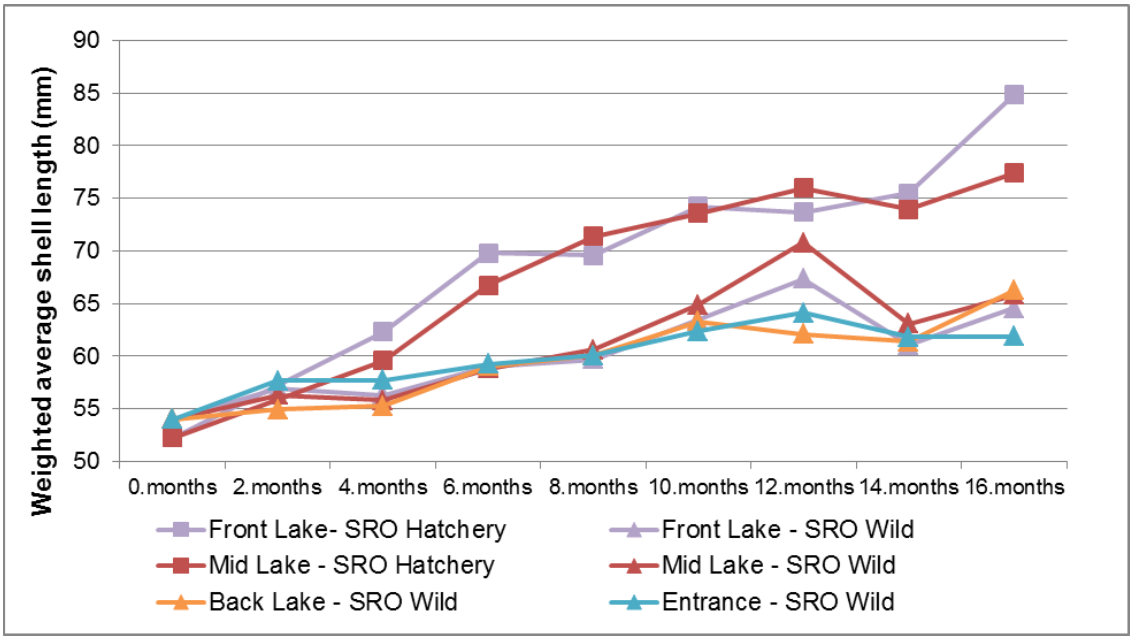



**Figure 24. Weighted average shell length of wild and hatchery oysters at Pambula Lake over time.**

#### 4.1.6.3 Condition

Oyster condition was assessed at two sites Mid Lake and Front Lake for both wild and hatchery stock. At the start of the program during Spring 2014, wild oysters at both sites were in good condition, whereas hatchery oysters were still developing condition. During Summer 2014-15 wild oysters were in 'very good' condition and hatchery oysters in 'good' condition. By Autumn, wild and hatchery oysters at both sites dropped condition significantly which remained like this through Winter, showing a slight improvement. Condition improved by the end of winter and reached good levels by Spring at the end of the program. All through the program, wild oysters at the Front Lake site showed improved condition index than the rest of the oyster batches (Figure 25).

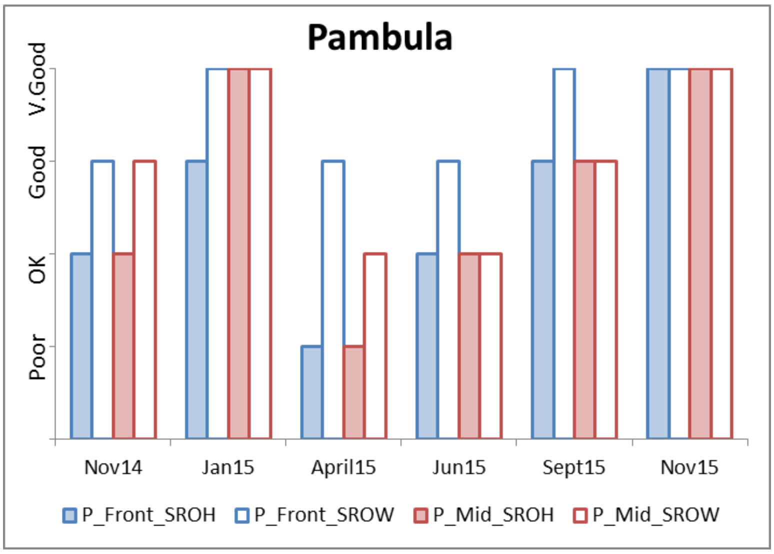



**Figure 25: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

#### 4.1.6.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Front Lake, Mid Lake, Back Lake and Entrance). At the start of the program in mid May 2014, water temperatures for all sites were between 13-18°C, over the following two month period, water temperatures dropped to 9-14°C. Back Lake recorded the lowest temperatures and Entrance the highest, this continued throughout winter, where four large rainfall events >20mm were recorded between at the start of June and mid-end August. Water temperatures increased over spring 2014 and summer 2015 to fluctuate between 19-26°C until the end of March 2015 when temperatures started to decline. Over summer, Front Lake had the highest temperature and Entrance the lowest. Temperatures then dropped to reach a low over winter and increase again during spring 2015 (Figure 26).

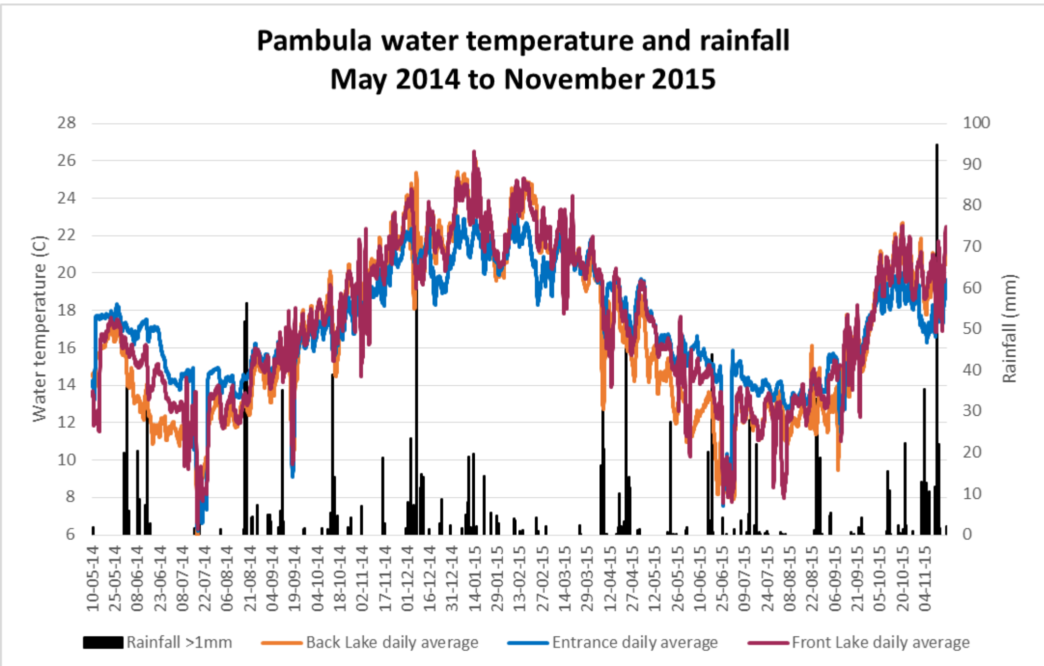



**Figure 26. Time series of temperature and rainfall for four monitoring sites within Pambula Lake**

#### 4.1.6.5 Phytoplankton

Phytoplankton species present at Site #17 (in the middle of the lake) indicate that the site is influenced by good oceanic flushing in which phytoplankton move with currents more than being produced in-situ. The breakdown of phytoplankton groups are approximately 50% diatoms; 13% dinoflagellates and 37% corresponds to small flagellates and 'other plankton' groups. Within the diatom group there are more planktonic species than benthic species. Levels of harmful species per sample overall were very low (2%) resulting in no closure of the harvest areas. Oyster mortalities recorded appear to be more driven by periods of low algal levels. High oyster growth rates occurred during low levels of diatoms (in particular planktonic diatoms) and high levels of dinoflagellates and small flagellates.

During the colder months water temperature at sites closer to the mouth/ocean were warmer than inside of the lake. During summer the situation reverses. Water temperature at the Entrance location tends to be different to the other sites within Pambula Lake (i.e. major gradient difference of 2°C). Rain events (i.e. increased in nutrient run-off) result in a slight increase in algal levels in particular dinoflagellates and small flagellates.

Full phytoplankton report included in Appendix 4

### 4.1.7 Wonboyn Lake

#### 4.1.7.1 Mortality

There were high mortalities >5% at Broadwater for wild oysters at 2 and 4 month grading. Increased mortalities also were recorded in the Corner Channel site during at 12 & 14 months (Figure 27). Low mortalities were seen at all other sites for the first 12 months. Mortality levels for hatchery oysters were generally lower than wild oysters except at Broadway location were 20% of the hatchery oysters only were lost during the first grading two months after starting the monitoring program. Oysters were tested by the DPI veterinarians but no explanation for the losses was identified. Cumulative wild SRO mortality levels at Wonboyn ranged from 13-40% and for hatchery oysters from 20-46% at the conclusion of the program (Figure 27).

**Table 8. % Mortality/grading and shell growth increment (mm/month) for wild, hatchery and TPO oysters at Wonboyn**

| | % Mortality/grading | | Shell growth increment (mm/month) | |
|---|---|---|---|---|
| **Location** | **SRO-Wild** | **SRO-Hatchery** | **SRO-Wild** | **SRO-Hatchery** |
| **Broadwater** | 2.86 | 5.75 | 0.41 | 1.30 |
| **The River** | 2.35 | - | 0.80 | - |
| **Red Rock** | 2.17 | 2.66 | 0.75 | 1.76 |
| **Corner Channel** | 5.83 | - | 0.70 | - |

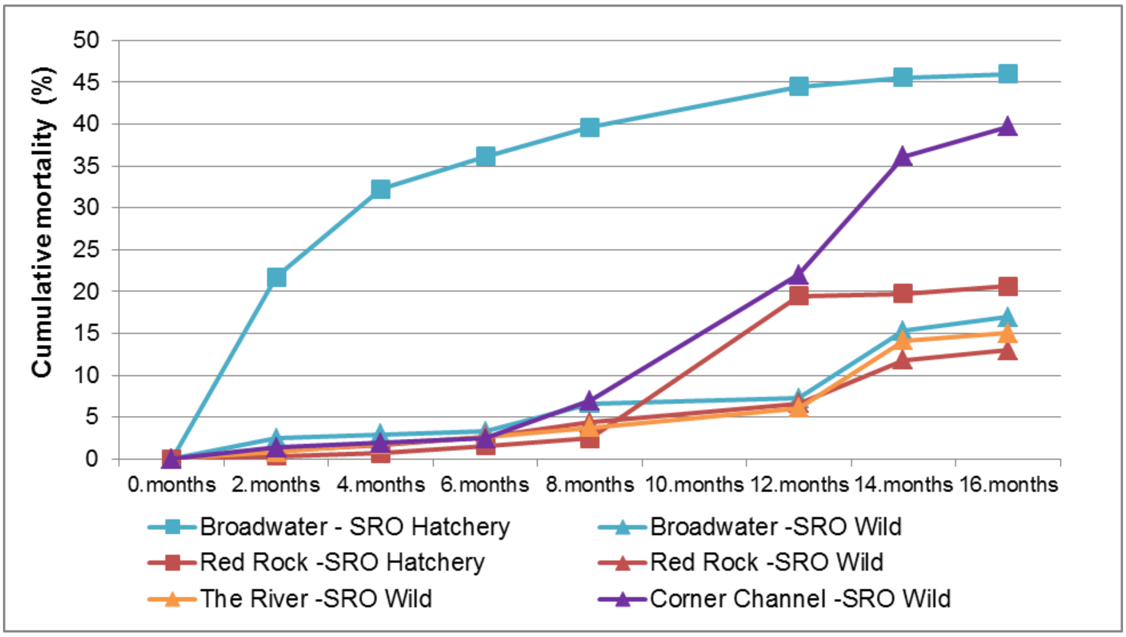



**Figure 27. Cumulative mortality of wild and hatchery oysters at each grading for all Wonboyn sites**

N.B. Data is missing for 5th grading (April 2015) at 10 months as a result of severe floods at the time in Wonboyn Lake.

#### 4.1.7.2 Growth

Shell growth increments (mm/month) are displayed in Table 8. Broadwater wild oysters lagged behind the other monitoring sites all through the program. Red Rock, The River and Corner Channel were all similar in length at the final grading (Figure 28). Overall hatchery oysters grew more than wild oysters. After 6 months, hatchery oysters at Red Rock outperformed Broadwater hatchery oysters by 7mm and by end of the program showed a growth increment of 28mm from the start.

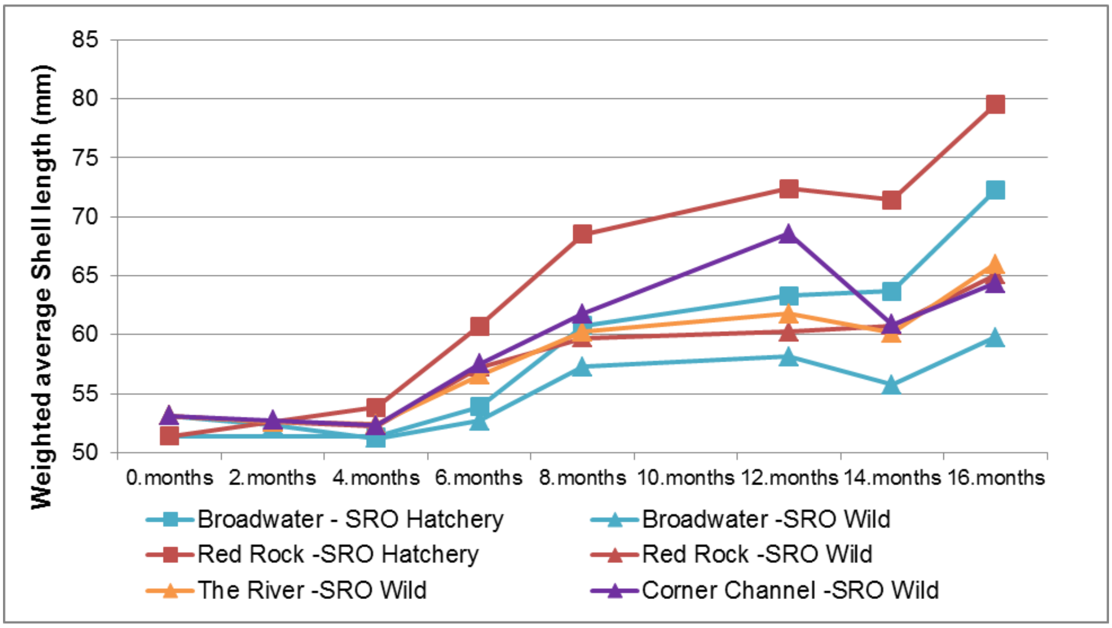



**Figure 28. Weighted average shell length of wild and hatchery oysters at Wonboyn Lake over time.**

N.B. Data is missing for 5th grading (April 2015) at 10 months as a result of severe floods at the time in Wonboyn Lake.

#### 4.1.7.3 Condition

Oyster condition was assessed at two sites Broadwater and Red Rock for both wild and hatchery stock. At the start of the program during Spring 2014, all oysters showed good condition with the exception of hatchery oysters at Red Rock. During Summer 2014-15 oyster condition remained the same. No grading occurred in Autumn due to major rainfall event. By winter, Red Rock hatchery oysters had improved and Broadwater oysters were also in very good condition. Oyster condition remained good and very good from the end of winter to the end of the program at the end of Spring. Red head hatchery oysters were the only group of oysters that showed fluctuating oyster condition.

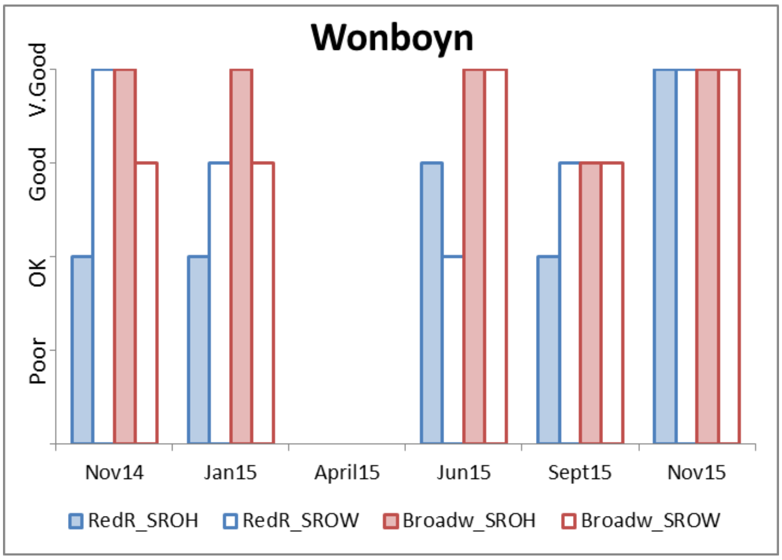



**Figure 29: Overall Condition Index through time for wild (SROW) and hatchery (SROH) oysters**

N.B. Data is missing for 5th grading (April 2015) at 10 months as a result of severe floods at the time in Wonboyn Lake.

#### 4.1.7.4 Water temperatures

Water temperatures were recorded hourly at all four sites (Broadwater, Corner Channel, Red Rock and The River). At the start of the program in mid May 2014, water temperatures for all sites were between 14-17°C, over the following two month period, water temperatures dropped to 8-13°C. Red Rock (downstream site) recorded the lowest temperatures and The River (upstream site) the highest, this continued throughout winter, where four large rainfall events >20mm were recorded between at the start of June and mid-end August. Water temperatures increased over spring 2014 and summer 2015 to fluctuate between 19-27°C until the end of March 2015 when temperatures started to decline. Over summer, The River had the highest temperature and Red Rock the lowest. Temperatures then dropped to reach a low over winter and increase again during spring 2015. There were five large rainfall events>50mm throughout the monitoring period, during June, August and December 2014 and again in November 2015 (Figure 30).

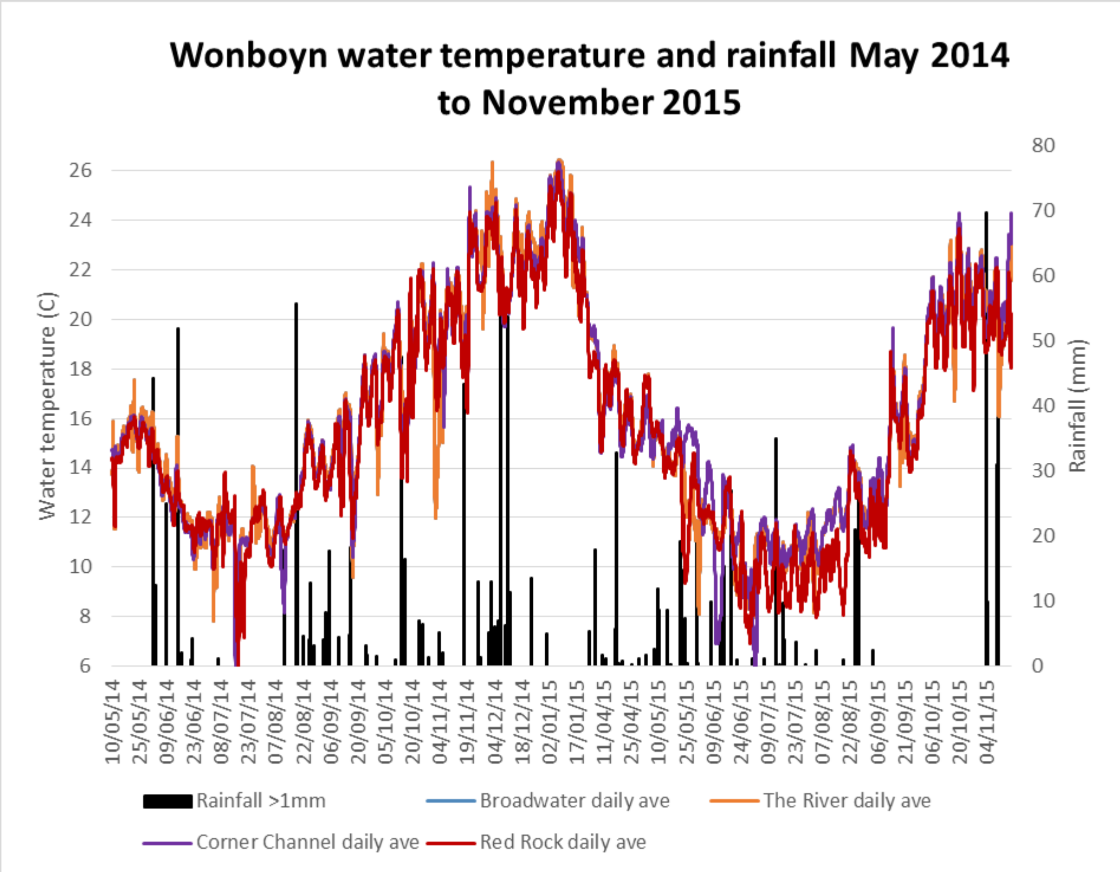



**Figure 30. Time series of temperature and rainfall for four monitoring sites within Pambula Lake**

#### 4.1.7.5 Phytoplankton

The phytoplankton community present most of the times at both Site#1 and #2 is composed by a wide range of small flagellates and planktonic diatoms, in particular the genus *Dactyliosolen* which is found frequently in this lake in comparison with the diatoms present in other lakes in the Far South Coast. Site#2 had overall more algal biomass than Site#1. The breakdown of phytoplankton groups is similar among sampling sites with approximately 38% diatoms; 10% dinoflagellates and 52% corresponds to small flagellates and ‘other plankton’ groups. Species of harmful algal species accounted for 5-7% of the overall phytoplankton species with the exception of the summer months from mid-November to mid-January when the toxicity percentage increased to 15 and 50% attributed to the planktonic diatom species of the group Pseudo-nitzschia. Overall total algal levels were correlated with oyster growth.

All water temperatures’ locations in the lake were very consistent, probably as a result of similar water depth and water movement across the lake. A significant correlation was found between total algal levels and water temperature. Diatoms were also correlated with salinity indicating that blooms of toxic diatoms of Pseudo-nitzchia are not a result of rainfall events.

Full phytoplankton report included in Appendix 4

## 4.2 Comparison between estuaries

### 4.2.1 Cumulative mortalities

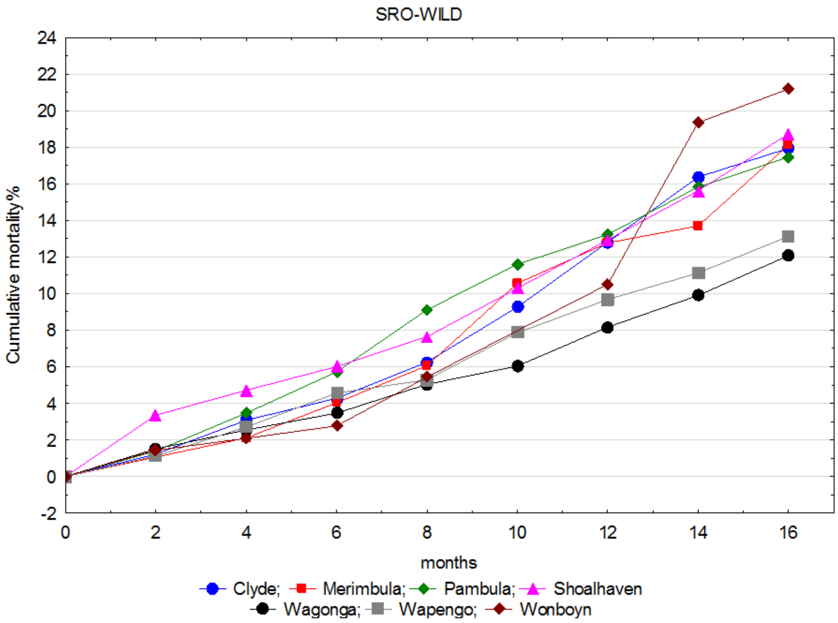
After 16 months of monitoring, cumulative mortality levels for wild SRO independently of lease location across the seven estuaries ranged from 16% to 40% and for hatchery oysters ranged from 7% to 17%, with the exception of Wonboyn that suffered from unusual mortalities in hatchery oysters increasing the level to 46% (Figure 31). TPO oysters mortalities ranged from 1.7% at Shoalhaven to 8.8% at the Clyde. Wonboyn Lake had the highest cumulative mortality for both wild and hatchery SROs while Wagonga Inlet showed the lowest mortality.


**Figure 31. Percentage cumulative mortality for wild and hatchery SRO and TPO's across all estuaries.**

N.B. Data presented for SRO data was collected during 16months and data for TPO was collected during 10 months. Also mortalities recorded in Merimbula at MidLake at the 10months grading have not been included in this summary as were not a result of natural mortalities but as a result of mishandling oysters

Overall % mortality per grading (i.e. every 2months) was on average 2±2.5% for wild SRO; 1.4±2.8% for hatchery SRO and 0.7±1.3% for TPO's. Percentage SRO mortalities increased slightly from the $5^{th}$-$6^{th}$ grading at 8-10 months of program (end of Jan-March 2015) and remained higher during the $7^{th}$ grading at 12 months (May-June 2015, Figure 32). During the 6th grading, oysters also started to grow quicker than in previous gradings (Figure 34). TPOs had slightly higher mortalities during Sept14 and Mar15 grading in the Clyde only. TPO mortalities were extremely low at the Shoalhaven.

A)




B)

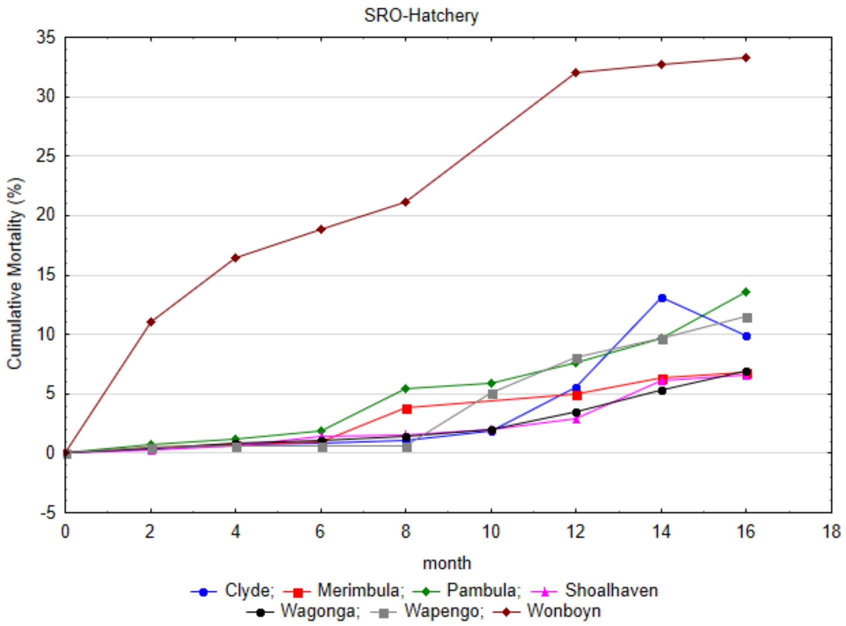



**Figure 32. Cumulative mortality (%) per estuary by oyster type A) SRO Wild; B) SRO Hatchery**

### 4.2.2 Growth

For both wild and hatchery SROs, the highest growth rates were recorded at Wapengo (Figure 33). Shoalhaven had the slowest growth rates for both wild and hatchery oysters. TPO oysters were grown at two estuaries and showed similar growth rates with slightly higher growth rates at Clyde compared to Shoalhaven. Overall, TPO growth rates were 40% faster than the average hatchery SRO rates, and 75% faster than wild SRO growth. SRO hatchery oysters reached twice the shell length of wild SROs.

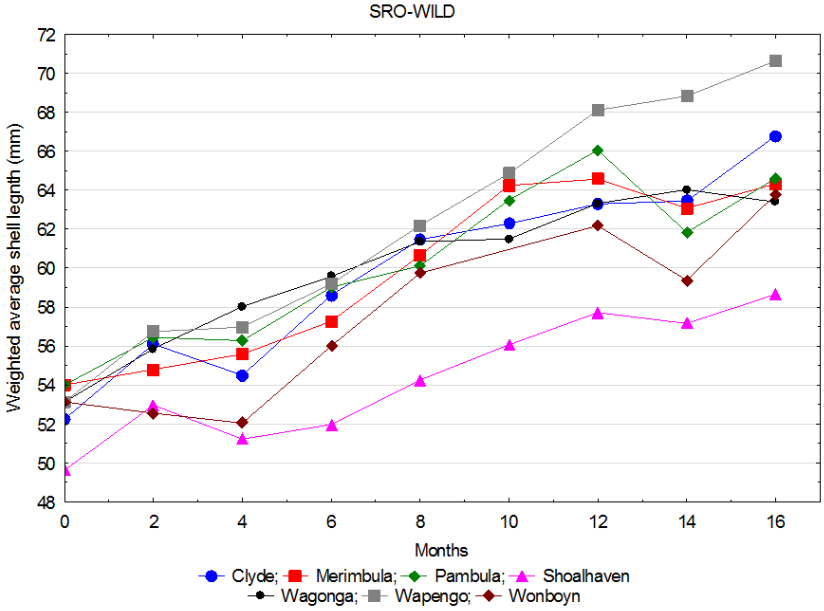

(*time=SOAP sampling period ie TPO=10months; SRO=16months)

**Figure 33. Total growth increment for wild and hatchery SRO and TPO's across all estuaries.**

Overall weighted average shell lengths are displayed in Figure 34a. The graph shows that Shoalhaven wild SROs remained below all other estuaries for the duration of the program. Wonboyn was the second lowest for shell length throughout the 16 month period. All other sites were more closely aligned throughout the program with a pulse of growth during the first 2 months of monitoring and during 4 to 12 months. Wapengo oysters, both hatchery and wild, recorded the highest growth rates throughout the program, finally reaching on average 71mm in wild oysters and 87mm in hatchery oysters (Figure 34 a,b). Clyde and Pambula showed the second highest average shell lengths at 67mm (wild) and 82mm (hatchery). All wild growing sites, except Shoalhaven, performed very similar reaching all a shell length of around 64mm. Hatchery oysters showed a slightly different growth pattern with Shoalhaven and Wonboyn both tracking with the lowest weighted average shell length (Figure 34b). Pambula showed the highest average growth rates after 6 months and then Wapengo took the lead after 8 months.

A slight reduction in weighted average shell lengths were recorded during the 14month grading. At this point the grader recipe had to be changed slightly to accommodate the larger size oysters. In addition, during this period slight increases in mortalities were recorded at some locations influencing the weighted average shell length results, probably as a result of large oysters dying.

A)




B)

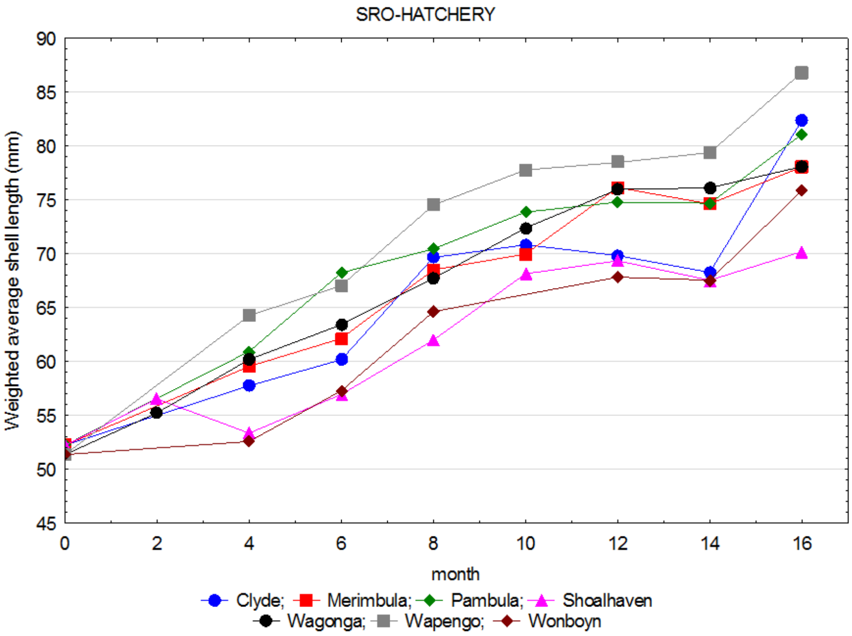



**Figure 34. Weighted average shell length comparison between estuaries over time for a) wild and b) hatchery SRO oysters.**

### 4.2.3 Condition Index

Overall oyster condition index was better in wild oysters compared to hatchery oysters except for the Clyde where hatchery oysters scored slightly better results than wild oysters. However condition index overall for all oyster type in the Clyde was the lowest compared with the other estuaries. Large difference in condition index was found across oyster type in Merimbula, Pambula, Wapengo and Wagonga. Both oyster types recorded similar and good condition index in Wonboyn and Shoalhaven (Figure 35).

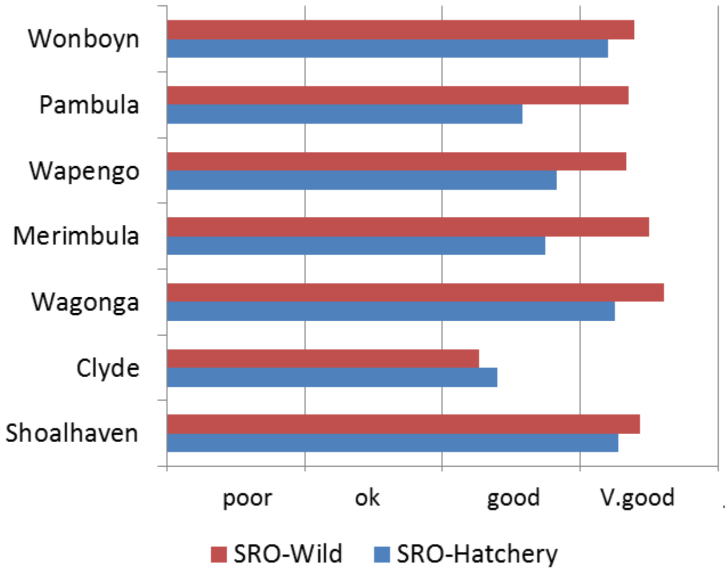



**Figure 35. Condition index summaries across estuaries for wild and hatchery oysters.**

### 4.2.4 Phytoplankton communities

Phytoplankton is the key source of micronutrients, vitamins, oils and trace elements for aquatic communities like oysters. They are rich sources of macronutrients, protein, carbohydrates and especially specific essential fatty acids. The nutritional value of phytoplankton is species-specific which can also vary according to nutrient and light availability, and other physical and chemical conditions experienced during growth. Consequently, a wide range of phytoplankton species is needed to support healthy oyster populations. In the wild oysters generally have access to a wide range of phytoplankton species.

Total Phytoplankton can be used as a rough indication of the algal density in an estuary, however care should be taken using this data as the biovolume of the algae species have not been taken into account in the results presented here (ie. since algal cell size varies quite a lot, you can have millions of a small size algae species in comparison with fewer larger algae species, however overall the biomass could be the same). Using this data to evaluate the food supply to oysters is not straight forward but long-term data series help identify overall changes in the overall algal community. Phytoplankon data was only collected at one location in the 4 furthest southern estuaries in the south coast as part of a regional grant. Hence data is only presented for Wapengo, Merimbula, Pambula and Wonboyn.

When looking at the breakdown of the type of algal groups found in the samples, Wapengo and Wonboyn showed larger percentage of small microalgal species (in general have small size cells) than Pambula and Merimbula (Figure 36). On the other hand, Pambula and Merimbula had higher percentages of diatoms overall. Within the group of diatoms, Wapengo and Wonboyn had higher number of benthic diatom species while Pambula and Merimbula had more planktonic species. Presence of benthic diatoms means that the sites have been influenced by resuspension processes. Small flagellates and benthic diatoms are known to be key components of an oyster diet. Planktonic diatoms are generally more related to oceanic input than in situ (estuary) production. These diatoms are also good oyster food source but a large percentage of these diatoms in NSW estuaries belong to toxic species that impact human health.

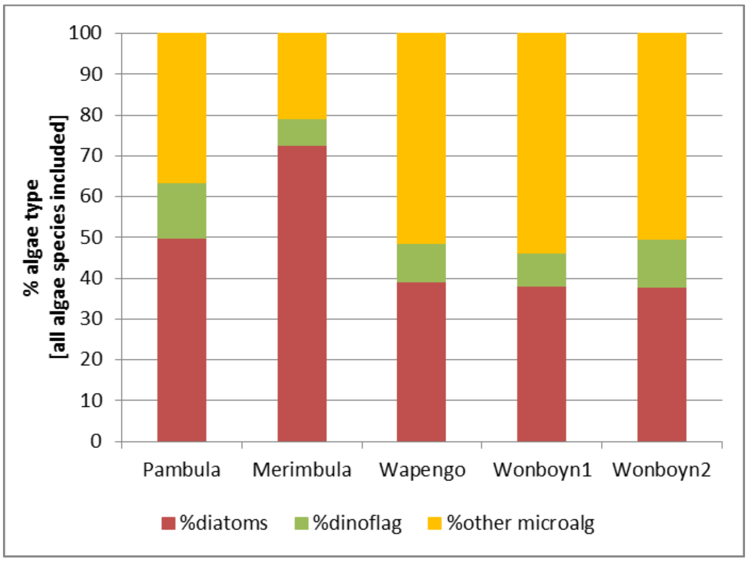



**Figure 36: Characteristics of the overall phytoplankton community by main algal groups for each estuary sampled**

The percentage of toxic species related to public health/ food safety was low, ranging from 0.5% to 5% across estuaries sampled (Figure 37). Once again the %levels are influenced by the size of the algal cell and the number of cells in the sample. Hence this should be used as a rough guide. The algal species groups contributing to the levels of %harmful are consistent across estuaries instead the difference found is based on the cell quantity. However in Wonboyn Lake a larger number of toxic dinoflagellates species were present in the samples in comparison with the other 3 estuaries. Diatoms like *Pseudo-nitzschia,* and dinoglagellates like *Alexandrium, Dinophysis and Prorocentrum* are the dominant toxic species at all estuaries. High levels of toxic species were not consistently related to post-rainfall events.

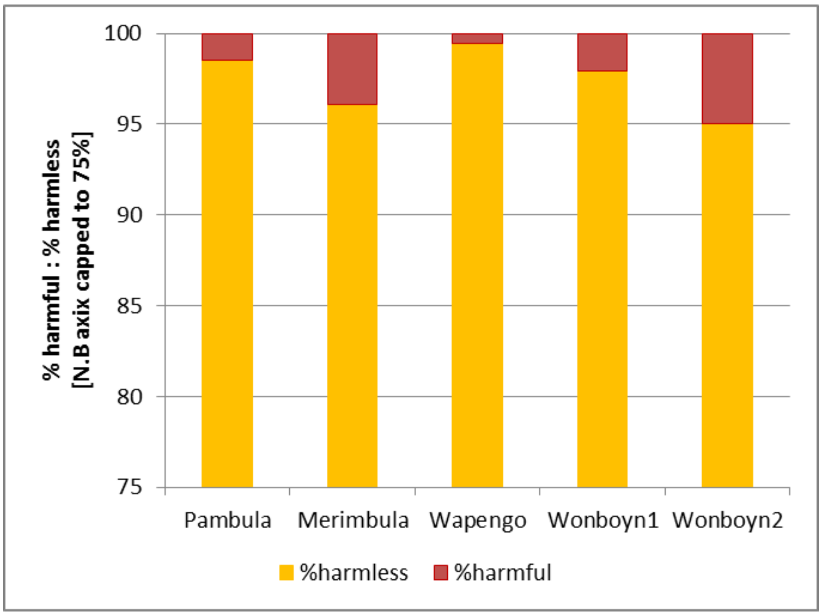



**Figure 37: Percentage proportion of harmful versus harmless phytoplankton species for each estuary sampled**

### 4.2.5 Water Temperature

Environmental parameters like water temperature are known to influence the maximum feeding rates of suspension-feeders like oysters (see references in Shumway 2011). Water temperature was recorded using loggers that were deployed in one of the oyster baskets used as part of the monitoring program. Each main growing area was monitored. Water temperature levels are influenced by significant rainfall events. Long-term monitoring of water temperature allows for the calculation of anomalies so that warmer or cooler than usual months could be easily identified. Water temperatures declined quickly between the months of April and June (Figure 38). The lowest monthly temperature was recorded in Wonboyn Lake (10.3°C) in the middle of winter. The highest monthly temperatures were recorded in the Clyde and in Wonboyn Lake (24°C) during January and February. The widest range of temperatures was recorded in Wonboyn Lake probably as a result of its geographical location (i.e. Furthest south) and due to its bathymetry (i.e quite shallow in most areas of the lakes, Table 9).

Over the duration of the monitoring program, oyster shell length at most locations increased the greatest over the warmer months of November to January, most probable as a consequence of increased water temperatures and food availability. In most of the estuaries water temperature tended to follow the same seasonal pattern, whereby water temperatures upstream or in the mid/back areas of estuaries were colder in winter than at the entrance/front lake locations where sites had greater exposure to oceanic waters at this time. In summer this pattern reversed and water in the upstream locations of the estuary tended to be warmer than at the downstream sites closer to the entrance. This pattern has been captured in the three last years of monitoring. Oyster growth tends to be minimal during the winter months once water temperatures drop below 12°C around July. Therefore by trying to grow oysters in slight warmers areas, over the low temperature threshold, could result in significant advantage in oyster growth during winter.

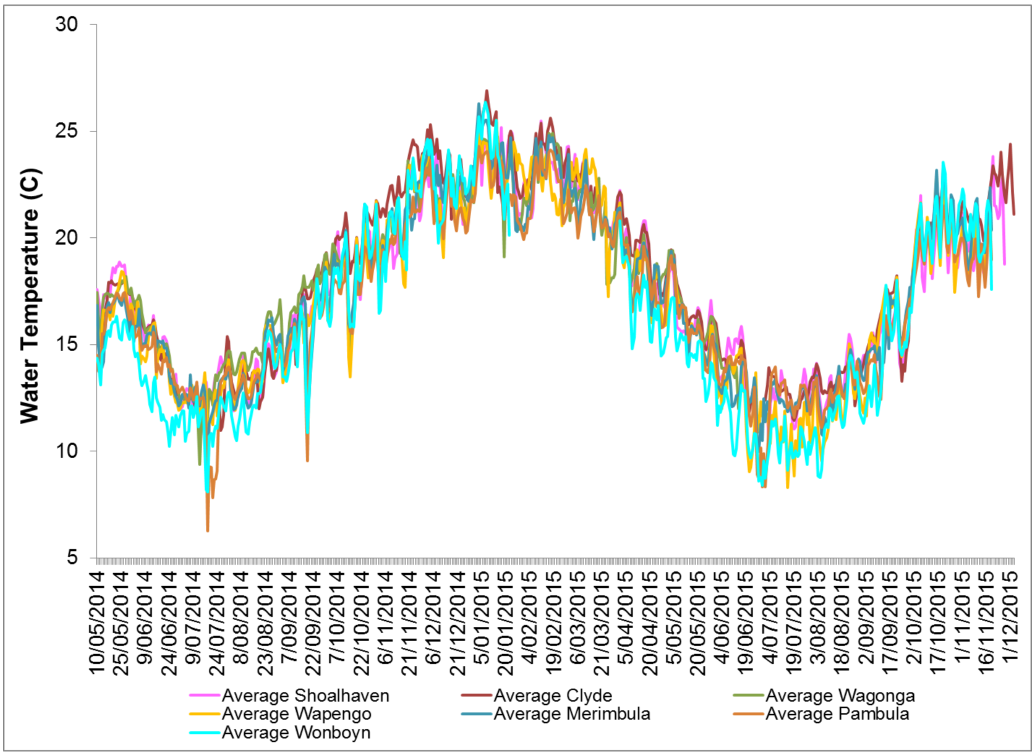



**Figure 38: Time series of daily water temperature averaged for all locations within an estuary**

**Table 9: Monthly averaged water temperatures for the length of SOAP (May 2014-Nov 2015)**

| | Shoalhaven | Clyde | Wagonga | Wapengo | Merimbula | Pambula | Wonboyn |
|---|---|---|---|---|---|---|---|
| **2014** | | | | | | | |
| **5** | 17.7 | 17.3 | 17.4 | 16.9 | 16.3 | 16.4 | 15.4 |
| **6** | 15.0 | 15.1 | 15.3 | 14.5 | 14.8 | 14.5 | 12.5 |
| **7** | 12.9 | 12.4 | 12.7 | 12.5 | 12.5 | 11.8 | 11.4 |
| **8** | 13.4 | 13.4 | 14.9 | 13.9 | 13.7 | 13.7 | 12.8 |
| **9** | 16.2 | 16.7 | 17.2 | 16.0 | 15.9 | 15.4 | 15.3 |
| **10** | 18.6 | 19.9 | 18.7 | 18.3 | 18.6 | 17.8 | 18.5 |
| **11** | 20.7 | 22.7 | 21.2 | 21.1 | 20.8 | 20.3 | 20.8 |
| **12** | 22.2 | 23.2 | 22.2 | 21.9 | 22.7 | 21.5 | 22.6 |
| **2015** | | | | | | | |
| **1** | 23.3 | 24.0 | 23.0 | 23.6 | 23.5 | 22.6 | 24.1 |
| **2** | 23.2 | 24.0 | 23.3 | 22.6 | 23.1 | 22.5 | |
| **3** | 22.0 | 22.6 | 21.1 | 22.1 | 21.3 | 20.9 | |
| **4** | 18.8 | 19.4 | 18.8 | 18.2 | 18.5 | 18.0 | 17.0 |
| **5** | 16.1 | 16.8 | 16.6 | 16.1 | 16.0 | 16.0 | 14.7 |
| **6** | 14.4 | 14.1 | 13.9 | 12.6 | 12.7 | 12.7 | 11.0 |
| **7** | 12.5 | 12.8 | | 11.0 | 12.4 | 12.4 | 10.3 |
| **8** | 13.3 | 13.5 | | 12.1 | 12.9 | 12.8 | 11.8 |
| **9** | 15.6 | 16.0 | | 15.9 | 15.5 | 15.1 | 14.7 |
| **10** | 19.6 | 20.6 | | 20.0 | 20.7 | 19.7 | 20.5 |
| **11** | 20.4 | 21.7 | | 19.4 | 20.2 | 18.9 | 20.5 |

### 4.3 Comparison between leases

As a result of this year's set-up for the monitoring program using same oyster batches across estuaries, oyster performance data can be compared across estuaries or across sampling sites (i.e. leases). This information provides industry members with a good baseline across estuaries and growing areas.

#### 4.3.1 Cumulative mortalities

Mortalities in Golden Mile at Wagonga (0.5%) and Mid Lake at Wapengo(1.1%) both had the lowest percentage mortalities for wild SRO whereas Mid Lake in Merimbula (0.5%), Crookhaven at Shoalhaven (0.6%) and Armstrong Bay at Wapengo (0.64%) recorded the lowest percentage mortalities for hatchery SRO. The lowest mortalities recorded in TPOs were found at the three locations from the Shoalhaven used in this program. Highest mortalities for wild SRO were seen at Corner Channel at Wonboyn (5.8%) for wild SRO and Broadwater at Wonboyn (5.7%) for hatchery oysters. For TPO's highest mortalities were seen at the three locations used in the Clyde, in particular in Moonlight (1.4%,

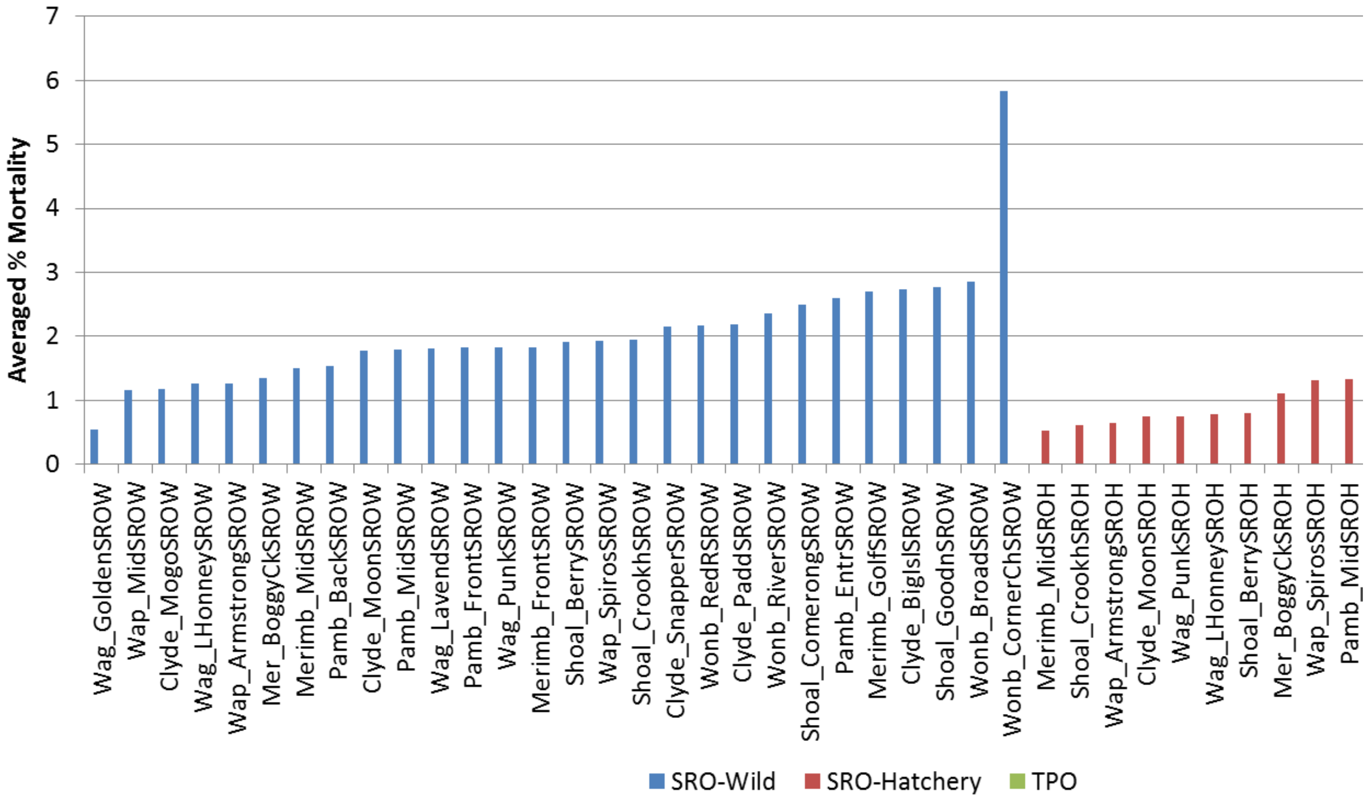



Figure 39).

#### 4.3.2 Growth

The lowest wild SRO growth increments were seen at Broadwater at Wonboyn, Lavender Point at Wagonga, Berry's at Shoalhaven and Entrance at Pambula (increments ranged between 6.6 and 7.8mm/month,

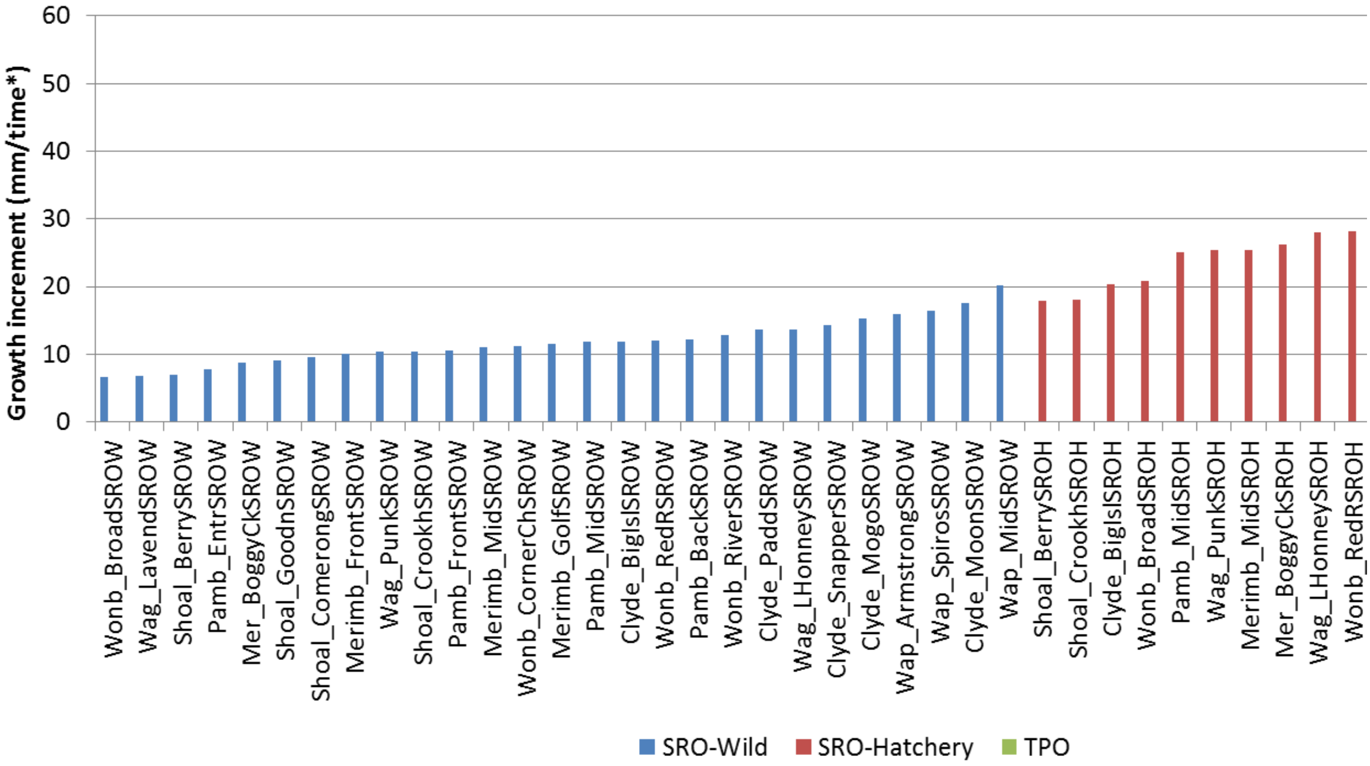



Figure 40). Lavender Point and Entrace sites are both located downstream, whereas Broadwater and Berrys are located in mid and upstream areas. The highest wild SRO growth rates were seen at Moonlight at Clyde (17mm/month) and Mid Lake at Wapengo (20.2mm/month) which were both located furthest downstream. Lowest hatchery SRO growth rates were seen at both locations used in the Shoalhaven (Berrys and Crookhaven, 17-20mm/month), Big Island at Clyde and Broadwater at Wonboyn, both with average growth rates of 20.5mm/month. Interestingly, the lowest growth rates of hatchery oyster equal the highest growth rates recorded for wild oysters. The highest growth rates for hatchery oysters were seen at Moonlight at Clyde (39.9mm/month) and Armstrong Bay at Wapengo (41.9mm/month). TPO oysters showed the lowest growth at Curleys in the Shoalhaven (27.3mm/month) and at Big Island in the Clyde (31.9mm/month), which are located upstream and has significant freshwater influences. The highest growth rates for TPOs were recorded at Snapper (52.7mm/month) and Moonlight at Clyde (51.34mm/month).

### 4.3.3 Condition

Condition Index across leases was very variable as a result of site-specific conditions. Condition Index was also overall temporally influenced by season, which resulted in more consistent patterns. For instance oysters were ranked as with ‘good’ and ‘very good’ condition during the warm months, in particular Spring months. However, most oyster batches dropped in condition during the early winter months, in particular in the Clyde, Wagonga and Pambula Lake. The following estuaries had most of the time oysters in good condition independently of the oyster type: Wagonga, Wonboyn and Shoalhaven. Overall it was noted that wild oysters were more consistent in regards to condition levels within a growing areas, while hatchery oysters were more variable (i.e. the subset of hatchery oysters sampled will have oysters representing all subcategories of condition level from poor to very good)

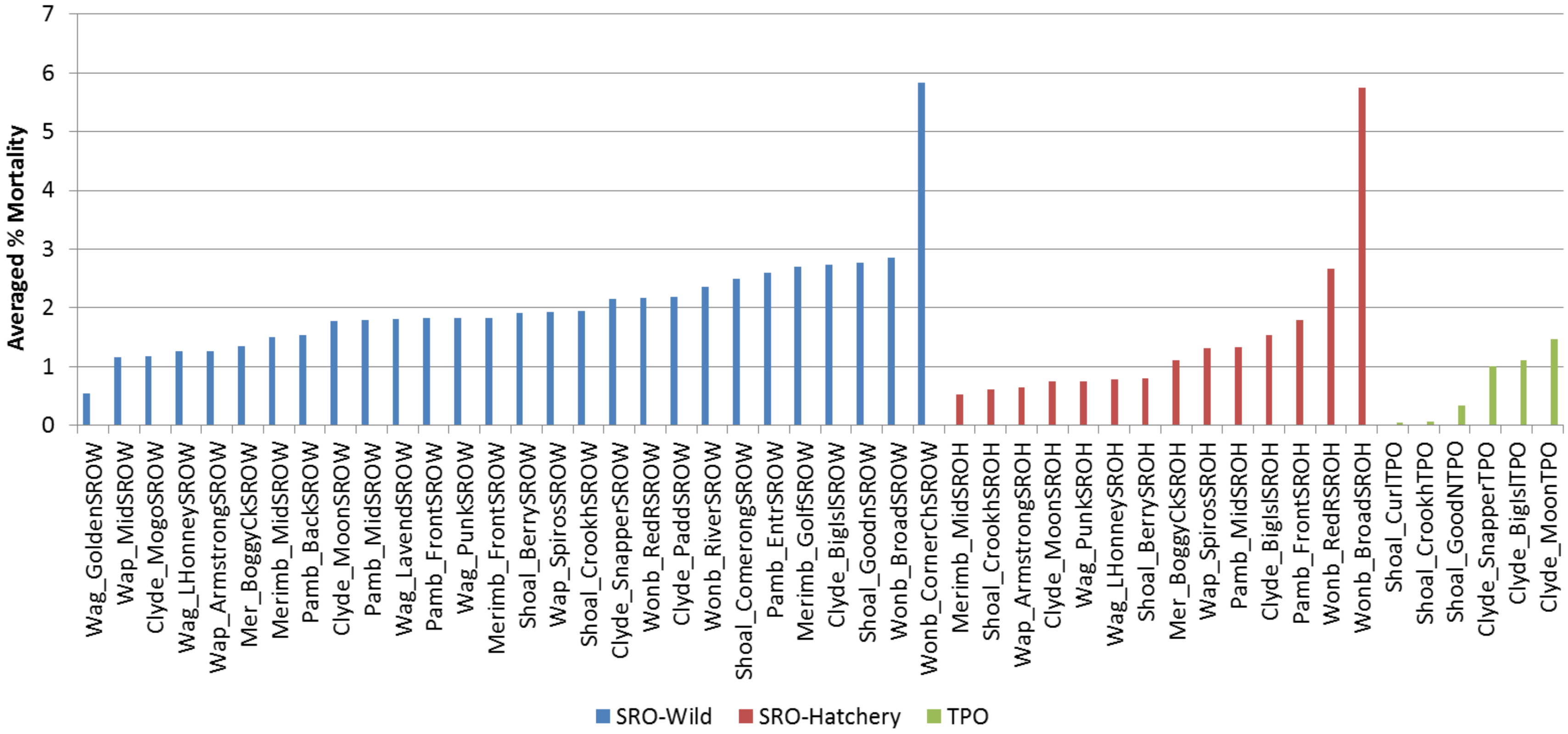



**Figure 39. Average percentage mortalities for oyster type at different localities within each estuary.**

**N.B. Mortalities that resulted from mishandling of oysters at MidLake in Merimbula during the fifth grading were not included in this plot**

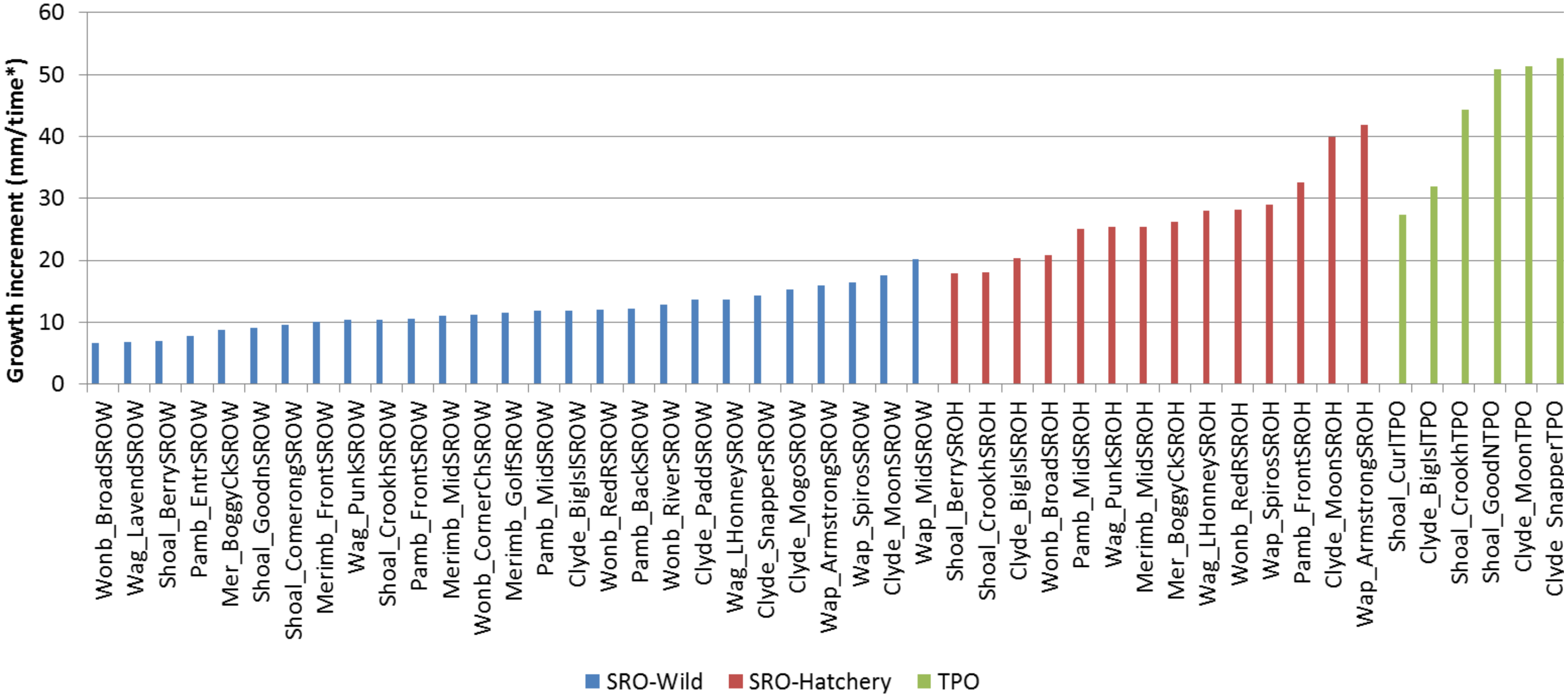



**Figure 40. Total growth increment across all sites and estuaries for wild and hatchery SRO and TPO's.**

(*time=SOAP sampling period ie TPO=10months; SRO=16months)

# 5 Value of Oyster Monitoring Programs

By establishing oyster monitoring programs a two-fold benefit ensues. The first benefit enables the oyster industry to quantify current production at the lease levels and to modify its husbandry practices to maximise production across higher performing and more profitable areas, while the second benefit arms catchment managers with an improved ability to understand and manage catchment processes, in turn, supporting a viable oyster industry.

One of the data sets that is vital to the oyster industry is oyster performance data (e.g. growth and mortality) and water quality. Since this data is scarce and in some instances is confidential, there is a need to establish an estuary-wide long-term monitoring program that will oversee and facilitate collective oyster management. Baseline performance and environmental data is required to assess unusual conditions and the associated effects on the surrounding aquatic ecosystems. Estuarine systems are subjected to a variety of stressors, both natural and anthropogenic. Through greater understanding of the drivers influencing oyster performance, industry and managers will be in a better position to respond to unexpected events and be equipped with management options for responding to environmental change.

This year's innovation was to monitor the growth and mortality of the same cohort of oysters across different growing areas along the Southern Rivers region, with the aim of gathering information to characterized different estuaries and cultivation sites. Specific batches were chosen for each of the oyster types involved in SOAP. This year the program also expanded the oyster species and origin (i.e. wild and hatchery sourced oysters). In addition two new south coast estuaries decided to be part of the program: Wagonga Inlet and Wonboyn.

The oyster monitoring program has now been running for three years. Unfortunately funding has not been secured so there is no plan to continue the program at this stage. There are already some data gaps between the programs running during the last three years. However the data collected so far has been collated for each estuary and compared across the years (Table 10 and Table 11).

Distinctive patterns in overall cumulative mortality levels were found across the seven estuaries involved in SOAP. Overall mortality levels during Program 3 have reduced significantly, probably as a result of a low number of major rainfall events. For example SROs in the Shoalhaven used to have the highest mortalities (around 30%) as per level in program 1 & 2. However levels during Program 3 dropped to half. This pattern was observed in almost all estuaries except in Pambula were the mortality levels reduced slightly but not to half. Interestingly mortality levels for TPOs are still markedly low in the Shoalhaven and the Clyde in comparison with the levels recorded for SROs. The drop in overall mortalities is a positive outcome for the profitability of the industry.

Growth rates for each monitoring program also showed distinct patterns across estuaries. As well as experiencing more acceptable levels of mortality, the estuaries of Wapengo, Merimbula and Pambula, also recorded steady growth over time. Wapengo has recorded for the second year in a row the highest overall increment in shell length per month followed by Pambula. However growth rates at the Shoalhaven keep resulting in the slowest for the wild stock only. Both hatchery SROs and TPOs performed well in the Shoalhaven.

It is accepted that some species within the same taxon could exhibit different tolerances to the same environmental conditions, thus, resulting in the differentiation of species distribution (Shumway 2011). A higher growth rate was recorded for TPO than for SRO as Pacific oysters tend to have the highest filtration rates (Bayne 1999).

Ideally to maximise profitability in an area, oyster growth must be maximised while mortality levels minimised. Data collected through SOAP can assist industry in improving profitability by understanding oyster productivity across different growing areas and cultivation methods. This improvement can be achieved by taking advantage of localised environmental conditions favourable to stronger oyster performance (higher growth and lower mortality). With more information on the expected profitability over the three-year life cycle of SRO, greater benefit can be derived by growers, who can maximize returns and achieve sustainable production. This type of information can also be further analysed by economists and contribute towards current oyster projects like the Hunter LLS Farm Profiles and/or part of the development of stock management tools.

**Table 10: Cumulative mortality (%) by estuary and oyster type at 12 months of running the oyster monitoring programs (2011 -2015)**

| | SRO-Wild | | | TPO | | |
|---|---|---|---|---|---|---|
| | Program_ 1 2011/12 | Program_ 2 2012/14 | Program_ 3 2014/15 | Program_ 1 2011/12 | Program_ 2 2012/14 | Program_ 3 2014/15 |
| **Shoalhaven** | 30±11 | 32±9 | 13±3.6 | 1.8±0.1 | 9±4.5 | 0.32±0.01 |
| **Pambula** | 18±4 | 16±4 | 13±2 | | | |
| **Merimbula** | 13±2 | 15±7 | 7.5±1 | | | |
| **Clyde** | | 26±7 | 13±3.8 | | | 7±1.5 |
| **Wapengo** | | 25±4 | 10±1.8 | | | |
| **Wagonga** | | | 8±4 | | | |
| **Wonboyn** | | | 10±7.6 | | | |
| **AVERAGE:** | 20.3% | 22.8% | 10.6% | 1.8% | 9% | 0.32% |

**Table 11: Growth rates (mm/month) by estuary and oyster type at 12 months of running the oyster monitoring program (2011-2015)**

| | SRO-Wild | | | TPO | | |
|---|---|---|---|---|---|---|
| | Program_ 1 2011/12 | Program_ 2 2012/14 | Program_ 3 2014/15 | Program_ 1 2011/12 | Program_ 2 2012/14 | Program_ 3 2014/15 |
| **Shoalhaven** | 0.40 | 0.56 | 0.64 | 0.80 | 2.60 | 3.40 |
| **Pambula** | 1.40 | 1.52 | 1.00 | | | |
| **Merimbula** | 1.40 | 1.30 | 0.87 | | | |
| **Clyde** | | 0.38 | 0.90 | | | 3.70 |
| **Wapengo** | | 1.83 | 1.26 | | | |
| **Wagonga** | | | 0.85 | | | |
| **Wonboyn** | | | 0.76 | | | |
| **AVERAGE:** | 1.07% | 1.12% | 0.9% | 0.8% | 2.6% | 3.6% |

N.B. Oyster size at the start of each program was different (Table 1). In addition, program 1 & 2 used oysters with different origin (genetics and husbandry).

# 6 The future of oyster monitoring programs

Here a prototype oyster monitoring program has been trialled with the aim of building baseline information on oyster performance across and within key oyster producing estuaries of the Southern Rivers region of NSW.

As a pre-cursor for a potential Australian-wide oyster monitoring program, SOAP can also support a key role of managers in their requirement to report on the state of our catchments. SOAP can align with key objectives of the NSW Monitoring, Evaluation and Reporting (MER) Strategy (2010-2015). The NSW MER guides the efforts of natural resource and land management agencies, including CMAs (the central agency involved in the OMP), to better understand whether the overall health of the natural resources of NSW are changing and to assess the effectiveness of remedial action in reversing observed trends. Like the MER strategy SOAP aims to contribute to the monitoring and evaluation of the condition of, and pressure, on the oyster industry. SOAP strives to improve data collection addressing knowledge gaps and improving the sharing of information across stakeholder groups. SOAP also aims at developing and enhancing partnerships between industries, catchment users and managers.

## 6.1 Improvements and recommendations

While the process involving the use of automated graders to recorded information about oyster growth has been proven as an efficient method for capturing relevant oyster performance data, improvements could be made in the design and set-up of future programs.

The use of a unique oyster stock allows comparisons within growing areas in an estuary and across estuaries. This information is vital so that industry groups can benchmark their oyster performance among other estuaries on the south coast.

In order to achieve a better understanding of the relationship between food availability and oyster performance, there is a need to collect phytoplankton data more frequently (every two weeks) and to monitor additional sites within an estuary (i.e. upstream and downstream sites) so that the data gives a better representation of the dynamics taking place in the waterways. A range of other environmental parameters such as chlorophyll-a (a proxy for calculating available food for oysters or phytoplankton biomass), suspended organic matter and dissolved oxygen have also been suggested to influence oyster performance. If high frequency environmental data is collected as part of SOAP, the oyster grading frequency might also need to increase so that there the robustness of the data analysis increases as a result of having a larger number of data points.

Additional estuaries in NSW should be included in this program as we now have 3 years of data for some of the south coast estuaries. Further monitoring of TPOs is crucial as we only have one and a bit year of information. There is also a need to combine programs like SOAP with disease surveillance programs.

Increased stakeholder engagement is crucial for the good operational of the program. Feedback from growers has indicated that they were especially interested to see how different areas of the estuary performed at different times of the year the data gained has also given them key information that will determine their total farm management plan. This includes where to place oysters at various times in their growth cycle, to maximise their potential. The fact that the program ran concurrently in other estuaries allowed them to compare their growing conditions with others. Many farmers have used the same stock rotation plan for 35 years. It has been based on advice from ‘old time growers’ who have learnt over the previous 50 years what works and what doesn’t. The plan entails placing young (less than 12 month old spat) in the back waters to avoid over catch and to generate vibrant shell production. When the oysters are about 2.5 years they old moved down to the river entrance to finish them off, and produce a harder shell with good consistent condition. The results from the SOAP program have helped to prove that this information was correct. Feedback has also indicated that the results have been presented in a clear and easy to understand format for the farmers, following each grading.

## 7 Related documents

This document collates information included in the bimonthly reports delivered to industry after every grading event. For more detail on bimonthly observations and results please refer to the website http://www.southcoastoysterindustry.com.au/monitoring-programs.html


- Nash, C; Rubio, A; Davies, H; Gietzelt, A: Keating, J (2013) Monitoring the canaries of our catchments – A cooperative and innovative monitoring program quantifying oyster performance and relationaships with estuarine health. A final report to the Southern Rivers Catchment Management Authority
- Nash, C and Rubio, A (2012) Monitoring the canaries of our catchments. Conference paper for NSW Coastal Conference 2012, Kiama, NSW, Australia
- Rubio, A., Winberg, P. and Kirkendale, L. (2012). Oyster Information Portal: a user-group focused 'Coastal Google' for the future. Conference paper for NSW Coastal Conference 2012, Kiama, NSW, Australia
- O'Sullivan, D. (2012). Assessing long term lease performance using automatic oyster graders.Austasia Aquaculture. 26 (2): 33-38


## 8 Acknowledgements


SOAP would not have been possible without the commitment of the oyster industry, support from South East Local Land Services, oyster researchers and the key role of the program coordinators funded through the South East Local Land Services and Catchment Action NSW in partnership with Sapphire Coastal Wilderness Oysters. Hatchery Sydney Rock Oysters were donated by the Select Oyster Company (http://selectoysterco.com.au/) and Triploid Pacific Oysters were donated by Shellfish Culture ( http://www.shellfishculture.com.au/ ).

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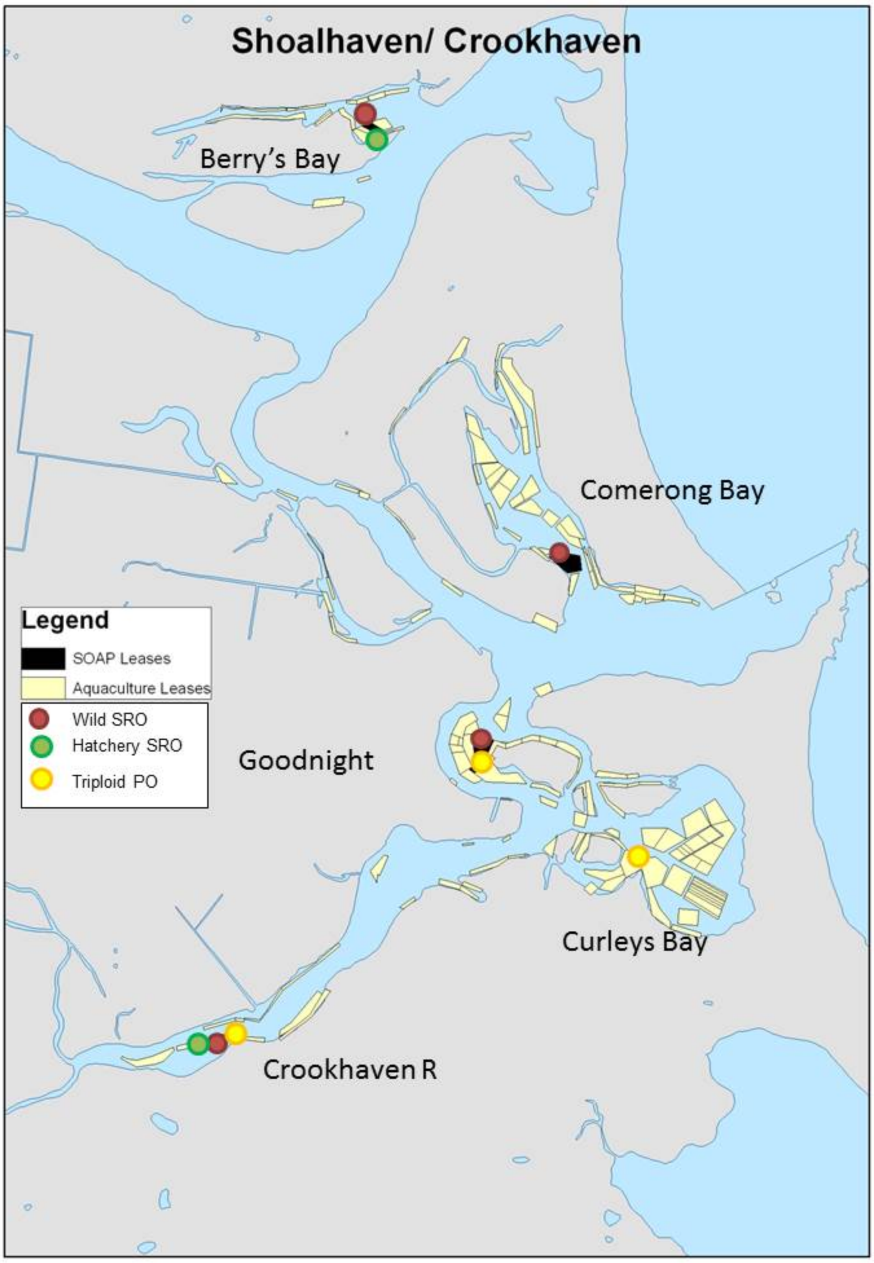
Songsangjinda, P., O. Matsuda, T. Yamamoto, N. Rajendran & H. Maeda. 2000. The role of suspended oyster culture on nitrogen cycle in Hiroshima Bay. J. Oceanogr. 56:223-231.

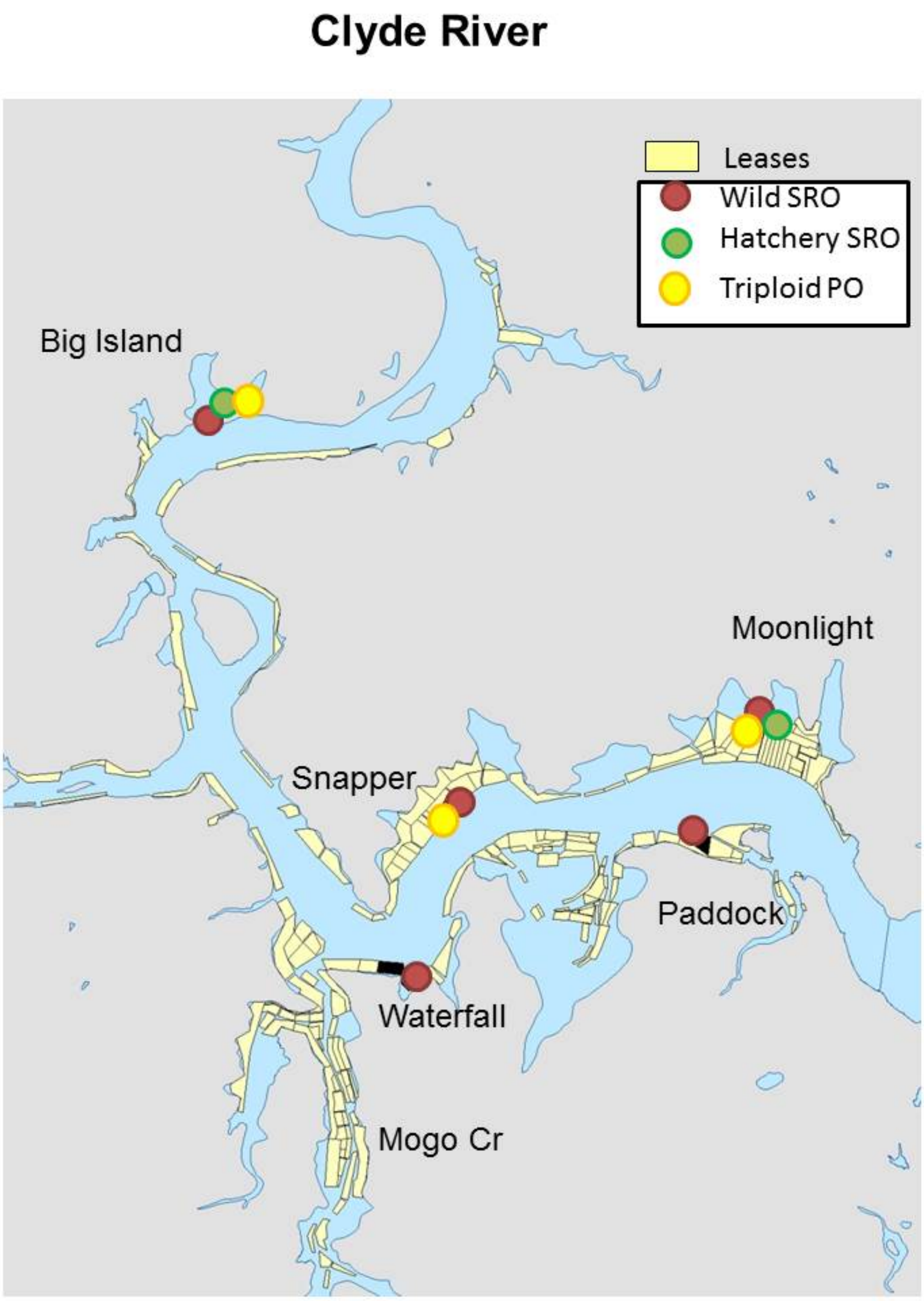
Woodford, P. 2015. Sustainable oyster program 2014-2015 program TPO results. Program 3, final report, April 2015.

# Appendix 1. Location of Oyster Monitoring sites, phytoplankton collection points, and temperature logger recording sites

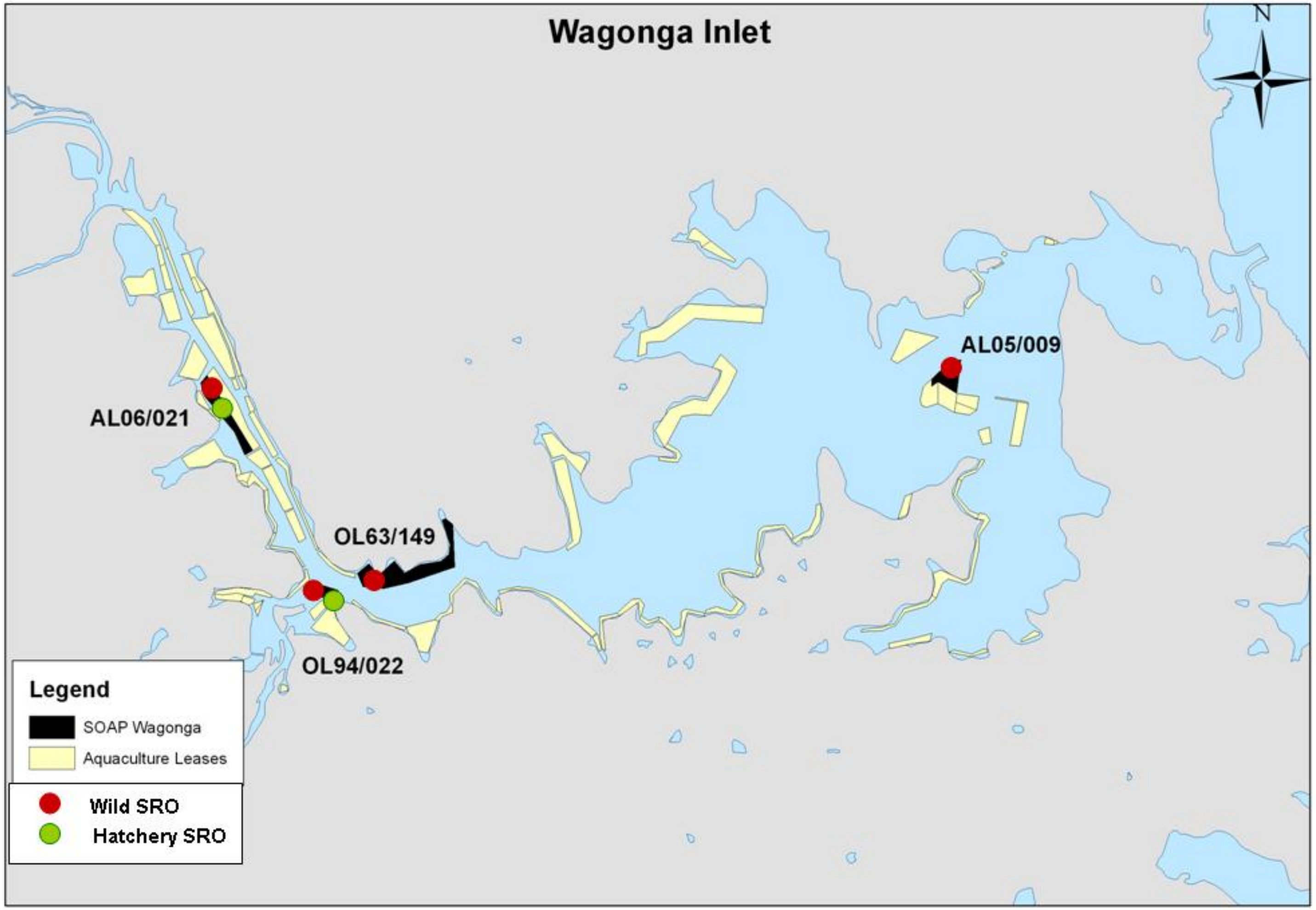
## 1.1 Shoalhaven Oyster Monitoring Program



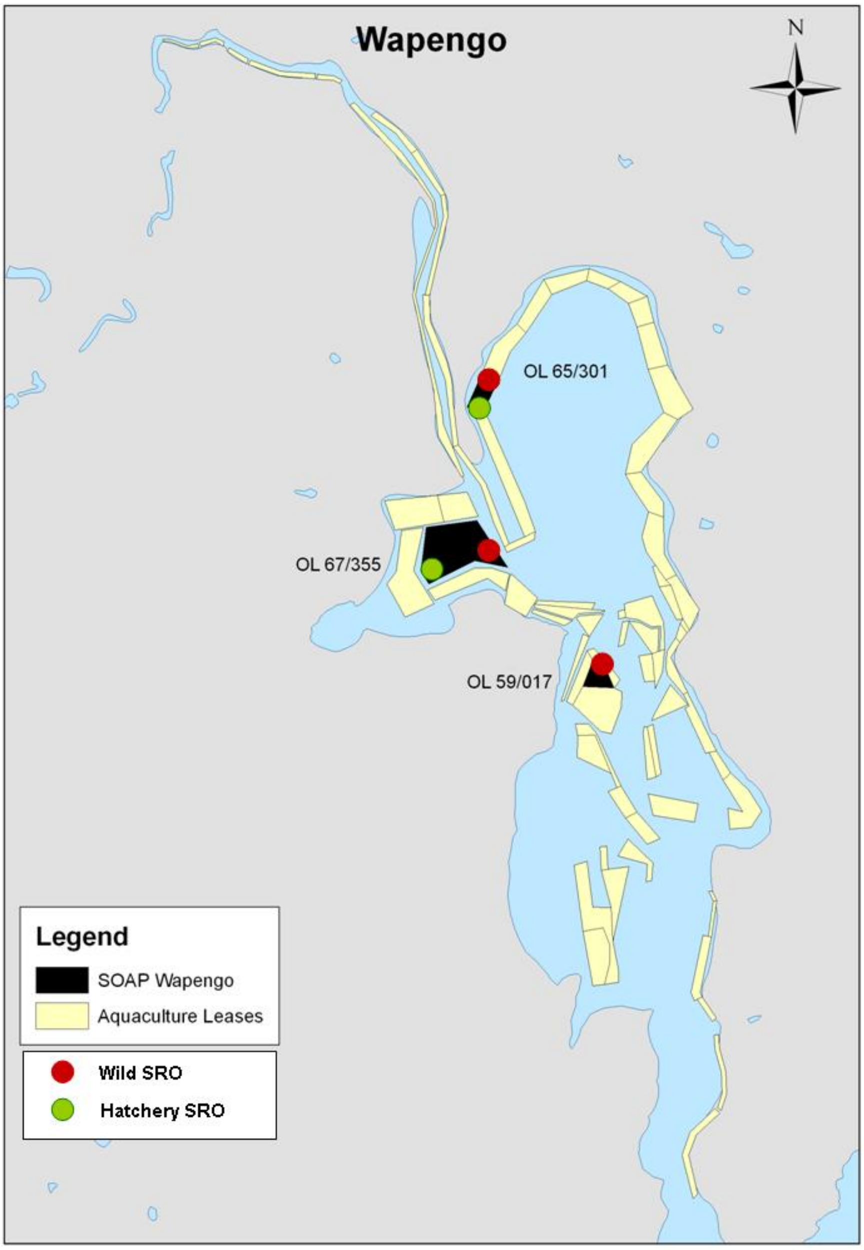
## 1.2 Clyde River Oyster Monitoring Program



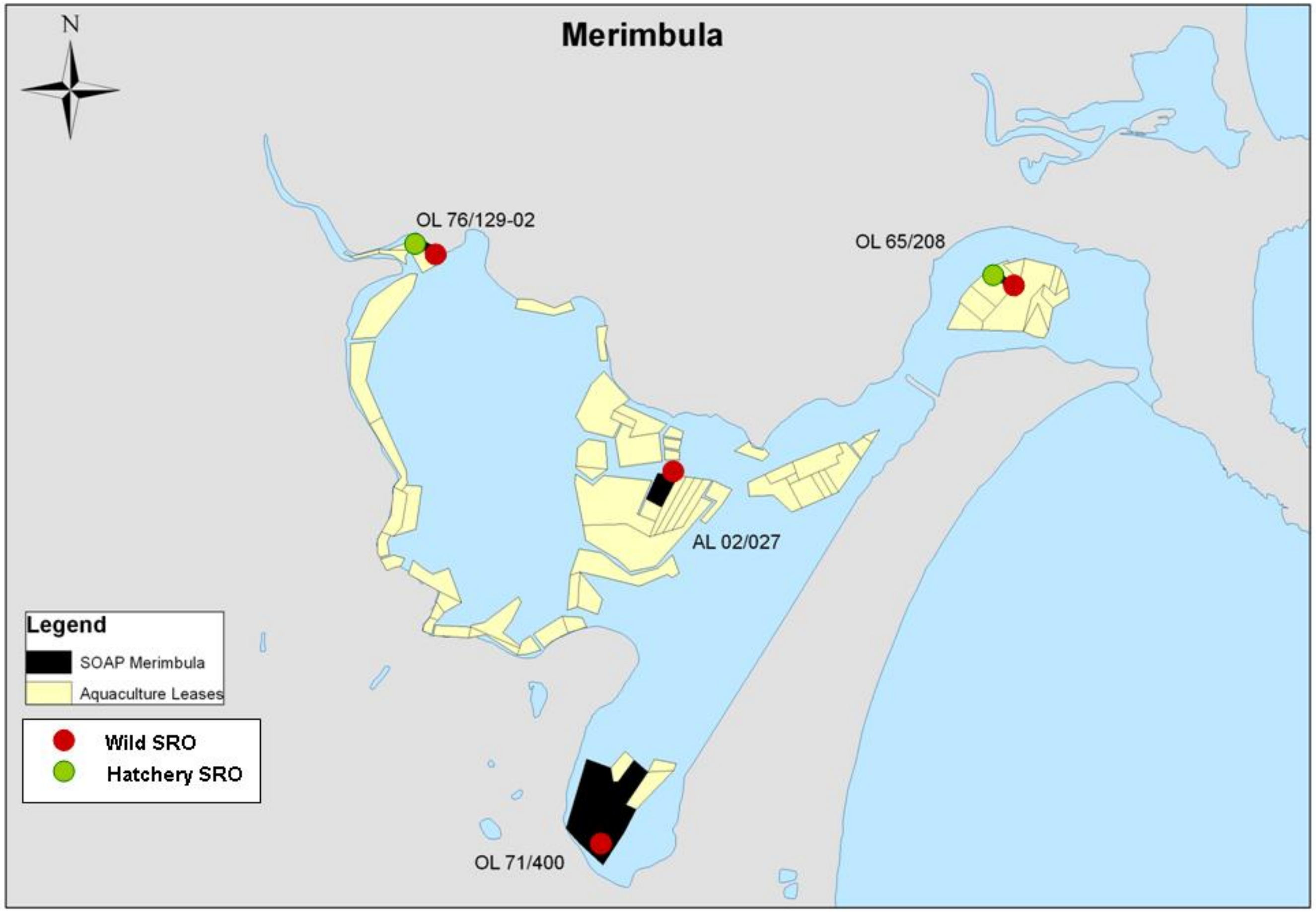
## 1.3 Wagonga Oyster Monitoring Program



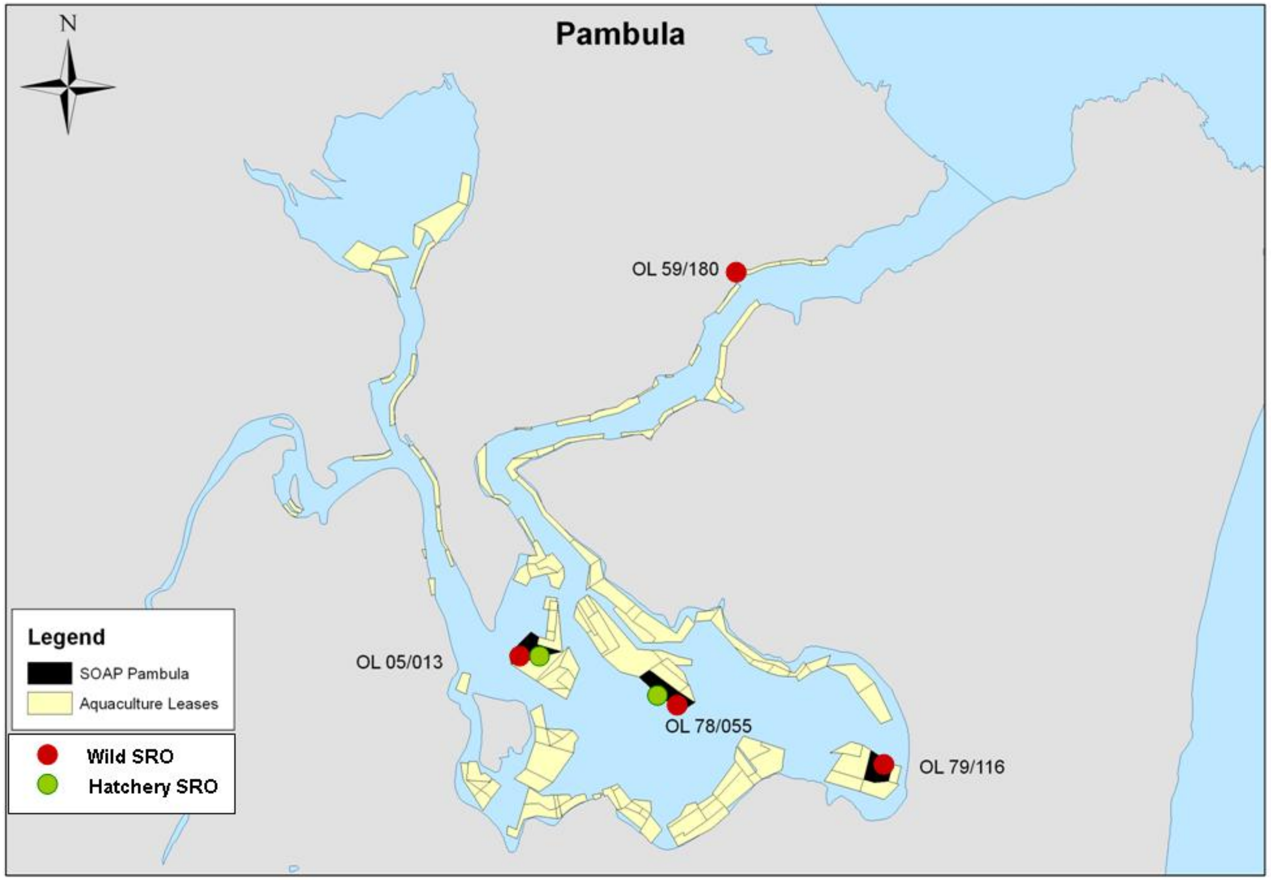
## 1.4 Wapengo Oyster Monitoring Program



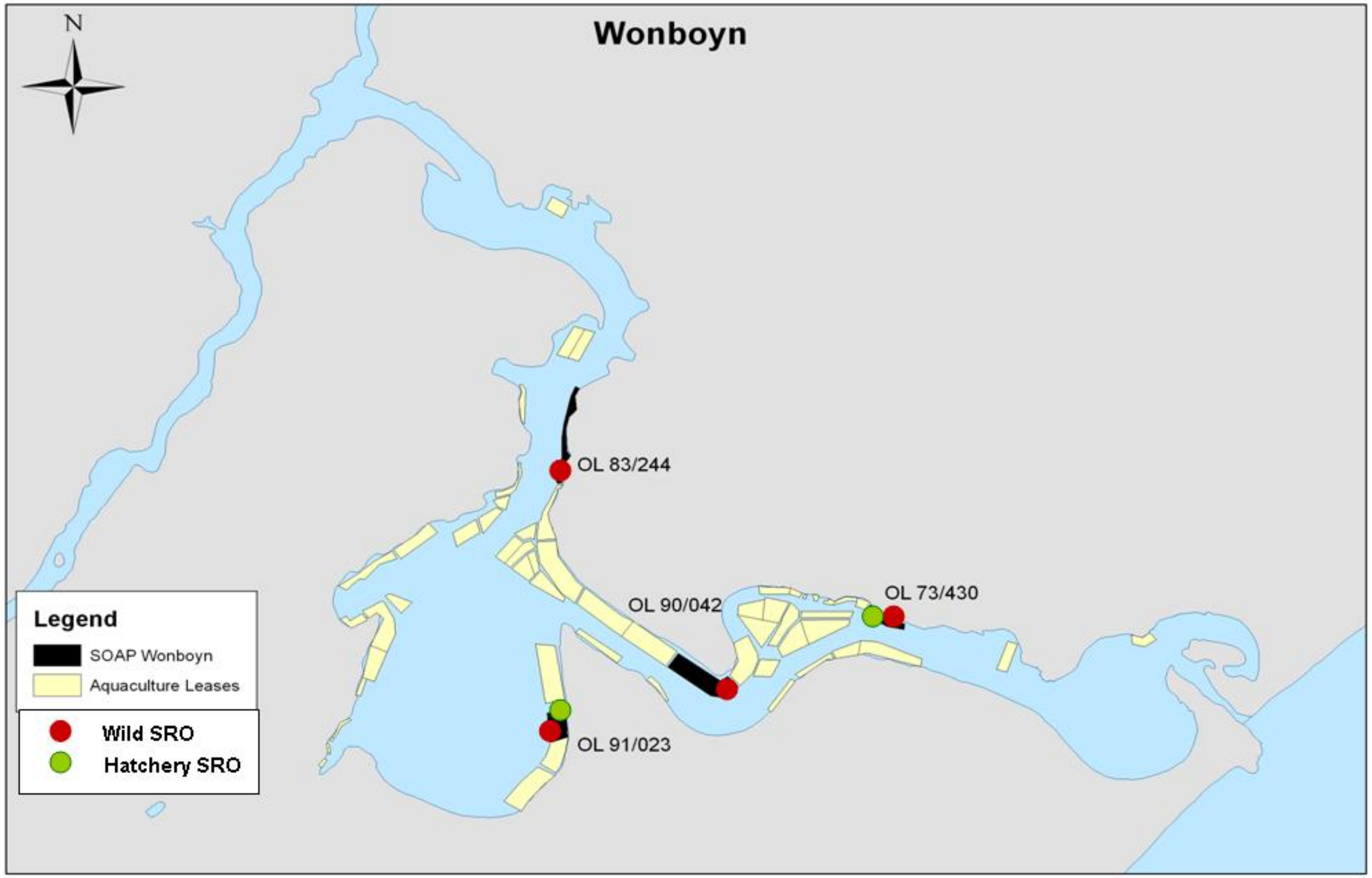
## 1.5 Merimbula Oyster Monitoring Program



## 1.6 Pambula Oyster Monitoring Program



## 1.7 Wonboyn Oyster Monitoring Program



## Appendix 2. Oyster Monitoring Program grading process

1. Retrieve oysters from the different locations (engage as many oyster growers as possible)
2. Separate oyster groups by locations and grade oysters from one location at a time
3. For location 1: Empty oysters from the cultivation method used into the grader bins
4. Allocate a bucket for dead oysters – Please count dead oysters and record them
5. Start grader:
    a. Remember to wet the belt and calibrate the grader
    b. Upload the grader recipe (i.e. Pambula/Merimbula monitoring program)
    c. Make sure that oyster densities are set as agreed in the program (i.e 100 oysters/grade 1, 100 oysters/ grade 2 etc)
    d. Re-start the run so counts are re-set to '0'
    e. Set speed of grader to a medium/slow speed
    f. Place a bucket at the end of grader to collect 'rejects'- count & record them
6. Inspect oysters while the oysters travel on the inspection belt. Dead oysters are thrown into the bucket and doubles are set aside. At the end doubles will be chipped and put back through the machine and dead oysters need to be counted and recorded.
7. Once all oysters have been graded put the rejects through the grader again and grade the doubles you have already chipped. Look for oysters that might have fallen through the singulator and try to grade them again
8. Once grading has finished, switch window view to statistics and write down the average sizes of the oysters for each grade
9. Write down the number of oysters graded in each grade (this is a back-up in case the electronic report does not get saved)
10. Stop grader and save report – use a good name for the file (e.g. Date_Lease name_Pambula.txt)
11. Make sure you have recorded: mortalities (number of dead oysters), rejects that have not been graded, number of oysters per grade
12. If at the end of the grade a cultivation unit is not complete (based on the densities of the recipe) make a decision whether you leave the cultivation unit as it is (i.e. if it is close to the total density) or combined 'left-over' oysters with oysters from different grades
13. Make sure that the different cultivation methods have the right colour tags (per location)
14. Take a sample of 10 oysters representing all grades. Store them in a zip lock bag and label bag with Date / Lease name / Pambula. Freeze them until Ana picks them up. Take a sample of 6 oysters from the hatchery and wild sites for condition assessment.
15. Repeat the above steps for the rest of the locations
16. Save recipe and Report files in a USB drive- you can find the files in c:/Batchfiles

# Appendix 3. Oyster Monitoring Program 2014/15 grading events

| Estuary | Grading No. | Grading event | Date |
|---|---|---|---|
| Shoalhaven | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 10/07/2014 |
| | 3 | Second grading | 11/09/2014 |
| | 4 | Third grading | 14/11/2014 |
| | 5 | Fourth grading | 16/01/2015 |
| | 6 | Fifth grading | 20/03/2015 |
| | 7 | Sixth grading | 19/06/2015 |
| | 8 | Seventh grading | 25/09/2015 |
| | 9 | Final grading | 27/11/2015 |
| Clyde | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 25/07/2014 |
| | 3 | Second grading | 10/09/2014 |
| | 4 | Third grading | 13/11/2014 |
| | 5 | Fourth grading | 15/01/2015 |
| | 6 | Fifth grading | 18/03/2015 |
| | 7 | Sixth grading | 23/06/2015 |
| | 8 | Seventh grading | 24/09/2015 |
| | 9 | Final grading | 3/12/2015 |
| Wagonga | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 14/07/2014 |
| | 3 | Second grading | 7/10/2014 |
| | 4 | Third grading | 17/11/2014 |
| | 5 | Fourth grading | 19/01/2015 |
| | 6 | Fifth grading | 23/03/2015 |
| | 7 | Sixth grading | 15/06/2015 |
| | 8 | Seventh grading | 1/10/2015 |
| | 9 | Final grading | 16/11/2015 |
| Wapengo | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 27/07/2014 |
| | 3 | Second grading | 16/09/2014 |
| | 4 | Third grading | 18/11/2014 |
| | 5 | Fourth grading | 20/01/2015 |
| | 6 | Fifth grading | 24/03/2015 |
| | 7 | Sixth grading | 16/06/2015 |
| | 8 | Seventh grading | 1/09/2015 |
| | 9 | Final grading | 17/11/2015 |

| Estuary | Grading No. | Grading event | Date |
|---|---|---|---|
| Merimbula | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 17/07/2014 |
| | 3 | Second grading | 19/09/2014 |
| | 4 | Third grading | 21/11/2014 |
| | 5 | Fourth grading | 23/01/2015 |
| | 6 | Fifth grading | 9/04/2015 |
| | 7 | Sixth grading | 26/06/2015 |
| | 8 | Seventh grading | 11/09/2015 |
| | 9 | Final grading | 19/11/2015 |
| Pambula | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 17/07/2014 |
| | 3 | Second grading | 18/09/2014 |
| | 4 | Third grading | 20/11/2014 |
| | 5 | Fourth grading | 22/01/2015 |
| | 6 | Fifth grading | 9/04/2015 |
| | 7 | Sixth grading | 25/06/2015 |
| | 8 | Seventh grading | 10/09/2015 |
| | 9 | Final grading | 19/11/2015 |
| Wonboyn | 1 | Set-up | 8/05/2014 |
| | 2 | First grading | 17/04/2014 |
| | 3 | Second grading | 18/09/2014 |
| | 4 | Third grading | 20/11/2014 |
| | 5 | Fourth grading | 22/1/2015 |
| | 6 | Fifth grading | 9/04/2015 |
| | 7 | Sixth grading | 25/06/2015 |
| | 8 | Seventh grading | 10/09/2015 |
| | 9 | Final grading | 19/11/2015 |

## Appendix 4. Phytoplankton Report for Wapengo, Merimbula, Pambula and Wonboyn

Date 12/10/2015
Author: SOAP/ Ana Rubio

### Table of Content

# 1. Background:

SOAP has recently expanded to assess the performance of SRO in 7 estuaries and TPOs in 2 estuaries using a unique batch of oysters with the same genetic, environmental and husbandry background. This will enable growers from one estuary to benchmark oyster performance against neighbouring estuaries. SOAP is now also directly comparing the performance of wild-caught and hatchery SRO stock to inform both hatchery and local farm operations. In addition water temperature has been logged at the different monitoring sites using electronic loggers set-up to record temperature every hour. The four estuaries in the Far South Coast also contributed phytoplankton/microalgal analysis to the program which was funded via the Wilderness Sapphire Coast Wilderness Oysters. The aim of this report is to focus mainly on the phytoplankton data collected. Towards the end of the year a final report will be collated with all the data (oyster and environmental data) recorded through the SOAP program from May 2014 to December 2015. Hence phytoplankton data will also be added to this report.

Phytoplankton data was collected every two weeks at one location in each estuary: Wapengo, Merimbula and Pambula and at two locations in Wonboyn Lake. The period monitored was August 2014 to June 2015 with 21 samples collected during this period. Phytoplankton samples were analysed covering the full spectrum of algae species (harmful and harmless) and were identified taxonomically by Microalgal Services. Raw results were collated by Microalgal Services and sent to SOAP for Dr Ana Rubio to undertake analysis as part of SOAP 2014/15 project. Data on water temperature and salinity was provided by growers at the time of the phytoplankton sample collection.

This report will focus mainly on the phytoplankton results collected at the four estuaries in the Far South Coast of NSW per estuary basis. Correlations with oyster growth, and water temperature and salinity at the SOAP site closest to the phytoplankton monitoring site have been also included, however a more intensive analysis will be undertaken as part of the Final Report that will be submitted for the 2014/15 SOAP program. This report focuses on:

1- Characteristics of the overall phytoplankton community dominating the phytoplankton monitoring sites
2- Description of the levels of harmful and harmless phytoplankton species during the monitoring period
3- Correlations of phytoplankton levels with available environmental data
4- Correlations of phytoplankton levels with oyster performance data from SOAP
5- Recommendations for future monitoring and data analysis

## 2. Oyster Leases and Phytoplankton Sites

| SOAP 2014/15 | | | | | | |
|---|---|---|---|---|---|---|
| **Estuary** | **Loc Number** | **Loc Name** | **Lease number** | **colour cattle tag - WILD** | **colour cattle tag- Hatchery** | **Phyto Sites** |
| Wapengo | Loc1 | Mid Lake | OL59/017 | blue | | #2 |
| | Loc2 | Spiros | OL67/355 | purple | yellow | #2 |
| | Loc3 | Armstrong Bay | OL65/301 | white | red | |
| **Total Wapengo** | 3 | | | | | |
| Pambula | Loc1 | Front Lake | 05/013 | blue | red | #17 |
| | Loc2 | Mid Lake | OL78/055 | white | yellow | |
| | Loc3 | Back Lake | 79/116 | purple | | |
| | Loc4 | Entrance | OL 84/154 | orange | | |
| **Total Pambula** | 4 | | | | | |
| Merimbula | Loc1 | Top Lake/Front | 87/143 | orange | | |
| | Loc2 | Golf Lake | OL71/400 | white | | |
| | Loc3 | Boggy Creek | OL76/129-2 | purple | red | |
| | Loc4 | Mid Lake | AL02/027 | blue | yellow | #2 |
| **Total Merimbula** | 4 | | | | | |
| Wonboyn | Loc1 | Broadwater/main lake | 91/023 | blue | yellow | |
| | Loc2 | Corner Channel | 90/042 | white | | #1 |
| | Loc3 | Red Rock | 73/430 | purple | red | #1 |
| | Loc 4 | The River | 83/244 | orange | | #2 |
| **Total Wonboyn** | 4 | | | | | |

Oyster growth and mortality rates used in this report correspond to the SOAP information for wild oysters collected as per table above. Where a Phytoplankton site is associated to more than one oyster lease average growth and mortality data was used. Temperature and Salinity data corresponds to the day when the phytoplankton samples were collected while Rainfall corresponds to the entire period between samples. Harmful algal corresponds in most cases to human health, not toxicity to oysters.

Rainfall BoM stations used:

www.bom.gov.au/climate/data/?ref=ftr

Nowra (Shoal) 68213

Batemans 69134

Merimbula and Pambula 69147

Eden (Wonboyn) 69015

Narooma 69022

Tathra (Wapengo) 69068

# 3. Phytoplankton community at the Far South Coast Estuaries:

## 3.1 Pambula Lake:

Data background: Phytoplankton samples were collected from the unique NSW Food Authority Site #17 which is close to lease OL 05/013 (or Front Lake as referred to in the SOAP program). Oyster growth and mortality rates have been used from this lease only. A total of 21 samples were collected between 19/8/2014 and 2/6/2015. Raw data will be provided with this report.

Characteristics of the overall phytoplankton community

Data collected showed that the phytoplankton community present most of the times at Site#17 is a well-mixed sample dominated by planktonic diatoms of the genus *Chaetoceros, Guinardia* and *Pseudo-nitzschia* and small flagellates of the class *Cryptomonads, Prasinophytes, Prymnesiophytes* and fewer dinoflagellates. A variety of species normally makes up the sample. Benthic diatoms like the genus *Navicula* have been noted in fewer occasions. These results indicate that the site is influenced by good oceanic flushing in which phytoplankton species move with currents more than being produced in-situ. It is important to note that these results might change if the samples are collected at different points in the tide (analysis have been undertaken assuming that samples are collected roughly at the same time of the day and tide).

Approximate levels of total phytoplankton ranged from 650,000cell/litre to 3,800,000cell/litre in a sample. The breakdown of phytoplankton groups are approximately 50% diatoms; 13% dinoflagellates and 37% corresponds to small flagellates and 'other plankton' groups. Within the diatom group there are more planktonic species than benthic species.

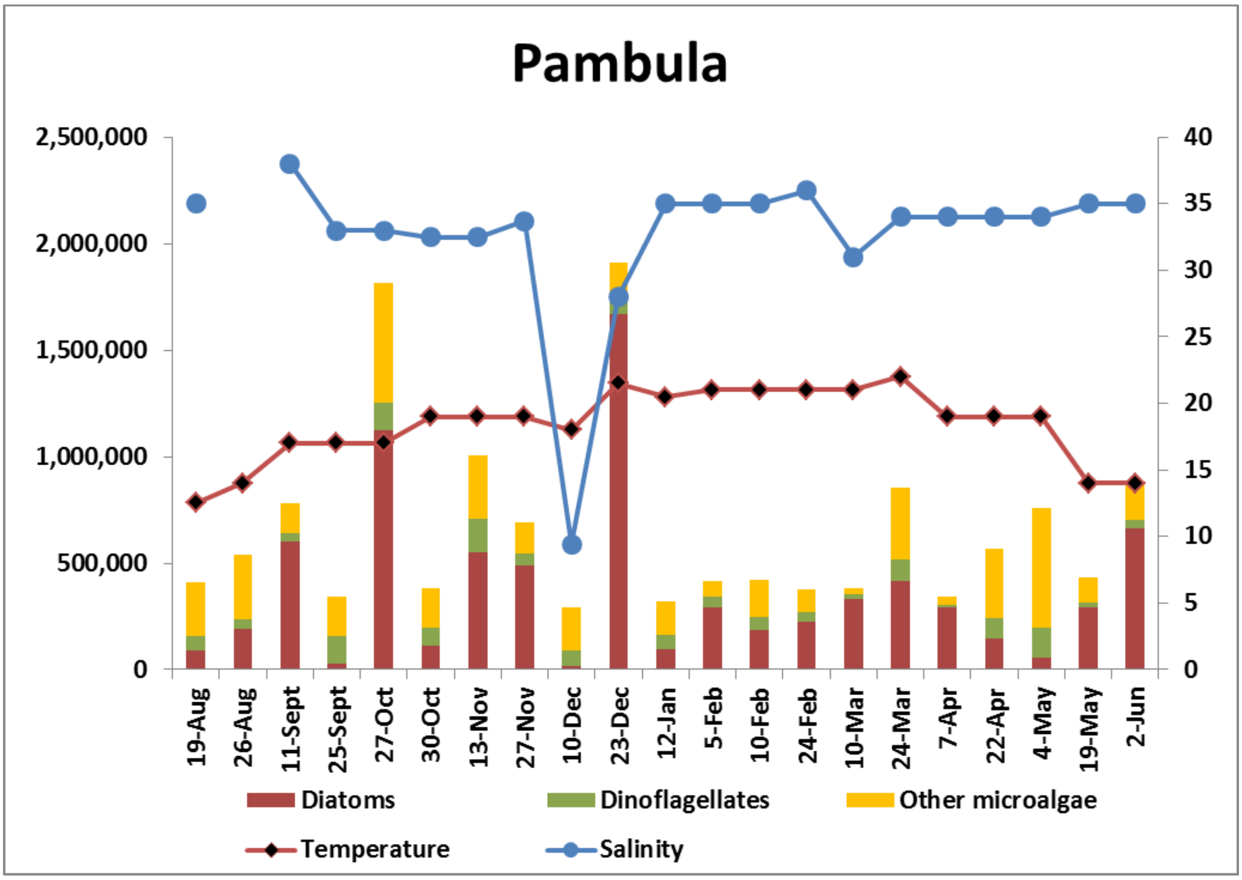



Figure 1. Total biomass of major phytoplankton (microalgae) groups and temperature (°C) and salinity (ppt) levels. Left Y axis- number of algal cells; Right Y-axis= Temperature °C and Salinity ppt

Levels of harmful and harmless phytoplankton species

Species of harmful algal species were recorded in all samples collected but at very low levels. The data collected shows that more than 98% of the algal cells counted are harmless at any point in time. Slight increases (2%) of harmful algal levels are seen post major rain events but levels are kept low otherwise. Highest levels of harmful species were recorded in Sept-Nov-14 and Feb-May15. Higher levels of harmful algal were more correlated to higher levels of diatoms, in particular of *Pseudo-nitzschia* species, than dinoflagellates or small flagellates. *Pseudo-nitzschia* levels were kept below the NSW Food Authority's Phytoplankton Action Limits (PAL). In a couple of occasions, levels of *Prorocentrum* and *Alexandrium* species just reached levels to trigger additional flesh sampling as per the NSW Food Authority Biotoxin Manual, however the levels did not increase to result in harvest areas closures.

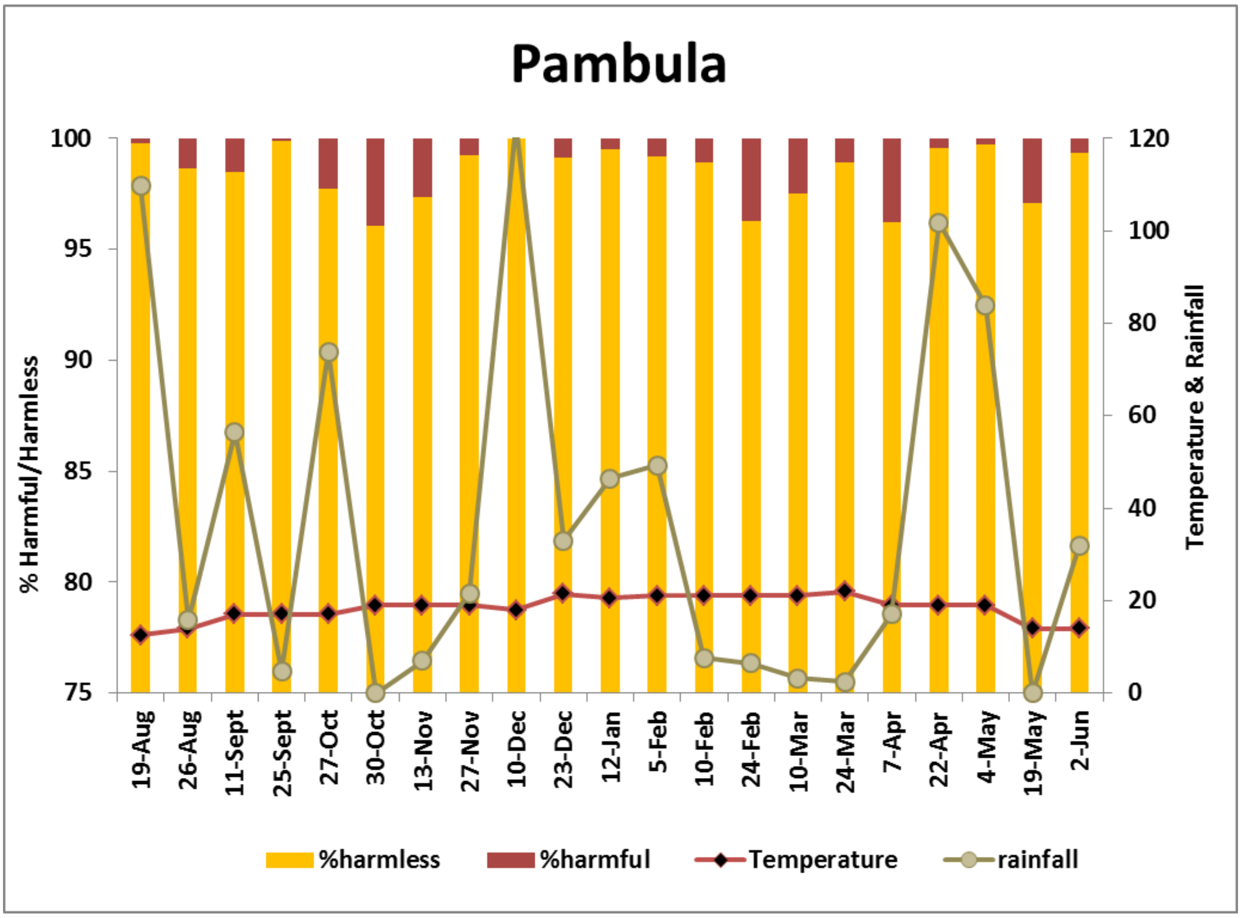



Figure 2. Percentage of harmful and harmless phytoplankton (microalgae) species and temperature (°C) and rainfall (mm) for the period in between samples. Left Y axis- percentage of algal cells; Right Y-axis= Temperature °C and Rainfall mm

Correlations of phytoplankton levels with available environmental data

Water temperature was recorded using electronic loggers that were attached to oyster baskets from the SOAP program. During the colder months water temperature at sites closer to the mouth/ocean were warmer than inside of the lake. During summer the situation reverses. Water temperature at the Entrance location tends to be different to the other sites within Pambula Lake (i.e. major gradient difference of 2°C). Large temperature variations were recorded at times in the Front Lake lease, this maybe a result of baskets being exposed to large tidal ranges in which baskets become exposed to air at certain tides. Daily water temperature variations and monthly averages have been plotted and collated in tables below. Slight reductions in water temperature were recorded after the main rain events: September and December 2014, March and June 2015

Water temperature was found to be positively correlated with the levels of %harmful species and Diatoms, although this correlation was weak (r=0.2-0.3). On the other hand salinity levels were found to be negatively correlated to the levels of % harmful and Dinoflagellates (r=-0.5). This means that rain events (i.e. increased in nutrient run-off) result in a slight increase in algal levels in particular dinoflagellates and small flagellates. During the influence of extreme low salinities (e.g. <10ppt) the only phytoplankton species present in the sample were small size of flagellates as seen in the results for December 2014 and May 2015.

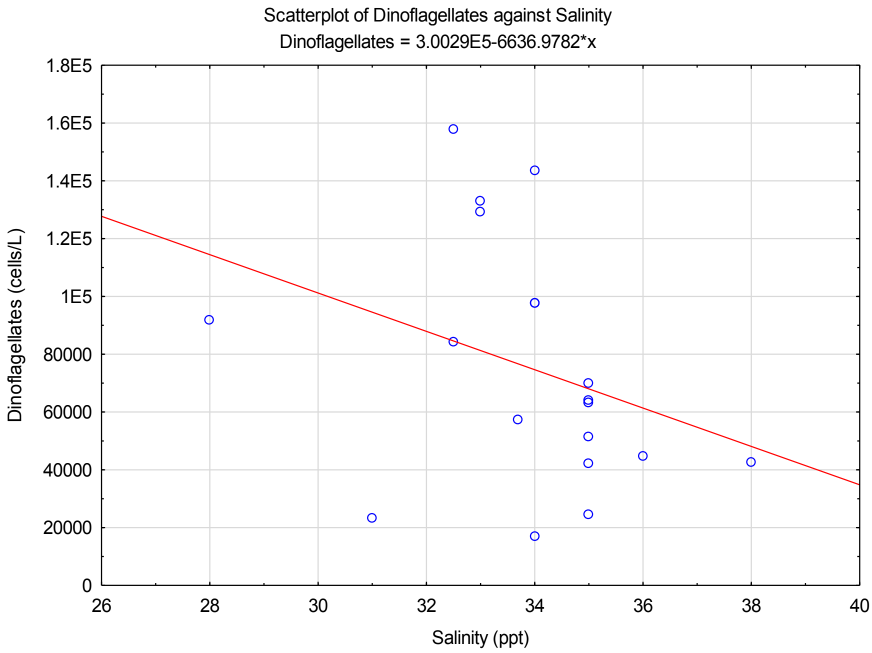



Figure 3 Correlation between levels of Dinoflagellates and Salinity

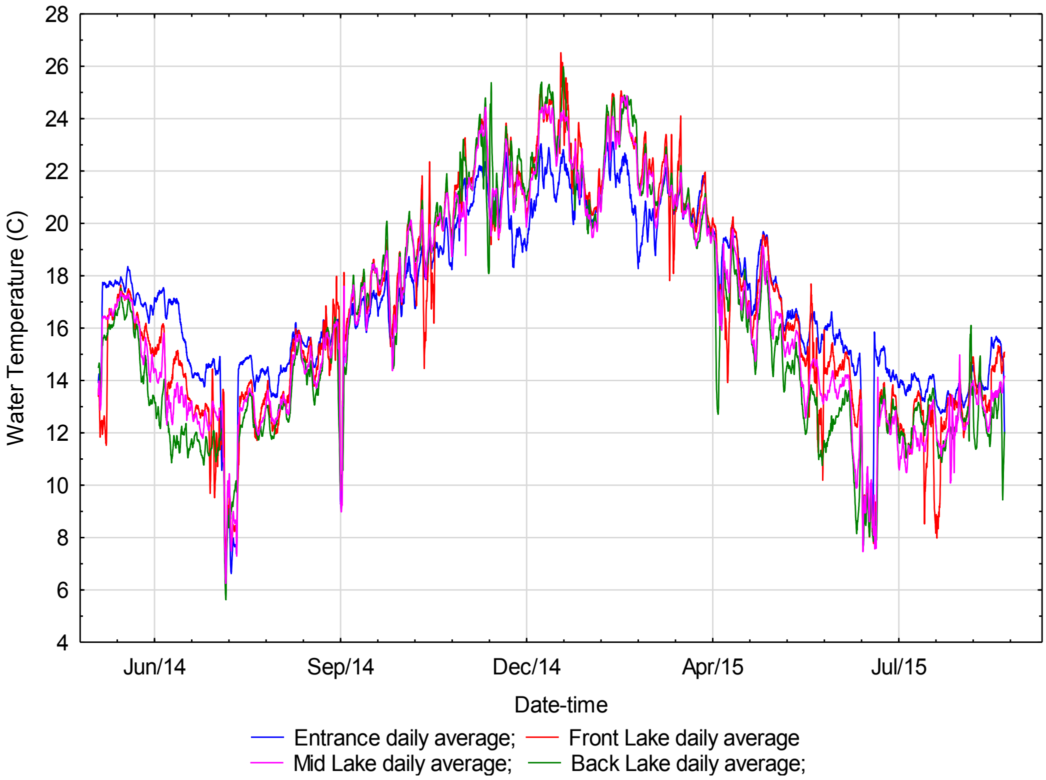



Figure 4. Daily water temperature at the four sampling locations in Pambula for the period August 2014 to June 2015

Correlations of phytoplankton levels with oyster performance data from SOAP

Oysters in Pambula Lake after 14months of monitoring had an overall cumulative mortality of slightly under 15% at all sites except at the Entrance where cumulative mortalities were 5% higher. Oyster mortality levels were weakly correlated with the presence of harmful species but negatively correlated to the levels of each algal group. Hence oyster mortalities appear to be more driven by periods of lower algal levels. Please note that this correlation is weak and environmental parameters do influence oyster performance. Overall higher mortality levels were seen at the Back and Mid lake lease at the start of the program (during 2014) while mortality levels were reduced during 2015 at these locations but they increased significantly at the Entrance lease.

Oyster growth rates were negatively correlated to levels of diatoms (a large percentage are planktonic diatoms) but positively correlated to levels of dinoflagellates and small flagellates. It is worth noting that these correlations are weak but these patterns do exist. Hence oyster productivity at the Front Lake area appears to be driven by levels of dinoflagellates and small flagellates. Overall growth rates were reduced to a minimal during the winter months from June to Sept when water temperatures were between 12-16ºC

## 3.2 Merimbula

Data background: Phytoplankton samples were collected from the NSW Food Authority Site #2 which is close to lease AL 02/027 (or Mid Lake as referred to in the SOAP program). Oyster growth and mortality rates have been used from this lease only. A total of 21 samples were collected between 19/8/2014 and 2/6/2015. Raw data will be provided with this report.

Extremely high levels of mortalities were recorded at Mid Lake during the period of Jan-April 2015, however these mortalities were associated with mishandling of the oysters which remained out of the water for a long period during hot days in January. Hence this data point was removed from the analysis as mortalities were not driven by algal or environmental conditions.

Characteristics of the overall phytoplankton community

The phytoplankton community at site #2 in Merimbula is normally represented by a well-mixed with a good diversity of diatoms and flagellates. Typical algal species corresponds to planktonic diatoms like *Chaetoceros, Dactyliosolen, Skeletonema, Lioloma, Leptocylindrus* and *Pseudo-nitzschia*. In particular *Leptocylindrus minimus*, a non-harmful species, tend to bloom from time to time in the lake. Benthic diatoms do appear from time to time dominated by *Ceratoneis* and *Nitzchia*. Flagellates species that tend to dominate the samples corresponds to the groups of *prymnesiophytes, cryptomonads* and *prasinophytes*. Low numbers of dinoflagellates are typically seen in the samples at times but conversely a wide range of toxic dinoflagellates species tend to be present in the samples. In most cases the levels of toxic species are below or close to the NSW Food Authority's Phytoplankton Action Limits (PAL).
Approximate levels of total phytoplankton ranged from 180,000 cell/litre to 5,100,000 cell/litre in a sample. The breakdown of phytoplankton groups are approximately 71% diatoms; 6% dinoflagellates and 22% corresponds to small flagellates and 'other plankton' groups. Within the diatom group there are more planktonic species than benthic species.

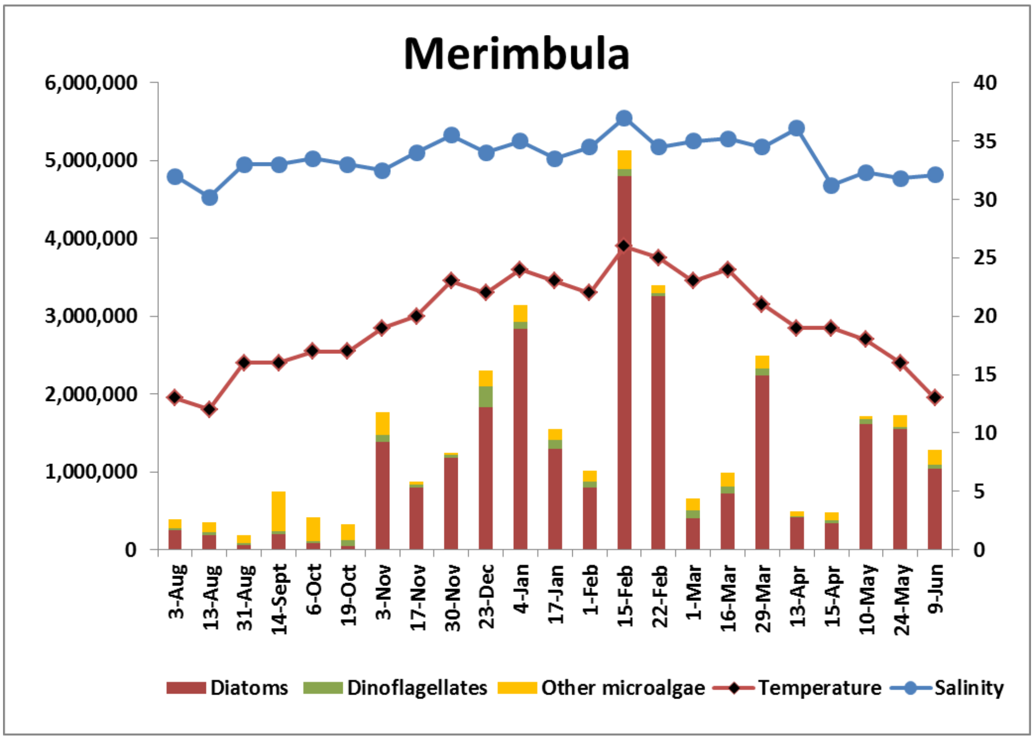



Figure 5. Total biomass of major phytoplankton (microalgae) groups and temperature (°C) and salinity (ppt) levels. Left Y axis- number of algal cells; Right Y-axis= Temperature °C and Salinity ppt

Levels of harmful and harmless phytoplankton species

Species of harmful algal species were recorded in almost all samples collected. On average the phytoplankton population is composed of 96.7% of harmless algal cells, although at times these percentages are reduced to 80%. Spikes in harmful algal levels were recorded on 3/11/14; 1/2/15 and 1/3/2015. These dates are not fully associated with high rainfall but resulted in high levels of certain toxic species over the NSW Food Authority's Phytoplankton Action Limits, with species such as *Pseudo-nitzschia delicatissima group; Pseudo-nitzschia pungens/multiseries, Prorocentrum cordatum, Prorocentrum rhathymum, Fibrocapsa japonica and Heterosigma akashiwo*. Rainfall did occur in November and February but not in March. Hence a different trigger influences the blooms of toxic algae. In fact major rainfall events did occur during the sampling period without resulting in increases of harmful algae species.

A positive correlation was found between the %Harmful algae and diatom species but was negatively correlated with levels of small flagellates as shown below, in particular for those dates when a peak in harmful species occurred. Hence toxic diatoms species dominate the pool of toxic species found in the samples.

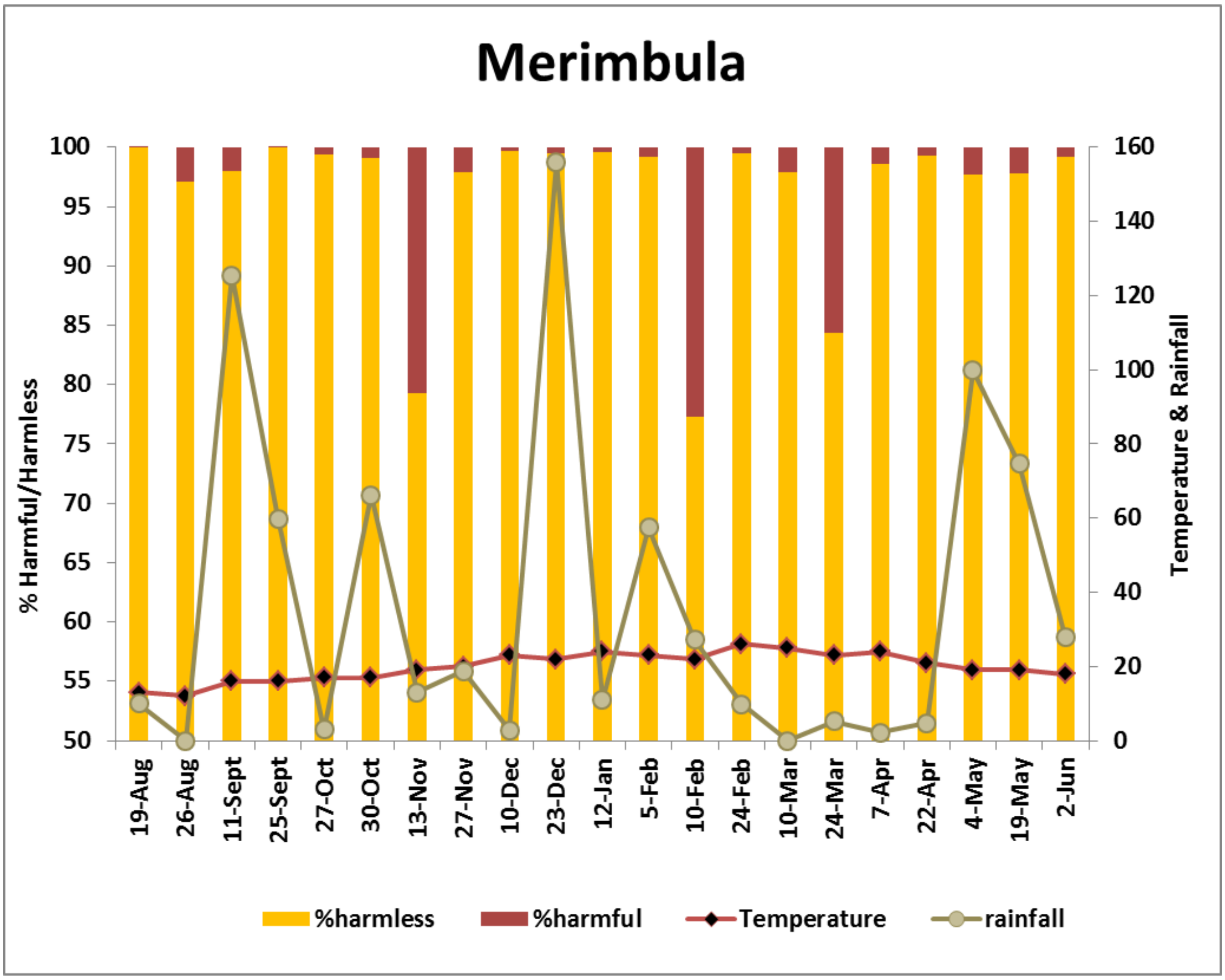



Figure 6. Percentage of harmful and harmless phytoplankton (microalgae) species and temperature (°C) and rainfall (mm) for the period in between samples. Left Y axis- percentage of algal cells; Right Y-axis= Temperature °C and Rainfall mm

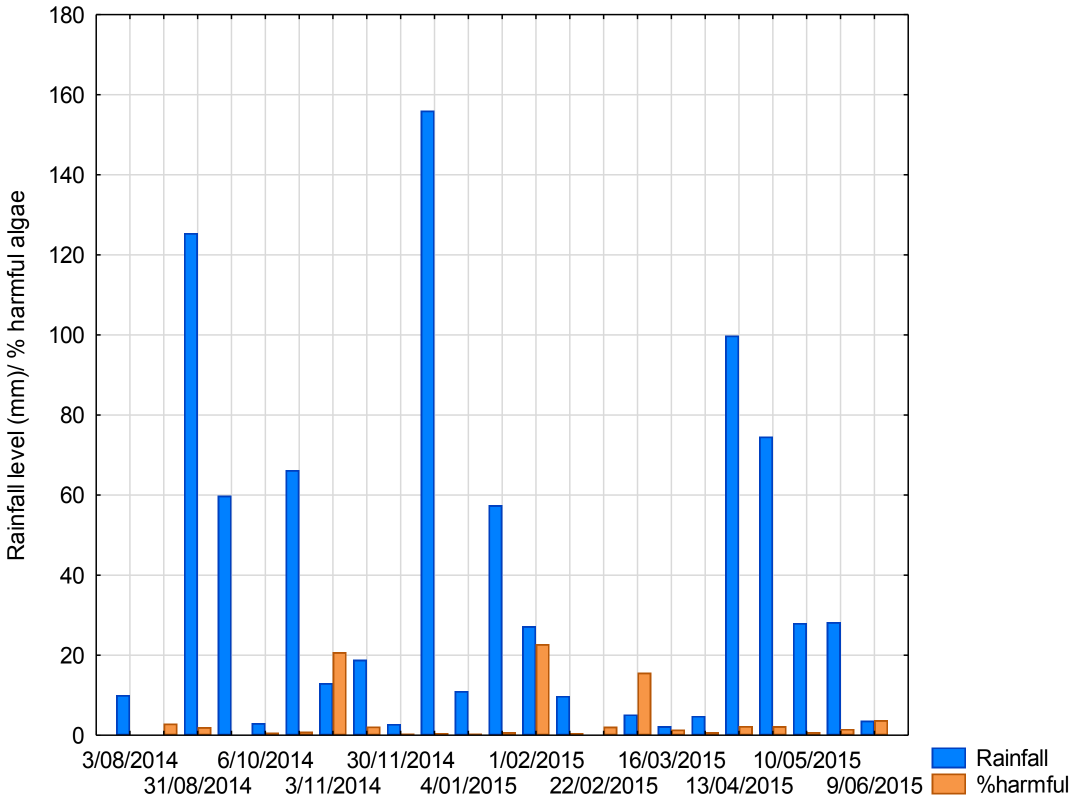



Figure 7. Levels of rainfall and %harmful algae through time.

## Correlations of phytoplankton levels with available environmental data

Water temperature was recorded using electronic loggers that were attached to oyster baskets from the SOAP program. During the colder months water temperature at sites closer to the mouth/ocean were warmer than inside of the lake. During summer the situation reverses.

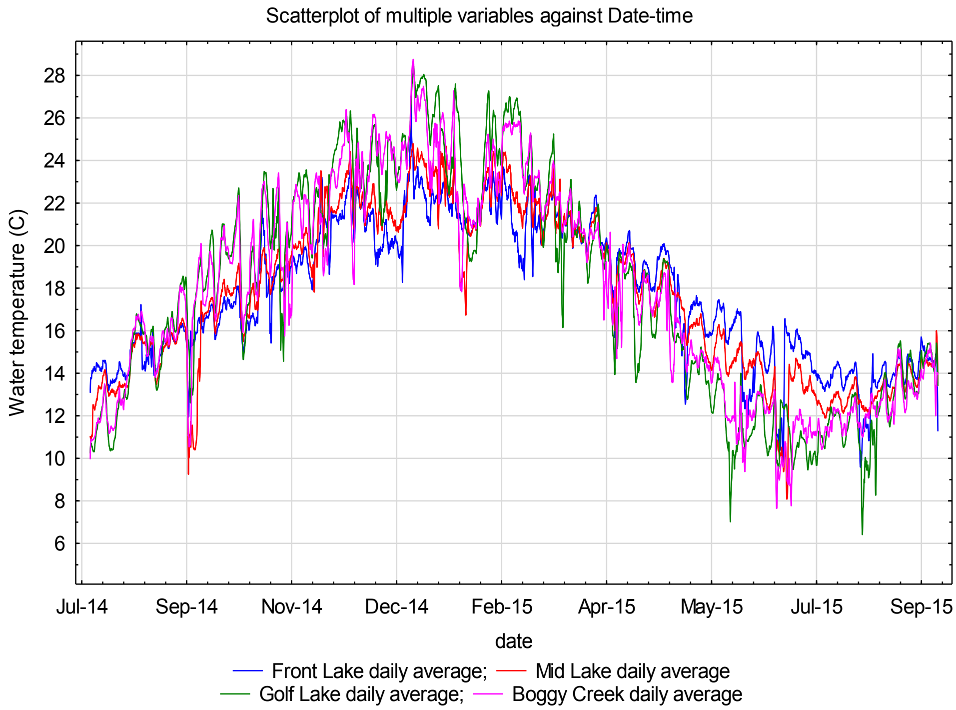



Figure 8. Daily water temperature at the four sampling locations in Merimbula for the period August 2014 to June 2015

Dinoflagellates and small flagellates were positively correlated with salinity, rainfall and water temperature. This correlation was not seen for the diatom group. The percentage of harmful species was also found to be slightly negatively correlated to salinity and rainfall. This means that at low salinities, after rainfall, there was a slight increase in the levels of harmful species. It is worth noting that these correlations were not found to be statistically significant but instead are considered trends in the data.

Correlations of phytoplankton levels with oyster performance data from SOAP

A statistically significant correlation ($r=0.95$, $p<0.012$) was found between levels of Dinoflagellates and the growth of wild Sydney Rock Oysters at the Mid Lake lease, which is the lease closer to the phytoplankton sampling site. Less strong correlation was also seen with levels of diatoms but not with small flagellates, despite the latter group being a key group for oyster food. Based on the correlations above, %harmful algal species were found negatively correlated with growth this group is mainly dominated by diatom species.
All algal groups were found negatively correlated with oyster mortality levels meaning that periods of higher than usual mortalities occur when algal levels for all groups were lower than average.

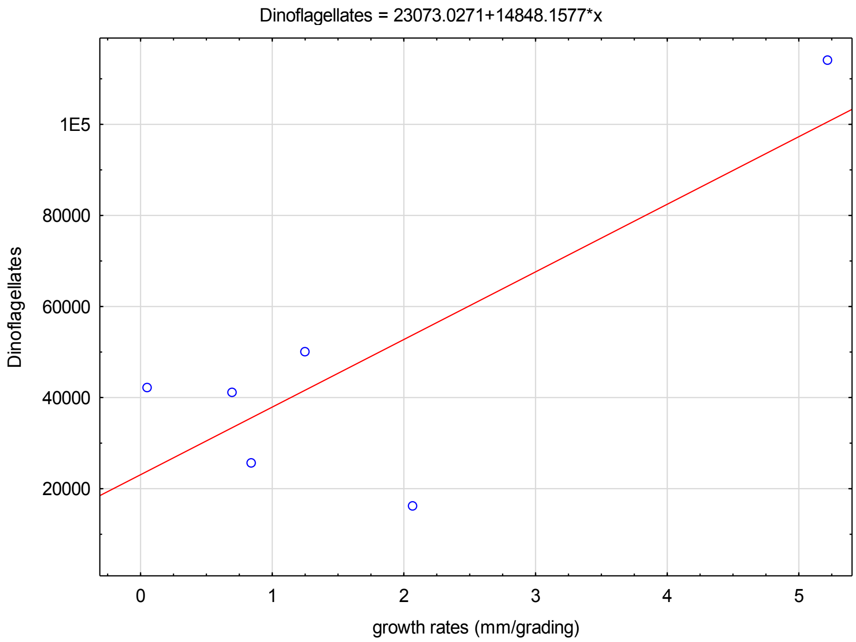



Figure 9 Correlation between levels of Dinoflagellates and growth rates of wild SRO at Mid lake lease

## 3.3 Wapengo

Data background: Phytoplankton samples were collected from the NSW Food Authority Site #2 which is between leases OL 59/017 (or Mid Lake) and OL67/355 (or Spiros as referred to in the SOAP program). In fact the phytoplankton site is located in the middle of the lake representing the algal community within the lake. Phytoplankton site #1 is closer to the entrance of the lake, hence representing the algal species that enter the lake from the ocean. Oyster growth and mortality rates have been used from this lease only. A total of 21 samples were collected between 19/8/2014 and 2/6/2015. Raw data will be provided with this report.

Characteristics of the overall phytoplankton community

Data collected showed that the phytoplankton community present most of the times at Site#2 is a well-mixed sample with a variety of small flagellates (*prasinophytes, cryptomonads, prymnesiophytes*) in high levels. The samples also are dominated by planktonic diatoms like *Chaetoceros* and *Thalassiosira* and at times *Skeletonema*. From time to time samples also contain large number of benthic diatoms of the genus *Ceratoneis*. All samples have representatives of dinoflagellates but with no dominant species as such. It was noted that most of the algal samples sent contained high levels of sediment and organic detritus which are not considered in this report but it is worth noting that organic detritus are also known to be a food source for oysters as bacteria and virus tend to live attached to these particles.

Approximate levels of total phytoplankton ranged from 250,000 cell/litre to 2,700,000 cell/litre in a sample. The breakdown of phytoplankton groups are approximately 40% diatoms; 9% dinoflagellates and 50% corresponds to small flagellates and 'other plankton' groups. The percentage of small flagellates in the samples is 20% higher than what dominates the samples in Pambula, Merimbula and Wonboyn.

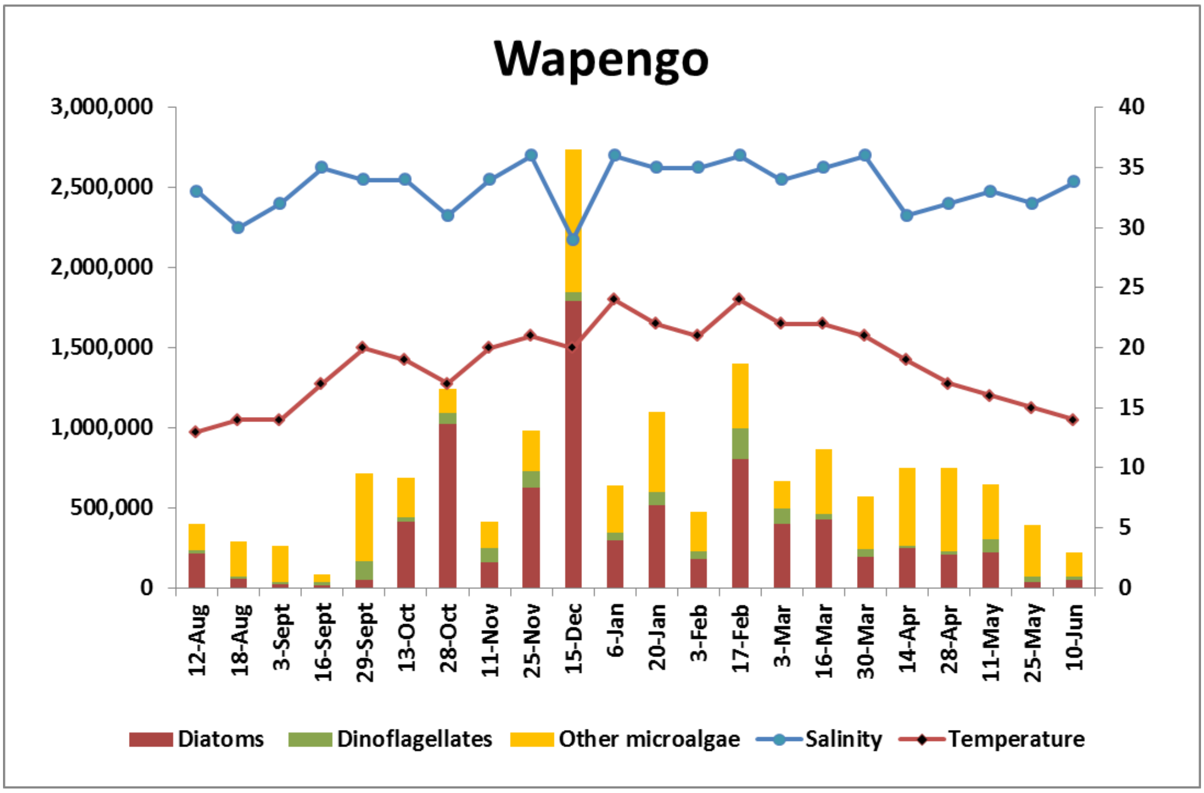



Figure 10. Total biomass of major phytoplankton (microalgae) groups and temperature (°C) and salinity (ppt) levels. Left Y axis- number of algal cells; Right Y-axis= Temperature °C and Salinity ppt

Levels of harmful and harmless phytoplankton species

Species of harmful algal species were extremely low in the samples. The data shows that 99% of the algal cells counted are harmless in almost all samples except for 3 samples in the year in which the percentage decrease to 97.5%. Those dates in which the %Harmful algal increased by 2% are slightly associated to rainfall events. %Harmful algae was correlated only with the dinoflagellates group, out of which only three species appear to be present in slightly higher levels. *Alexandrium* species were present in low numbers towards the end of the summer. *Dinophysis* and *Prorocentrum* species were present, also in low levels, from time to time. In addition levels of the diatom *Pseudo-nitzschia spp* were slightly higher during the summer months between Jan-April. Overall toxic levels were extremely low, in fact were the lowest observed in comparison with Pambula, Merimbula and Wonboyn.

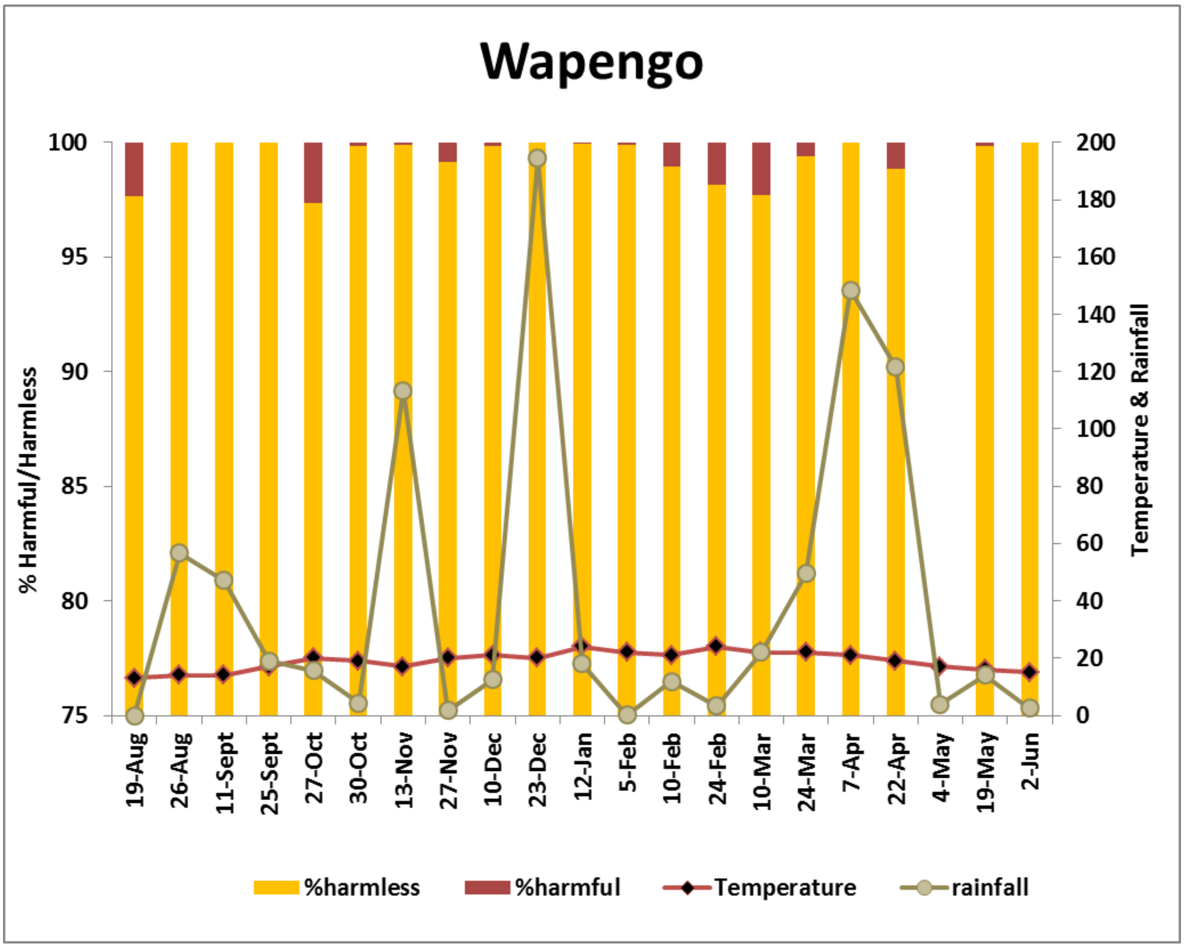



Figure 11. Percentage of harmful and harmless phytoplankton (microalgae) species and temperature (°C) and rainfall (mm) for the period in between samples. Left Y axis- percentage of algal cells; Right Y-axis= Temperature °C and Rainfall mm

Correlations of phytoplankton levels with available environmental data

Water temperature was recorded using electronic loggers that were attached to oyster baskets from the SOAP program. Water temperatures at the Mid Lake lease was lower than at the other two locations during most of the year but a larger difference in the middle of the summer and from the end of May to September 2015. Last year's winter temperatures were more similar to each other sites. Spiros water temperature is the highest in summer, followed by the Armstrong site.

All algal groups were significantly positive correlated to water temperatures (r=0.5) and to rainfall with a weaker correlation (r=0.35). Dinoflagellates was the only algal group with a positive correlation to salinity levels (r=0.5). %Harmful algal levels were positively correlated to dinoflagellates, salinity and temperatures, indicating that toxic dinoflagellates species did not appear as a result of rainfall events.

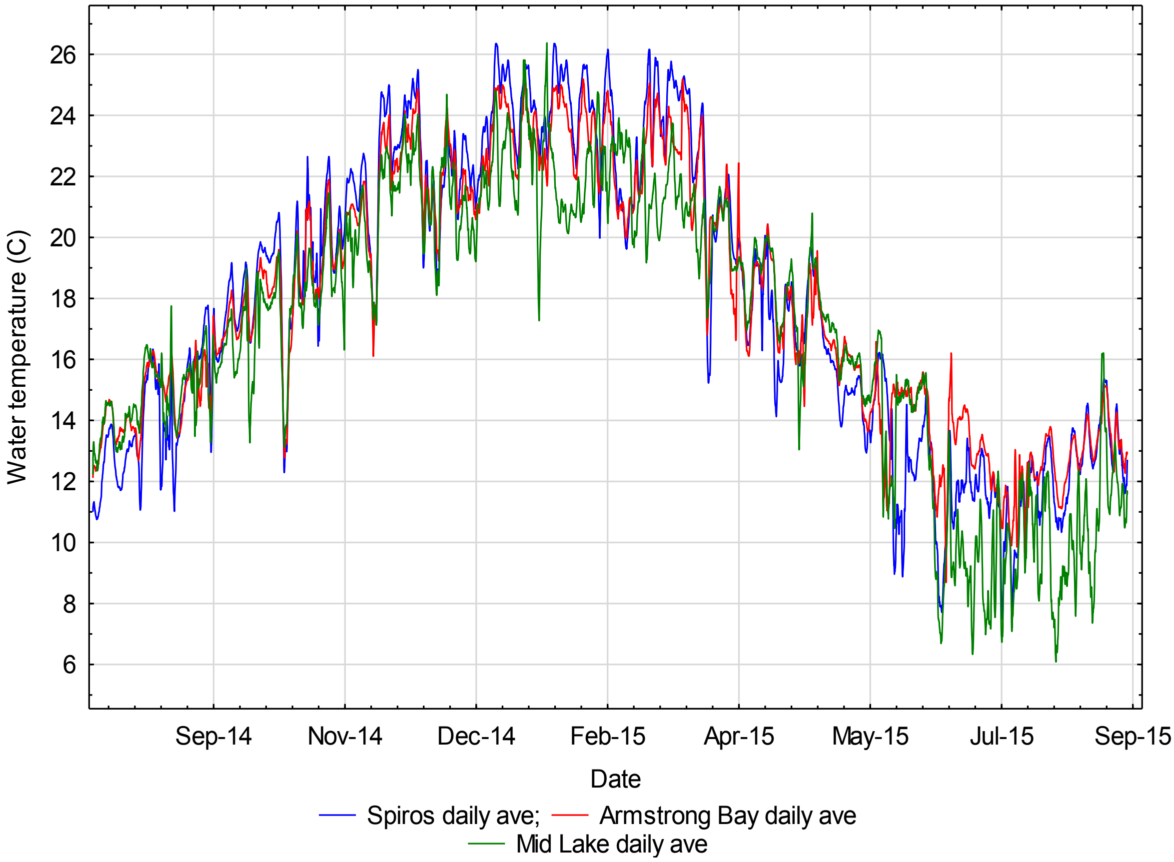



Figure 12. Daily water temperature at the four sampling locations in Wapengo for the period August 2014 to June 2015

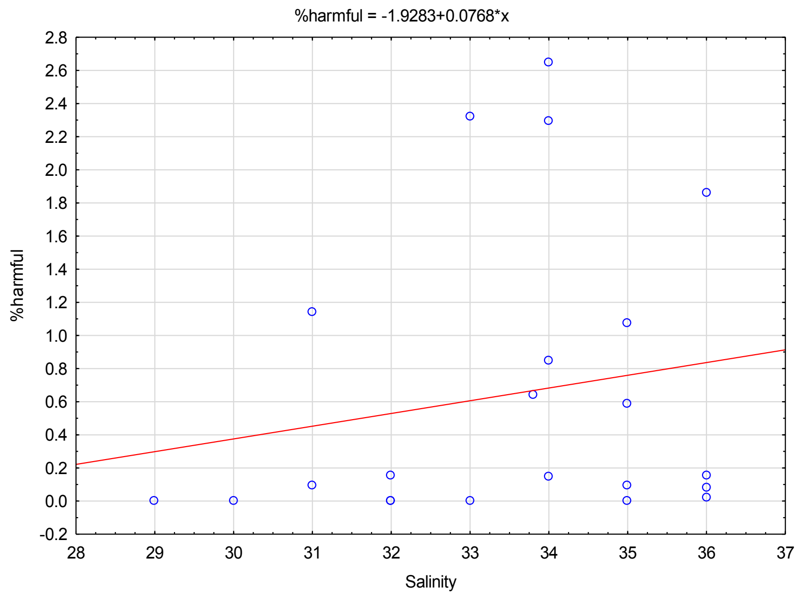



Figure13 Significant correlation between levels of %Harmful algal and Salinity (r=-0.88, p=0.018)

Correlations of phytoplankton levels with oyster performance data from SOAP

Overall oyster mortality data was less than 2% at every grading (approx. 6-7 weeks) except for the period between Jan-March during which mortality levels increased to 2.6%. Mortality levels were found to be negatively correlated to levels of algal species indicating that slight increases in mortality did occur during the periods in which the algal biomass was slightly lower. In addition algal groups were positively correlated with growth except for Dinoflagellates. This algal group dominates when high levels of harmful algal are present, which appears to interfere with oyster feeding, hence overall growth.

In addition oyster growth rates seem to be negatively correlated to salinity levels, however salinity did not reach lower levels than 33ppt

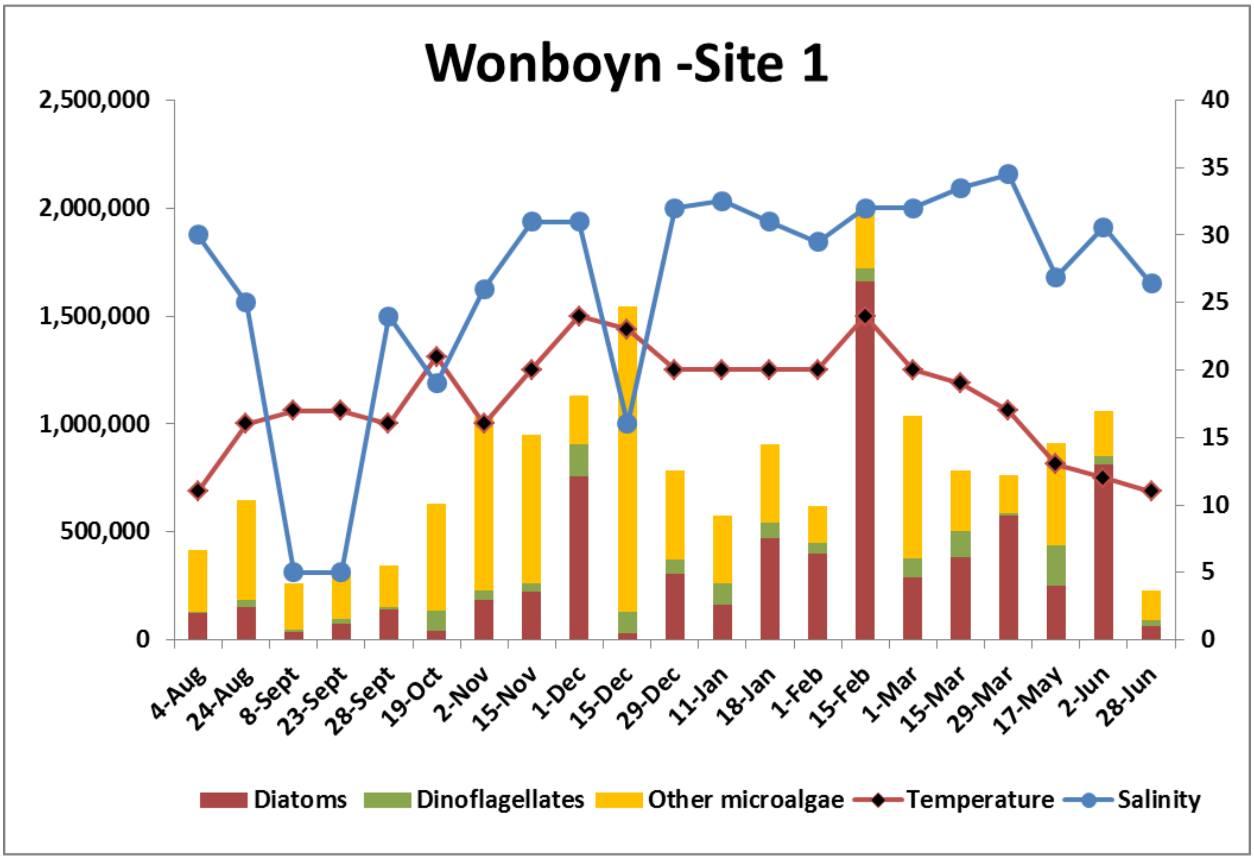
## 3.4 Wonboyn

Data background: Phytoplankton samples were collected at the two NSW Food Authority Sites #1 & 2. Site #1 is close to leases OL 90/042 (or Corner Channel) and OL73/430 (or Red Rock as referred to in the SOAP program). Site #2 is close to lease OL83/244 (or the River). Oyster growth and mortality rates have been used from these leases. A total of 21 phytoplankton samples were collected between 19/8/2014 and 2/6/2015. Oysters part of SOAP missed a grading period as a result of heavy rainfall that resulted in floods in February 2015. Hence a data point is missing in the oyster performance dataset, this reduces even further the data points used for analysis. Oyster growth and mortality Raw data will be provided with this report

Characteristics of the overall phytoplankton community

Data collected showed that the phytoplankton community present most of the times at both Site#1 and #2 is composed by a wide range of small flagellates (*Cryptomonads, Prasinophytes, Prymnesiophytes*) and planktonic diatoms (*Dactyliosolen, Chaetoceros, Skeletonema, Cerataulina, Minidiscus*). The diatoms of the genus *Dactyliosolen* are distinctive of this lake in comparison with the diatoms present at the other lakes in the Far South Coast despite being an offshore typical species. The samples contained very low levels of benthic diatoms and dinoflagellates in general. In addition, in a number of samples the existence of high levels of fine sediment and organic detritus was reported, which is also known to be part of the food composition of oysters as bacteria and viruses tend to attach to these type of particles.

The phytoplankton composition for Site 1 and 2 was similar at most times except that the overall algal biomass levels were double at Site$#2 overall. This difference in level is expected as Site#2 is located in the middle of the lake, where productivity is expected to be higher than at the oceanic influenced Site #1 Approximate levels of total phytoplankton ranged from 230,000 cell/litre to 2,000,000 cell/litre for Site#1 while levels ranged between 300,000 and 4,700,000 cell/litre for Site#2. While overall levels of phytoplankton biomass is different across sampling sites the breakdown of phytoplankton groups is similar among sampling sites with approximately 38% diatoms; 10% dinoflagellates and 52% corresponds to small flagellates and ‘other plankton’ groups



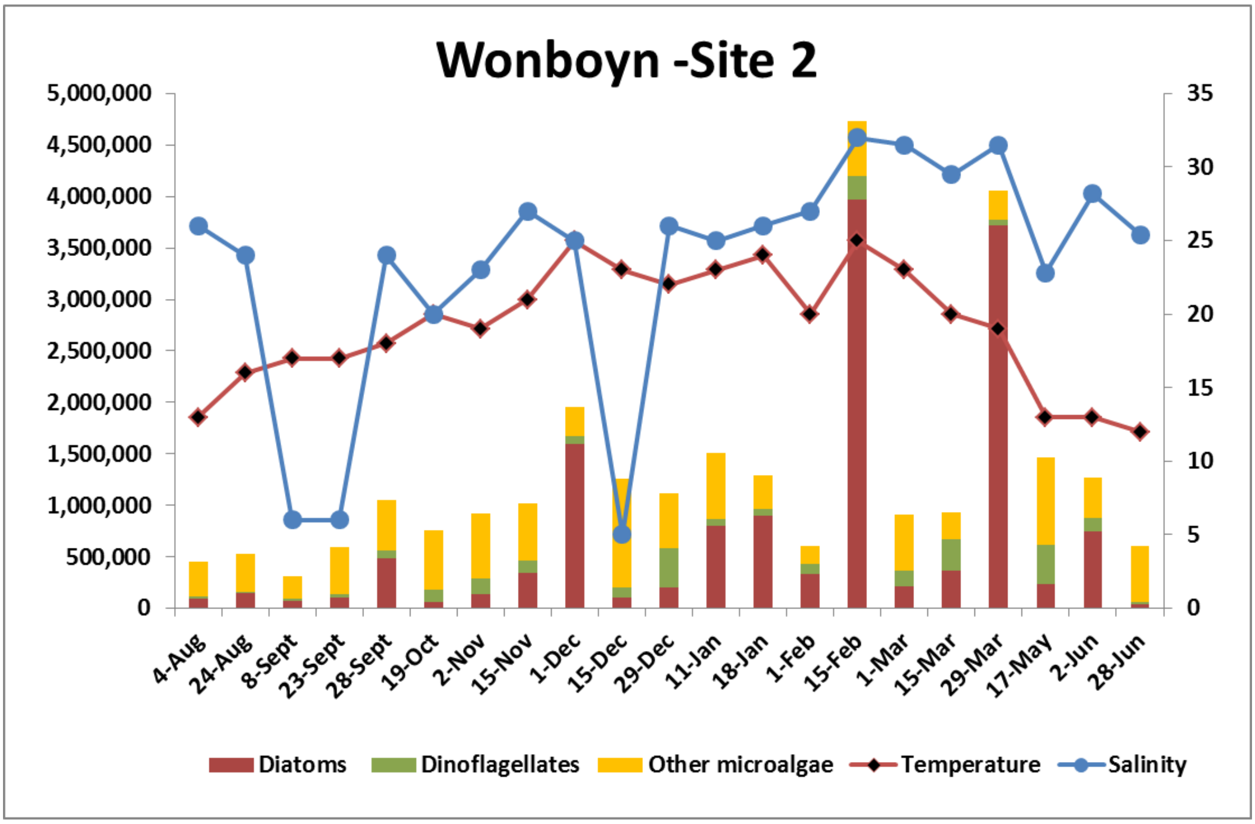
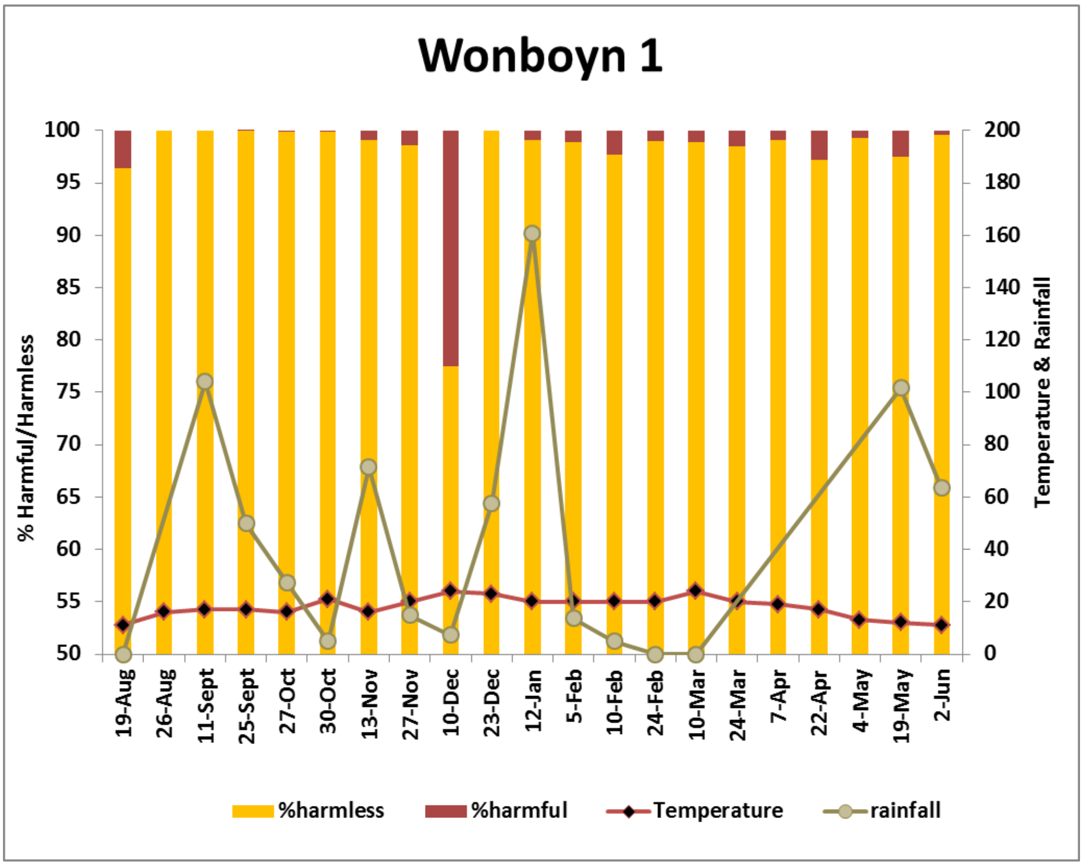




Figure 14. Total biomass of major phytoplankton (microalgae) groups and temperature (°C) and salinity (ppt) levels. Left Y axis- number of algal cells; Right Y-axis= Temperature °C and Salinity ppt

Levels of harmful and harmless phytoplankton species

Species of harmful algal species were recorded in all samples collected but at relatively low levels. The data collected at Site#1 shows that 95% of the algal cells counted are harmless at any point in time, with the exception of two samples between the end of November- December were extremely high levels of the diatom *Pseudo-nitzschia delicatissima* group were found. The overall percentage of harmless species in Site#2 was slightly lower around 93% although there was an increased number of sampling dates when the percentage of harmful species increased to 15 and 50%. Dates with higher levels of toxic species occurred during the summer months from mid-November to mid-January and the toxicity was attributed mainly to the planktonic diatom species of the group Pseudo-nitzschia as per Site#1. Most of the algal species contributing towards the levels of harmful species were reduced to 4 main species in addition to *Pseudo-nitzschia.* These algal species are *Alexandrium, Dinophysis, Karenia and Prorocentrum cordatum.*



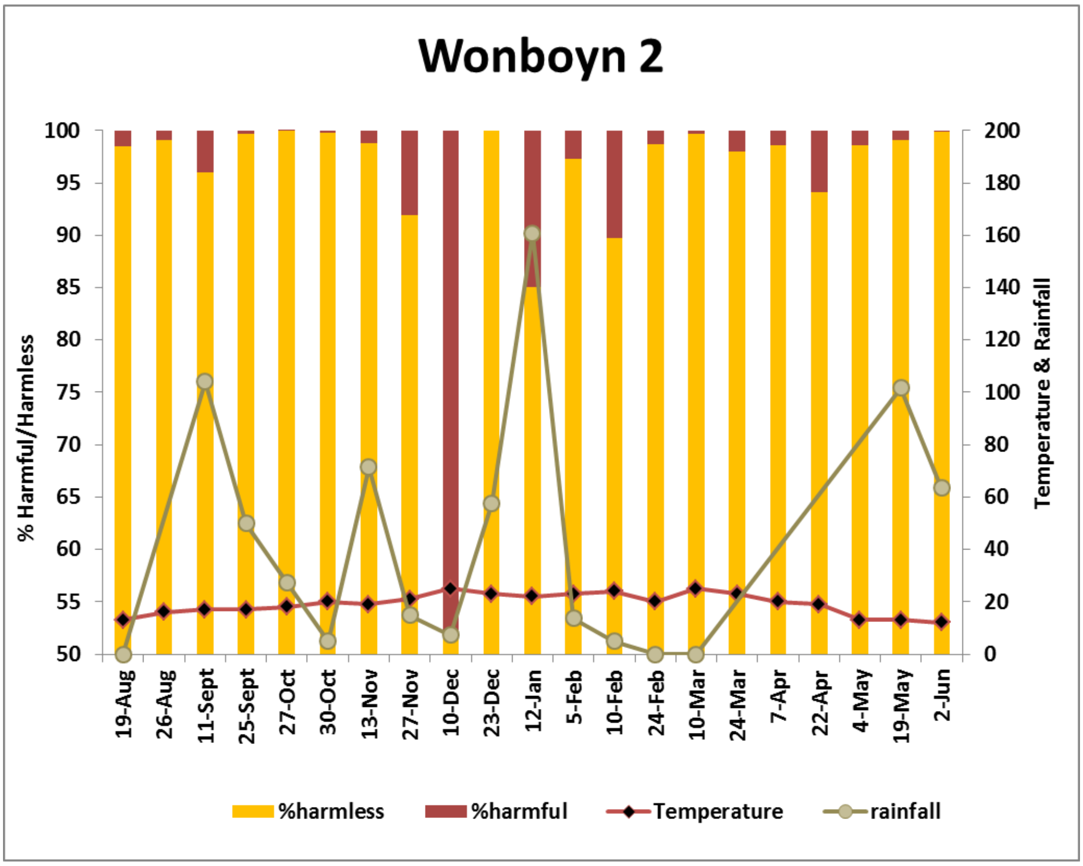




Figure 15. Percentage of harmful and harmless phytoplankton (microalgae) species and temperature (°C) and rainfall (mm) for the period in between samples. Left Y axis- percentage of algal cells; Right Y-axis= Temperature °C and Rainfall mm

Correlations of phytoplankton levels with available environmental data

Water temperature was recorded using electronic loggers that were attached to oyster baskets from the SOAP program. All water temperatures independently of the location in the lake were very consistent, probably as a result of same water depth and water movement across the lake.

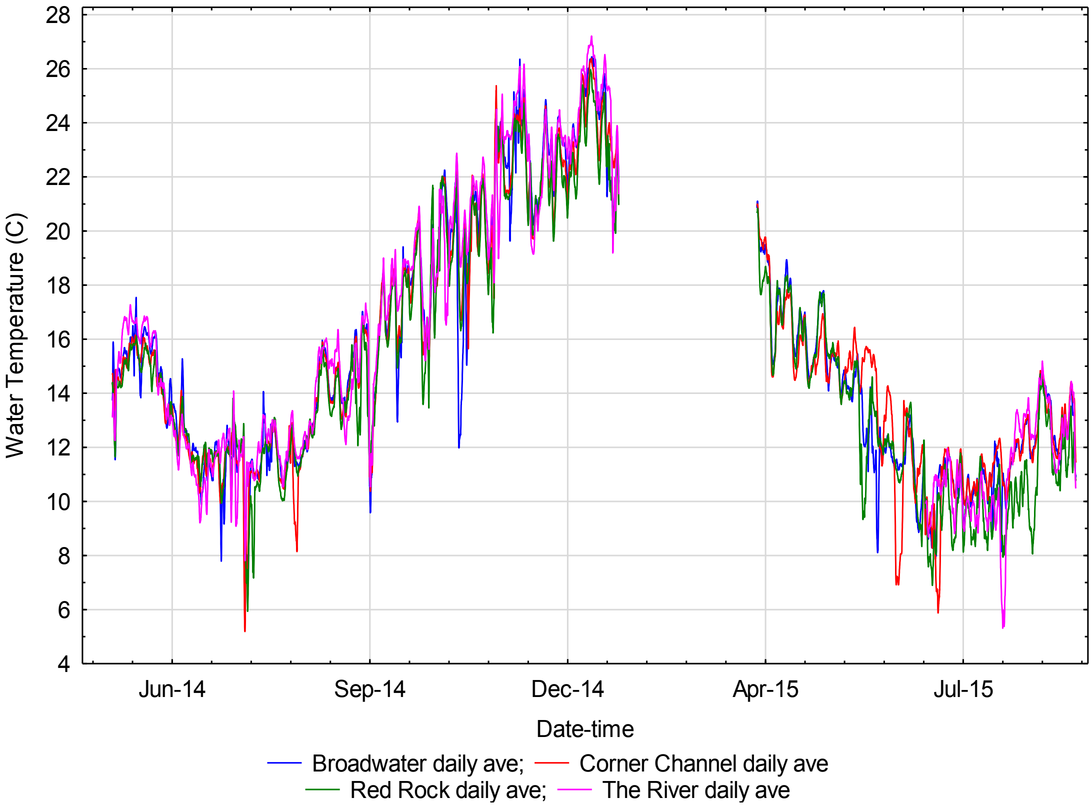



Figure 16. Daily water temperature at the four sampling locations in Wonboyn Lake for the period August 2014 to June 2015

At Site#1 a significant correlation was found between total algal levels and water temperature (r=0.5-0.6, p=0.025). All algae, but diatoms in particular, were significantly correlated with salinity (r=0.4, p=0.03) indicating that blooms of toxic diatoms of Pseudo-nitzchia are not a result of rainfall events. The %harmful species was positively correlated to the levels of Diatoms and Dinoflagellates since most of the key toxic species below to these groups of algal.

Site#2 data did not result in any significant correlations except for total algae to be positively correlated with salinity and temperature. This is consistent with result at Site#1

Correlations of phytoplankton levels with oyster performance data from SOAP

At both sampling sites total algal levels were correlated with oyster growth but not at a significant level. Oysters at Wonboyn Lake have been growing as per the other lakes but the oysters had good condition index all through the program except for the period after the major rainfall event that took place in Feb-15. Levels of diatoms were found to be positively correlated with oyster mortality probably as a result of the number of toxic diatom species present in the lake

# 4. Recommendations for future monitoring and data analysis

These results are a subset of the total results that will form part of the final report on SOAP 2014/15- Program3 which will be presented to the LLS in January 2016. This report has focused on the full counts of phytoplankton data collected during August 2014 to June 2015 at the four estuaries from the Far South Coast. Further information exists from previous SOAP programs which need to be integrated with these results in order to assess environmental conditions and phytoplankton patterns across years.

The data presented here for oyster performance (growth and mortality) corresponded to the lease/s closer to the phytoplankton sampling site only, hence patterns might change for different geographical locations (entrance vs mid lake). However, both phytoplankton sites in Wonboyn Lake were used in this report with little difference found in regards to phytoplankton diversity. This might not be the case in the other lake. In addition, oysters were graded less frequent than the collection of phytoplankton limiting the data points contributing to the correlations described in this report. It is not feasible to grade oysters as frequent as phytoplankton collection; hence there is a need for long-term oyster monitoring in order to increase the robustness of the results. Once data from previous SOAP programs is also incorporated the results will be more robust.

Data on condition index collated by SOAP was not taken into consideration here but it will also be part of the final report on SOAP 2014/15 with the goal of looking for correlations between good condition index and phytoplankton composition.

Full counts of phytoplankton give us information about the composition and abundance of the algae types contributing to the pool of oyster food, ecological food webs (i.e. role of algae in the estuary) and food health (i.e. presence of toxic algae). Having this information has allowed us to determine the type of algal groups present at the different lake systems and the variety and levels of harmful algae species present. However this measure of productivity is quite expensive. Hence based on the information gathered this year and in previous SOAP programs, I would be tempted to advice growers to reduce this sampling unless major catchment developments are expected in the closer future. Instead using other proxies like Chlorophyll-a might be a better approach to pursue if industry is interested in further monitoring. Chlorophyll-a has its limitations too as it only gives you an indication on the level of algal biomass in the waterway independently of the type of algae or the toxicity. Monitoring water quality is expensive and in order to get maximum benefit from it requires frequent monitoring. The ultimate set-up for monitoring is to have high-frequency monitoring using water quality instruments. Then it is possible to follow trends and changes in the water body.

If growers are interested in carrying capacities, having information on both phytoplankton and chlorophyll-a would be of advantage. However oyster performance data (growth and mortality) at different stocking densities is more important than water quality. Hence if resources are limited I will support the continuation of monitoring oysters (in more depth than current SOAP program) prior to investing resources in water quality. An attempt to give some guidelines to growers in gathering this information was raised at one of last year's ORAC meetings. It has also been raised at a meeting I have attended recently in Vancouver. Some feedback might come from overseas in regards to guidelines to collect oyster production data towards assessing carrying capacities.