LEAFY SEADRAGON POPULATION MONITORING IN THE AMLR NRM REGION - PILOT STUDY AT RAPID BAY

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Community project report for the Adelaide & Mt Lofty Ranges Natural Resources Management Board
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Dedication

This report is dedicated to Mr Carey Harmer, whose previous work on seadragon identification at Rapid Bay over many years, helped the public to understand the strong site association of these unique fishes, and forms a sound basis for advocating site-based protection of seadragon populations.

Acknowledgments

Thank you to the Adelaide and Mt Lofty Ranges Natural Resources Management Board for providing support that enabled this project to be undertaken between August 2013 and September 2014. Particular thanks to Mr Tony Flaherty, Manager of Coast and Marine at Natural Resources Adelaide and Mt Lofty Ranges, for his long-term interest in (and support of) seadragon research, monitoring and conservation management in South Australia. Thanks also to Kristy Manning of NR - AMLR for project administration.

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Thanks also to K. Newton (nee Hart) for graphic design work on the jetty pile site maps, which were used to label locations.

LEAFY SEADRAGON POPULATION MONITORING IN THE AMLR NRM REGION - PILOT STUDY AT RAPID BAY

SUMMARY

On the Fleurieu Peninsula in South Australia, the old jetty at Rapid Bay is a habitat for the leafy seadragon (*Phycodurus eques*), a species that attracts local, interstate and international attention. Rapid Bay is heavily promoted in dive tourism materials and on social media. Dive trips to Rapid Bay to view the seadragons have become increasingly popular during the past two decades, with dive tour businesses as well as social dive clubs. The jetty has also been commonly used for open water SCUBA diver training, over a number of decades.

In 2011, community concern was expressed about possible decline in numbers of seadragons at the old jetty, compared with observations and community-based data (via Dragon Search program) from previous decades. At the time, various hypotheses were suggested by community, and a project was devised to investigate concern about possible declining numbers in the vicinity.

From August 2013 and September 2014, with assistance from the Adelaide and Mt Lofty Ranges NRM Board (AMLR NRM), a project was undertaken by members of the SCUBA diving community in South Australia, to record the occurrence, location, facial features and breeding times of seadragons under and around Rapid Bay jetty. The project was managed by J. L. Baker, from South Australian Conservation Research Divers (SACReD), a community-based marine citizen science group that undertakes project work to learn more about the distribution and habitats of marine species in South Australia.

Following the pilot project, additional records were collected sporadically from volunteers, between September 2014 and January 2020. These records helped to determine whether any of the seadragons from the 2013-14 data set could be identified over a longer time frame, using the facial features and appendages. The additional data enabled more information about breeding frequency of individuals to be determined, and also illustrated some of the damage that can occur to individual seadragons over time.

This report describes the results of the pilot project, as well as the results from supplementary records collected up till the summer of 2019.

During the project, 12 individuals were identified at the outset, and re-sighted over periods ranging from less than 1 year to more than 5 years. Detailed results for 7 of these individuals are discussed in this report. The first 12 months of the project were funded via small grant, and during that time, 123 dives were undertaken at Rapid Bay, to search for and photograph seadragons. Several hundred further dives were undertaken by volunteers after the pilot phase was completed. Over the course of the project, which includes the follow-up period of volunteer work, more than 800 images were used to identify seadragons at Rapid Bay. More than half of the records were from the first 12 months of the project. Divers also provided photographic records from 2011 and 2012, to compare with the images taken during and after the pilot project.

The photographic data from 2011 to 2020, along with observations by divers, indicate that:

- Identifiable individuals could be recorded for at least 7 years at the same location. Some of those individuals were adults at the start of the project, so would have been at least 8 years old at the time this report was completed.
- Some leafy seadragons could be defined as “jetty residents”, and, unless disturbed, it appears that they do not move more than 100m from a "home base". Some were regularly recorded in the same location at the end of the jetty, for > 10 months in the first instance, and then periodically in the vicinity over several years.
- Long term residents recorded during this project were male leafy seadragons.

- Breeding period is consistent between years, and some male leafy seadragons have more than one brood per season.
- It is assumed that at least 2 leafy seadragons did not remain in the original sighting location for longer than 6 - 11 months. The 2 monitored seadragons both had distinctive markings and would have been recognisable from images if they were present in the jetty area after the first year of the project.
- Some leafy seadragons apparently move away from the jetty seasonally into deeper water.
- Leafy seadragons might also move offshore in response to groups of divers, as indicated by double dives over the course of a day, to record the same individual seadragons, before and after tour groups visited.
- There may be a greater number leafy seadragons offshore away from the jetty, than at the jetty at any one time.
- Weedy seadragons, previously recorded in groups at Rapid Bay during the Dragon Search program from 1997 to 2005, are now rarely sighted at Rapid Bay, and now only seen in small numbers.
- ***There may be multiple causes for the decline in seadragon numbers at Rapid Bay numbers over time***.

In 2019, AMLR NRM provided support for results from the long-term monitoring project to be written up.

During the project, a set of image markers for identifying seadragons was developed. These markers will be useful over space and time, for monitoring leafy seadragons.

Over the course of the project, the benthic habitat at Rapid Bay continued to decline, and sea surface temperatures also increased, compared with previous years. The area remained very popular as a dive training site.

Potential issues at the Rapid Bay site are discussed in this report, based on project results and ongoing observations by divers. A number of technical, administrative and management issues affected the pilot project. Recommendations are provided for volunteer-based monitoring of seadragons over time, so that future projects may achieve more consistent results.

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1. Introduction and Background

Rapid Bay jetty (RBJ) on the Fleurieu Peninsula in South Australia has long been recognised as one of the iconic shore-based dive locations where SCUBA divers can view seadragons, and is promoted as one of the best shore dive sites in the world (e.g. *Sportdiver Magazine* 2012), and in Australia (Christopher 1988; DIASA, undated; *SCUBA Diver Australasia*, cited by Davidson & Brook 2006; Culture Trip 2020).

Of particular interest to divers is the resident population of leafy seadragon *Phycodurus eques*. Seadragons and their relatives the seahorses, pipehorses and pipefishes, are legally protected from harm and from collection in South Australia, under the *Fisheries Management Act 2007*. The presence of seadragons at RBJ attracts local, interstate and international visitors to the site, and is therefore of economic as well as social importance (Davidson and Brook, 2006). In 2012, Rapid Bay was classified under the SA *Marine Parks Act* as a Special Purpose Area (SPA), within a General Managed Use Zone (GMUZ). The SPA and the GMUZ are part of Encounter Marine Park (DEWNR 2012). Shore-based line fishing is permitted in Special Purpose Areas. Although Rapid Bay is an important habitat for seadragons, which are fully protected species, as a SPA it does not have the restrictions in usage that are afforded to Sanctuary Zones in the marine parks system. Rapid Bay is promoted in news articles (e.g. Williamson 2013), dive tourism materials and social media. Dive trips to Rapid Bay to view the seadragons have become increasingly popular during the past 2 decades, with dive tour businesses as well as social dive clubs. The jetty has also been commonly used for open water SCUBA diver training, over a number of decades.

During the 1990s, a community-based seadragon monitoring program known as Dragon Search ran in southern Australia, and during the program, numerous divers and beachcombers logged seadragon sightings across South Australia. Dragon Search was developed by the former Marine and Coastal Community Network (MCCN), Threatened Species Network (TSN), the Australian Marine Conservation Society (AMCS) and around 20 other organisations. During the program, 173 sightings from Rapid Bay were submitted between 1991 and 2005. The majority of the sightings dated from the late 1990s to the early 2000s, when the Dragon Search program was most active. Both leafy seadragons ("leafies") and weedy seadragons ("weedies") were recorded at Rapid Bay during the Dragon Search program (see Baker 2009). Most seadragons were recorded whilst observers were SCUBA diving, under what is now known as the "old jetty", which was closed to fishing in 2004. A new jetty was constructed in 2009, north of the old jetty (Friends of Rapid Bay 2014).

In the Dragon Search database, between 1998 and 2005 there were 15 records of seadragon "groups" (e.g. between 5 and 14 leafies) sighted per dive. Most of these sightings occurred during late spring, summer and autumn, the most popular seasons for diving. Also, during the 1990s, SCUBA diver C. Harmer regularly recorded seadragons at Rapid Bay, and identified 30 breeding pairs, and 15 unpaired individuals. Some individual pairs were observed over 7 years.

In 2011, community concern was expressed about a possible decline in numbers of seadragons at the old jetty. Various hypotheses were suggested by community members, including migration to the new jetty to the east of the existing site; or disappearance from the old jetty due to other reasons, including disturbance by various dive practices. There was also some concern expressed within the diving community about seadragons occasionally being caught in crab pots at the new jetty.

In late 2012, the citizen science community group South Australian Conservation Research Divers (SACReD) was supported by the AMLR NRM Board, to devise a monitoring program, with the pilot phase to begin in 2013-14. The project opportunity was based on macro-photographic skills of divers associated with SACReD, the record of community grant projects undertaken and completed by SACReD since 2007, and the background in seadragon data analysis by J. Baker, who had worked intermittently on the national Dragon Search program between 1995 and 2005.
Support was provided for project coordination, field expenses (petrol, air fills etc), payments to divers for each seadragon photographed per dive, data analysis and reporting, and sharing of results with media and public.

From August 2013 and September 2014, the project was undertaken by members of the SCUBA diving community in South Australia, to record the occurrence, location, facial features and breeding times of seadragons under and around Rapid Bay jetty.

The project was managed by J. L. Baker, from South Australian Conservation Research Divers (SACReD), a marine citizen science group that aims to learn more about the distribution and habitats of rarely recorded, endemic, and other marine species of conservation interest in South Australia. Associates of SACReD who have assisted this monitoring project include non-affiliated divers, and also several members of Adelaide University Scuba Diving Club, M.E. Dive Club, Flinders University Underwater Club, and other dive clubs in South Australia. Some staff from dive businesses in South Australia have also assisted.

Following the pilot project, additional records were collected sporadically from volunteers, between September 2014 and January 2020. Some further support was provided by NRM to consolidate these later records and summarise the longer term data. This report discusses the results of the pilot project, from August 2013 to September 2014, and also the results from additional data collected opportunistically by divers, up to January 2020.

2. Methods

A meeting and presentation for project participants was held on 20th August 2013, to discuss:

- Background to the project, including current concerns, previous informal monitoring work - Dragon Search, and records from individual divers and dive tour operators
- The suitability of using facial markings and other markers as a record of individual seadragons, adapted from the initial work of Connolly et al. (2002a and 2002b)
- Draft monitoring plan for pilot phase
- Project personnel
- Proposed dive schedule
- Methods of recording and reporting
- *Code of Conduct* for diving with seadragons (Dragon Search et al. 2002, NR-AMLR 2020).
- Promotion of the project within the dive community

Examples of the topics of discussion are shown in **Figure 1**, as extracts from the slideshow. Some of the questions which the initial meeting aimed to address include:

- What length should the monitoring swim be on each dive, considering that the jetty is 488m long, and the T section at the end is 200m wide?
- Which depth should divers start the monitoring swim? It was noted that records of leafy seadragons submitted to the Dragon Search program were mainly between 5m and 12m deep, except 4 records from the mid 1990s, of juveniles sighted at 1m and 4m deep (data in Baker 2005, 2009).
- What is the best way of marking the locations where seadragons are sighted? Options included hand held GPS, or counting and recording closest pylon from dive platform, perhaps including exact depth on dive gauge.
- How often should the new jetty be surveyed? Should surveys include sections between the new and old jetties?
- Should the outside of the T-section be included, considering that there are currents running in the area, and this poses an additional risk for divers?
- How many divers should search per survey?
- Should weedy seadragons be recorded too? It was noted that the project brief related only to leafy seadragons, but weedy seadragons are also occasionally sighted in the area. Weedies may also have been more common in the nearshore waters during the 1990s compared with recent years (see Baker 2005, and section on **Weedy Seadragons** below in results).

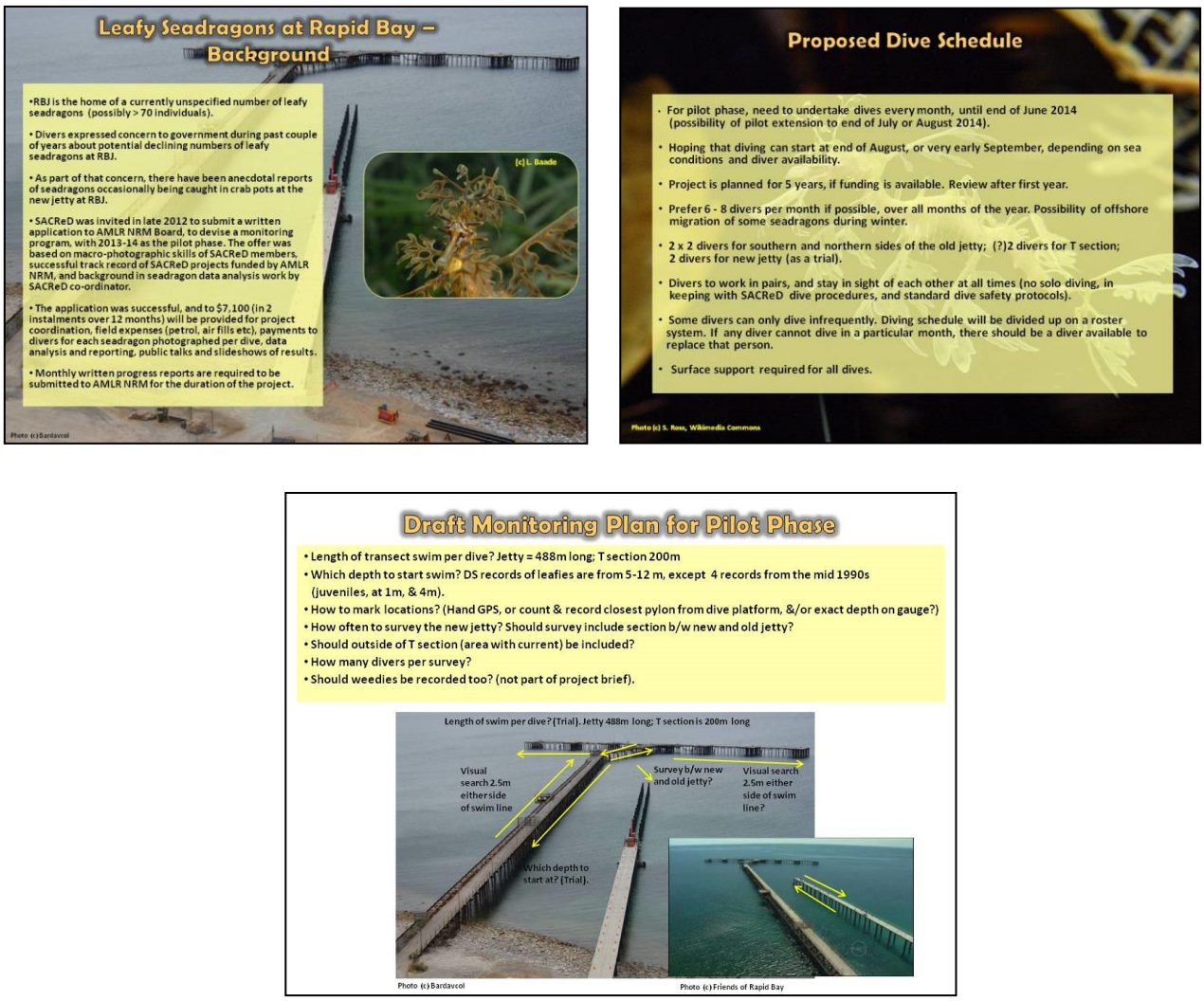


Figure 1: Examples of content in the presentation for divers in August 2013, which introduced the project and aimed to determine a suitable monitoring method and schedule.

After discussions with project personnel at the initial meeting, it was decided that:

- Macro-photos of the snout and facial markings of seadragons may be a useful method for recording individual seadragons in this project, as would be any distinctive features such as missing tail or missing appendages. Previous work had indicated that snout markings may be used for at least a year, particularly for adult animals (Connolly et al. 2002a). After one year, the length of time before changes in pattern occur had not been determined. Over a scale of months (at least), other features such as damage to appendages may be used in addition to the main recording method.
- Photos of both sides of face and body must be taken if possible, and labelled. Photo labels must be standardised between divers for this project (e.g. "131018 - 14PS - 1L6" = on the dive of 18th October 2013, location = 14th pylon from starting point, southern / western side; first seadragon, left side of face, 6th photo).
- For the pilot project, photos of each seadragon would not be very useful unless they were labelled to aid identification.
- For the pilot phase, dives would be scheduled for every month of the project period, until end of August 2014 (including project time extension due to poor weather conditions for diving from June - August 2013).
- For each survey, it would be preferable for pairs of divers to monitor specific sections of the site every month where possible. This would entail 2 divers on the southern / western side and 2 on the northern / eastern side of the old jetty, 2 divers for the T-section, and 2 divers for the new jetty.

- Divers would work in pairs, and stay in sight of each other at all times. No solo diving would be permitted, in keeping with SACReD's agreed dive procedures, and standard dive safety protocols.
- Each diver who is involved with the project should fill in the Government of South Australia's *Volunteer Activity Registration Form*, *On-site Hazard Identification Form*, and *Volunteer Attendance Record*, and would be provided with those forms.
- Diving schedule would be divided up on a roster system if possible, because some participants in the project could not dive in some months of the year, and other divers needed to be available to replace those persons periodically.
- Surface support would be recommended for all dives.

The project aimed to begin in July 2013, but conditions for diving were poor during July and August 2013, with low visibility due to rough sea conditions, and frequent rain. There were also issues with availability of divers during that period, due to a number of winter illnesses, and absences from South Australia.

In September 2013, divers P. Macdonald and J. Beacon identified individual jetty piles using numbered cattle tags (**Figure 2**), and attached the tags to the piles with cable ties. Some preliminary tagging work was also carried out the previous month by L. Baade. Divers marked 13 pairs of piles at 5-pile intervals which covers the area from the "break" in the jetty out to the T (see **Figure 3**).

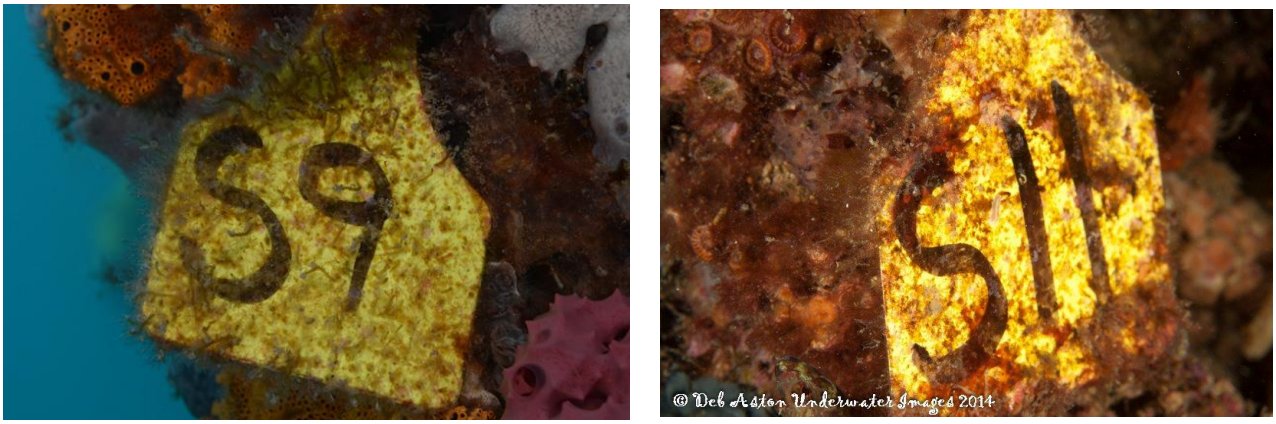


Figure 2: Examples of the cattle tags used to mark individual jetty piles at Rapid Bay jetty. "S" = southern side.

A map of the marked jetty piles was produced by K. Newton (**Figure 3**) and provided to participants in the monitoring project, so that locations where seadragons were sighted under and around the old Rapid Bay jetty could be logged in relation to the numbered piles. At the time monitoring commenced, a section after the first third of the old jetty had collapsed, and the planking had fallen into the sea (**Figure 4A**). The old jetty has further deteriorated since that time, and larger sections of the deck have collapsed (e.g. **Figure 4B**, taken in 2018).

Following the tagging, dives were planned for every month, commencing in October 2013. Due to the voluntary and opportunistic nature of the monitoring schedule, it was not possible to set a specific number of days and times per month when divers should search for seadragons. *The project aimed for at least 6 dive searches to be completed per month*, and this minimum number of dives was achieved (and usually exceeded) during 6 of the 12 months (**Table 1**). Divers were asked to record their search time, and the search path they travelled whilst looking for seadragons under and around the old and/or the new jetty.

Upon submission, photos were labelled with each photographer's name, date of image capture, code for left or right side of face (in cases where both sides were photographed) and an identifying label for each individual seadragon seen by a diver on each dive. Some of the images were colour-inverted using software, to enhance visible marks. White spots and stripes thus appear as black, in colour-inverted images.

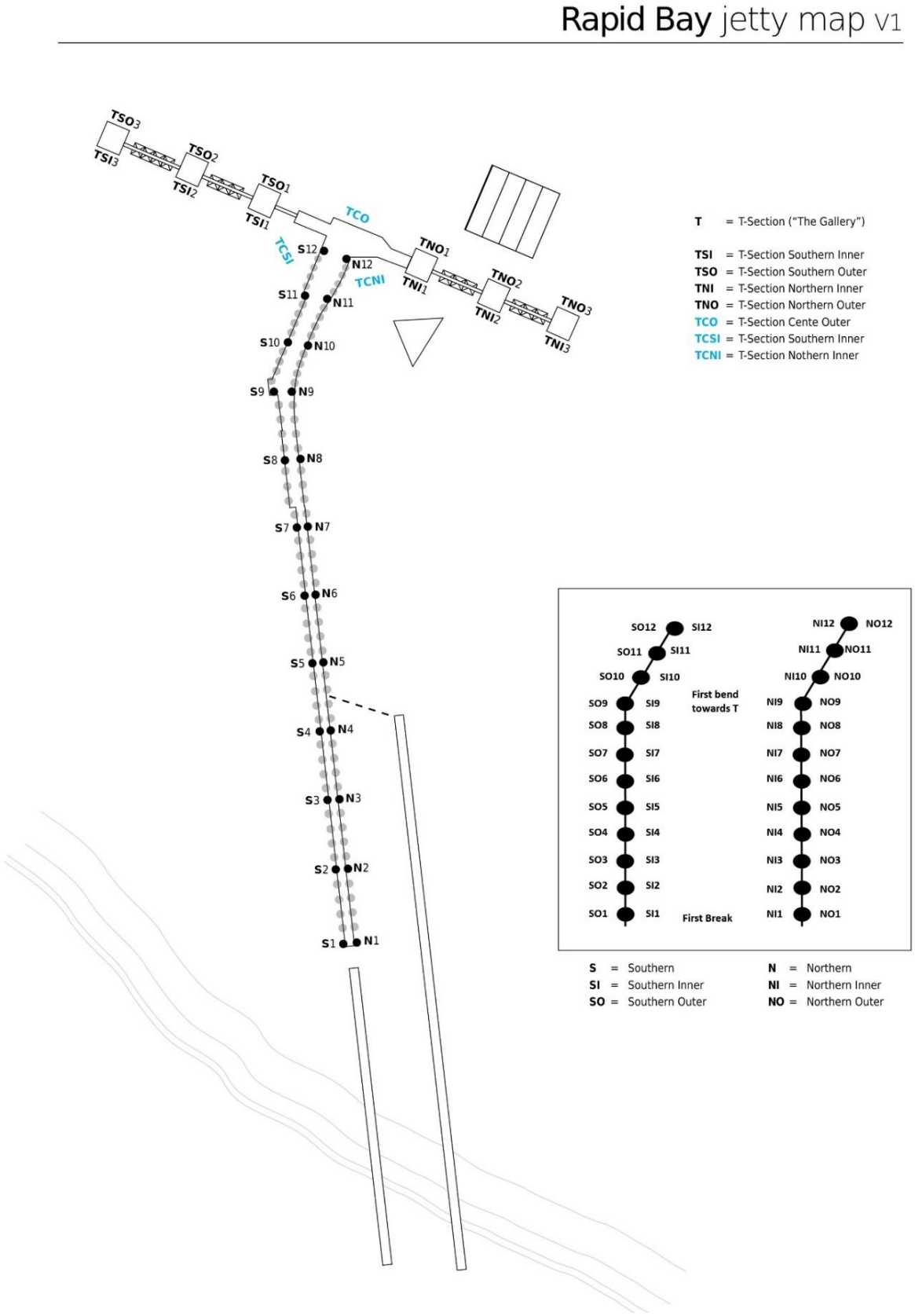


Figure 3: Map of marked jetty piles to assist divers in recording seadragon locations. Map by K. Newton and J. Baker.

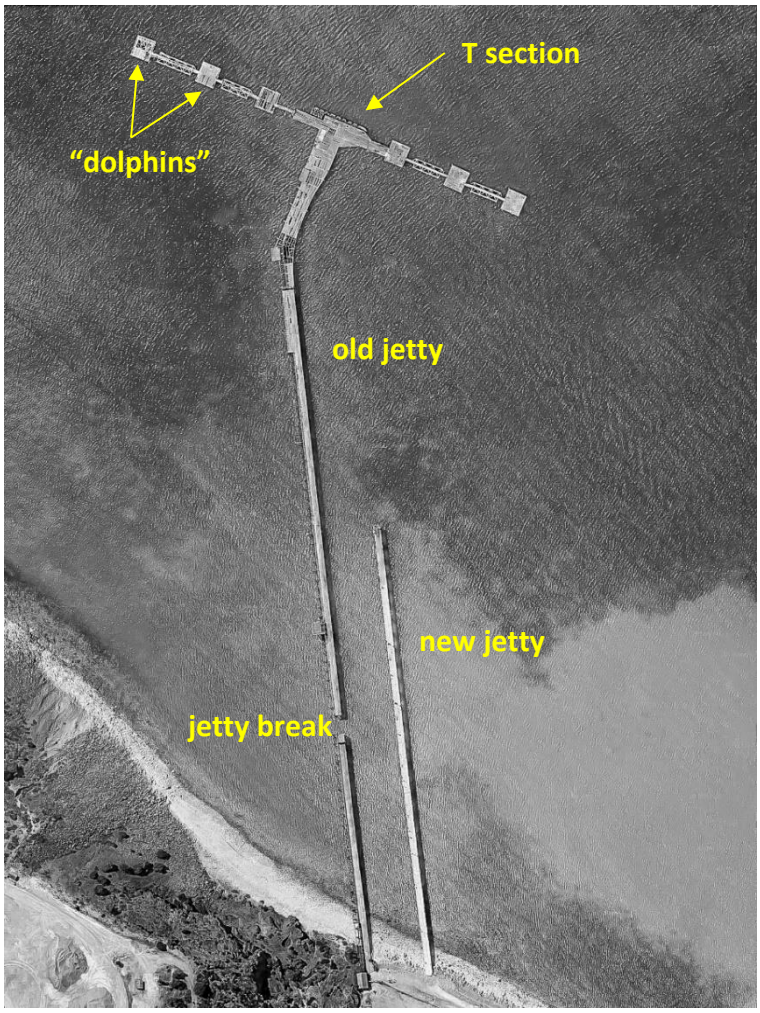


Figure 4A: Rapid Bay jetties in 2013, showing the main break in the old jetty where planking has fallen into the sea.

Figure 4B: Old Rapid Bay jetty in December 2018, showing collapse of decking, and severe corrosion of metal piles. Image: © J. Baker.

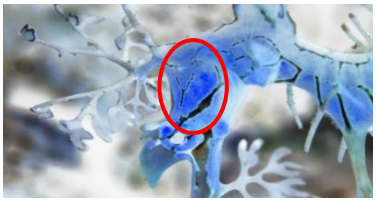
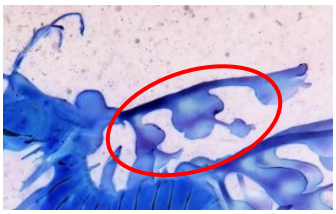
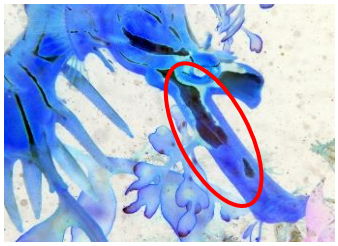
Seadragon Features Used for Identification of Individuals	
Head markings behind and/or above the eye 	**Cheek markings** 
Eye Spine and/or Nose Spine 	**Head spines (if present)**  
Crown shape and relative size 	**Shape and patterning of the basal and second "leaves" of the head appendage** 
Snout markings 	**Shape & patterning of "leaves" on 1st ventral appendage**  
Missing Appendages 	**Truncated / Damaged Appendages** 

Figure 5: Table of head and body markers used to identify leafy seadragons during the Rapid Bay seadragon monitoring project. Table © J. Baker.

The seadragon images were visually assessed by the first of two examiners (J. Baker), and identified using a number of distinct patterns and marks on the face and body, as shown in **Figure 5**. The suite of identification marks used for this project are an adaptation and expansion of pioneering work undertaken by Rod Connolly *et al.* (2002a, b), in which snout markings were used to identify individual leafy seadragons over a 14-month period at West Island in South Australia. For the current project, a larger number of markers were used, including:

- head markings behind and/or above the eye
- cheek markings
- relative size and shape of eye spine
- nose spine and/or head spine (if present)
- crown shape and relative size
- shape and patterning of the basal and second "leaves" of the head appendage
- snout markings
- shape & patterning of "leaves" on 1st ventral appendage
- missing appendages, and
- truncated or otherwise damaged appendages

In each image, an average of 4 to 6 markers were used for each identification. On some photos, not all of the markers were visible, or distinctive enough if visible. After examination, the images were sorted into named folders, one for each seadragon identified. Images were then provided to a second examiner (J. Macdonald), and any discrepancies were discussed and agreed upon. Images for which agreement could not be reached were removed from the folder assigned to that animal, re-examined for potential placement in another folder, and in some cases moved to a "miscellaneous" folder, containing images that were unsuitable for identification. The second examiner also sorted and identified images of seadragons from 2016 to 2019 that had been taken by several divers and collated by J. Baker as an extension of this project. This project used the traditional method of visual examination of images by researchers, without the aid of image analysis software.

3. Results

3.1. Summary of Records

Table 1 below summarises the sightings of seadragons during this pilot project. Many factors influenced the number of dives over the project period, and these are discussed in separate sections below.

Diver's search time and paths were variable. For the success of this project, it was considered important that directions for monitoring not be too prescriptive, which would interrupt the voluntary and recreational nature of the dives. All search paths are not detailed here, but examples of typical route descriptions provided by divers are as follows:

"(Began dive) *at 9.58am and were under for 58 minutes. We went across to the old jetty via the diagonal set of star droppers. We headed out to the end of the old jetty transiting 2 to 5 to the south of the old jetty piles. On reaching the T we went to the structure out from TNI1 before crossing over to TNO1 and the grid section out from there*."

"*Completed two x 1-hour dives to T area. Covered southern end and both the grids & A frames on northern side."*

"*Searched western end of the T, to eastern end of T.*"

"*One run down the main jetty from the T back to the dropper line at N6*."

Appendix 1 provides a summary of dives taken during the pilot period of the project, and the number of seadragons observed per dive. *Specific location codes have been removed, in this public version of the report.*

One of the divers who contributed to the initial phase of data collection, also provided photographic records of seadragons sighted on dives at Rapid Bay in 2012. Another diver provided images from earlier in 2013, prior to project commencement. From the combined data set of 2012 – 2014, 12 seadragons (including two juveniles) were identified, using the markers illustrated in the **Methods** section. Two examples of identified animals from the pilot phase set are shown below, in **Figures 6** and **7**.

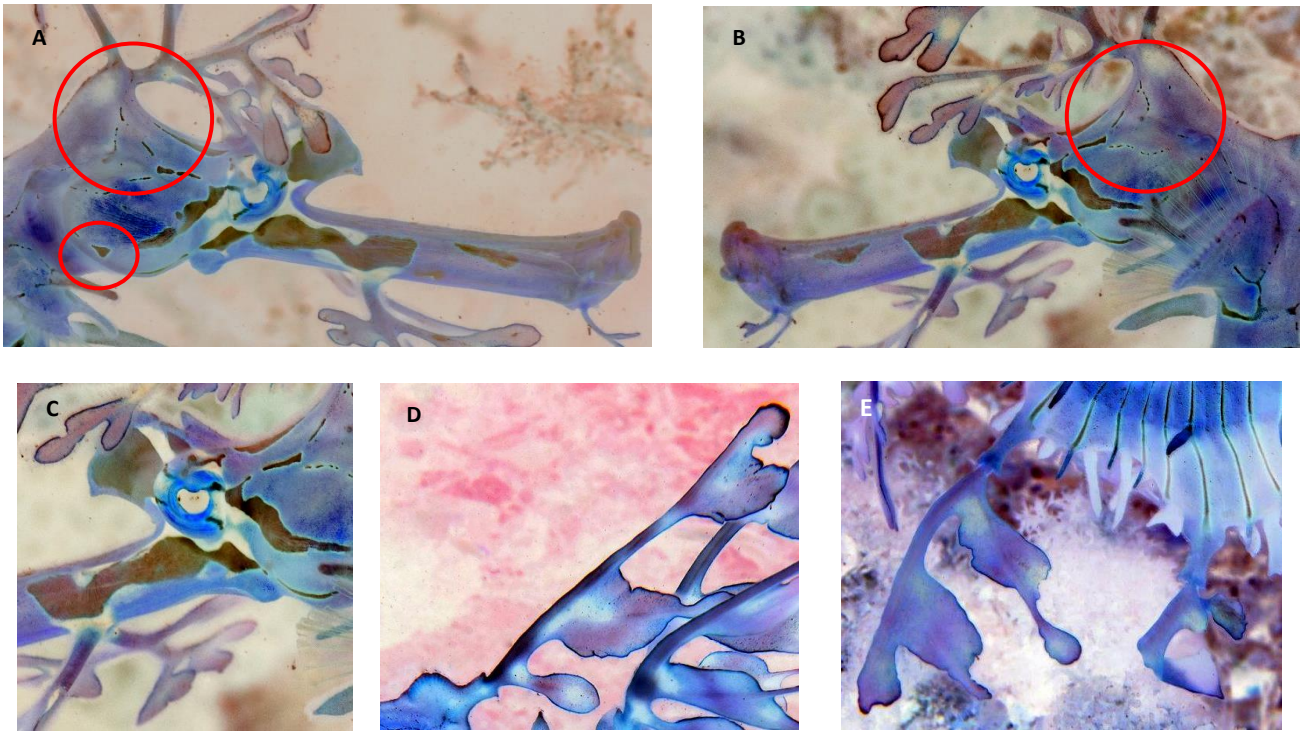


Figure 6: Facial markings of Seadragon 1 ("Line-Dots"), a male with 2 characteristic lines of dots on the head, particularly on the left side. On the right, there is a distinctive triangular patch below the cheek. Also distinctive are the shape of the left cheek and snout marks (6C), the head appendage (6D) and the front ventral appendages (6E). Images are colour-inverted.

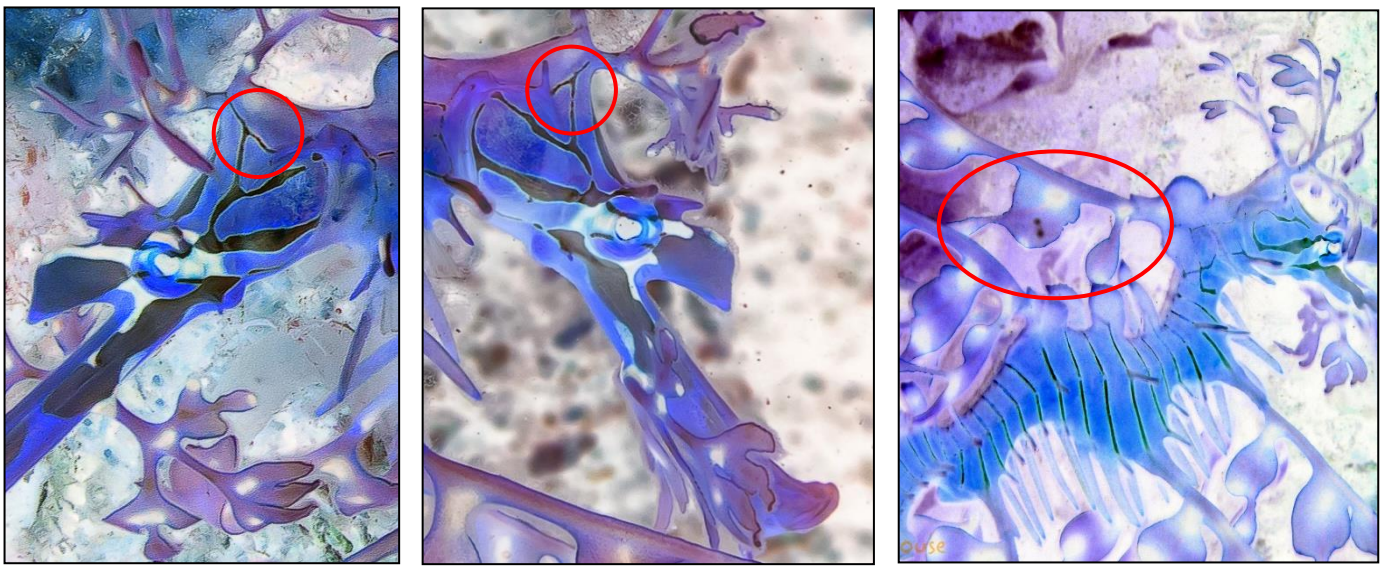


Figure 7: Animal 3 ("T-Face"), older juvenile or young adult, showing branched markings with "T-bar" on head, and distinct shapes of the first two "leaves" of the nape appendage. Images are colour-inverted.

The identified seadragons chosen for monitoring are summarised in **Table 1** below. For two strongly site-associated seadragons (Line-Dots and Wishbone), the number of repeated sightings during the first 12 months of the project is notable. These animals were regularly observed by divers, often at the same locations or within 50m of where they were initially sighted. Several of the seadragons sighted during the pilot project were re-sighted over time at Rapid Bay jetty, and could thus be considered long-term residents (see **Table 1**). One seadragon (Angry Y) which had a hooked nose spine, prominent head spine and other distinctive features, was recorded for between 6 and 7 months. Over that time, Angry Y lost the head appendage, and would have been easy to recognise if it had remained in the vicinity of the jetty. Another animal (Cut-Off), which had damaged and shortened dorsal appendages, was re-sighted in the area of the jetty for only 11 months. However, other identified seadragons were recorded over much longer periods, ranging from almost 2 years, through to 7+ years. The seadragons recorded over the longest periods were males (**Table 1**), which bred seasonally over the total time period in which they were observed by divers. Changes to appearance of facial and body markers over time are discussed in a separate section below.

Table 1. Seadragons identified during the pilot phase of the Rapid Bay Leafy Seadragon Monitoring Project, and also in subsequent years. Dates in bold font were for observations prior to the start of the pilot project. ***NOTE: Location data have been removed from this public version of the report, but have been made available to the AMLR NRM.***

Seadragon Name and Gender	Sightings During Project Period	Time Period recorded between First and Last Sighting, and Notes
Line-Dots (male)	**17/01/12, 08/01/13 and 16/06/13** (prior to project start), 11/10/13, 14/10/13, 19/10/13, 24/10/13, 27/10/13, 27/10/13, 29/10/13, 31/10/13, 11/11/13, 13/11/13 (2 sightings), 25/11/13, 30/11/13, 09/12/13, 17/01/14, 21/01/14, 23/01/14, 01/02/14, 02/02/14, 09/02/14, 15/02/14, 16/02/14, 26/02/14, 27/02/14, 02/03/14, 28/03/14, 19/05/14, 22/07/14, 08/08/14, 16/08/14, 30/08/14, 06/09/14, 30/08/14	**Confirmed records are available for 32 months, at 2 locations.** Animal observed regularly over 11 months during monitoring. Almost all records during monitoring period were from a single location at RBJ old jetty. Diver PM reported seeing same animal at same location since 2009. Image from January 2012 (confirmed by JB and JM as Line-dots) was available.
Wishbone (male)	14/10/13, 14/01/14, 01/02/14, 02/02/14, 09/02/14, 12/02/14, 15/02/14, 16/02/14, 26/02/14, 27/02/14, XX/02/14, 01/03/14, 02/03/14, 03/03/14, 07/03/14, 28/03/14, 28/04/13, 20/05/14, 02/06/14, 08/08/14, 22/08/14, 30/08/14, 06/09/14, XX/01/16 (video), 06/01/16, 07/01/16, XX/03/16, XX/10/16, 04/11/16, 05/11/16, 19/11/16, 27/11/16, 26/12/16, 16/02/17, 20/02/17, 21/02/17, XX/03/17, 26/03/17, XX/7/17, 19/08/17, 17/09/17, 17/10/17, 21/10/17, 23/10/17, 25/10/17, 28/10/17, 29/11/17, 30/11/17, 06/01/18, 07/01/18, XX/10/18	**61 months (5+ years) +** All appendages intact from October 2013 to January 2014. First injury (missing appendage) observed in March 2014 No confirmed records from 2015 First brood observed in November 2016

Table 1 (continued). Seadragons identified during the pilot phase of the Rapid Bay Leafy Seadragon Monitoring Project, and also in subsequent years. Dates in bold font were for observations prior to the start of the pilot project. ***NOTE: Location data have been removed from this public version of the report, but have been made available to the AMLR NRM.***

Seadragon Name and Gender	Sightings During Project Period	Time Period recorded between First and Last Sighting, and Notes
Club Flip / Flip Over / Club-Leaf (male)	**XX/02/12, 29/10/12, 6/12/12, 28/12/12, XX/04/13,** 06/12/13, 23/01/14, 27/02/14, 01/03/14, 07/04/14, 16/01/17, 13/02/17, 26/03/17, 11/02/17, 16/04/17, 22/10/17, 27/10/17	**69 months (6 years)** Was sub-adult in Feb 2012. First brood Oct 2012. Brood also recorded in Oct 2017. Distinctive dent in face, and several other characteristic features. Sometimes seen with a bent top leaf in head appendage.
T-Face (female)	**XX/02/11 and XX/12/11 (unconfirmed as T-Face)**, XX/04/13, 22/11/13, XX/06/14, 23/07/14, 03/03/14, 28/03/14, 22/09/14, 06/09/14, 28/09/15, 29/11/15, 23/02/16 *(Feb 2016 record unconfirmed)*	**32+ months (> 2 years, possibly > 5 years)** Presumed female partner of **Y Dash-Line.** Observed swimming close to male called Y Dash-Line, on several occasions during courting season in 2014
Hook Cheek	**XX/12/12,** 27/02/14, XX/03/14, 03/03/14, 06/09/14, 06/10/15 (*2015 record unconfirmed*)	**22 months definite (almost 2 years)** **35 months unconfirmed (almost 3 years)** Hook Cheek was an older juvenile in December 2012
Y Dash-line (male)	**04/02/12,** 28/12/13, 08/02/14, 10/02/14, 27/02/14, 02/03/14, 19/05/14, XX/09/15, 12/10/15, 17/10/15, 18/10/15, 20/10/15, 24/10/15, XX/11/15, XX/12/15, 26/12/15, 24/01/16, 25/01/16, 26/01/16, 12/02/16, 14/02/16, 22/02/16, 23/02/16, 12/03/16, 10/04/16, 25/04/16, 30/12/16	**59 months (almost 5 years)** Male partner of **T-Face** Lost 2 ventral appendages in 2015 Brooding in Dec 2015
Thorny (called Black Dot from 2012 – 2014) (male)	**XX/02/12, XX/02/13,** 24/11/13, 27/01/14, 28/03/14, 07/04/14, 08/08/14, 16/08/14, 06/09/14, 22/09/14, XX/02/15, 23/12/16, 26/12/16, 31/12/16, XX/01/17, 02/01/17, 8/01/17, 16/02/17, 14/10/17, 15/10/17, 17/10/17, 17/11/17, 18/11/17, 6/12/17, XX/10/18, XX/12/18, 02/01/19, 08/01/19, 18/01/19, 16/02/19	**85 months (7 years)** Bent head appendage in Feb 2012 straightened over time
Angry Y	22/02/14, 22/07/14, 17/08/14, 06/09/14	**6 months** Lost head appendage between March and August of 2014
Cut-off	15/02/14, 28/02/14, 02/03/14, 03/04/14, 08/08/14, 10/12/14	**11 months** Several dorsal appendages damaged and shortened, with missing "leaves"
Big Crown Club	*Not monitored*	
Big Black Spot	*Not monitored*	
Baldy	*Not monitored*	

3.2 Evidence of Strong Site Association

During the pilot project period, several animals were observed at the same location on multiple occasions, that were days, weeks, months and years apart. Examples are provided below.

***Line-Dots*:** A male seadragon named Line-Dots was recorded on 26 occasions at several locations within one area off the T-section of the jetty (**Figure 8**), over 11 months (**Table 1**). One of the divers (PM) involved with this project reports to have observed Line-Dots at the T-section since 2009, but no photographic evidence is available. The first reliable image of Line-Dots that is available for this project was dated January 2012.

Line-Dots was recorded at the T-section during spring 2013, summer 2013-14, autumn 2014, winter 2014 and spring 2014. Absolute movement distances were not monitored during this project due to the non-invasive procedures used, which relied on photo observations and did not include attaching transmitters to the animals. However, based on the size of the area at the end of the old jetty where Line-Dots was "stationed", and the location of sightings over time in the northern / eastern part of the T-section, it is estimated that Line-Dots did not move further than 70 - 80m during the 11 months of the pilot project monitoring period.

After the pilot project period elapsed, regular monitoring of Line-Dots did not occur in 2015 and 2016. However, it is noted that Line-Dots was recorded at the T-section in September 2017. Therefore, including the January 2012 image, Line-Dots was recorded at the end of Rapid Bay jetty for longer than 5 years (**Tables 1** and **2**).

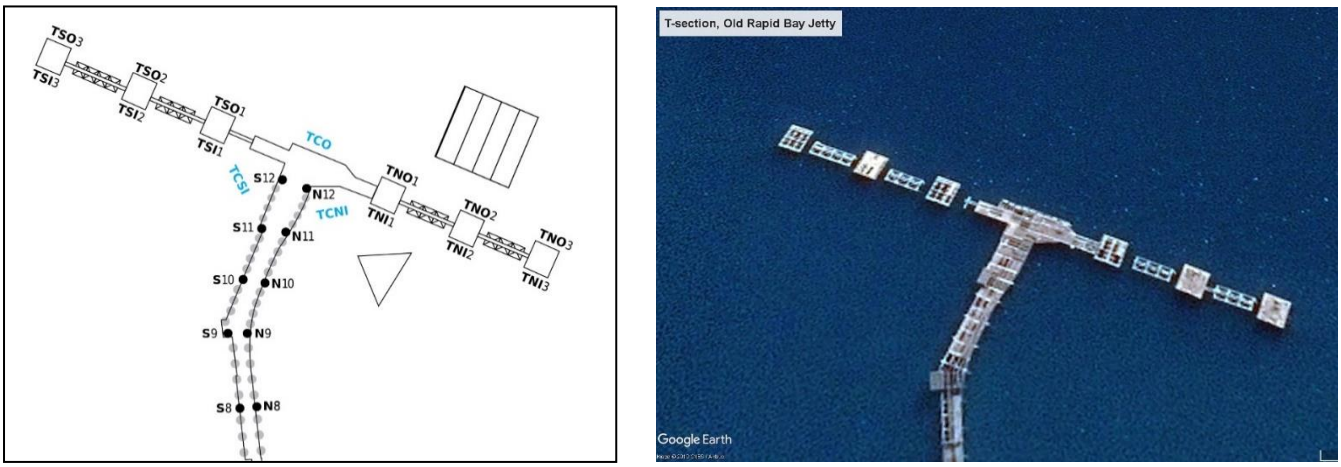


Figure 8. A: Unmarked locations in which brooding male "Line Dots" was recorded over the pilot project period. Diagram by K. Newton, A&K Diving. B: Satellite view of the T-section of the old Rapid Bay jetty.

Table 2: Sightings of Line-Dots at Rapid Bay jetty, before, during and after the pilot monitoring period of Spring 2013 to Spring 2014. Sp = spring; Su = summer; Au = autumn; W = winter. Numbers represent years (e.g. Su 14/15 refers to the period over the Austral summer, from December 2014 to February 2015).

Su	Au	W	Sp	Su	Au	Wi	Sp	Su	Au	W	Sp	Su	No data: Au 2015 to W 2017	Sp	Su
11/12	12	12	12	12/13	13	13	13	13/14	14	14	14	14/15		17	17/18

***Wishbone*:** Wishbone (**Figure 9**) is a distinctive male who has been photographed on 51 occasions, over more than 5 years. He was first observed during the pilot phase of this project in October 2013 (**Table 1**, **Table 3**), and subsequently recorded until October 2018. A number of records, particularly during the first year, came from one specific location, and other sites in the vicinity. The exact locations have not been detailed in this public version of the report, to help protect the "home bases" of seadragons. Wishbone was also recorded less than 100m east of his main area of residency. Wishbone sustained significant damage to his appendages, observed over the years of monitoring. This seadragon was recognisable by its crown shape and relative size, nose spine, facial markings, and head appendage. All ventral appendages were intact between the time of the first sighting (October 2013) and January 2014. The first missing appendage was noticed in images from divers dated March 2014. There are no confirmed records from 2015, but in 2016, two ventral appendages were missing. By 2018, Wishbone had lost 3 ventral appendages. This animal's first brood was recorded by divers in November 2016. Wishbone continued to brood annually until the most recent sighting (October 2018). At that time, Wishbone was observed by diver and marine photographer Anita Futterer, and he was swimming together with Thorny, another male "in berry". There have been no confirmed records of this animal from 2019 and 2020, despite regular searches for seadragons by divers over spring, summer and autumn.

Table 3: Sightings of Wishbone at Rapid Bay jetty, before, during and after the pilot monitoring period of Spring 2013 to Spring 2014. There are photographic records of this seadragon from October 2013 through to October 2018. Sp = spring; Su = summer; Au = autumn; W = winter. Numbers represent years (e.g. Su 13/14 refers to the period over the Austral summer, from December 2013 to February 2014).

Sp 13	Su 13/14	Au 14	W 14	Su 15/ 16	Sp 16	Su 16/ 17	Au 17	W 17	Sp 17	Su 17/ 18	Au 18	W 18	Sp 18

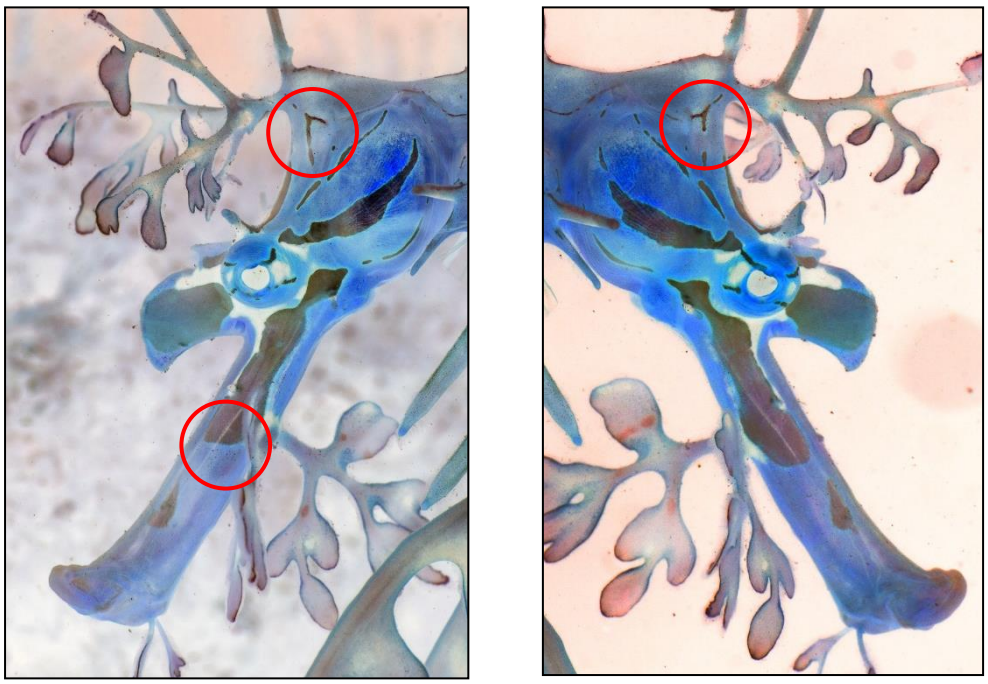


Figure 9: Animal 2 ("Wishbone"), showing Y-shaped markings on left and right sides of head, and distinctive blunt-edge to main marking on snout. Wishbone also has a notch in the basal "leaf" of the nape appendage. Images are colour-inverted.

3.3. Brooding Male Leafies

During this project, a male with eggs (Line-Dots) was observed by divers from the second week in October 2013 onwards (**Figure 10A**). The seadragon continued to occupy the same location until the birth of young, in the third week of November 2013 (**Figure 10B**), and in subsequent months. Eight weeks is the average brooding time for male seadragons (Kuiter 2009). Timing of breeding appears to have been consistent since the 2013 monitoring period started. Divers have observed males with eggs at Rapid Bay in October of 2012, 2015 and 2017, which hatched at a similar time (i.e. mid to late November) to those from 2013. Several brooding males are sometimes seen by divers during a single dive at the jetty. In October 2017, divers from the BSAC club observed 5 seadragons in a single dive, and 3 of those were carrying eggs.

Previously, during the Dragon Search program, there were 30 records in the database of brooding male leafy seadragons observed at Rapid Bay jetty, and most of these were from 1999 to 2001, when the program was very active and regularly promoted within the diving community. The majority of the Dragon Search records of brooding male leafies were reported between October and January, and divers in the current monitoring project have observed breeding in those same months.

Figure 10A, 10B: Line-Dots with a healthy brood in October 2013 (A), and his empty egg cups in late November 2013 (B). NB Identity of the seadragon in the second image as Line-Dots was verified using facial and body markings in other photos of the same animal, from the same dive. Photos copyright R. Paton (A) and L. Baade (B).

Some of the male seadragons at Rapid Bay carry more than one brood successively over the breeding season. Evidence comes from observations for a single recognised seadragon, of live eggs in early October; empty egg cups in late November, and another set of live eggs in December. Photos of a seadragon called Thorny (**Figure 11**) illustrate the double brooding in the summer of 2017 – 18. Photos and videos of eggs and egg cups from other dates indicate that Thorny bred every summer from 2016 to 2019 inclusive. Photos of Thorny are not available for other years.

Figure 11: Evidence of double brood by seadragon named Thorny in the summer 2017-18 breeding season. Egg brood in October 2017 (A); empty egg cups after birth in November 2017 (B) and second egg brood in December 2017 (C). Photos copyright BSAC (A), D. Kinasz (B) and B. Battersby (C).

3.4 Juvenile Leafy Seadragons

Single juvenile leafy seadragons, and occasional pairs, were recorded in each season during the pilot project period, and also in subsequent years. One juvenile remained stationed at a particular jetty pile for some weeks. The juvenile observed in late November 2013, was not a neonate, and may have come from an early season hatching in late October or early November. There are also records from previous decades (in the Dragon Search database for South Australia), of juveniles in the vicinity of the Rapid Bay jetty as early as October. Based on facial patterns and body markers (see **Methods**), it is probable that the young animal from the November 2013 hatching was the same one seen at a larger size in September 2014. At that time in 2014, it was observed in the vicinity of two adults (photo by L. Baade, September 2014). Two juveniles from the 2014 summer breeding period were observed by divers near the new jetty in the autumn and winter of 2015 (images by D. Muirhead).

Due to change in facial markings and the "leaves" of appendages on juveniles over time, it was not possible to compare images of juveniles from a specific period with adults from a later period.

A small number of juvenile leafy seadragons were observed at Rapid Bay jetty over the project period (**Table 5**, and examples in **Figure 12**). This is compared qualitatively with numbers recorded during the Dragon Search program that was running from the mid-1990s to mid- 2000s. At that time, singles, pairs or small groups (3, 4) of juveniles were sometimes recorded, either alone or in the vicinity of adults (data in Baker 2005). Small groups of juvenile leafy seadragons have rarely been observed over the past decade, and most records are of single animals.

Table 5: Examples of juvenile seadragons sighted at Rapid Bay during the 2013-14 monitoring period.

Date	No. of Divers Searching	Diver Code	No. Seadragons Observed	Approx. Size	Notes
23/11/13	2	CR	1		
24/11/13 and 25/11/13	>2	Anon.	1		
24/11/13	2	LB	1		
24/11/13	2	LM	1		
XX/11/13	>2	Anon.	1		Young seadragon in rubble. Sighted several times over one week in November.
1/02/14	2	LB	1		
1/03/14	2	Das	1	~ 14cm	
2/03/14	2	Das	1	~ 14cm	same animal as 1/3/14
2/03/14	2	KH	2	~ 11cm & 16cm	
19/05/14	> 2	Anon.	2		
28/05/14	-	JR	1		
04/06/14	2	MS	1	>15cm	Older juvenile; night dive
22/07/14	2	LN	1	~ 15cm	
08/08/14	2	CC	2	~ 18cm	2 individuals solitary; 1 over rubble
16/08/14	2	LM / CR	1		
22/08/14	2	CC	1		
06/09/14	2	LB / AM		>20cm	Possible animal from marked area over spring 2013 and summer-autumn 2014, photographed with 2 adults.
22/09/14	2	CC	1		
XX/11/14	2	PM	1		

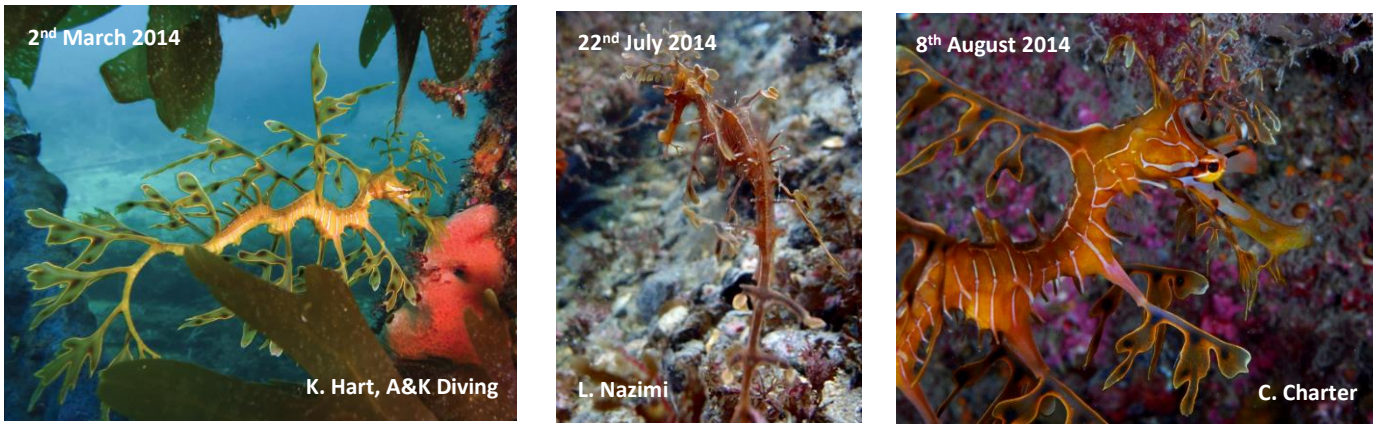


Figure 12: Examples of juvenile leafy seadragons recorded during the pilot phase of the project.

Small numbers of juveniles have continued to be observed under and near the jetty in years following the pilot project period. On 9th January 2020, a young juvenile (10cm) was observed and videoed near the end of the jetty (video by D. Lee). Given the size, that juvenile may also have been from a late November or December hatching.

3.6 Weedy Seadragons

Weedy seadragons (*Phyllopteryx taeniolatus*), known commonly by divers as "weedies", were not the focus of this project. However, they were recorded incidentally when found by divers searching for leafy seadragons. **Table 6** below summarises the weedy seadragon individuals recorded during the pilot project period, and opportunistically during subsequent years. Most notably, during the past 8 years or more, weedy seadragons have been an uncommon occurrence under and around Rapid Bay jetties. When weedies have been recorded in recent years, only one or two individuals have been observed (see examples in **Figure 13**).

More recently, in the summer of 2019, two young juvenile weedies were observed over a period of weeks, at an easily accessible location. Such was the interest in this uncommon occurrence, that news spread quickly amongst the diving community, and the young weedy seadragons were photographed regularly for the time they remained in the location. It is not known for this report whether all individual divers and tour group divers who observed and photographed the seadragons adhered to the Diving Code of Conduct.

Table 6: Examples of weedy seadragons sighted at RBJ, during & following the 2013-14 monitoring period.

Date	Diver Code	No. Seadragons Observed	Location Notes
During Pilot Project			
24/02/14	BB	1	
03/03/14	CC	1	Not the same individual as 24/02/14
XX/03/14	MS	1	Sub-adult
28/03/14	CC	1	
19/05/14	BBk	1	Hovering over mixed habitat of *Posidonia* tapeweed and rocks covered with brown algae such as *Scaberia* and *Sargassum*, and turf species.
XX/12/14		1	
Examples of More Recent Records			
XX/01/16		1	Seaward, in seagrass
13/01/19	LM	2	Juveniles
17/03/19	PL	1	

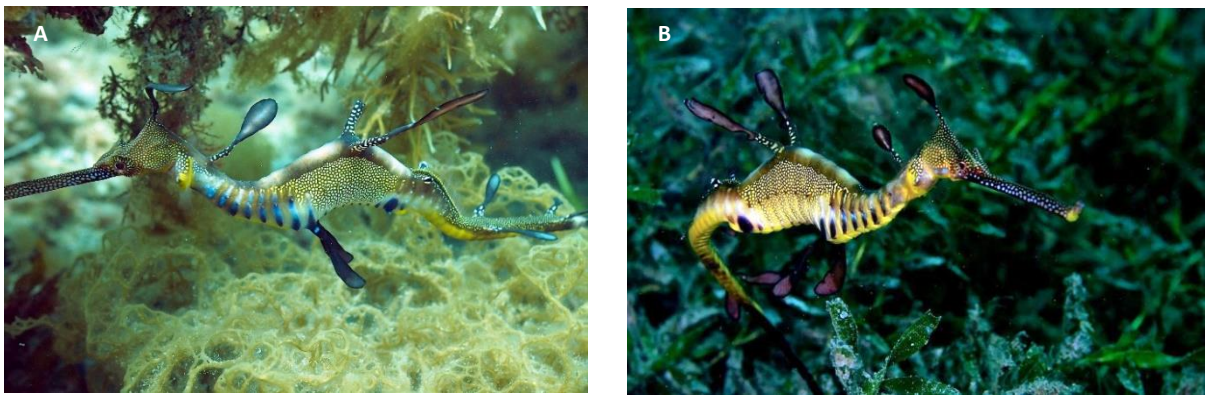


Figure 13: Examples of Weedy Seadragons observed at Rapid Bay during the pilot project period. Photos copyright B. Battersby (A); C. Charter (B).

The smaller numbers of weedy seadragons sighted under Rapid Bay jetty over the past decade contrast with records from previous years. For example, during the mid to late 1990s, when the Dragon Search program was active in South Australia, weedy seadragons were regularly sighted under Rapid Bay jetty, and in larger numbers than at present. In the Dragon Search database, between 1990 and 2005, there were 83 sightings of weedy seadragons reported from Rapid Bay, and 60 records of leafy and weedy seadragons sighted together (data in Baker 2005). Groups of weedies were sometimes observed. Examples included:

- Aggregation of 20 weedies (including 18 juveniles) recorded at 10m during a dive in March 1999;
- Aggregation of 16 weedies (including 12 juveniles) recorded at 10m during a dive in January 1999;
- Reports of 11 weedies and 7 weedies, recorded at the same depth (10m) at Rapid Bay, on 24th and 20th January 1997 respectively;
- 2 records of 5 adult weedies observed 2 days apart, both at 11m depth, at Rapid Bay jetty in July 2000;
- A group of 2 adult weedies plus 4 juveniles, and a group of 1 adult plus 3 juveniles, sighted a week apart at a similar depth at Rapid Bay, in October 2001;

Groups of weedy seadragons are no longer observed in the Rapid Bay jetty area, nor apparently in other Gulf St Vincent locations where they were periodically recorded during the Dragon Search program, from the 1990s to early 2000s. Divers have reported seeing fewer weedy seadragons in other Fleurieu Peninsula waters during the past decade, as well as in metropolitan waters, and most sightings are of single animals. In contrast, large aggregations of small juveniles are periodically swept close to shore in more exposed waters outside the gulf (observation by D. Kinasz, May, 2015).

4. Discussion

Over the decades since leafy seadragons were first recorded by divers at Rapid Bay, that site has been the most popular and well-publicised in South Australia for divers to view and photograph seadragons. The project on which this report is based, arose from community concern in 2011-12, that seadragon numbers had declined in the area since the 1990s and early 2000s.

The project has shown the value of using facial and body markers on seadragons, as a means of identifying individuals over space and time. This is disused in more detail below, in **Section 4.1.**

The sections below also discuss the results of the monitoring, and the numerous likely reasons for seadragon decline at the site. So far, it appears ***that there is no single cause for the decline in numbers over time***. ***Multiple stressors affect leafy seadragons at Rapid Bay, and several of the impacts are increasing over time.***

4.1 Value of Facial and Body Markers over Time

During 2013 and 2014, distinctive facial markers of *adult* seadragons generally remained consistent, and these features enabled continued identification, despite loss and wearing of appendages. Connolly et al (2002a, b), undertook a pioneering study on the use of facial markers to identify leafy seadragons, and found that individuals could confidently be identified over the 14-month period of that study. Martin-Smith (2016) recorded the same consistency over 18 months in abdomen spots and blotches, for adult weedy seadragons. ***Our results concur with those of Connelly et al., and substantially extend the period of individual recognition, based on a larger number of markers.***

For the current study, over a longer timeframe (> 2 years), we found that a suite of head and body markers was required to confidently assign an image as being any of the previously identified individuals. The basal "leaf" on the head appendage; the shape and markings on the "leaves" of the first ventral appendages (unless damaged), and the presence and shape of spines on the head and face, all tended to be consistently recognisable. The number of markers required for confident assignment of individuals, increased with the length of time between first and most recent images for each animal. This will be discussed in more detail in a research paper arising from this work. ***Importantly, the combination of markers we have used in this study have enabled seadragons to be recognised over long periods, of 5 to 7+ years.***

Connolly (2002a) considered that the identification of *adult* leafy seadragons could not be made using photographs of *juveniles* from an earlier date, due to potential changes in facial markers over time. During the current project, we also observed differences over time in facial markings between juveniles and adults. The red-rimmed (or brown-rimmed) white marks on the face and snout of juvenile leafy seadragons appear relatively larger than those of adults, until the head of the animal grows, and the marks subsequently appear reduced in size relative to the head size.

Even more noticeable were the changes to the size and shape of "leaves" on the appendages over time, as the juveniles grew. The "leaves" of juveniles, which are an important means of camouflage, are narrower than those of adults, and have pointed tips. The black spots are also smaller, and quite distinct, and these spots change into more diffuse black blotches as the animal matures.

4.2 Evidence of Leafy Seadragon Longevity

Our results have shown that seadragons remain in the same area for years. **Table 6** below summarises some sighting durations for 5 of the individuals that were monitored during this project.

Table 6: Summary of sighting data for 5 seadragon from Rapid Bay jetty, showing strong site association over years.

Seadragon Name	First sighting*	Most recent sighting	No. years sighted	Notes
Club Flip / Flip Over / Club-Leaf	Feb 2012	Oct 2017	6	Sub-adult in 2012. See **Table 2** for more details about this seadragon
Wishbone	Oct 2013	Oct 2018	5+ years	Wishbone was not a juvenile in October 2013, so would be older than 5 years.
Y Dash-line	Feb 2012	Mar 2017	5+ years	Y Dash-line was not a juvenile in Feb. 2012, so would be older than 5 years.
T-Face	*Possibly*: Feb + Dec 2011 *Definite*: April 2013	Nov 2015 Feb 2016 (unconfirmed)	2.5 years; possibly > 5 years if 2011 and 2016 sightings can be confirmed)	
Thorny	Feb 2012	Feb 2019	7+ years	Broods present in Dec 2016, Oct 2017, January 2017, Nov-Dec 2017, October 2018, December 2018, January 2019

***Also includes sightings prior to pilot project date**

As shown in **Table 2** and **Table 6**, a number of seadragons identified during this project were photographed by divers over long periods, including:

- 85 months (7 years)
- 69 months (6 years)
- 59 months (almost 5 years)
- 52 months (4+ years)

This is significant information about the longevity of this species in the wild, and confirms the long-held view by divers that seadragons are strongly site-associated, and may live in the same location for years. All of the seadragons monitored for this project photographed in several distinct locations at the old Rapid Bay jetty, some of which could be considered "home bases" for particular seadragons (See **Figure 4**). The exact locations are not discussed in this public version of the report.

4.3 Seadragon Distribution at RBJ over Space and Time

The number of seadragons recorded under and around the jetty during the 2013-14 pilot project, and during subsequent opportunistic monitoring from 2014 to 2019, are in stark contrast to the approximately 75 individuals (including 30 breeding pairs) recorded by dive tour operator C. Harmer during the mid-2000s. During the pilot phase of the current study, 12 adult seadragons were recognised, plus several juveniles. Divers occasionally recorded 5 to 7 seadragons during a single dive, but singles were more commonly sighted (**Appendix 1**).

It is likely that more than 12 adult leafy seadragons utilised the jetty during the pilot monitoring period, but some may not permanently reside there. One of the tour operators in South Australia (NB SCUBA) consistently records seadragons in the seagrasses offshore from the jetty, where male-female pairs and small groups of seadragons are reliably and frequently recorded. An article by journalist and photographer G. Anderson (2018) summarised one of the tours into seagrass, offshore from the T-section. Photos posted publicly by the tour operator over several years were examined at various times during the pilot project period and more recently. The images indicate that some of the seadragons offshore in the seagrass have been recorded under RBJ jetty, and some have not, at least from the time of the pilot program in 2013-14 to the present.

Recording the absolute numbers of seadragons in the vicinity of the old jetty at RBJ was also not possible for this community project. There is evidence that some of the seadragons from the deeper parts of Rapid Bay jetty, periodically move further offshore into the seagrasses. Community divers for this project did not dive in that area, for safety reasons, and personal reasons. Records for this project relied on voluntary participation by divers, who preferred to dive under and around the jetty.

Matching the seadragons from the RBJ jetty monitoring project, with the seadragons recorded offshore in the seagrass by tour operators, would be a useful extension of this monitoring work. Such comparison was not possible within the resource limits of the current project.

Seadragon movements can most easily be confirmed through ultrasonic tagging and telemetry (Connolly 2002a, b), but resources to use that method were not available for the current community-based study. Despite the opportunistic nature of the recording in this study, some seadragons could definitely be defined as "jetty residents", as they were consistently recorded in the same locations. Some seadragons were consistently recorded in an area spanning less than 120m from west to east, for periods of months and/or years. Others may have moved periodically between that specific area and offshore (seaward), or between the specific area and a number of marked piles at shallower depths (landward). Further analysis of site-specific data is required to ascertain the spatial extent of movements. However, given the size of the area where the majority of sightings occurred, and the distance offshore from that area to the *Amphibolis* and *Posidonia* seagrass beds, it appears that the resident animals do not move more than approximately 100m from a "home base", unless disturbed (e.g. **Section 4.4** provides examples).

Some individuals were regularly recorded in the same location for > 10 months in the first instance, and then periodically in the vicinity over several years.

In 2019, numbers of leafy seadragons recorded by divers again declined, to the point that recreational divers were not recording any seadragons during their dives after April 2019. One tour operator recorded 6 leafies in February 2019, and several in March 2019. Recreational divers under the jetty were recording 1 or 2 seadragons during most dives in January and February of that year. Divers did not record seadragons during spring of 2019, a season when resident leafies would usually be present. The male seadragons with eggs that were usually stationed at the specific area where most sightings had occurred each summer, were not observed in the spring of 2019, nor the summer of 2019-2020. Reasons for the disappearance have not been investigated, but it is noted that the period of absence coincides with increased dive training numbers in the Rapid Bay area, due to the inaccessibility of another other popular diving location further north (Port Noarlunga), following the dislodgement of access steps by a storm. In the summer of 2019 – early 2020, several tour operators moved their tours from Rapid Bay to Second Valley and/or Encounter Bay, to ensure that clients would have an opportunity to view seadragons. At the time this report was completed (March 2020) small numbers of leafy seadragons were beginning to be seen again at Rapid Bay jetty, perhaps because the number of divers visiting the site reduced in autumn, compared with the very high numbers in summer of 2019-20.

Other than periodic movements offshore, which have not been investigated for this project., there are likely numerous other reasons for both the previous (late 2000s – early 2010s) and more recent (2010s – 2020+) declines in seadragon numbers at Rapid Bay jetty, and these are discussed below.

4.4 Observations of Diver Behaviour and Tour Boats

There has been ongoing concern from within parts of the diving community, about insensitive practices occurring during seadragon observation and photography, particularly by tour groups of inexperienced divers. In 2013, one experienced diver who participated in this project stated:

"*I've seen - time and time again - people who'll take photos and then as they finish, kick away straight over the Leafy Seadragon or habitat they were seconds ago admiring!*"

A pertinent example is provided from 17th January 2014, when another long-term experienced diver and photographer did two dives at Rapid Bay for this monitoring project. During the morning dive (58 mins), 2 seadragons were observed and photographed. Following the first dive, when the diver and dive buddy left the water, they observed a boat anchoring at the end of the jetty, with approximately 8 divers and a tour guide. Several other divers were also observed entering the water at the same time. Collectively, the tour group and other divers reportedly had several cameras (both large and small), strobes and video lights. During the second dive by the seadragon monitoring pair, no seadragons were seen in the same locations at the end of the jetty where they had been observed 2 hours previously. The following day, another diver who was involved with this project visited the same locations where the 2 seadragons had been observed the previous morning, and no seadragons were seen. The project divers considered that the noise of the tour boat and the actions of the tourist divers had driven the seadragons offshore, away from the jetty.

In response to ongoing concerns by divers, the SCUBA Divers Federation of South Australia issued a statement in January 2014, requesting that both dive charter boats and fishing boats do not moor on top of seadragon habitat at the end of the old Rapid Bay jetty. The SDFSA considered that boat noise and presence, multiple divers entering the water, finning over / against seadragons, divers surrounding seadragons, and regularly or continuously illuminating them with camera flashes, video lights and/or strobes, may be enough to drive the animals away from their chosen site (statement by S. Reynolds, SDFSA 22/01/14).

At the time, the SDFSA statement sought to remind divers in South Australia of the Seadragon Diving Code of Conduct (http://www.conservationsa.org.au/PDF/dscode.pdf), developed by the former Marine and Coastal Community Network and partner organisations during the 1990s, for the Dragon Search program. The code was also supported by other marine NGOs, government agencies, and the SDFSA. In 2020, a revised and updated version of the Conduct was released, by Natural Resources Adelaide & Mt Lofty Ranges. The revised code was developed in association with dive shops and seadragon researchers (NR AMLR 2020).

During the past decade a number of divers have also expressed concern about the possible impacts of shark shields (shark deterrent / repellent devices) on seadragons, because these devices emit electrical currents. The devices target the electrical receptors in the snouts of sharks (i.e. ampullae of Lorenzini), but the limited research to date has not yet provided enough information about the potential effects on bony fishes.

In a study from New South Wales, Broad et al. (2010) tested reef fish response to baits in the presence or absence of shark shields. The study could not detect behavioural changes at the scale of approach (i.e. fishes swimming in the vicinity of a shark shield). Differences were detected only at the finest scale (i.e. fish taking the food bait): half of the number of contacts were made by fishes when the shark shield was on, compared to when it was off. It is not known if the presence of shark shields might reduce the feeding potential of seadragons. There are many factors that may contribute to the effective range of shark shields, including sea temperature, salinity, habitat, and the deterrent threshold of the species in the vicinity of the device (McGowan and Kajiura 2009, cited by Kemster et al. 2016). Of note is the discharge frequency (1.67Hz) of one of the most common shark deterrent devices, which is reported to closely match the frequency of respiratory signals produced by some bony fishes, as well cartilaginous fishes such as rays (Bedore & Kajiura 20013; Sisneros & Tricas 2002, cited by Kempster et al. 2016). Note that research studies have not yet determined the possible impacts of groups of divers trailing shark shields through leafy seadragon habitat.

Some individual divers have also reported the increasing number of divers in the Rapid Bay jetty area over time as a concern for the welfare of the resident seadragons. The area is very popular for tour groups (both shore and boat dives), and also for Open Water SCUBA training. It is notable that between March 2019 and March 2020, divers did not report seeing seadragons under or around the old Rapid Bay jetty. This absence of seadragons from the usual positions under and around the jetty coincided with an apparent increased number of divers visiting the area, following the temporary closure of another location in Gulf St Vincent where Open Water SCUBA training is popular (see **Section 4.3**).

The seadragon monitoring project at Rapid Bay was not designed to monitor any potential effects of boat noise, anchoring, strobes / flash photography / video lights, shark shields, fin kicks, groups of divers and total number of divers surrounding single seadragons, pairs, or groups of seadragons. However, each of these have been reported as potentially impacting the resident seadragons at Rapid Bay jetty. ***Dive-based impacts on seadragon behaviour is an understudied area of research, that needs attention at some locations across southern Australia, including Rapid Bay.***

Promotion of the revised Code of Conduct for diving with seadragons is urgently required, as insensitive behaviour continues in the Rapid Bay area. In May 2019 for example, S. Reynolds from the SDFSA observed a group of student divers swimming directly over the top of a damaged, juvenile seadragon, “brushing it aside”. The group had just observed the seadragon after it had been pointed out by a dive leader. It is notable that the juvenile was missing numerous appendages (Reynolds 2019).

4.5 Disintegration of Old Jetty and Construction of New Jetty

The Rapid Bay jetty was constructed in 1940, and the T section was rebuilt in 1968 (Warneke 1987). When a single jetty existed at Rapid Bay, it was periodically maintained by the Department of Marine and Harbours, and repairs such as re-decking were made to sections when required.

During the 1980s, the structural steel was considered to be in poor condition (Warneke 1987), and by the early 1990s, the high costs of repair and upgrade were considered untenable (DMH 1992). A report on the condition of the timber piles in 2000 concluded that the piles had deteriorated below the bracings, well into the subtidal zone. 'Shipworm' attack and severe weather conditions were considered to be contributing factors (Integrity Testing Pty Ltd 2000).

At that time, steelwork was also too severely corroded to be repaired (Transport SA 2004, 2005), and the jetty posed a significant risk to users. Following a complete structural assessment, at the end of 2004 it was recommended that the jetty be closed immediately, to avoid a two-span collapse in the mid-section (Transport SA 2004). In 2008, a new jetty was constructed, adjacent to the old jetty (**Figure 14A**), and opened in 2009 (Friends of Rapid Bay Jetty 2014). The old jetty at Rapid Bay has gradually deteriorated since maintenance stopped, and significant parts of the mid-section on the approach jetty have now completely collapsed (**Figure 14B, 14C**). The T section is degraded, but much of it is still intact (**Figure 15**).

Seadragons tend to occur near 3D structure in subtidal habitat, including canopy macroalgae ('seaweeds' such as *Ecklonia* kelp, *Sargassum*, *Cystophora, Scytothalia* and *Scaberia*), seagrass, or artificial structures (Baker, 2003, 2005, 2009, and see **Section 4.6** below). Artificial structures such as jetty piles and structural debris on the sea floor – especially those that become covered with macroalgae – provide a suitable environment for seadragon camouflage and shelter. Seadragons eat mysid crustaceans from the water column (Kendrick & Hyndes 2005; Kuiter 2009; Manning et al. 2019), and their mysid food tends to aggregate around the edges of structure.

The timing of the construction of the new jetty in 2008 coincided with reports from divers that seadragons were declining in the area under and around the old Rapid Bay jetty. It is possible that the noise, and local damage to habitat associated with the development at the time, may have been a temporary disturbance to seadragons. Examples would include the impacts of construction machinery and pile driving equipment, which may remove seaweed and seagrass cover, and increase turbidity in the waters.

Following the construction of the new jetty, divers also reported movement of seadragons from the old jetty to the new one. One diver (D. Aston) reported that in February 2012, before the commencement of the pilot monitoring project, there were two resident leafy seadragons under the new jetty that could be found on every dive, but others would come and go, moving between the seaweed and seagrass patches around the new jetty, both seaward of the jetty, and adjacent to the jetty, including the space between the old and new jetties. Occasionally, 5 or more leafy seadragons have been found in the vicinity of the new jetty, during single dives in 2012, and 2015. One diver reported 14 seadragons recorded in one dive during the summer of 2012, collectively at the old and new jetties. Given the distances in tens to hundreds or metres that seadragons are capable of moving (Connolly, 2002a, b), it is feasible the animals may move between the old and the new jetties. During the pilot phase of the project, most photos were taken under and around the old jetty at Rapid Bay. A useful extension of the project would compare time-stamped photos of seadragons taken under the new jetty, with those from the old jetty, to ascertain movements between the jetties.

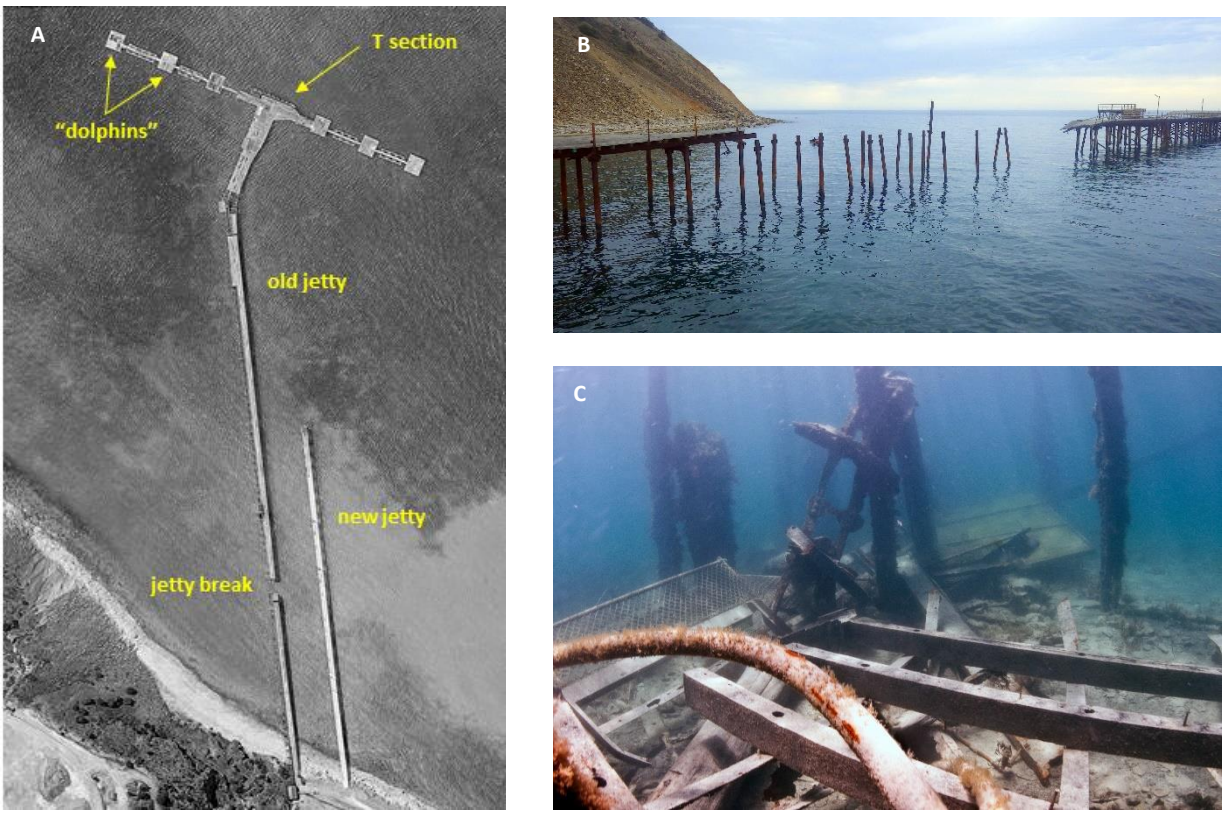


Figure 14: Images of Rapid Bay jetty. Aerial view in 2013 (14A); missing sections in 2018 (14B); collapsed jetty debris in 2016 (14C). Photos copyright: Google Earth (14A); J. Baker (14B); R. van der Marel (14C).

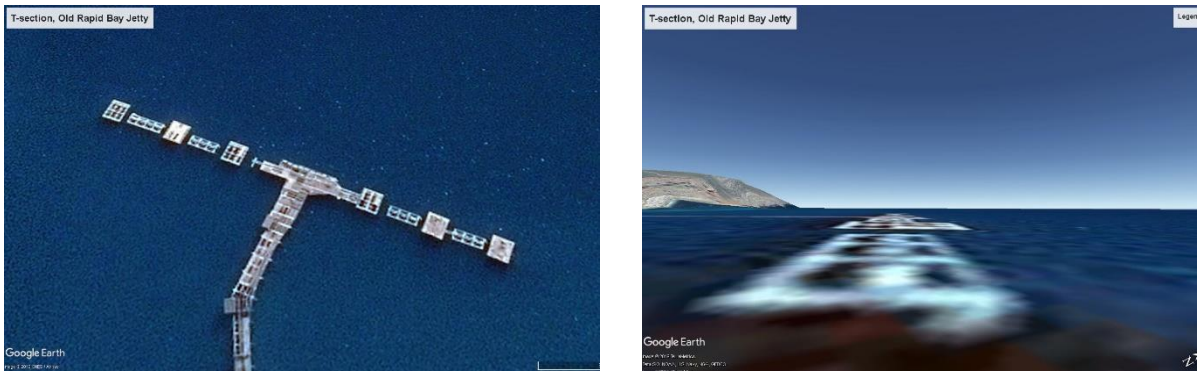


Figure 15: Images of T section of Rapid Bay jetty. Photos copyright: Google Earth.

4.6 Observations of Habitat Change over Time

Both seagrass and large brown seaweeds ("macroalgae") form important structural habitats that are utilised by seadragons (Dragon Search data, cited in Baker 2003, 2005, 2009; Sanchez-Camara & Booth 2004; Kuiter 2009). Large, brown macroalgae include *Ecklonia* kelp; the "fucoid" algae in order Fucales (such as species in the genera *Sargassum* and *Cystophora*; the common brown "wartyweed" *Scaberia agardhii*, and seaweeds such as *Sericoccus* and *Scytothalia,* which have narrow, strap-like blades. Seagrasses utilised by seadragons include species of wireweed (*Amphibolis*), and strapweed (*Posidonia*). Seadragons in South Australia have been found in the vicinity of all of these species (Dragon Search data 1990-2005; images from 2005 to 2019 examined by J. Baker). Seasonal, branched brown seaweeds with thinner blades, such as *Dictyopteris muelleri*, can also provide habitat for leafy seadragons at Rapid Bay (video data by T. Aston, 2014).

The vegetation cover at different depths along the old Rapid Bay jetty has been documented only sporadically during the past decades. The Dragon Search program, which provided some information about habitats in which leafy seadragons were sighted, was most active in South Australia from the mid 1990s to the early 2000s. During that program, 41% of the 623 sightings of leafy seadragons sighted by SCUBA or snorkeling, specified *seaweed* (macroalgae) as the main habitat type in the vicinity of those seadragons. An additional 30% specified *seagrass* as the main habitat type (Dragon Search data 1990 – 2005). Of the 172 sightings from Rapid Bay collected during the Dragon Search program, 89% specified habitat details. At Rapid Bay during the Dragon Search program, most records of *leafy* seadragons came from *seaweed* (macroalgae) habitat, and most records of *weedy* seadragons came from *seagrass*, adjacent to the jetty. However, it is noted that both species of seadragon utilise both major habitat types. During the Dragon Search program, the majority of leafy seadragon sightings were made in the vicinity of:

- jetty piles covered with large brown macroalgae such as *Ecklonia* and *Sargassum*. NB *Ecklonia* kelp is an important physical habitat where weedy seadragons find mating partners (Sanchez-Camara & Booth 2004), and the same is likely for leafy seadragons, which are commonly found in and adjacent to reef with *Ecklonia* as a structurally dominant species;
- smaller brown and red seaweeds on rubble; and
- benthic structure – such as steel debris broken off the jetty, or rocks that formed vertical relief on the sea floor – covered with brown and red algae and invertebrates.

(Dragon Search data 1990 - 2005)

The habitats specified above provide camouflage for seadragons, and also provide feeding opportunities, when food sources such as mysids concentrate at the edges of 3D structure (K. Martin-Smith, pers. comm., cited by Brown et al. 2008; Baker, pers. obs.).

In the case of Rapid Bay, 3D structure is provided by macroalgae and attached invertebrates on jetty piles, and by hard structures that sit on the sea floor, such as the "grid" adjacent to the T-section. Mysids also aggregate in the water above the vegetative detritus on the sea floor. This crustacean food source also aggregates at the edges of seagrass beds and stands of macroalgae that syngnathid fishes hide in (J. Baker, pers. obs), and more generally, in the water column over seagrass (Kendrick & Hyndes 2005). Therefore, the seagrass beds offshore from the old jetty are likely a suitable feeding area for leafy seadragons, which would explain their ongoing presence in that area. During the Dragon Search program, divers commonly reported leafy seadragons "hovering" next to jetty piles. Some divers also reported leafies being initially observed in kelp habitat, and then heading out towards the seagrass habitat seaward of the jetty. Those observations were supported by results from the current project.

Previous fish surveys at Rapid Bay during the early and mid-2000s (Shepherd & Baker 2008) documented the habitat cover qualitatively, in terms of visually dominant cover. At that time, *Ecklonia* kelp and *Sargassum* species were structurally dominant brown macroalgae on jetty piles in the mid-section of the jetty. The bottom under and around jetty piles from the shallows to the mid-section comprised mainly rubble and small boulders, with *Cystophora*, *Scaberia* and turfing algae (Shepherd and Baker, unpubl. data, 2005). Other data about the benthic cover come from the Reef Life Survey program, in which benthic transect data were collected by divers in 2008, 2010, 2011, from 6m, 8, and 9m depth. However, these transects were on the seafloor, and taken at different depths, and did not include kelp and other brown seaweeds growing on the jetty piles. Therefore, the RLS data cannot be utilised to assess changes in structural seaweed cover over time at Rapid Bay.

During the past decade, some divers have reported a reduction in the cover of *Ecklonia* kelp, and *Sargassum,* and other large brown macroalgae on hard structures at the end of the Rapid Bay jetty. Although video imagery and photographs are available for several years of this study (e.g. by T. Aston 2013, 2014, 2019, and A. King, 2005 - 2019), no comparative imagery from the exact same positions under and around the jetty during the 1990s and early 2000s is currently available.

Unfortunately, there are no long-term photo points for Rapid Bay jetty habitat, and that is a significant gap in quantitative and visual data that could be used to assess habitat change. Currently, change over time in jetty cover is limited to anecdotal evidence from divers, and various photos of the habitat taken opportunistically over the past 15 years.

Ecklonia kelp has a holdfast that attaches to hard surfaces such as rock or metal, and the gradual degradation of jetty structure over time (see **Section 4.5**) to form artificial reef surfaces on the sea floor, would be expected to favour the settlement of kelp spores. However, despite the availability of settlement surfaces at Rapid Bay jetty, a major and ever-increasing impact on kelp and other canopy-forming seaweeds is occurring. Sea surface temperature can significantly affect both the resilience and distribution of *Ecklonia* kelp. *Ecklonia radiata* seaweed has two distinct phases to the life cycle (large sporophyte and microscopic gametophyte), and experimental research has shown that the gametophyte phase of *Ecklonia* cannot survive beyond ~ 26°C (tom Dieck, 1993; Novaczek, 1984; Martinez et al. 2018). In areas of southern Australia where mean temperatures are higher than 20°C, the growth of both life phases of *Ecklonia* show an inverse relationship with temperature (Mabin et al. 2013; Mohring et al. 2013; Bearham et al., 2013; Hatcher et al., 1987; Xiao et al. 2015, cited in Martinez et al. 2018). In WA, high seawater temperatures have been shown to reduce the tolerance of *Ecklonia radiata* forests to additional perturbations such as storms (Wernberg et al. 2010). Also in WA, an extreme marine heatwave resulted in substantial loss of *Ecklonia* canopy cover across several hundred kilometres (Smale & Wernberg 2013; Wernberg et al. 2013; Wernberg et al. 2016, cited by Martinez et al. 2018). Distribution modelling of future seaweed cover on reefs across southern Australia has shown that of 9 environmental variables used as predictors, summer sea surface temperatures (SST), followed by winter SSTs, were the strongest distribution predictors for temperate habitat-forming seaweeds such as *Ecklonia*. The fact that summer sea surface temperatures continue to increase in SA waters (see Bureau of Meteorology summaries in **Section 4.7** below) significantly threatens the future health of canopy seaweed cover in South Australia, and therefore of the populations of numerous species that rely upon it.

In addition to warming waters, studies in parts of the Adelaide and Mt Lofty NRM region report that increased sediments from coastal sources have contributed to a decline in native, canopy-forming brown kelp over time, and an increase in smaller, opportunistic "turf" species (Turner 2005, Turner & Kildea 2006, Turner et al. 2007, Gorman 2009). Once turfs become established in the place of canopy seaweeds, they can trap sediment and further inhibit the re-establishment of canopy species such as *Ecklonia* kelp and other important structure-forming species of brown seaweeds in the genera *Sargassum* and *Cystophora* (Gorman 2009). Rapid Bay has historically been the site of additional sediment input into the coastal zone, due to the existence of a limestone mine near shore, which operated between 1942 and 1991 (Ford 1999, cited by Cowan 2006). Although the quarry no longer operates, the ground surface at the mine site has not been filled and the area has not been replanted with vegetation to stabilise the surface and reduce erosion. Sediments from the coastal area can still wash off into the coastal waters after heavy rainfall. Eroding cliffs are considered to be one of several significant sources of sedimentation on coastal reefs in Gulf St Vincent (Caton et al. 2007; Fernandes et al. 2008). There has been continued migration of quarry gravel nearshore, which has contributed to burial of nearshore habitats, pocket beaches and shore platforms, to Second Valley and beyond (Caton et al. 2007, cited by T. Flaherty, AMLR NRM, pers. comm. 2020). Turbidity occurs in the Yattagolinga River estuary, which flows into Rapid Bay. A medium-term threat in the area is storm runoff from farmland in the catchment area, and from cliffs adjacent to the old quarry.

Although increased nutrient load into coastal waters has long been considered a significant impact on marine plants and macroalgae in some parts of Gulf St Vincent (e.g. Shepherd 1970; Westphalen et al 2004), nutrient input is not considered to be a significant factor affecting vegetation cover at Rapid Bay. Adjacent to the jetty, there are no major rivers, creeks, stormwater drains, or other sources of run-off into the nearshore zone.

Another potential impact on brown macroalgae cover utilised by seadragons may be physical damage from dive fins, and from new divers holding on to macroalgae for support, to maintain their neutral buoyancy. There have been periodic reports of this behaviour, but the potential impact of physical damage to macroalgae by inexperienced divers at Rapid Bay has not been assessed over space or time.

In summary, temperature changes, sedimentation, reduced availability of hard structure over time for algal spore settlement, and diver behaviour all have the capacity to reduce the quality and cover of *Ecklonia* kelp and other macroalgae that grow in the vicinity of Rapid Bay jetty.

4.7 Ocean Temperature Increases Over Time

Rapid Bay is part of southern Gulf St Vincent in South Australia, biogeographically positioned in southern Australia between the warm to cool temperate waters of the Flindersian Province, and the cool to cold temperate waters of the Maugean sub-province (Womersley 1990; Waters et al. 2010). The marine species that exist in gulf waters have adapted over millennia, to thrive in a distinct seasonal temperature regime, but temperature data from Australian Bureau of Meteorology (BoM) during the past decade have shown that the seasonality of temperature is changing over time.

Multiple, climate-mediated changes in the southern Australian marine environment were predicted by researchers almost two decades ago (e.g. McInnes et al. 2003; Hobday & Matear 2005, Hobday et al. 2006, Suppiah et al. 2006, IPCC 2007), and these predictions have eventuated. According to the BoM, the sea surface temperatures across coastal waters of South Australia were ***the highest on record*** in 2017 and very much above average in 2018. The data resulting in that conclusion are summarised in **Figure 16**, from the BoM. The South Australian results follow a global trend towards ocean warming, in which 2016, 2017 and 2019 were the three warmest years on record, for sea surface temperatures (NOAA data, cited by BoM, 2018, 2019). According to CSIRO and BoM (2015, 2016), there is very high confidence in the data that predict that near-coastal sea surface temperatures in southern Australia will continue to rise, principally as a consequence of increased carbon dioxide in the atmosphere. Climate researchers have predicted with high confidence that near-coastal sea surface temperature rise around Australia will range from 0.4 – 1.0 °C by 2030 and around 2 – 4 °C (or even up to 5°C) by 2090 under a high emissions scenario, compared to the data from 1986–2005 (CSIRO and BoM 2015, 2016).

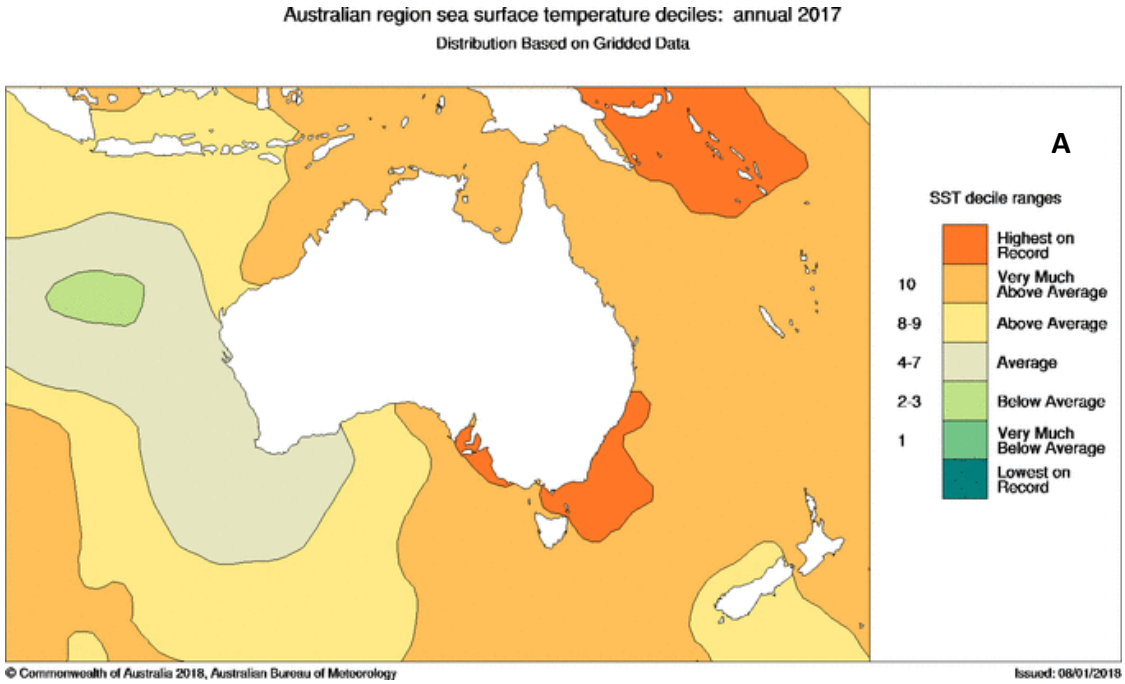


Figure 16: Summary of sea surface temperature anomalies for waters around Australia in 2017 (A) and 2018 (B). From Australian Bureau of Meteorology: http://www.bom.gov.au/climate/current/annual/aus/#tabs=Sea-surface-temperature

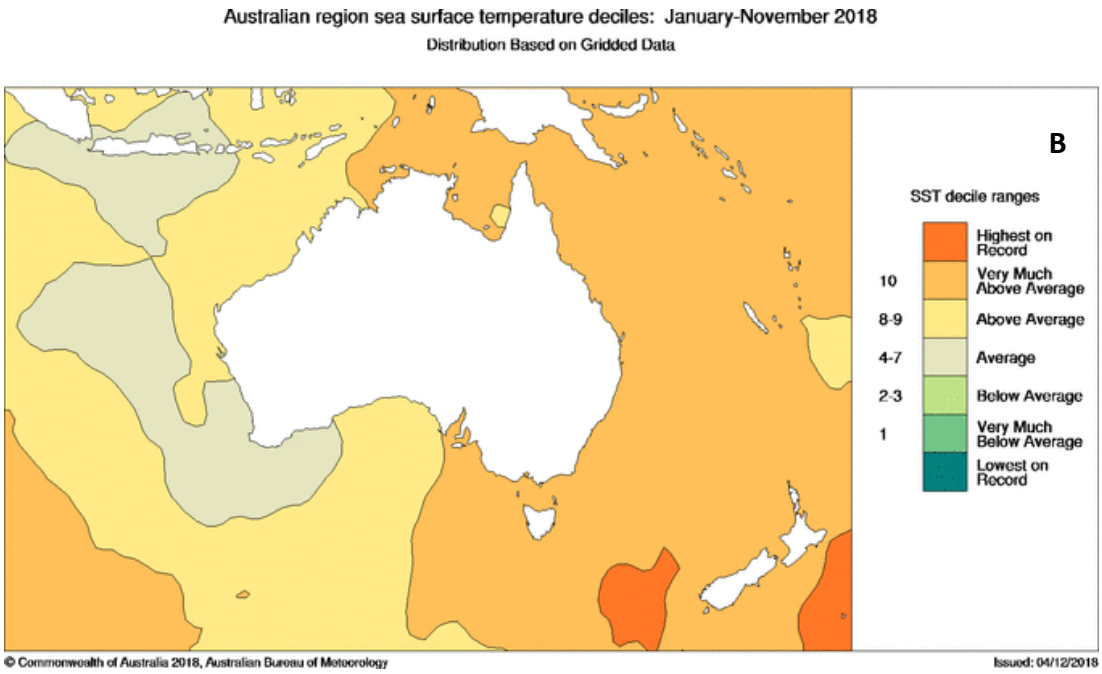


Figure 16 (continued): Summary of sea surface temperature anomalies for waters around Australia in 2017 (A) and 2018 (B). From Australian Bureau of Meteorology: http://www.bom.gov.au/climate/current/annual/aus/#tabs=Sea-surface-temperature

It is noted that ocean warming has been more marked in southern, south-eastern and eastern Australia than in other parts of the continent, according to real data (BoM data, 1970 – 2019). In contrast, ocean warming predictions for future decades assume greater relative increases in sea surface temperature in northern Australian waters compared with southern (CSIRO & BoM 2015, Chapter 8). A decade earlier than the CSIRO and BoM report cited above, Suppiah et al. (2006) summarised sea surface temperature data for South Australia, and reported a probable increase in sea surface temperature in Spencer Gulf and the Great Australian Bight of 0.11ºC per decade from 1950 to 2005. Irrespective of whether the greatest SST increases are seen in northern or southern Australia over time, the southern waters will continue to warm.

Additional issues include sea level rise, altered rainfall patterns (including more rainfall in summer, and a greater number of extreme rainfall events), and increased ocean acidification - i.e. decreased pH from more dissolved carbon dioxide. CSIRO (2016) reported with very high confidence that the ocean around Australia will become more acidic, with a net reduction in pH, and that the rate of acidification will be proportional to the carbon dioxide emissions.

Examples of climate-mediated impacts on the marine environment include changes in phytoplankton productivity; changes in distribution and local abundance of various species; changes in reproductive timing for various marine fishes and invertebrates, and changes in community structure (IPCC 2007; CSIRO & BoM 2015; Commonwealth of Australia 2017). Local species of seaweeds that have a limited temperature tolerance may "retreat" further south to cooler waters (e.g. Wernberg et al. 2011; Martinez et al. 2018), making way for tropical and subtropical species to take their place in current habitats. In both eastern Australia (e.g. Johnson et al. 2011; Harasti 2015) and Western Australia (e.g. Pearce et al. 2011; Lenanton et al. 2017), southward migrations of tropical species have been recorded during the past decade. In New South Wales, this range extension into cooler waters includes the tropical Thorny Seahorse (Harasti et al. 2015), which is in the same family as seadragons. The government-sponsored community project Redmap (Range Extension Database and Mapping Project http://www.redmap.org.au/) provides examples of climate-mediated range extensions in eastern, western and southern Australia. Mass kills of fish, and also of large invertebrates such as abalone and lobsters, have been linked to warmer-than-usual summer sea surface temperatures (Pearce et al. 2011). Death rates in marine animals from heat stress can be exacerbated by algae blooms that occur during warmer-than-average periods.

It is very likely, given the temperate distribution of seadragons, that increases in sea temperature over time pose a threat to their populations, and the ecology of their natural environments. Examples of changes may include avoidance of increasingly warm coastal waters in summer; change in distribution patterns; altered patterns of seadragon reproduction over time, and degradation of preferred habitat cover over time. *Ecklonia* kelp is one of the major habitats in which leafy seadragons occur, and warming waters pose a significant risk to this species (see **section 4.6** above).

4.8 Alleged Poaching Events

In the two years prior to the start of the pilot monitoring project in 2013, there were anecdotal reports from divers that seadragons might have been removed illegally from the Rapid Bay jetty. No licences for collection of seadragons from Rapid Bay have been approved (PIRSA, pers. comm. 2014), so if any seadragons have been taken from the area in the past, it would not be by legal means.

Further west, on Yorke Peninsula, there is some indirect evidence from a long-term diver in SA that a seadragon population which he was monitoring at Wool Bay, was illegally removed (C. Harmer, pers. comm.). Similar specific observations apparently have not been made at Rapid Bay. Although no firm evidence is available for poaching in the Rapid Bay area, some in the diving community believe that when seadragons disappear from an area, poaching is the likely reason. As indicated in this report, there are multiple disturbances – both short and long term – to seadragons at Rapid Bay, and there is evidence that some seadragons move offshore periodically out to the seagrass.

During part of the 1990s and 2000s, the fisheries regulatory body in SA (PIRSA) provided for an aquarist from Victoria to remove small numbers of brooding male seadragons from sites such as Encounter Bay, for breeding purposes. In the captive breeding operation, a small number of specimens with eggs are taken from the wild, and those specimens are bred in an aquaculture facility, and the progeny are exported to overseas buyers. The potential impacts of removing one breeding male per year from a site-attached population of seadragons have not been examined to date. It is noted here that seadragons have not been collected under permit from Rapid Bay or Second Valley for aquarium purposes, as both sites were excluded from the permitted schedule (e.g. South Australian Government Gazette 2005, 2007).

Public articles (e.g. Silcock 2017) that allege and/or emphasise poaching as the most likely reason for changes in seadragons numbers at Rapid Bay, do not assist the need to present factual information about changes in population numbers, based on evidence.

4.9 Weedy Seadragons

The apparent decline in the number of weedy seadragons observed at Rapid Bay and other nearshore locations in the SA gulf is concerning. Reductions in previous higher densities and broader range within Gulf St Vincent may have been linked with seagrass decline (see citation of research by S. Shepherd, in Baker 2005), but more recent reductions in sightings and number of animals per sighting may point to larger scale impacts, such as gradual ocean warming (see **Section 4.7**). Weedy seadragon decline in South Australia has not been investigated to date, but is the subject of research projects in eastern Australia.

5 Issues During Pilot Phase of Project

The 2013-14 project was a trial to determine the feasibility of volunteer divers monitoring the seadragon population at Rapid Bay jetty over the long term. Whilst the project has had some useful outcomes – as discussed in this report – there were a number of technical issues which impeded progress. Issues that affected data collection during the initial 12-month pilot project period and beyond, included:

- Inconsistency in dive schedules of volunteers. Inconsistency in dive schedules affected data quality. Six of the 9 divers who agreed to participate in the project prior to commencement, did not do any dives for the project after it began, due to various changes in life circumstances. One of the 9 divers did a single dive. Therefore, new personnel had to be sought at the outset of the project. None of the divers involved with the project could dive every month, and it was difficult to find replacement divers in some months, because diving for the project was voluntary and opportunistic. In some months, none of the divers who agreed to participate in the project chose to dive.
- Inconsistency search paths and dive durations. Divers were asked to choose a specific path to follow on each dive, so that locations of seadragons could be more easily documented. Divers were also asked to choose a duration for each dive, for consistency. Most divers did not record the path they followed, and for those who did document a path, their chosen path changed in subsequent dives. Duration of dives was not often recorded (see **Appendix 1**), and varied between divers, due to personal choice, and environmental conditions etc.
- Few divers participating longer than 3 months. The project participation time for some divers was shorter than expected, despite the incentives offered (i.e. gratuity payment for images, plus reimbursement for fuel and air fills). One diver participated intermittently for 7 months, and developed a separate business during that time, to take paying tourist divers to see seadragons on the monitoring dives.
- Inconsistency in reporting sightings. Some divers reported their sightings for one or more months and then discontinued, despite continuing to dive the area.
- Mislabelling of images by some participants. In some cases, images of the left and right sides of the same seadragon were labelled by a diver as being 2 different animals, and vice versa (i.e. 2 different animals were labelled as being the same seadragon). The recommended labelling system cited above in **Section 2** was not used by most divers. Results indicated that labels on submitted images were generally unreliable, and each image needed to be checked carefully by J. Baker. Documented dates of image capture were sometimes unreliable. For example, on some images the date stamp from the camera was erroneous. In other cases, the date stamp was correct, but the date in the file name was not.
- Lack of participation by some divers who regularly record seadragons at Rapid Bay. Some regular divers at Rapid Bay chose not to participate in the project, even though their data would have been very helpful, and payment for photographs was offered. Some divers run dive tour businesses to view seadragons, and did not wish to disclose the locations where they regularly find seadragons, even for research and monitoring purposes.
- Time required by project management to seek out seadragon sighting data and images in public media. Many seadragon images throughout the pilot project period were recorded by divers in a variety of media (e.g. on Facebook pages and groups, and dive club web sites), rather than submitted to the project as data. Some divers who regularly dived Rapid Bay to record seadragons and had agreed to participate in the project, did not report their sightings, but instead chose to place the images on social media, without mentioning their finds to the project. It quite time-consuming to find seadragon images in social media pages and seek approval for their use.
- Time required to regularly contact many of the divers who were involved with the project. Significant project time was required to contact divers regularly, to ask if they had dived and recorded seadragons. Divers who found seadragons and forgot to (or chose not to) provide timely data were contacted regularly. Also, when some participants dived, information was not provided about number of seadragons sighted (or not sighted), location of sightings, search path, duration and depth of dive etc. Such information had to be sought at regular intervals in cases where it was not voluntarily provided. More than 30 divers were involved with the pilot project over the 12 months, and managing the correspondence with divers took much longer than anticipated at the outset.

- Negative publicity for seadragon dives at RBJ, via news media article. During the pilot phase, a newspaper article on diving with seadragons was published in South Australia. The article misconstrued information, and omitted some of the factual information that was provided by the project manager and one of the regular participants, upon the journalist's request. The article aimed to provide a sensationalist story about why fewer seadragons are being sighted at Rapid Bay, and unjustly implied that deliberate interference by divers was the primary reason for decline in seadragon numbers around the jetty. A reduction in the participation rate of some divers in the project, correlated with the timing of that article's publication.
- Volunteer participant paperwork: Although participants in SACReD projects are comprehensively insured by SAICORP, it was preferable for each diver to fill out attendance forms and one-site risk assessment forms, and the detailed and frequent paperwork deterred some volunteer divers from participating regularly.
- Unpredictable sea conditions, which limited diving opportunities during the first quarter of the pilot project period. The project started 3 months later than scheduled, due to rough weather nearshore and consistent rain. The conditions adversely affected visibility in spring of 2013, and made diving conditions unsafe during that season. Swell, current patterns, water temperature and clarity are the main oceanographic factors that must be considered when planning and undertaking dives. During the pilot phase, there was a marked decrease in participation from April 2014 onwards. This was partly due to cooler sea conditions, and thus fewer divers chose to dive during late autumn and winter of 2014.

It is recommended that ways of overcoming these issues be identified and implemented, if this type of monitoring project is to continue in future years at any location in SA. The section below provides recommendations, based on the experiences during the pilot project.

6 Recommendations for Future Monitoring Projects

- If monitoring is to be continued over the longer term, ensure as far as possible that core teams of committed divers remain involved for specified periods, and continue to provide data consistently.

- After an initial meeting to determine monitoring strategy, regular group meetings were not held throughout the pilot project period. In hindsight, meetings might have ensured more consistent and longer term commitment from divers to the project. After the pilot phase, results were reported periodically through social media (e.g. Facebook) from 2015 – 2020. The project updates were often provided in response to divers posting photos of seadragons that matched the individuals monitored during this project. Updates of results on social media helped to re-invigorate the interest of some divers in the program, as well as introduce other divers to the long-term results. Some of those divers have agreed to assist a newer, State-level visual database project, of which the RBJ monitoring project forms a small part. It is recommended that regular means of engaging and re-engaging divers and attracting new divers be undertaken. Examples include seasonal meetings, periodic blog posts, updates of results on social media, public slideshows, and presentation evenings for divers.

- If permissible, compare all of the seadragons identified and photographed in seagrass offshore from Rapid Bay jetty by tour operator NB SCUBA, with images that were collated for this project from under and around the main sections of the old Rapid Bay jetty. The collective photo set, which would amount to thousands of images, may provide a better indication of seadragon behaviour, including periodic movements between the jetty and waters further seaward.

- Compare habitat images from previous years and decades, with recent images from the same locations, and set up habitat monitoring points at Rapid Bay jetty, to photograph the change in seaweed cover over time. Divers have photographs from most seaward third of the Rapid Bay jetty, dating from the mid and late 2000s and it would be useful to try to match the locations with those in recent images from the late 2010s, into the 2020s. Examining habitat images in detail was beyond the scope of the current project.

- Compare time-stamped photos taken under the new jetty, with those from the old jetty, to ascertain movements between the jetties.

- Consider expanding the scope of the project to other areas of SA, via an “Adopt a Dragon’s Lair” program. As part of such a program, local divers and dive teams in each location could monitor seadragon numbers, identities, and potential impacts from site usage and interactions. Such an initiative already occurs at Tumby Bay jetty, where a resident has been monitoring the local population over a long period.

7 Recommendations for Education and Activity Management

- Promote within the diving community of South Australia, the revised Code of Conduct for diving with seadragons (NR AMLR 2020). There are ongoing reports of insensitive practices in the presence of seadragons, particularly by new divers in training, and by some tourist divers visiting Rapid Bay.

- Investigate the frequency of boat mooring at the end of the old Rapid Bay jetty. That area is significant for the resident seadragons of Rapid Bay.

- Investigate the frequency of illegal spearfishing in the vicinity of the old Rapid Bay jetty. Such incidences have been publicly reported in the past (e.g. DiveOz Discussion Forum, 13th March, 2012).

- Ensure that educational signage at Rapid Bay jetty is maintained in good condition.

- Develop a specific, Statewide conservation plan for seadragons in South Australia. Currently, both species are protected from harm or collection under the *Fisheries Management Act*, but their habitat is either not protected, or partly protected under the *Marine Parks* Act. There is little connection between the two pieces of legislation for addressing seadragon habitat impacts, or potential impacts from excessive interactions with divers and dive groups, and associated equipment.

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Appendix 1

Appendix 1: Summary of dives taken during the pilot period of the project, and the number of seadragons observed per dive. Grey shading indicates that photos were taken, for identification of individual seadragons. Note: *Locations have been removed from the table for the public version of this report.*

Date and Time	No. of Divers Searching	Diver Code	Search Time (mins)	No. Leafies Observed	Notes
11/10/13	2	RR		1	Male with eggs.
14/10/13	2	RR		2	Male with eggs + second animal 1m away.
19/10/13	2	RR		1	Male with eggs.
24/10/13	2	RR		1	Male with eggs.
27/10/13	2	RR		1	Male with eggs.
29/10/13	2	RR		1	Male with eggs.
31/10/13	2	RR		1	Male with eggs.
2/11/13; 12.30PM	2	RR		1	Male with eggs.
4/11/2013; 9:15pm	2	RR		2	Male with eggs + second animal 1m away.
7/11/13; 10AM	2	RR		0	
10/11/13; 3:45PM	2	RR		1	Male with eggs
10/11/13	2	PM	63	0	
10/11/13	2	AF		0	Dive for other purpose (macro-photography), but no seadragons seen during dive
09/11/13 or 10/11/13	> 2	Anon.		0	Seadragon tour, reported to divers that no seadragons were found during dive search
11/11/13; 8:50AM	2	RR		1	Small-medium seadragon (young adult?); first time seen by diver. This is the 3rd seadragon seen at the specific location by diver RR during Oct and Nov 2013.
13/11/13; 10.50AM	2	PM	76		Male with eggs.
13/11/13; 12.53PM	2	PM	73		Male with eggs.
16/11/13; 10:15AM	2	SR	69	0	
17/11/13	2	RM		1	Male with eggs hatched
18/11/13	2	CCh		0	
20/11/13	2	Anon.		1	Male with eggs hatched (video)
22/11/13	2	RR		1	Older juvenile or young adult
24/11/13	>2	LM, CR			sub-adult
24/11/13	2	LB			sub-adult
25/11/13	2	CCh			Male with eggs hatched
25/11/13	>2	RM			sub-adult
**/11/13;	>2	Anon.		1	Young seadragon in rubble. (Sighted several times over one week in November). PM reported that there was previously a resident adult leafy in same location for ~ 3 years.
6/12/13		TB		1	
9/12/13		JB			Male with eggs hatched
20/12/13	2	DM		0	
23/12/13	2	DM		0	
27/12/13, 10:15AM	2	SR	73	0	
28/12/13		TB		2	
30/12/13	2	MS	120	0	
4/1/14	2	RP		1	
**/1/14	> 2	Anon.		5	9 sightings over two dives, totalling 5 seadragons.
10/01/14	>2	Anon.		6	

Appendix 1 (continued): Summary of dives taken during the pilot period of the project, and the number of seadragons observed per dive. Grey shading indicates that photos were taken, for identification of individual seadragons. Note: *Locations have been removed from the table for the public version of this report.*

Date and Time	No. of Divers Searching	Diver Code	Search Time (mins)	No. Leafies Observed	Notes
14/1/14	2	RM		2	
17/1/14, 9:58AM	2	PM	58	2	
17/1/14, 12:18PM	2	PM	79	0	
19/1/14	2	LB	90	0	
23/1/14	2	CCh		1	
26/1/14; afternoon	2	AM		0	
26/1/14	2	SS		1	
27/1/14	2	CCh		1	
27/1/14	2	Anon.		1	
27/1/14	2	RR		1	
01/2/14	2	LB	100	2	
01/2/14	2	CCa		1	
01/2/14	2	JB		1	Resident animal, observed same two locations for ~ 3 months
01/2/14	2	SS		1	
1/2/14 and 2/2/14	~ 8	Anon.	>300	4	Summary report of 4 or 5 animals recorded over weekend, some more than once.
8/2/14, AM	2	LB	150	1	Same animal as that seen on 1st February
8/2/14, PM	2	LB	60	0	
8/2/14, PM	2	RH		2	
8/2/14	2	JB		1	
8/2/14	2	BB		1	
8/2/14	2	Anon.		2	
7/2/14 and 8/2/14	2	Anon.		2	S of TS section. Total 4 separate animals sighted over 7th - 8th February
7/2/14	>2	Anon.		8	Seaward of T
15/2/14; 2:41PM	2	PM	96	0	See notes for dive path:
15/2/14; 10:30AM	2	PM	81	1	See notes for search path.
15/2/14	2	KH		1	
15/2/14	2	JM		1	
16/02/14	2	BB		1	
23/2/14	2	Das		3	
23/2/13	> 2	Anon.		9	
24/2/14	2	Das		4	
24/2/14	2	JM		1?	
25/2/14	2	Das		0	
26/2/14	2	Das		2	
27/2/14; 10:26AM	3	PM/ LM / BB	83	0	Search path provided
27/2/14; 12:47PM	3	PM/ LM / BB	85	2	One of the two leafies sighted twice on search route (provided)
27/2/14	2	Das		5	L1 - not seen on 26/02/14 L2 - same one as 26/02/14 L3 - same one as 26/02/14 L4 - west away from jetty L5 - west away from jetty

Appendix 1 (continued): Summary of dives taken during the pilot period of the project, and the number of seadragons observed per dive. Grey shading indicates that photos were taken, for identification of individual seadragons. Note: ***Locations have been removed from the table for the public version of this report.***

Date and Time	No. of Divers Searching	Diver Code	Search Time (mins)	No. Leafies Observed	Notes
28/2/14	2	Das		2	L1 = L3 from 27/2/15 L2 = smaller animal, not recalled as being seen before over the week the diver was recording.
1/3/14	2	Das		4	Divers reported possibly 7 seadragons total amongst the sightings over that week
2/3/14	2	Das		5	
2/3/14; 12:00PM	2	KH		3	1 x 10-12cm; 1 x 15-17cm; 1 x 30cm. None of these were same as animal from 15/2/14 (i.e. 4 animals sighted by KH in February and March dive, and a 5th large leafy recorded by other divers).
3/3/14	2	CCh	2 dives (> 120 mins)	2	Also 1 x weedy.
3/3/14	> 2	RM		2	
3/3/14	> 2	Anon.		1	
3/3/14	> 2	Anon.		1	
7/3/14	2	AB		2	
8/3/14	2	SR		0	
8/3/14	2	AF		1	
8/3/14	3	DC		1	
8/3/14	> 2	Anon.		several	2 locations
**/3/14	> 2	Anon.		9	
12/3/14	> 2	RM		1	
28/03/14	3	CCh		5	
7/4/14	2	MS		2?	
**/05/14	>2	Anon.		9	
11/5/14 - Newspaper article released, attributing long-term decline in seadragon population at Rapid Bay to diver numbers and behaviour. The article impacted diver participation in this project.					
19/5/14	2	RM		4	2 adults; 2 juveniles; + 1 of the 2 weedy seadragons seen in May
20/05/14	2	DK		1	
28/05/14	2	Anon.		1	
5/6/14	2	MS		1	
22/07/14	2	CCh / LN	45	2	Animals 1.5m apart. 1 x 15cm; 1 x 30cm
8/08/14	2	CCh / SS		8	2 pairs were together. 4 x 30cm; 2 x 25cm; 2 x 15-20cm
16/08/14	2	LM / CR		3	1 adult; 1 sub-adult; 1 juvenile
20/08/14	2	CCh		5	
30/08/14	2	LM / CR		1	Large adult.
6/9/14	2	LB	87	5	4 of the 5 in one location
20/09/14	2	Anon.		4	
22/09/14	2	CCh		5 or 6	2 adults and 3 or 4 juveniles